wakefieldmetals

Technical Handbook

of

Bar Products

www.wmetals.co.nz
0800 ALL METALS

PRINTED:* August 2014 – *EDITION #1

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It is the responsibility of the user to ensure product specified is fit for the purpose intended.

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Published by Wakefield Metals Technical Services Department

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1.1 COMPANY PROFILE

Wakefield Metals is New Zealand's leading importer and distributor of aluminium, brass, copper, stainless steel, zinc, fasteners and other specialty products for New Zealand manufacturers. Major market sectors include building and construction, white goods, marine, transport, electrical and the wine and dairy industries. Utilising an established international network we also source and provide logistics services for imported components and finished goods for manufacturers. We also operate a full indent service.

1.2 PROCESSING SERVICES

Wakefield service centres operate automated bandsaw and hacksaw facilities offering a complete cutting service for your bar requirements. The local markets and regional centres are supported by the nearest capital city when required.

1.3 TECHNICAL SERVICES

Wakefield Metals has for many years taken a leadership role in the stainless and special steels market by providing technical service support to users through our qualified and experienced staff at our distribution and processing operations.

The Wakefield Metals Technical Department supports customers and sales personnel in order to:

- assist with grade selection and metallurgical properties of our products
- assist with product selection to meet specific needs
- assist with the nomination and interpretation of specifications
- recommend fabrication procedures
- investigate problems when they occur and
- train staff and those of our customers in the use of stainless and specialty steels

The Department establishes and maintains the quality standards for product supply from mills and conducts a testing program to ensure product sold by Wakefield Metals meets those standards.

Customers are invited to take advantage of the technical service provided by Wakefield Metals; all enquiries can be directed to:

Freecall: 0800 ALL METALS
Email: inquiries@wmetals.co.nz

1.4 WEBSITE

www.wmetals.co.nz has a lot to offer, including more information about our company, products and services, however it is the quantity and quality of our technical and product information that makes our site unique. As it contains some of the information from this technical manual, we believe there is no other Australian website that contains such detailed and practical information for Engineering Products.

1.5 FREE MACHINING CARBON STEELS

1.5.1 MAIN GRADES STOCKED

1214FM

Is a low carbon free-machining steel with excellent machinability for non-critical engineering applications.

12L14FM

Is a low carbon free-machining steel with lead addition. Machinability superior to 1214FM in high-speed machining. Application in non-critical engineering applications. Cannot be welded.

1.5.2 SOME FACTS ON FREE MACHINING STEELS

Free machining steels are designed to optimise the results of machining by:

- the use of high cutting speeds and feedrates (low cycle times)
- high tool life
- good chip form, good chipability
- high surface finish in the minimum of operations
- low energy consumption
- accurate dimensional control
- consistency of performance.

Free machining steels are steels to which Sulphur and Phosphorus are added, hence they are called resulphurised and rephosphorised steels. The role of adding Sulphur is to create manganese sulphide inclusions which are very soft and act as an internal lubrication during the machining operation. The role of rephosphorising is to create embrittlement of the ferritic matrix in order to give rise to "micro-cracking" which improves chip breakability and dimensional stability during machining. Lead is also added to some free machining steel as lead particles in steel also act as an internal lubricant. It must be mentioned that additions of sulphur and lead have detrimental effects on hot workability, weldability, and formability. Elongated manganese sulphide inclusions also impair transverse ductility and toughness. Therefore, the use of machinability enhancers (especially sulphur) may have to be restricted for safety critical applications of engineering steels where functionality is the primary consideration.

The addition and combination of sulphur and lead in a low carbon free machining steel is very effective in reducing the cutting loads. The lead addition to free machining steels also contributes to reducing the height of the 'built-up-edge' on the tool while maintaining its effectiveness in protecting a high speed steel cutting edge. Leaded free-machining steels are very suitable for machining at extremely high speeds (surface speed > 400 m/min).

1.6 CARBON STEELS

1.6.1 MAIN GRADES STOCKED

M1020:
All-purpose low carbon steel with good ductility and weldability. Application in non-critical engineering applications.

M1030:
All-purpose medium carbon steel with intermediate strength, good ductility and weldability. Application in low-stress engineering applications.

1045:
Carbon steel for low to medium stress mechanical and automotive components. Can be heat treated by hardening and tempering (recommended for small and medium sections only) and surface-hardened.

1.6.2 SOME FACTS ON CARBON STEELS

A plain carbon steel is essentially an iron and carbon alloy which also contains minor amounts of manganese and a number of residual elements. Two relevant groups of carbon steels are low carbon steels with C-content lower than 0.30% and medium carbon steels with C-content in the range 0.30-0.60%. Low carbon steels like M1020 have essentially a ferritic micro-structure which is soft. Medium carbon steel have a ferritic-pearlitic micro-structure and have therefore higher hardness. Low carbon steels are quite tough but have low tensile strength and wear resistance. Medium carbon steels can be heat treated in order to create a martensitic structure that has a good combination of strength and toughness after tempering. The response of medium carbon steels to a quench and temper heat treatment is very limited and the depth of hardening is low. Carbon steels are successfully used where strength requirements are not too critical. For large sections, higher required material strengths and critical applications low-alloy steels would normally be suggested.

1.7 THROUGH-HARDENING ALLOY STEELS

1.7.1 MAIN GRADES STOCKED

4140:
General purpose CrMo-alloyed heat-treatable steel with high toughness, for mechanical engineering and mining applications, such as fasteners, connecting rods and pins. The grade is generally used for lighter cross-sections. It is also suitable for components for certain low-temperature applications.

4340:
CrNiMo-alloyed heat-treatable steel for highly-stressed parts in general mechanical engineering with large cross-sections and high toughness requirements, such as axles, pins, fasteners, shafts and gear components.

6582:
CrNiMo-alloyed heat-treatable steel with very high hardenability for highly-stressed parts in general mechanical engineering applications where large cross-sections and very high toughness are the requirements, such as axles, pins, fasteners, shafts and gear components.

6580:
CrNiMo-alloyed heat-treatable steel for components under high dynamic stress in mining and general engineering applications. Especially suited for medium and large cross-sections where high and uniform toughness requirements over the cross-section exist, such pinions, gear parts and drive shafts.

1.7.2 SOME FACTS ON THROUGH-HARDENING STEELS

Through-hardening steels are engineering steels that, because of their chemical composition, are suitable for hardening. They have good toughness at a given tensile strength in the quenched and tempered condition.

From the perspective of component manufacture, it is usually desirable that the steel assumes roughly the same mechanical properties over the component cross-section after heat treatment. For small sections this can be achieved with unalloyed steels (like 1045), for medium sized sections Cr-Mo steel are required (like 4140) and for very large sections only Cr-Ni-Mo can give the desired properties.

The combination of high strength and high toughness in through-hardening steels is the result of achieving a 100% martensitic structure in the steel after quenching. This structure is very hard and will be tempered by reheating the steel again to a lower temperature in order to decrease hardness and improve ductility and impact properties of the steel. The final strength and ductility of a through-hardening steel depend on the tempering temperature and time chosen. Generally through-hardening steels are tempered in the range 500 – 700°C. With a higher tempering temperature, the final strength decreases and the final ductility of the steel increases. These effects are shown in the tempering diagram for each steel grade.

A nearly 100% martensitic structure can be achieved with 4140 steels up to approximately 120mm diameter bar. For larger sections Wakefield 6582, 4340 or Wakefield 6580 are required to achieve a near 100% martensitic structure. It should be noted that if unalloyed steels like M1030 and 1045 are heat treated, they cannot transform into a near 100% martensitic structure. The ductility and impact properties of the retained pearlitic-ferritic micro-structure will greatly deteriorate when increasing the tensile strength of these steels by heat treatment.

Good through-hardening steels exhibit a high degree of cleanliness, particularly in regards to non-metallic inclusions and need careful balancing of chemical composition in order to react uniformly to heat treatment.

1.8 CASE-HARDENING ALLOY STEELS

1.8.1 MAIN GRADES STOCKED

8620H:
NiCrMo-alloyed case-hardening steel primarily for small components in mechanical and automotive applications where only intermediate core strength is required, such as gears, spiders and shafts.

6587:
CrNiMo-alloyed case-hardening steel for heavy-duty and highly stressed transmission components in mechanical engineering and mining applications with high demands on toughness, such as gears, pinion gears and large shafts.

6657:
NiCrMo-alloyed case-hardening steel with exceptional impact and fracture-toughness characteristics in the core. Application in mining and mechanical engineering in areas requiring resistance to high wear and high dynamic stresses.

1.8.2 SOME FACTS ON CASE–HARDENING STEELS

Case-hardening steels are essentially alloy steels with low carbon content in which a high hardness in the surface zone (or "case") is developed by altering the chemical composition of the surface zone through absorption and diffusion of carbon into the steel. This is performed during a treatment called carburising. Case hardening is the complete heat treatment which involves carburising,

holding the steel at the appropriate temperature and then quenching the steel and subsequently tempering it at a low temperature.

After case hardening a component is characterised by a surface with high hardness and a relatively soft core zone which has good toughness. Typically surface hardness of 57 – 63 HRC can be achieved, whilst the carbon content in the surface layer has increased to approximately 0.7%.

Case hardening of plain carbon steels is possible, but such steels have poor core strength and the application is limited to low-stressed and small components.

If a component is subject to high stresses, then apart from a high surface hardness for wear resistance purpose, strength of the core is also needed. For such applications alloyed case-hardening steels are needed. Alloyed case-hardening steels have better through-hardening properties and hence as a result of the heat treatment the core areas will also be affected. In order to maintain the toughness of the core, thus avoiding the risk of brittle fracture at the higher tensile strength levels, Nickel is added as an alloying element. Nickel also contributes to retaining toughness in the surface area after carburising. Cr-Ni-Mo case-hardening steels, like Wakefield 6587 and Wakefield 6657, have been developed to ensure good wear resisting properties in the case whilst have high strength and toughness in the core area even in very large cross-sections.

Good case-hardening steels exhibit a high degree of cleanliness, particularly in regards to non-metallic inclusions, and need careful balancing of chemical composition in order to react uniformly to heat treatment. The quality of case-hardening steels shows also in their fine-grain stability. Fine-grain stability results in low distortion of the component after the case hardening process. Good mills achieve fine-grain stability through control of aluminium and nitrogen content.

1.9 STAINLESS STEELS

1.9.1 MAIN GRADES STOCKED

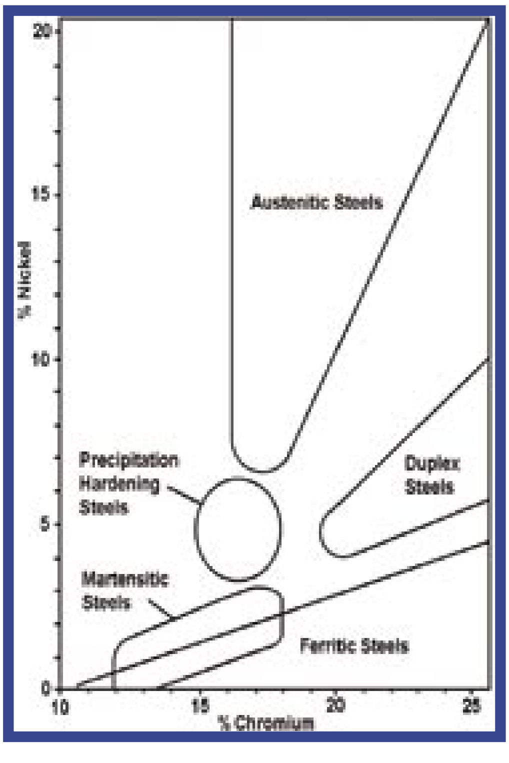
303:

Wakefield 303 represents the optimum in machinability among the austenitic stainless steels. It is primarily used when production involves extensive machining.

Wakefield 303 is generally available as a and new generation 2 with machinability significantly higher than that of the standard 303.

304:

Wakefield 304 is dual certified as grades 304 and 304L. Grade 304 is the standard "18/8" stainless. It has excellent forming and welding characteristics. Grade 304L, the low carbon version of 304, does not require post-weld annealing and so is extensively used in heavy gauge components.



316:

Wakefield 316 is dual certified as grades 316 and 316L. Wakefield 316 is the standard molybdenum-bearing stainless steel, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics.

420:

Wakefield 420 stainless steel can be hardened by quench-and-temper heat treatment. It contains a minimum of 12 per cent chromium, just sufficient to give corrosion resistance properties. It has good ductility in the annealed condition but is capable of being hardened up to Rockwell Hardness 50HRC, the highest hardness of the 12 per cent chromium grades. Like all martensitic stainless steels its best corrosion resistance is achieved when the metal is hardened and surface ground or polished. Variants of grade 420 are available with different carbon contents; these are designated as 420A, 420B, etc.
Atl

431:
A heat treatable martensitic, nickel-bearing grade with the best corrosion resistance properties of all the martensitic grades. It has excellent tensile and torque strength, and good toughness, making it ideally suited to shafting and bolt applications. It can be hardened to approximately 40HRC. Wakefield 431 is generally available as a new generation with machinability significantly higher than that of the standard 431.

2205:
Wakefield 2205 is the most widely used duplex (ferritic/austenitic) stainless steel grade. It finds applications due to both excellent corrosion resistance and high strength, which is about double of that of the austenitic grades 304 and 316. The duplex structure also results in excellent resistance to stress corrosion cracking.

UR52N+:
UR52N+ is one of a group of "super duplex" grades, combining high strength with exceptional corrosion resistance. The addition of copper to this grade gives it greatly improved resistance to strong reducing acids, particularly sulphuric acid. UR52N+ is also very highly resistant to pitting/ crevice corrosion in high chloride, hot environments. Its duplex structure also results in excellent resistance to stress corrosion cracking.

630:
630 is a precipitation-hardening steel that has a combination of high hardness and strength after suitable heat treatment. It has corrosion resistance similar to Wakefield 304. Grade 630 is often referred to as 17/4 PH.

1.9.2 SOME FACTS ON STAINLESS STEELS

Stainless steels are iron based alloys containing a minimum of about 10.5% chromium; this forms a protective self-healing chromium-oxide film, which is the reason why this group of steels have their characteristic "stainlessness" or corrosion resistance. The ability of the oxide layer to heal itself means that the steel is corrosion resistant, no matter how much of the surface is removed. Although all stainless steels depend on the presence of chromium, other alloying elements are often added to enhance their properties. The categorisation of stainless steels is unusual amongst metals in that it is based upon the nature of their metallurgical structure.

1.9.2.1 Austenitic Stainless Steels

This group contain at least 16% chromium and 6% nickel (the basic grade 304 is sometimes referred to as 18/8) and range through to the high alloy or "super austenitics" such as 904L and 6% molybdenum grades. Additional elements can be added such as molybdenum, titanium or copper, to modify or improve their properties, making them suitable for many critical applications involving high temperature as well as corrosion resistance. This group of steels is also suitable for cryogenic applications because the effect of the nickel content in making the steel austenitic avoids the problems of brittleness at low temperatures, which is a characteristic of other types of steel.

1.9.2.2 Ferritic Stainless Steels

These are plain chromium (10.5 to 18%) grades such as Grade 430 and 409. Their moderate corrosion resistance and poor fabrication properties are improved in the higher alloyed grades such as 434 and 439. Resistance to stress-corrosion cracking is the most obvious advantage of the ferritic stainless steels. Ferritic steels resist chloride and caustic stress corrosion cracking very well.

1.9.2.3 Martensitic Stainless Steels

Martensitic stainless steels are also based on the addition of chromium as the major alloying element but with a higher carbon and generally lower chromium content (eg 12% in Grade 420) than the ferritic types; Grade 431 has a chromium content of about 16%, but the microstructure is still martensite despite this high chromium level because this grade also contains 2% nickel.

1.9.2.4 Duplex Stainless Steels

Duplex stainless steels such as 2205 and 2507 (these designations indicate compositions of 22% chromium, 5% nickel and 25% chromium, 7% nickel but both grades contain further minor alloying additions) have microstructures comprising a mixture of austenite and ferrite. Duplex ferritic - austenitic steels combine some of the features of each class: they are resistant to stress corrosion cracking, albeit not quite as resistant as the ferritic steels; their toughness is superior to that of the ferritic steels but inferior to that of the austenitic steels, and their strength is greater than that of the (annealed) austenitic steels, by a factor of about two. In addition the duplex steels have general corrosion resistances equal to or better than 304 and 316, and in general their pitting corrosion resistances are superior to 316. They suffer reduced toughness below about -50°C and after exposure above 300°C, so are only used between these temperatures.

1.9.2.5 Precipitation Hardening Stainless Steels

These are chromium and nickel containing steels which can develop very high tensile strengths. The most common grade in this group is "17-4 PH"; also known as Grade 630, with the composition of 17% chromium, 4% nickel, 4% copper and 0.3% niobium. The great advantage of these steels is that they can be supplied in the "solution treated" condition; in this condition the steel is just machinable. Following machining, forming etc. the steel can be hardened by a single, fairly low temperature "ageing" heat treatment which causes no distortion of the component.

1.9.2.6 General characteristics of Stainless Steels

ALLOY GROUP	Magnetic Response (note 1)	Work Hardening Rate	Corrosion Resistance (note2)	Hardenable	Ductility	High Temperature Resistance	Low Temperature Resistance (note 3)	Weldability
Austenitic	Generally No	Very High	High	By Cold Work	Very High	Very High	Very High	Very High
Duplex	Yes	Medium	Very High	No	Medium	Low	Medium	High
Ferritic	Yes	Medium	Medium	No	Medium	High	Low	Low
Martensitic	Yes	Medium	Medium	Quench & Temper	Low	Low	Low	Low
Precipitation Hardening	Yes	Medium	Medium	Age Hardening	Medium to Low	Low	Low	Low

NOTES:

1) *Attraction of the steel to a magnet. Note some austenitic grades can be attracted to a magnet if cold worked.*
2) *Varies significantly between grades within each group. e.g. free machining grades have lower corrosion resistances, those grades higher in molybdenum have higher resistances.*
3) *Measured by toughness and ductility at sub-zero temperatures. Austenitic grades retain ductility to cryogenic temperatures.*

1.10 HOLLOW BAR

1.10.1 MAIN PRODUCTS STOCKED

Carbon Steel Hollow Bar:
Wakefield Carbon Steel Hollow Bar is supplied in two grades. Grade 20MnVS6 (WNr 1.5217) for sizes 32-250mm and Grade St 52.0 or E355 in new nomenclature (WNr 1.0421) for all sizes 250-457mm.

20MnVS6 is a micro-alloy steel with improved mechanical properties and with controlled sulphur content to improve machinability. St52.0 is a plain carbon steel defined by specific mechanical properties. Wakefield carbon steel hollow bar is an all-purpose mechanical tube suited for low and medium-stress applications.

4140 Hollow Bar:
Wakefield 4140 Hollow Bar is a low-alloy through-hardening steel hollow bar, generally supplied in the hardened and tempered condition. It is used in mining and general engineering for medium and high stress applications.

316 Hollow Bar:
Wakefield 316 Hollow Bar is a stainless steel Grade 316L hollow bar. It possesses good corrosion resisting properties, particularly higher resistance to pitting and crevice corrosion in chloride environments compared to grade 304. It has excellent forming and welding characteristics.

1.11 CAST IRON AND HYDRAULIC PRODUCTS

1.11.1 MAIN PRODUCTS STOCKED

Chrome Bar:
Wakefield Chrome Bar is a hard chromium-plated centreless ground bar supplied in Grade 1045 or in Grade 4140 heat treated. The standard 1045 Chrome Bar is supplied in the normalised condition but it is also available in an induction hardened condition.

Chrome bar is primarily used as piston rod material in all standard applications in hydraulics and pneumatics. Standard 1045 chrome bar is used for low to medium stress applications.

Chrome bar 4140 HT is used when high yield strength for medium to high stress applications is the dominant design parameter. Chrome bar 1045 induction-hardened is used when surface hardness (55-65 HRC) is the primary design criterion and lower strength of the core is acceptable.

Hydraulic Line Tube:
Wakefield Hydraulic Line Tube is a cold drawn seamless, low carbon steel tube supplied in the normalised condition. It is characterised by excellent weldability and formability ensuring ease of bending and flaring. Hydraulic line tube is applied in the hydraulic and pneumatic industries, as well as in general engineering.

U250 Cast Iron:
Ferritic-Pearlitic flake-graphite cast iron grade. This is a cast iron product of medium hardness (180 – 220 HB) and is therefore recommended for uses where a balance is required between mechanical properties and machinability.

U300 Cast Iron:
Pearlitic flake-graphite cast iron grade. This is one of the hardest qualities in flake or grey iron with hardness range 200 – 250 HB. It is therefore used when high tensile strength and/or wear-resistance is required, because of its pearlitic structure. Its surface finish is excellent because of its superior structural cohesion. This grade can be surface hardened.

U400 Cast Iron:
Spheroidal-graphite ferritic cast iron grade, also referred to as ductile or “SG” cast iron. It is applied when higher strength, machinability and a good surface finish are the required characteristics. Because of its ferritic structure it is recommended for uses requiring high heat and/or electrical conductivity, as well as good magnetic permeability. It possesses high ductility and reasonable toughness.

1.12 ALUMINIUM MACHINING BAR

1.12.1 MAIN GRADES STOCKED

2011
This aluminium alloy has superior machining performance, it is especially suitable for high-speed machining. It is a short-chipping aluminium alloy due to additions of Lead and Bismuth and can be applied to minimize machining costs. It has limited corrosion resistance and anodizing properties and is generally not recommended for welding and/or brazing. Aluminium alloy 2011 has strength that is comparable to that of a mild steel.

6262
This is contemporary aluminium alloy that combines very good machinability with excellent corrosion resistance and anodizing properties. It is has good weldability and can be brazed as well. The machinability of this alloy is significantly higher than that of comparable alloys like 6061 and 6082.

1.12.2 SOME FACTS ON ALUMINIUM ALLOYS

Aluminium alloys are classified by composition using a 4 digit number, where the first digit specifies the major alloying element(s). The table below gives an overview over the different groups of aluminium alloys and their designation.

1xxx	Super- or commercial-purity aluminium	Non-heat-treatable
2xxx	Al-Cu(-Mg)	Heat-treatable
3xxx	Al-Mn(-Mg)	Non-heat-treatable
4xxx	Al-Si	Non-heat-treatable
5xxx	Al-Mg	Non-heat-treatable
6xxx	Al-Mg-Si	Heat-treatable
7xxx	Al-Zn-Mg(-Cu)	Heat-treatable
8xxx	Other alloys	

As aluminium is naturally a very soft metal, some aluminium alloys can be subjected to a heat treatment process in order to increase the final mechanical properties. This heat treatment is called precipitation hardening or age hardening: 2xxx, 6xxx and 7xxx alloys can be strengthened by precipitation hardening, or 'ageing'.

Small, finely dispersed precipitates are formed during this heat treatment, which significantly increase the strength of the alloy. Temper designations are used to indicate whether an alloy has undergone any heat treatment. Temper designations are also used to indicate whether the alloy has been subjected to cold-working after extrusion.

Wakefield Metals stock 1700 different bar products. The table gives an overview of the stocking program.

Product	Section	Finish	Condition	Size Range	Metric	Imperial	# of Sizes
U1004	Flat	CD		16.0x3.0mm – 100.0x5.0mm	x	x	20
M1020	Round	CD/SMTP		4.76 - 152.40mm 9.52x4.76mm –	x	x	65
	Flat	CD/SMTP		152.40x25.40mm	x	x	40
	Square	CD/SMTP		25.40 - 101.60mm	x	x	10
M1030	Round	CD/SMTP		6.0mm - 130mm	x	x	60
1214FM	Round	CD/SMTP		4.76 - 152.40mm	x	x	85
	Hex	CD/SMTP		6.35 - 76.20mm	x	x	50
	Square	CD/SMTP		4.76 - 100.0mm	x	x	30
12L14FM	Round	CD/SMTP		3.97mm - 90.0mm	x	x	60
	Hex	CD/SMTP		7.94 - 55.00mm	x	x	55
	Square	CD/SMTP		12.70 - 70.0mm	x	x	15
1045	Round	BLK	AR/NOR	36 - 455mm	x		60
1040/1045	Round	SMTP	AR	10 - 110mm	x	x	65
	Round	CG	AR	25.40 - 130.0mm	x	x	15
4140	Round	BLK	H&T	16 - 220mm	x		35
	Round	CD/SMTP/PLD	H&T	6.35 - 450mm	x	x	100
	Round	CG	H&T	12.70 - 110.0mm	x	x	25
	Hex	CD	H&T	24 - 55mm	x	x	10
4340	Round	BLK/PLD	H&T	38 - 320mm	x		55
6582	Round	PLD	H&T	80 - 380mm	x		25
6580	Round	BLK	H&T	40 - 200mm	x		30
8620H	Round	CD/PLD	ANN	35 - 90mm	x		10
6587	Round	BLK/PLD	ANN	50 - 360mm	x		40
6657	Round	PLD	ANN	30 - 185mm	x		25
EN39B	Round	PLD	ANN	90 - 200mm	x		10
20MnVS6	Hollow	CD/BLK	AR	32x16mm - 419x319mm	x		160
4140	Hollow	CD/BLK	H&T	45x32mm - 200x140mm	x		40
316	Hollow	CD/PLD	ANN	32x16mm - 250x200mm	x		40
303	Round	CD/SMTP	ANN	4.76 - 63.50mm	x	x	40
	Hex	CD	ANN	9.53 - 31.75mm		x	15
304	Round	CD/STP/PLD	ANN	4.76 - 203.20mm	x	x	80
316	Round	CD/STP/PLD	ANN	4.76 - 350.0mm	x	x	110
316	Hex	CD	ANN	9.35 - 57.15mm		x	35
316	Square	CD	ANN	6.35 - 40.0mm	x	x	15
431	Round	CD/SMTP/CG	H&T	6.35 - 116.0mm	x	x	35
2205	Round	CD/CG	ANN	12.0 - 101.60mm	x	x	25
Cast IronU250,U300	Hollow	RM	AC	60x40mm – 300x180mm	x		55
Cast Iron U250, U400, U500	Round	BLK	AC	40-400	x		36
Chrome Bar 1045	CG/CR	IND HARD		19.05 - 101.60mm	x	x	10
Chrome Bar 4140	CG/CR	H&T		25.00 - 101.60mm	x	x	35
Hydraulic Line Tube	Hollow	ASTM A179		6.40x0.90-50.80x4.88mm		x	55
Alloy 2011	Round, Hex and Square in CD/EX			10 – 200mm	x	x	45
Alloy 6262	Round, Hex and Square in CD/EX			10 – 120mm		x	30

Finish: CD = cold drawn, SMTP = smooth turned and polished, PLD = peeled, CG = centreless ground, BLK = black, RM = rough machined, CR = hard chrome plated, EX = extruded

Condition: AR = as rolled, AC = as cast, ANN = annealed, H&T = hardened and tempered, IND HARD = induction hardened, NOR=normalised

3. PROPERTIES OF STEEL GRADES COMPARED

3.1 CHEMICAL COMPOSITION OF THE VARIOUS STEEL GRADES

Typical composition in % of weight

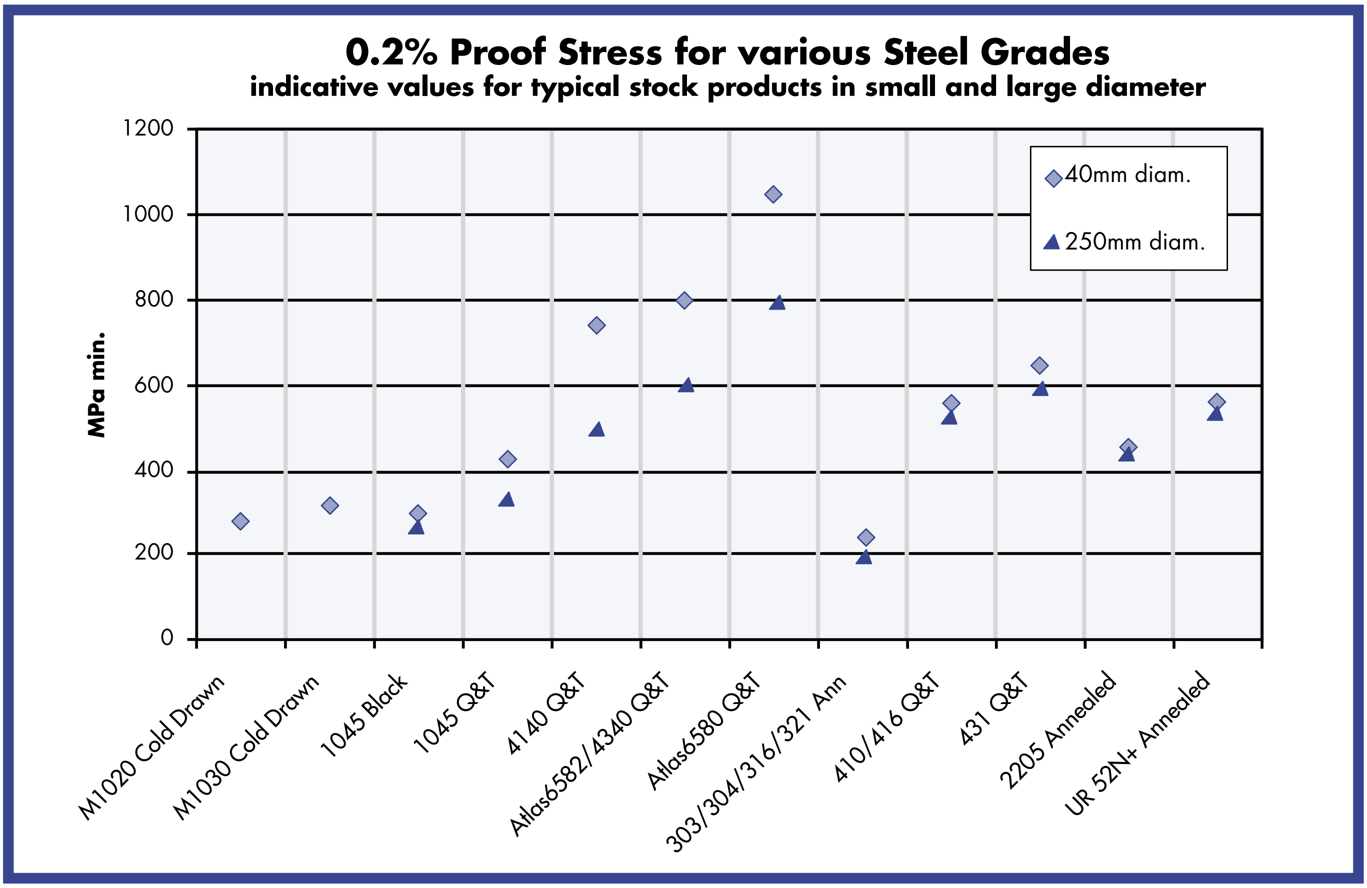
Product	C	Mn	Si	S	P	Cr	Ni	Mo	Other
M1020	0.15-0.25	0.30-0.90	≤ 0.35	≤ 0.050	≤ 0.050				
M1030	0.25-0.35	0.30-0.90	≤ 0.35	≤ 0.050	≤ 0.050				
1045	0.43-0.50	0.30-0.90	0.10-0.35	≤ 0.040	≤ 0.040				
1214FM	≤ 0.15	0.70-1.20	≤ 0.10	0.24-0.40	0.04-0.12				
12L14FM	≤ 0.15	0.80-1.50	≤ 0.10	0.25-0.40	0.04-0.11				Pb: 0.15-0.35
4140	0.37-0.44	0.65-1.10	0.10-0.35	≤ 0.040	≤ 0.040	0.75-1.20		0.15-0.30	
4340	0.37-0.44	0.55-0.90	0.10-0.35	≤ 0.040	≤ 0.040	0.65-0.95	1.55-2.00	0.20-0.35	
6582	0.30-0.38	0.50-0.80	≤ 0.40	≤ 0.035	≤ 0.035	1.30-1.70	1.30-1.70	0.15-0.30	
6580	0.26-0.34	0.30-0.60	≤ 0.40	≤ 0.035	≤ 0.035	1.80-2.20	1.80-2.20	0.30-0.50	
8620H	0.17-0.23	0.60-0.95	0.10-0.40	≤ 0.040	≤ 0.040	0.35-0.70	0.35-0.75	0.15-0.25	
6587	0.15-0.21	0.50-0.90	≤ 0.40	≤ 0.035	≤ 0.035	1.50-1.80	1.40-1.70	0.25-0.35	
6657	0.11-0.17	0.30-0.60	≤ 0.40	≤ 0.035	≤ 0.035	0.80-1.10	3.00-3.50	0.10-0.25	
En25	0.27-0.35	0.45-0.70	0.10-0.40	≤ 0.040	≤ 0.035	0.50-0.80	2.30-2.80	0.45-0.65	
En26	0.36-0.44	0.45-0.70	0.10-0.40	≤ 0.040	≤ 0.035	0.50-0.80	2.30-2.80	0.45-0.65	
En36A	0.10-0.16	0.35-0.60	≤ 0.35	≤ 0.040	≤ 0.040	0.70-1.00	3.00-3.75		
En39B	0.12-0.18	0.25-0.50	0.10-0.35	≤ 0.040	≤ 0.035	1.00-1.40	3.90-4.30	0.15-0.30	
Micro900	0.35-0.40	1.20-1.50	0.50-0.70	0.04-0.07	≤ 0.025				Al: 0.015-0.030 Ti: 0.010-0.016 V: 0.08-0.13
XP1600	0.25	1.60				2.00			Cu,Nb,Ti
Hy-Tuf	0.25	1.35	1.50			0.30	1.80	0.40	
303	≤ 0.15	≤ 2.00	≤ 1.00	≥ 0.15	≤ 0.20	17.0-19.0	8.0-10.0		
304	≤ 0.03	≤ 2.00	≤ 1.00	≤ 0.030	≤ 0.045	18.0-20.0	8.0-12.0		
316	≤ 0.03	≤ 2.00	≤ 1.00	≤ 0.030	≤ 0.045	16.0-18.0	10.0-14.0	2.0-3.0	
420	≤ 0.15	≤ 1.00	≤ 1.00	≤ 0.030	≤ 0.040	12.0-14.0			
431	≤ 0.20	≤ 1.00	≤ 1.00	≤ 0.030	≤ 0.040	15.0-17.0	1.25-2.50		
329	≤ 0.08	≤ 1.00	≤ 0.75	≤ 0.030	≤ 0.040	23.0-28.0	2.0-5.0	1.0-2.0	
2205	≤ 0.03	≤ 2.00	≤ 1.00	≤ 0.020	≤ 0.30	21.0-23.0	4.5-6.5	2.5-3.5	N: 0.08-0.20
UR52N+	≤ 0.03	≤ 1.50	≤ 0.80	≤ 0.020	≤ 0.035	24.0-26.0	5.5-8.0	3.0-4.0	Cu: 0.5-3.0 N: 0.20-0.35

3.2 GRADE QUICK REFERENCE CHART

		C	Mn	Cr	Ni	Mo	Other	Type of Steel	Typical Applications
CARBON	**M1020**	0.20	0.60					Low Carbon	Low strength steel for non-critical applications
	M1030	0.30	0.60					Medium Carbon	For non-critical applications with higher strength than M1020
	1045	0.45	0.60					Medium Carbon	Medium strength steel which can be through hardened (small sections)
	1214FM	≤ 0.15	0.95				S = 0.32, P = 0.08	Free Machining	Low-strength but highly machinable steel for repetition engineering
	12L14FM	≤ 0.15	1.15				S = 0.32, P = 0.08, Pb = 0.25	Free Machining	Low-strength steel suitable for high-speed machining in repetition engineering environment
	Micro900	0.38	1.35				Al = 0.022, Ti = 0.013, V = 0.11	Micro-alloy	Medium-high stress, **alternative to 1045 and 4140**, very good weldability and machinability
LOW-ALLOY	**4140**	0.40	0.90	0.90		0.25		Through Hardening	Medium-high stress in smaller cross-sections, has good fatigue properties
	4340	0.40	0.75	0.80	1.80	0.30		Through Hardening	Permanent/fluctuating stress, larger cross-sections
	6582	0.34	0.65	1.50	1.60	0.25		Through Hardening	Permanent/fluctuating stress, larger cross-sections with high core strength; **preferred alternative to 4340**
	6580	0.30	0.45	2.00	2.00	0.40		Through Hardening	Highest dynamic stresses, excellent fatigue properties**, preferred alternative to En25/En26**
	Hy-Tuf	0.25	1.35	0.30	1.80	0.40	Si = 1.50	Through Hardening	Medium stresses combined with high ductility requirement
	En25	0.30	0.60	0.65	2.55	0.55		Through Hardening	Highest dynamic stresses
	En26	0.40	0.60	0.65	2.55	0.55		Through Hardening	Highest dynamic stresses
	8620H	0.20	0.75	0.55	0.55	0.20		Case Hardening	Small diameter transmission parts, medium-low stress exposure
	6587	0.18	0.65	1.65	1.55	0.30		Case Hardening	Transmission parts subject to highest stresses and wear conditions
	6657	0.14	0.45	0.95	3.25	0.20		Case Hardening	Parts subject to highest stresses and wear conditions, high core strength and toughness required, **preferred alternative to En36A, can replace En39B** in certain applications
	En36A	0.13	0.50	0.85	3.35			Case Hardening	Transmission parts subject to highest stresses and wear conditions
	En39B	0.15	0.40	1.20	4.10	0.20		Case Hardening	Parts subject to highest stresses, high core strength and toughness required
	XP1600	0.25	1.60	2.00			Cu, Nb, Ti	Wear Resistant	Highest dynamic stresses combined with abrasive wear environment
STAINLESS	**303**	0.07	≤ 2.00	18.0	8.0			Free Machining Austenitic	Repetition engineering for general parts manufacture
	304	0.05	≤ 2.00	19.0	8.0			Austenitic Stainless	Food processing, fasteners and springs
	316	0.05	≤ 2.00	17.0	10.0	2.0		Austenitic Stainless	More corrosion resistance required than 304 in similar applications
	420	0.2	≤ 1.00	13.0				Martensitic	High-strength components in fluid applications like shafts and sleeves
	431	0.15	≤ 1.00	16.0	1.9			Martensitic	High-strength shafts, fasteners with higher corrosion resistance than 420
	329	0.03	≤ 1.00	25.0	3.5	1.5		Duplex	Medium stress with excellent corrosion resistance required
	2205	0.02	≤ 2.00	22.0	5.5	3.0	N = 0.15	Duplex	Medium stress with excellent corrosion resistance required
	UR52N+	0.02	≤ 1.50	25.0	6.8	3.5	Cu = 1.8, N = 0.30	Super-Duplex	High-stress with excellent corrosion resistance required

3.3 THE STRENGTH OF THE VARIOUS STEEL GRADES

The graph below shows indicative values for the 0.2% proof stress for various products stocked by Wakefield Metals.



M1020 and M1030 have typical min. 0.2% proof stress values of 290MPa and 300MPa respectively in cold drawn condition for 40mm diameter bar. Cold drawn bar in these grades is available up to100mm. Cold drawn bar of 100mm diameter would generally have a 30MPa lower min. 0.2% proof stress than 40mm bar.

Wakefield 1045 in hot rolled condition has a typical 0.2% proof stress value of 305MPa min. for 40mm. As this grade has a relatively uniform, mixed ferrite-pearlite microstructure, this value is typical for all sizes up to a 100mm. Wakefield 1045 bar in 250mm diameter would typically have a min. 0.2% proof stress value which is 30MPa lower than that of 40mm bar.

Quenching and tempering of Wakefield 1045 is reasonably effective for small diameter bar but not so for large diameter. Due to lack of alloying elements the through-hardening response of Wakefield 1045 is quite shallow. The graph shows that in 40mm bar an increase in 0.2% proof stress of over 100MPa or 35%-40% can be achieved by a heat treatment. Heat treatment of a 250mm section shows only a marginal increase in strength though. It should be stressed, that hardening and tempering of Wakefield 1045 adversely affects the impact properties of the steel no matter what size the cross-section.

Wakefield 4140, Wakefield 4340, Wakefield 6582 and Wakefield 6580 are all alloyed through-hardening steels. As can be seen in the graph the advantage of Atlas6582/4340 over Wakefield 4140 lies in greater hardenability and the significantly higher min. 0.2% proof stress that can be achieved in larger cross sections. Wakefield 6580 is the ultimate through-hardening steel that gives extremely high 0.2% proof stress for small cross-section whilst, as can be seen in the graph, a 250mm cross section still has a 0.2% proof stress of 800MPa min.

Austenitic stainless steels, like Wakefield 303, 304, 316 and 321 have the lowest 0.2% proof stress of all the steels shown in the graph. The values shown in the graph are for hot rolled and/ or turned product in the annealed condition. The low 0.2% proof stress should be seen in connection with the extremely high ductility of stainless steels. The tensile strength of these stainless steel products would be comparable to that of Wakefield M1030.

It should be noted that for all austenitic grades, annealed cold drawn bar (normally up to 25.4mm diameter) has a 0.2% proof stress that is considerably higher and typically is at 380MPa minimum, but can be significantly higher than this.

Martensitic stainless steels like Wakefield 410/416 and Wakefield 431 have the highest strength of all stainless steels, particular Wakefield 431 for which the 0.2% proof stress is almost three times as high as that of Wakefield 304/316. This is particularly interesting as Wakefield 431 also possesses reasonable corrosion resistance properties and good toughness. As can be seen in the graph, unlike the alloy through-hardening steels, the 0.2% proof stress of martensitic stainless steels does not drop substantially as the diameter of the cross-section increases. This is because the martensitic stainless steels have a hardenability that is exceptionally high, which is shown by the shape of the Jominy curves.

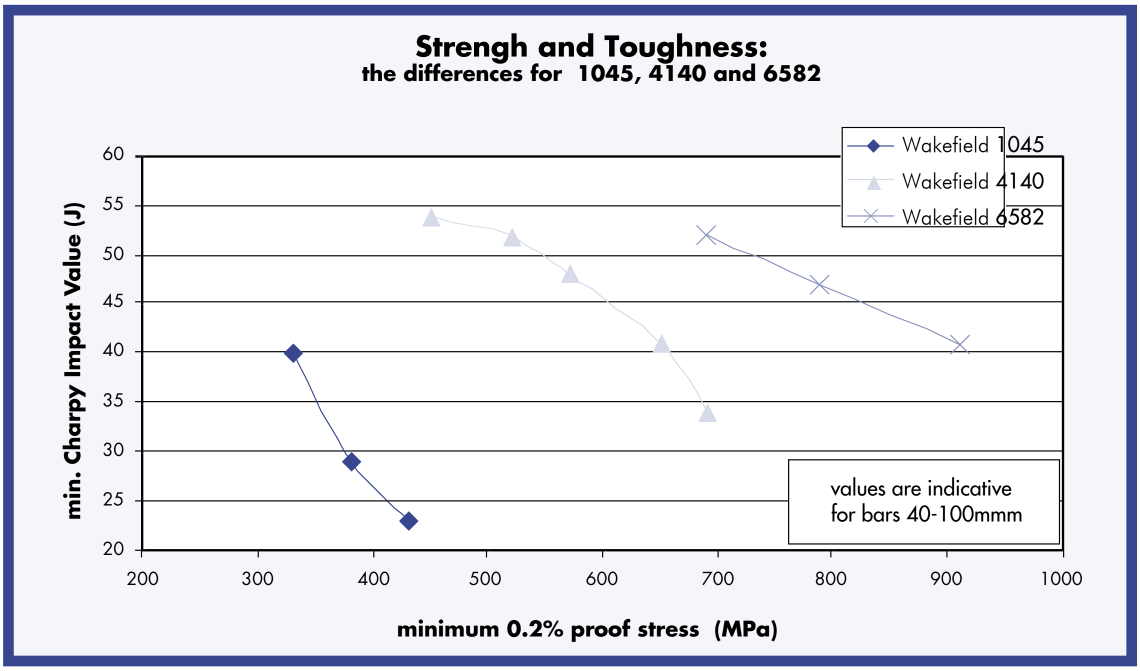
In case a strength even higher than this is required it may be necessary to use a precipitation-hardening stainless steel such as Wakefield 630, but this implies a sacrifice in corrosion resistance as compared to a duplex or a super-duplex stainless steel.

3.4 STRENGTH AND TOUGHNESS

Often and mistakenly, the tensile strength of a material is taken as the sole indication of its performance capability. A combination of strength and toughness is the true characteristic of a good steel. This is particularly true when the properties of carbon and alloy through-hardening steels are compared. Toughness is a major design criterion when semi-brittle or brittle fracture needs to be avoided.

The graph below shows the minimum 0.2% proof stress and the minimum impact values for grades Wakefield 1045, Wakefield 4140 and Wakefield 6582.

It can be seen that with Wakefield 1045 only limited strength levels can be achieved and the impact



properties of this grade greatly deteriorate when hardened to higher strength. At comparable strength levels the minimum toughness of Wakefield 4140 is about three times higher than that of 1045.

The graph shows that the toughness of Wakefield 4140 decreases when hardening the steel to a greater strength, but still remains at a reasonable level. If good toughness is required at higher strength levels the application of Wakefield 6582 or Wakefield 6580 needs to be considered. With 6582 an approximately 50% higher strength can be achieved whilst maintaining the toughness of the material.

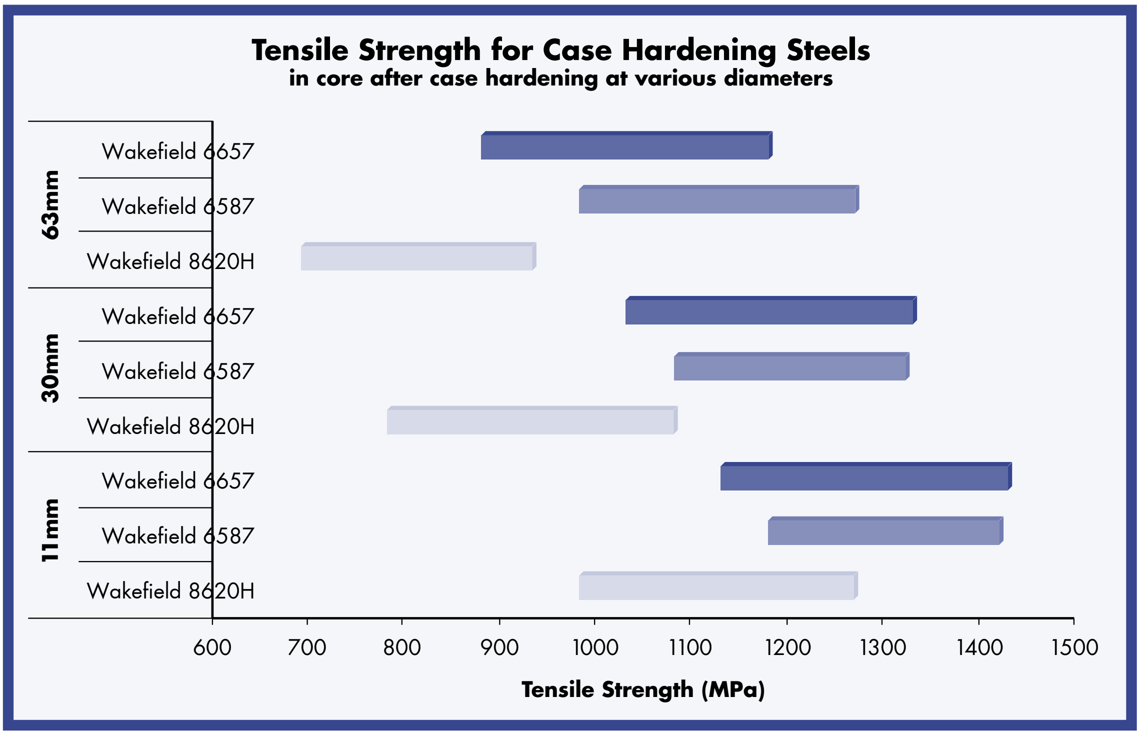
3.5 PROPERTIES OF CASE–HARDENING STEELS

The strength and toughness of the core after case hardening are among the most important properties of engineering steels. For case-hardening steels that are applied in low stress situations the case hardness and depth of the case is the most important criterion. Once the component operates in an environment of substantial static stresses, core strength also becomes an important variable. If in addition, dynamic stresses are present, the toughness of the core then also becomes important.

The core strength of a case-hardening steel depends, just like a through-hardening steel, on the hardenability of the steel as expressed in the Jominy diagram (see product datasheets contained in this handbook). After carburising of the surface layer the steel is quenched and subsequently tempered. A major difference between case-hardening steels and through-hardening steels is the tempering temperature. Case-hardening steels must be tempered at very low temperatures (150 – 200°) in order to retain the high hardness of the carburised layer achieved after quenching the steel. Because of the low carbon content in the core section, the steel maintains some ductility even at such low tempering temperatures.

As for alloyed through-hardening steels, a higher alloy content is needed to ensure a deeper hardening. The following graph shows the tensile strength after the case hardening operation for Wakefield 8620H, Wakefield 6587 and Wakefield 6657. It shows that Wakefield 8620H can achieve high core strength in small cross-sections, but the core strength quickly drops off as the cross-section gets bigger. Wakefield 6582 and Wakefield 6657 have excellent hardenability response and can achieve high core strength at larger diameters.

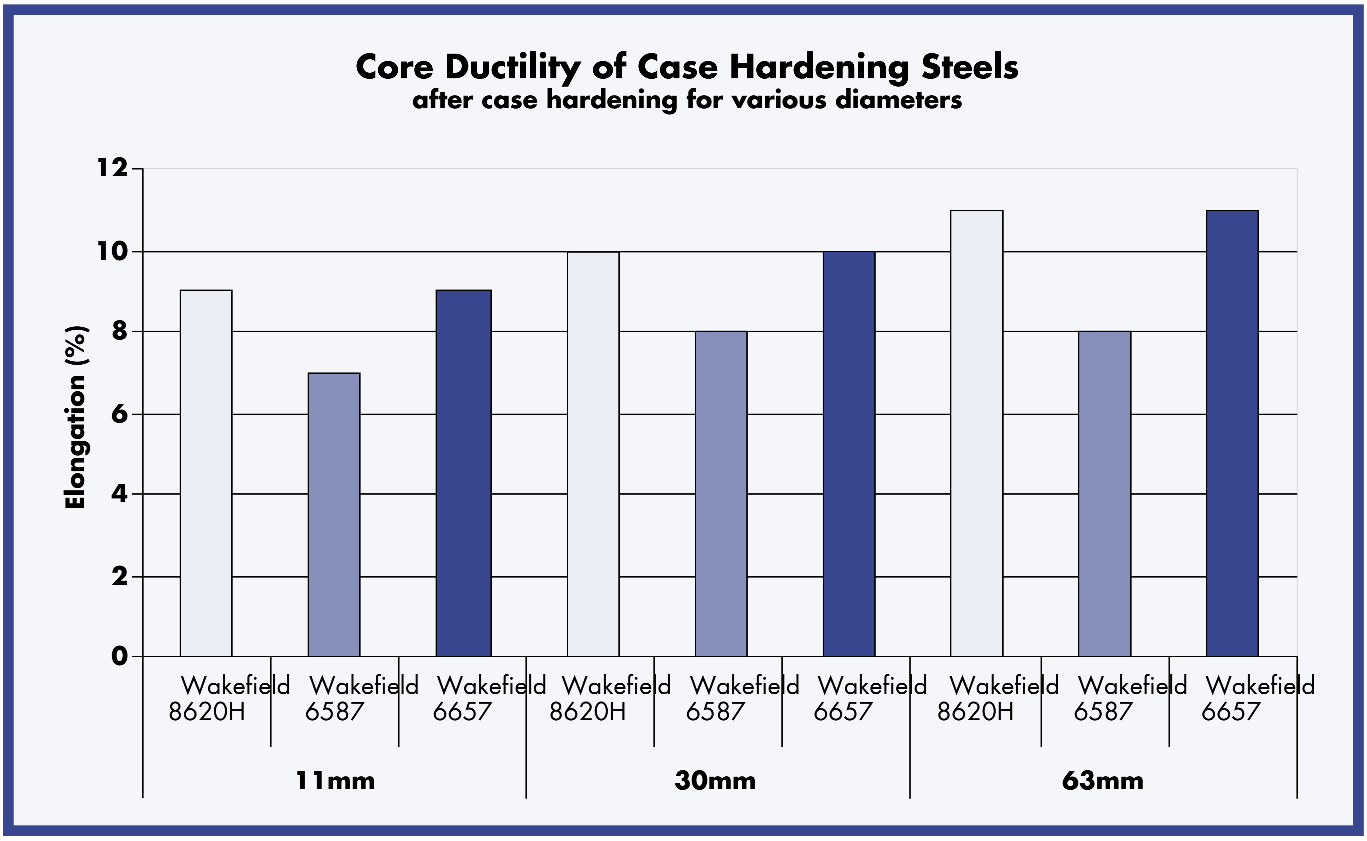
If a component is applied in an environment of high dynamic stresses and has to be able to



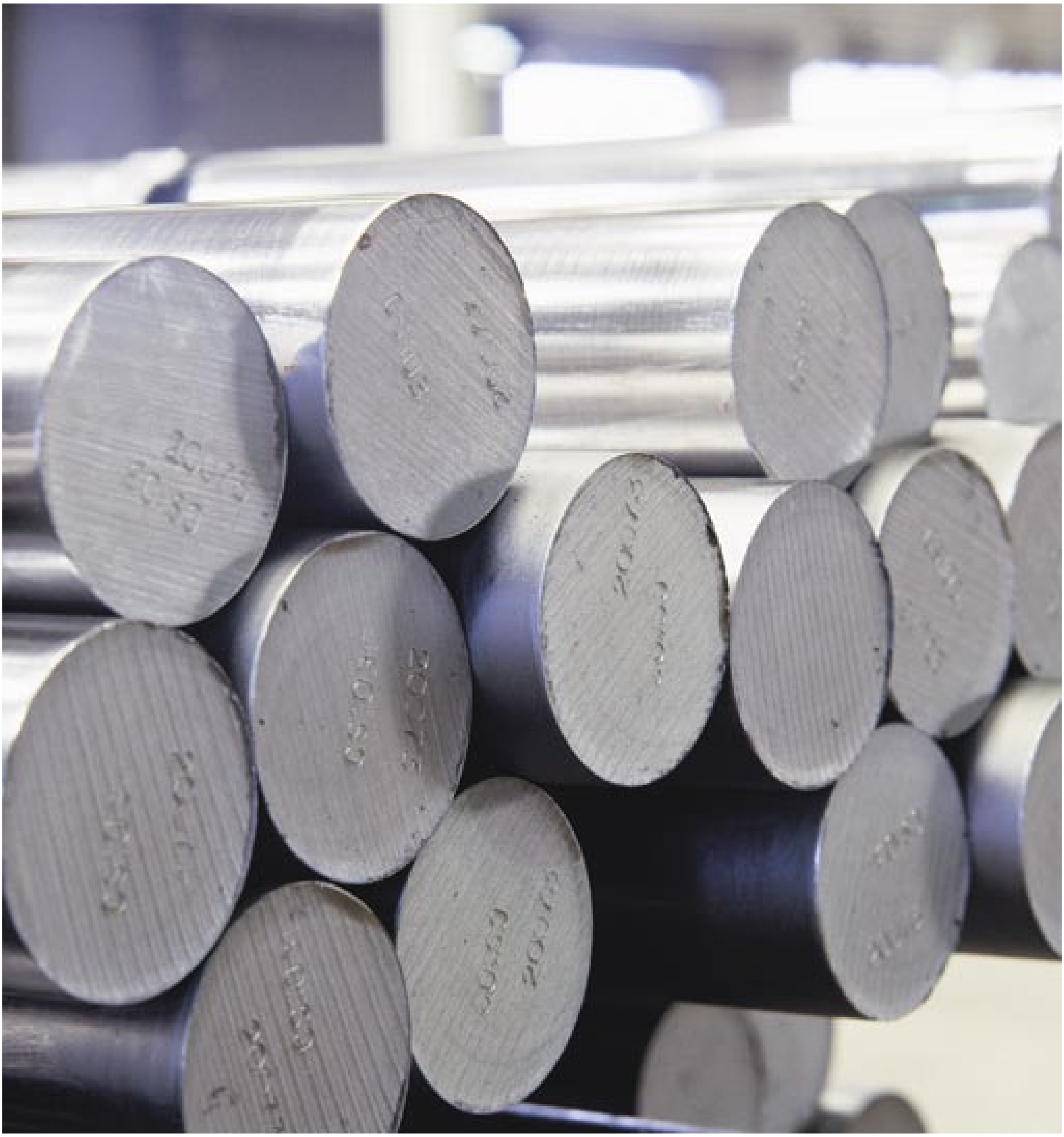
withstand sudden impact and fluctuating stresses in various directions, the toughness of the steel becomes a significant parameter. The toughness of the case-hardening steel is related to the ability to withstand sudden high impact and to the level of fatigue strength.

The graph below shows the ductility of the core after the case-hardening operation for Wakefield 8620H, Wakefield 6587 and Wakefield 6657 in various diameters. It shows that Wakefield 8620H and Wakefield 6657 generally have a higher ductility than Wakefield 6587.

If a high core strength is required and toughness also needs to be maximised, then Wakefield 6657 needs to be considered. Wakefield 6657 is a tougher steel than Wakefield 6587 due to its higher nickel content. The nickel content also increases the toughness of the case layer.



4. PRODUCT DATASHEETS



4.1 M1020: CARBON STEEL BRIGHT BAR

Colour Code: Yellow

4.1.1 INTRODUCTION

Wakefield M1020 carbon steel bar is a merchant grade plain carbon steel bar containing nominally 0.20% carbon. Wakefield M1020 has wider chemical composition limits than grade 1020. Grade M1020 is supplied based on it meeting specified chemical composition requirements only.

4.1.2 RELATED SPECIFICATIONS

Bar in grade M1020 is supplied in accordance with the requirements of AS1443 Grade M1020

4.1.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S
0.15-0.25	≤ 0.35	0.30-0.90	≤ 0.050	≤ 0.050

4.1.4 CONDITIONS OF SUPPLY – TYPICAL MECHANICAL PROPERTIES

Wakefield M1020 is not guaranteed to meet any specified minimum mechanical properties and the values in the table below reflect typical properties only. These values reflect grade D3 (AS 1443) for cold drawn sections and grade T3 (AS 1443) for turned and polished sections. Brinell Hardness (HB) limits are not specified in AS 1443.

Condition (mm)	Diameter (mm)	Tensile Strength (MPa)	Yield Stress (MPa)	Elongation (% in 50mm)	Hardness (HB)
Cold Drawn	Up to 16mm inclusive	480 min	380 min	12 min	142 min
	>16mm to 38mm inclusive	460 min	370 min	12 min	135 min
	>38mm to 100mm inclusive	430 min	340 min	13 min	126 min
Cold Finished / Turned and Polished	To 50mm inclusive	410 min	250 min	22 min	119 min
	>50mm to 250mm inclusive	410 min	230 min	22 min	119 min

M1020 can be supplied as D3 or T3 (or equivalent) with guaranteed mechanical properties on special order request.

4.1.5 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.1.5.1 Surface Finish

Bright round bar up to 63.5mm diameter is all cold drawn. Bright round bars 63.5-100mm diameter are cold drawn or smooth-turned and polished. Bright round bars over 100mm diameter are all smooth-turned and polished. All hexagon bar and all square bar is cold drawn. Flat Bar is cold drawn and supplied sharp-edged or round edged.

4.1.5.2 Diameter and A/F tolerances

Round Bar: Cold drawn h10; Smooth-turned and Polished h11 or h10, Ground h8
Square Bar: h11
Hex Bar: h11
Flat Bar: h11.

4.1.5.3 Straightness – maximum deviation from a straight line

Round Bar: 1 in 1000mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.1.5.4 Length Tolerance

Mill Lengths (3.5 to 6.0m): ± 250mm max.
Set Lengths (3.0 to 7.0m): -0/+40mm max. tolerance is possible subject to enquiry

4.1.6 SURFACE HARDENING

The following temperature ranges are applicable for the respective heat treatment operations.

Annealing	Normalising	Carburising	Tempering
870 – 910°C	890 – 940°C	880 – 980°C	150 – 200°C

Wakefield M1020 is not a case-hardening steel, however, it may be case hardened by the blank carburising process. It should be taken into account that Carbon content varies between 0.15% and 0.25%, therefore the result of the blank carburising process may greatly vary. If surface hardening is critical then the test certificate should be checked. Wakefield M1020 is not suitable for through-hardening, flame or induction hardening due to the low carbon content of this steel.

4.1.7 WELDING

M1020 can be readily welded by all conventional welding processes, MIG, TIG, MMAW etc. Pre or post heating is normally not necessary as part of the welding procedure. Preheat heavier sections. Do not weld components after blank carburising.

4.1.8 APPLICATIONS OF Wakefield *M1020*

Suitable for general engineering applications where the lower strength of this grade is sufficient. Grade M1020 is not able to be through-hardened and is not hardenable by either flame or induction hardening processes. It can be case hardened by a blank carburising process. Applications such as fasteners of various types, engineering applications where strength is not the major consideration (shafts, jack handles, threaded bar) and a grade is required that can be readily welded.

4.1.9 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of M1020
1214FM	Where welding and bending are not required and improvement in machinability is required.
M1030	Where higher strength is required and welding and bending may be required. Pre and post heat may be required as part of the welding procedure, whereas M1020 can be readily welded without pre & post heating.
1040/1045	Further increase in strength required above that of M1030, and the lower ductility and toughness of 1040/1045 can be tolerated. Welding of 1040 or 1045 requires pre & post heat as part of the weld procedure.

4.2 M1030: CARBON STEEL BRIGHT BAR

Colour Code: White

4.2.1 INTRODUCTION

Wakefield M1030 carbon bar is a merchant grade plain carbon steel product containing nominally 0.30% carbon. Wakefield M1030 is supplied based on it meeting specified chemical composition requirements only.

4.2.2 RELATED SPECIFICATIONS

Bar in grade M1030 is supplied in accordance with the requirements of AS1443 Grade M1030.

4.2.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S
0.25-0.35	≤ 0.35	0.30-0.90	≤ 0.050	≤ 0.050

4.2.4 CONDITIONS OF SUPPLY – TYPICAL MECHANICAL PROPERTIES

Wakefield M1030 is not guaranteed to meet any specified minimum mechanical properties and the values in the table below reflect typical properties only. These values reflect grade D4 (AS 1443) for cold drawn sections and grade T4 (AS 1443) for turned and polished sections. Brinell Hardness (HB) limits are not specified in AS 1443.

Condition	Diameter (mm)	Tensile Strength (MPa)	Yield Stress (MPa)	Elongation (% in 50mm)	Hardness (HB)
Cold Drawn	Up to 16mm inclusive	560 min	440 min	10 min	164 min
	>16mm to 38mm inclusive	540 min	430 min	11 min	160 min
	>38mm to 100mm inclusive	520 min	410 min	12 min	154 min
Hot Finished or Turned and Polished	All sizes to 260mm	500 min	250 min	20 min	147 min

M1030 can be supplied as D4 or T4 (or equivalent) with guaranteed mechanical properties as above on special order request.

4.2.5 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.2.5.1 Surface Finish

Bright round bar up to 63.5mm diameter is all cold drawn. Bright round bars of 63.5-100mm diameter are cold drawn or smooth-turned and polished. Bright round bars over 100mm diameter are all smooth-turned and polished. All hexagonal bar and all square bar is cold drawn. Flat Bar is cold drawn and supplied sharp-edged. As rolled (black) bars available upon enquiry.

4.2.5.2 Diameter and A/F tolerances

Round Bar: Drawn h10; Smooth-turned and polished h11 or h10; Ground h8
Square Bar: h11
Hex Bar: h11
Flat Bar: h11

4.2.5.3 Straightness – maximum deviation from a straight line

Round Bar:	1 in 500mm
Squares, Flats and Hexagon:	1 in 375mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.2.5.4 Length Tolerance

Mill Lengths (3.5 to 6.0m):	± 250mm max.
Set Lengths (3.0 to 7.0m):	-0/+40mm max. tolerance is possible subject to enquiry

4.2.6 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Annealing	Normalising	Quenching	Quenching medium	Tempering
850 - 900°C	870 - 920°C	850 - 890°C	Water or Brine	550 - 660°C

The tempering temperature range in the table refers to tempering after quenching. For tempering after a blank carburising process a temperature range of 150-250°C is appropriate.

4.2.7 SURFACE HARDENING

Wakefield M1030 is not a dedicated case-hardening steel, nor is it a dedicated through-hardening steel. If Carbon content is below 0.30% (check test certificate) it may be case hardened by the blank carburising process, though this procedure is not generally recommended. If Carbon is above 0.30% (check test certificate) Wakefield M1030 may be quenched and tempered although only a limited and shallow (up to 5mm from surface) hardening response will be achieved.

4.2.8 WELDING

M1030 can be welded by all conventional welding processes, MIG, TIG, MMAW etc. Pre and Post heating may be required as part of the welding process so as to avoid cracking, particularly in heavier sectional sizes

4.2.9 APPLICATIONS OF M1030

Grade M1030 is used in general engineering applications. It offers an improvement in tensile strength and yield strength as compared to grade M1020 (when equivalent sectional sizes and metallurgical condition are compared). Applications such as fasteners of various types, engineering applications where strength is not the major consideration (shaft, threaded bar) and a grade is required that can be welded.

4.2.10 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of Wakefield M1030
M1020	Where a lower tensile and yield strength grade is acceptable. Pre and Post heating can not be used but would be required if M1030 is used.
1214	Where lower strength is acceptable and welding and/or bending are not required. Substantial improvement in machinability required over that offered by either grades M1030 or M1020.
1045	Further increase in strength required above that of M1030 and the lower ductility and toughness of 1045 can be tolerated. Pre and post heat recommended as part of the welding procedure if grade 1045 is used and it is to be welded

4.3 Wakefield 1045: MEDIUM-TENSILE CARBON STEEL BAR

Colour Code: Jade Green

4.3.1 INTRODUCTION

1045 is a fully killed plain carbon steel product containing nominally 0.45% carbon. This grade was formerly designated as K1045. Wakefield 1045 is supplied based on it meeting specified chemical composition requirements only.

4.3.2 RELATED SPECIFICATIONS

Bar in grade 1045 is supplied in accordance with the requirements of JIS J4051 grade S45C and/or AS1442 grade 1045 in the case of black bar, and AS1443 grade 1045 in the case of bright (cold finished) bar.

4.3.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S
0.43-0.50	0.10 - 0.35	0.30-0.90	≤ 0.040	≤ 0.040

4.3.4 CONDITIONS OF SUPPLY – TYPICAL MECHANICAL PROPERTIES

Wakefield 1045 is not guaranteed to meet any specified minimum mechanical properties and the values in the table below reflect typical properties only. These values reflect grade D6 (AS 1443) for cold drawn sections, grade T6 (AS 1443) for turned and polished and grade 6 (AS 1442) for rolled (black) sections. Brinell Hardness (HB) is not specified in these standards.

Condition	Diameter (mm)	Tensile Strength (MPa)	Yield Stress (MPa)	Elongation (% in 50mm)	Hardness (HB)
Cold Drawn	Up to 16mm inclusive	690 min	540 min	8 min	207 min
	>16mm to 38mm inclusive	650 min	510 min	8 min	195 min
	>38mm to 80mm inclusive	640 min	500 min	9 min	190 min
As rolled/Turned and Polished	All sizes to 260mm	600 min	300 min	14 min	179 min

Wakefield 1045 Bright Bar can be supplied as D6 or T6 (or equivalent) with guaranteed mechanical properties on special order request. Wakefield 1045 Black Bar can be supplied in the normalised condition with guaranteed mechanical properties on special order request.

4.3.5 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.3.5.1 Finish

Wakefield 1045 is stocked and supplied in three different surface finish classes:

as rolled/forged (black)
cold drawn or smooth-turned and polished
centreless ground

4.3.5.2 Diameter and A/F tolerances

Wakefield 1045 black round bar is supplied with max. dimensional tolerance on diameter of ±1.5% (min. 0.4mm).

Wakefield 1045 cold drawn/turned round bar is supplied in tolerance h10 or h9. Wakefield 1045 centreless ground round bar is supplied in tolerance h8 or better.

Wakefield 1045 square bar, hexagonal bar and flat bar are supplied in tolerance h11.

4.3.5.3 Straightness – maximum deviation from a straight line

As rolled (black) round bar: 3mm in 1000mm
Bright round bar: 2mm in 1000mm
Centreless ground: 0.3mm in 1000mm
Square, flat and hexagonal bar: 1mm in 375mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.3.5.4 Length Tolerance for Bright Bars

Mill Lengths (3.5 to 6.0m): ± 250mm max.
Set Lengths (3.0 to 7.0m): -0/+100mm max, better tolerance subject to enquiry

4.3.6 MACHINING ALLOWANCES FOR 1045 ROUND BAR (MM ON DIAMETER)

Bar diameter (mm)	Black (hot rolled or forged)		Bright (drawn or peeled bar)	
	Part length <120mm	Part length >120mm	Part length <120mm	Part length >120mm
Up to 50 incl.	2.8mm	2.8 + 6mm/m	1.0mm	1.0 + 4mm/m
>50 to 100 incl.	4.5mm	4.5 + 6mm/m	1.0mm	1.0 + 4mm/m
>100 to 150 incl.	5.3mm	5.3 + 6mm/m	1.0mm	1.0 + 4mm/m
>150 to 200 incl.	9.0mm	9.0 + 6mm/m	1.5mm	1.5 + 4mm/m
>200 to 500 incl.	-	-	1.5mm	1.5 + 6mm/m

Hot-rolling surface defects are retained in cold drawing. For bright bar in the range of cold drawing (up to 50mm) it is essential to take machining allowance into account. Peeled bar is generally free of surface defects. A certain allowance for surface defects is recommended however, as minor defects are permitted by the various national standards (AS, JIS, EN etc.).

4.3.7 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

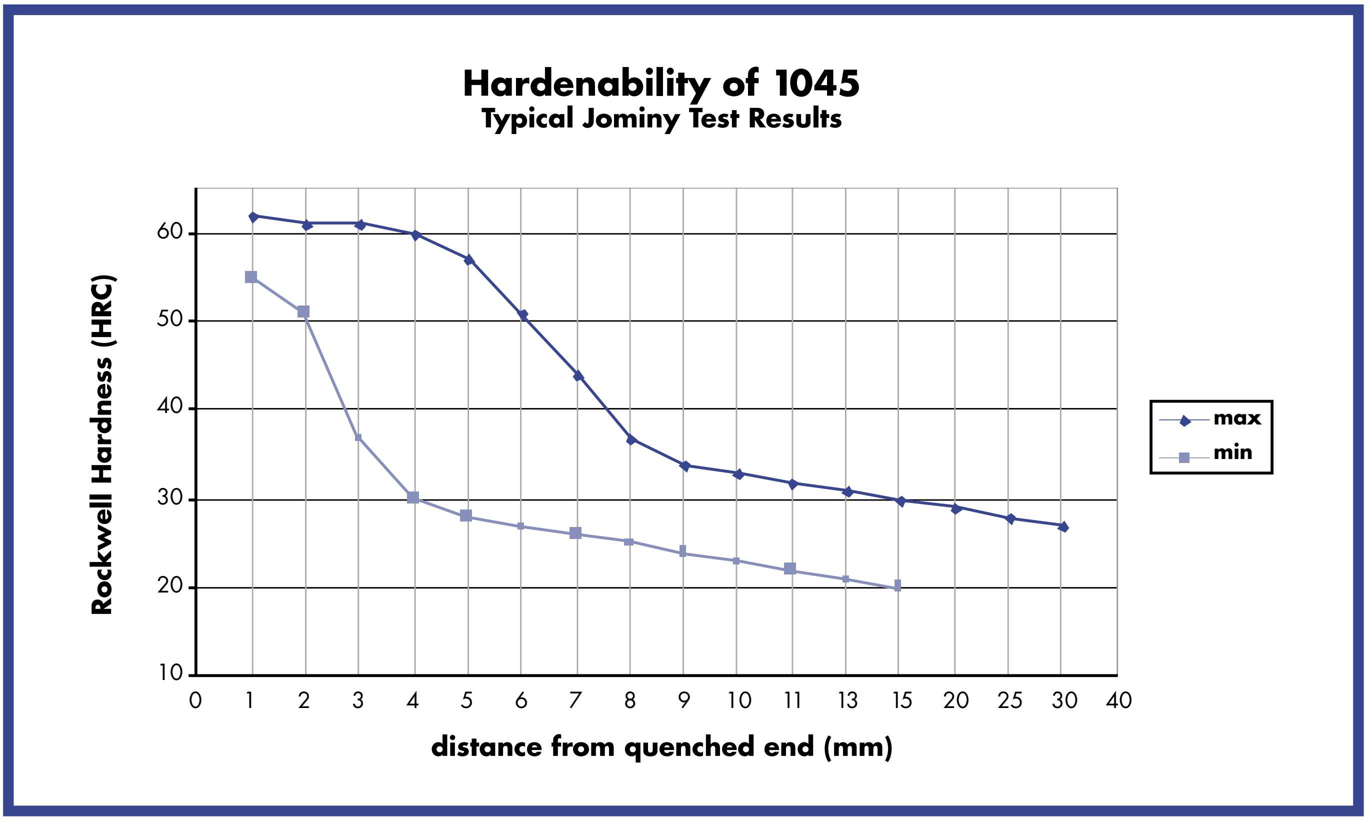
Full Annealing	Normalising	Hardening	Quenching medium	Tempering
800 - 850°C	840 – 880°C	820 – 860°C	Water or Oil	550 – 660°C

4.3.8 TYPICAL MECHANICAL PROPERTIES IN HEAT TREATED CONDITION

After quenching and tempering1045 achieves typically the following mechanical properties.

Diameter (mm)	Tensile Strength (MPa)	0.2% proof stress (MPa)	Elongation (%)	Reduction of Area (%)	Impact 4.3.8.1 Charpy (J)
up to 40 incl	650 – 800	430 min	16 min	40 min	25 min
>40 to 100 incl	630 – 780	370 min	17 min	45 min	25 min
>100 to 250 incl	590 - 740	340 min	18 min	-	22 min
>250 to 500 incl	590 - 740	320 min	17 min	-	20 min

4.3.9 HARDENABILITY DIAGRAM



4.3.10 SURFACE HARDENING

Wakefield 1045 is suitable for induction hardening and flame hardening.

4.3.11 WELDING

Wakefield 1045 can be welded by all conventional welding processes, MIG, TIG, MMAW etc. Pre and Post heating (also in light sections) are required as part of the welding procedure so as to avoid cracking.

4.3.12 APPLICATIONS OF 1045

Grade 1045 is used in general engineering applications. This grade is used in engineering applications where better strength that that offered by either M1020 or M1030 is a requirement. Typical applications include hydraulic rams, shafts and medium to higher strength threaded fasteners. Wakefield 1045 is generally not recommended for critical applications, particularly those where high strength is required in combination with ductility or toughness. For these application low-alloy steels are generally recommended (or in certain cases micro-alloy steels).

4.3.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 1045
M1030	Where a lower tensile and yield strength grade is acceptable. If grade M1030 is used as an alternative then pre and post heat would normally still need to be used, particularly in heavier sections.
4140	Further increase in strength required, plus guaranteed tensile properties are a requirement. Better impact properties are required. Higher core strength required. Welding of grade 4140 would not normally be recommended. In case of attempting to weld this grade guidance from an experienced and qualified welding engineer must be sought.

4.4 1214FM: FREE MACHINING BRIGHT CARBON STEEL BAR Colour Code: Rose Pink

4.4.1 INTRODUCTION

Wakefield 1214FM is a free machining, resulphurised carbon steel bar containing nominally 0.14% carbon. Wakefield 1214FM has similar chemical composition as the grade 1214. Wakefield 1214FM is supplied based on it meeting specified chemical composition requirements only.

4.4.2 RELATED SPECIFICATIONS

Free machining bar Wakefield 1214FM is supplied as per one of the following alternative standards.

AS1443 grade 1214,

ASTM A108 grade 1213 or grade 1215,

Euronorm EN 10087 grade 11SMn30 (1.0715) or grade 11SMn37 (1.0736).

4.4.3 CHEMICAL COMPOSITION

Specification values in %

Grade	C	Si	Mn	P	S
AS 1214	≤ 0.15	≤ 0.10	0.80–1.20	0.04–0.09	0.25–0.35
ASTM 1213	≤ 0.13	–	0.70–1.00	0.07–0.12	0.24–0.33
ASTM 1215	≤ 0.09	–	0.75–1.05	0.07–0.12	0.26–0.35
11SMn30	≤ 0.14	≤ 0.05	0.90-1.30	≤ 0.11	0.27-0.33
11SMn37	≤ 0.14	≤ 0.05	1.00-1.50	≤ 0.11	0.34-0.40

The grades are characterised by high and consistent machinability and the ability to be electroplated. Grades can be interchanged without problems and no marked changes are to be expected by the user. Grade 11SMn37 has the highest machinability of these alternatives.

4.4.4 CONDITIONS OF SUPPLY – TYPICAL MECHANICAL PROPERTIES

Wakefield 1214FM is not tensile tested therefore it is not guaranteed to meet any specified minimum tensile property requirements. The mechanical properties stated below (except HB values) are specified in AS1443 grade D12 (cold drawn) and AS1443 grade T12 (peeled and polished). Grades D12 and T12 are grade 1214 with guaranteed mechanical properties.

Condition	Diameter (mm)	Tensile Strength (MPa)	Yield Stress (MPa)	Elongation (% in 50mm)	Hardness (HB)
Cold Drawn	Up to 16mm inclusive	480 min	350 min	7 min	142 – 226
	>16mm to 38mm inclusive	430 min	330 min	8 min	126 – 210
	>38mm to 100mm inclusive	400 min	290 min	9 min	119 – 200
Cold Finished/ Turned and polished	To 260mm inclusive	370 min	230 min	17 min	105 - 154

Wakefield 1214FM can be supplied with guaranteed mechanical properties on special order request.

4.4.5 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.4.5.1 Surface Finish

Bright round bar up to 63.5mm diameter is all cold drawn. Bright round bars 63.5-100mm diameter are cold drawn or smooth-turned and polished. Bright round bars over 100mm diameter are all smooth-turned and polished.

All hexagon bar and all square bar is cold drawn. Flat Bar is cold drawn and supplied sharp-edged.

4.4.5.2 Diameter and A/F tolerances

Round Bar: Drawn h10; Smooth-turned and polished h11 or h10;
Square Bar: h11; Hex Bar; h11; Flat Bar: h11.

4.4.5.3 Straightness – maximum deviation from a straight line

Round Bar: 1 in 1000mm
Squares, Flats and Hexagon: 1 in 375mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.4.5.4 Length Tolerance Bright Bar

Mill Lengths (3.5 to 6.0m): ± 250mm max.
Set Lengths (3.0 to 7.0m): -0/+40mm max. tolerance is possible subject to enquiry

4.4.6 WELDING

Wakefield 1214 can be welded by all conventional welding processes, MIG, TIG, MMAW etc, however this grade is rich in manganese sulphide inclusions and when welded a low strength poor quality weld normally results. Unless such a weld can be tolerated in the intended application, then welding of this grade should not be attempted.

4.4.7 APPLICATIONS OF 1214FM

General repetition engineering applications where the lower strength and ductility are acceptable. Wakefield 1214FM cannot be through hardened and is not hardenable by either flame or induction hardening processes. It can be case hardened by a blank carburising process. Typical applications are domestic bin axles, concrete anchors, padlock shackles (case hardened), hydraulic fittings. 1214FM has low ductility, so it is unsuitable for applications requiring extensive bending or forming.

4.4.8 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 1214FM
12L14FM	12L14FM might be used where better tool life and a slight improvement in machinability over that of grade 1214FM is a requirement.
M1020	Where welding and/or bending are required and machinability is a secondary requirement. Also where the finally machined components are to be electroplated and a better quality plated finish is a requirement. Where higher ductility is needed than offered by 1214FM because of significant bending or forming operations.
M1030	Where higher strength is required and welding and bending may be required. Pre and post heat may be required as part of the welding procedure for M1030.

4.5 12L14FM: FREE MACHINING STEEL BRIGHT CARBON BAR Colour Code: Violet

4.5.1 INTRODUCTION

Wakefield 12L14FM is a free machining carbon steel bar containing maximum 0.15% Carbon. Due to the addition of Lead (Pb) this grade has the highest machinability and is suitable for high-volume ultra-high speed machining.

4.5.2 RELATED SPECIFICATIONS

Free machining bar 12L14FM is supplied as per the following alternative standards.

- AS1443 grade 12L14, ASTM A108 grade 12L14,
- Euronorm EN 10087 grade 11SMnPb37 (1.0737).

4.5.3 CHEMICAL COMPOSITION

Specification values in %

Grade	C	Si	Mn	P	S	Pb
12L14	≤ 0.15	≤ 0.10	0.80–1.20	0.04–0.09	0.25–0.35	0.15-0.35
11SMnPb37	≤ 0.14	≤ 0.05	1.00-1.50	≤ 0.11	0.34-0.40	0.20-0.35

The grades are equally characterised by very high and consistent machinability and the ability to be electroplated. Grades can be interchanged without problems and no marked changes in machinability are to be expected.

4.5.4 CONDITIONS OF SUPPLY – TYPICAL MECHANICAL PROPERTIES

Wakefield 12L14FM is not guaranteed to meet any specified minimum tensile property requirements. The values in the table below reflect typical properties only. These mechanical properties (except for HB values) are specified in AS1443 grade D13 (cold drawn) and AS1443 grade T13 (peeled and polished). Grades D13 and T13 are essentially grade 12L14FM with guaranteed mechanical properties.

Condition	Diameter (mm)	Tensile Strength (MPa)	Yield Stress (MPa)	Elongation (% in 50mm)	Hardness (HB)
Cold Drawn	Up to 16mm inclusive	480 min	350 min	7 min	142 – 226
	>16mm to 38mm inclusive	430 min	330 min	8 min	126 – 210
	>38mm to 100mm inclusive	400 min	290 min	9 min	119 – 200
Cold Finished/ Turned and polished	To 260mm inclusive	370 min	230 min	17 min	105 - 154

12L14FM can be supplied with guaranteed mechanical properties on special order request.

4.5.5 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.5.5.1 Surface Finish

Bright round bar up to 63.5mm diameter is all cold drawn. Bright round bars of 63.5-100mm diameter are cold drawn or smooth-turned and polished. Bright round bars over 100mm diameter are all smooth-turned and polished.

All hexagon bar and all square bar is cold drawn. Flat Bar is cold drawn and supplied sharp-edged.

4.5.5.2 Diameter and A/F tolerances
Round Bar: Drawn h10; Smooth-turned and polished h10 or h11;
Square Bar: h11; Hex Bar: h11; Flat Bar: h11.

4.5.5.3 Straightness – maximum deviation from a straight line
Round Bar: 1 in 1000mm
Squares, Flats and Hexagon: 1 in 375mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.5.5.4 Length Tolerance
Mill Lengths (3.5 to 6.0m): ± 250mm max.
Set Lengths (3.0 to 7.0m): -0/+40mm max. tolerance is possible subject to enquiry

4.5.6 WELDING

Wakefield 12L14FM is not suitable for any welding. Lead fumes originating during the welding operation constitute a health hazard.

4.5.7 APPLICATIONS OF 12L14FM

General repetition engineering applications where the lower strength of this product is acceptable. Wakefield 12L14FM is not capable of being through hardened and is not hardenable by either flame or induction hardening processes. It can be case hardened by a blank carburising process. Applications such as domestic bin axles, concrete anchors, padlock shackles (case hardened), hydraulic fittings, vice jaws (case hardened). Ductility of Wakefield 12L14FM is low, so it is not suitable for applications requiring significant bending or forming.

4.5.8 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 12L14FM
1214FM	Slightly lower machinability than 12L14FM. Recommended in case the use of leaded steels is a factor of concern, such as in welding or general environmental concern.
M1020	Where welding is required and machinability is a secondary requirement. Also where the finally machined components are to be electroplated and a better quality plated finish is a requirement. Where higher ductility is required because of significant bending and forming.
M1030	Where higher strength is required and welding and bending may be required. Pre and post heat may be required as part of the welding procedure, whereas M1020 is readily welded without pre & post heating.

4.6 4140: THROUGH-HARDENING LOW ALLOY STEEL BAR

Colour Coding: Jade (band) - Bluebell

4.6.1 INTRODUCTION

Wakefield 4140 is a Chromium-Molybdenum through-hardening steel of medium hardenability. It is a general purpose high-tensile steel with medium strength level and good impact properties.

4.6.2 RELATED SPECIFICATIONS

Material stocked by Wakefield complies with grade AS1444 Grade 4140 and/or ASTM A434 (A29) Grade 4140 and/or Euronorm EN 10083 grade 42CrMo4 (Material Number 1.7225/17227).

4.6.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Cr	Mo	Ni
0.37-0.44	0.10-0.35	0.65-1.10	≤ 0.040	≤ 0.040	0.75-1.20	0.15-0.30	–

4.6.4 CONDITIONS OF SUPPLY – MECHANICAL PROPERTIES

Wakefield 4140 is supplied in the hardened and tempered condition. The level of hardness is selected to give useful strength while still maintaining the ability to machine the material into finished components.

Diameter (mm)	Heat Treated Condition	Tensile Strength (MPa)	0.2% proof stress (MPa)	Elongation (% in 50mm)	Impact Izod (J) or Charpy (J)	Hardness (HB)
up to 180 incl	AS1444 Condition U	930 – 1080	740 min	12 min	47 min 42 min	269 - 331
>180 to 250 incl	AS1444 Condition T	850 – 1000	665 min	13 min	54 min 50 min	248 – 302
>250 to 450 incl	AS1444 Condition T	850 – 1000	665 min	13 min	not guaranteed	248 – 302

Wakefield 4140 can be re-heat-treated to higher strength or tempered back to lower strength levels than those supplied as standard. Assistance with heat treatment should be sought from reputable heat treatment companies

4.6.5 CONDITIONS OF SUPPLY – SURFACE FINISH AND MACHINING ALLOWANCE

Wakefield 4140 Black is supplied with +/– tolerances according to DIN 1013 or better. Wakefield 4140 Bright is supplied cold drawn with h10 tolerance for bar diameters up to 25mm; bars with diameters 25 to 75mm are supplied as cold drawn with h10 tolerance or peeled with k12 tolerance, diameters 75-220mm are supplied peeled to k12, sizes over 210mm are supplied peeled to -0/+2mm.

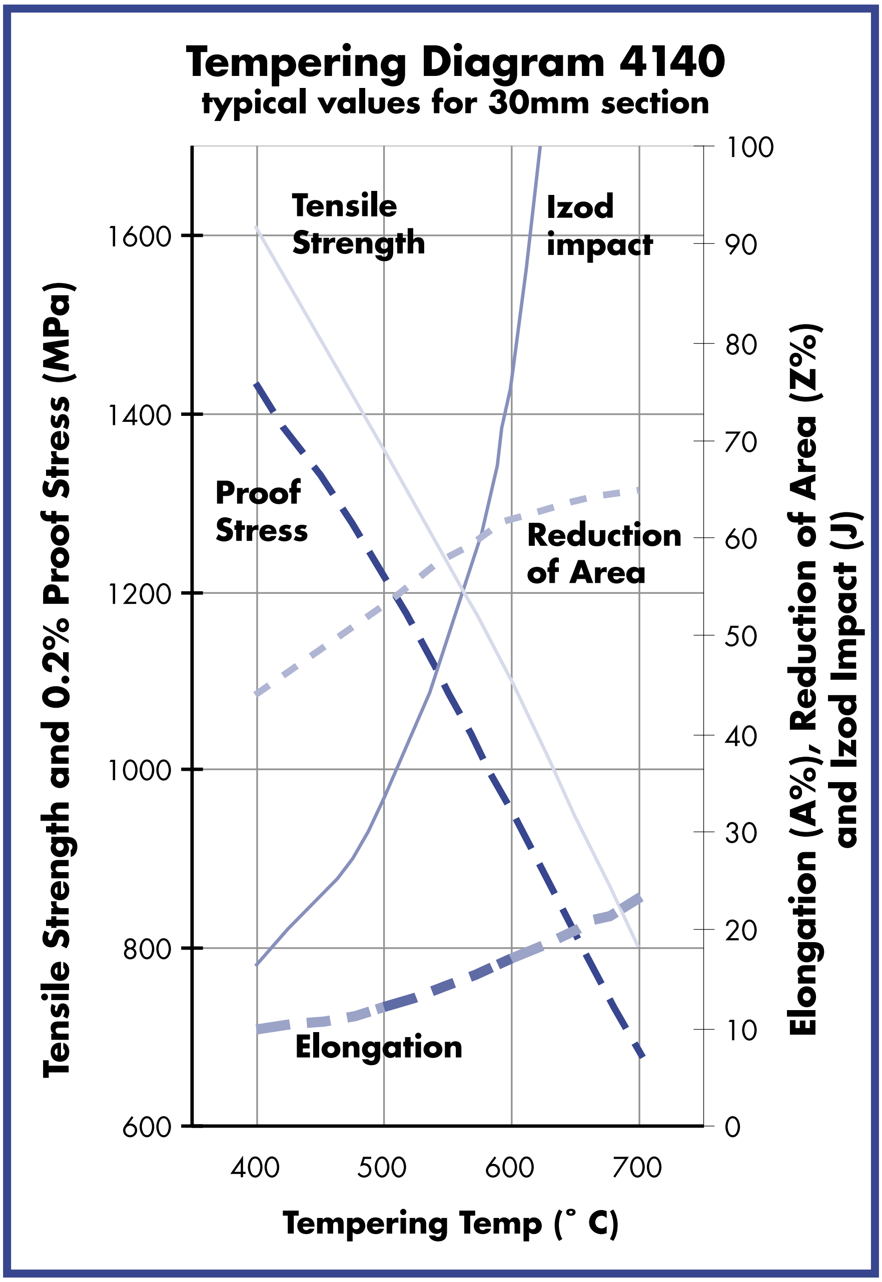
4.6.6 MACHINING ALLOWANCES FOR 4140 ROUND BAR (MM ON DIAMETER)

Bar diameter (mm)	Black (hot rolled or forged)		Bright (drawn or peeled bar)	
	part length <120mm	part length >120mm	part length <120mm	part length >120mm
0-50	1.5mm	1.5 + 6mm/m	1.0mm	1.0 + 4mm/m
50-100	2.3mm	2.3 + 6mm/m	1.0mm	1.0 + 4mm/m
100-150	4.5mm	4.5 + 6mm/m	1.0mm	1.0 + 4mm/m
150-210	6.5mm	6.5 + 6mm/m	1.5mm	1.5 + 4mm/m
210-450	-	-	1.5mm	1.5 + 6mm/m

Hot-rolling surface defects are retained in cold drawing. For bright bar in the range of cold drawing (up to 50mm) it is essential to take machining allowance into account. Peeled bar is generally free of surface defects. A certain allowance for surface defects is recommended however, as minor defects are permitted by the various national standards (AS, EN, etc.).

4.6.7 HEAT TREATMENT

Annealing	Normalising	Hardening	Quenching medium	Tempering
850°C	850 – 920°C	850 – 860°C	Oil	500 – 680°C



Hardening

Components should be heated slowly to 850 to 860°C, held until uniform, then quenched vigorously in oil (or polymer with an equivalent quench rate to between 80 to 110°C). Polymer quenchants have similar cooling capacities to oil, while having the advantage of a being less likely to ignite.

Tempering

While still warm, re-heat to tempering temperature, hold one hour per 25mm of section (2 hours minimum) and cool in air. Select tempering temperatures according to the required mechanical properties (refer to tempering curve).

Holding in the temperature range 230 to 370°C should be avoided due to possible temper embrittlement ("Blue Brittleness"). For yield strengths above 1380MPa: temper 1/2 to 2 hours at between 175 and 230°C, while for yield strengths below 1380MPa temper in the temperature range 500 to 680°C, then air cool or water quench.

4.6.8 SURFACE HARDENING

Nitriding: Nitride at approximately 510°C for 10 to 60 hours, depending upon required case depth. Surface hardness achievable is 600 to 650HV.

Induction or Flame Hardening: Wakefield 4140 can be surface hardened to 58HRC (typical value).

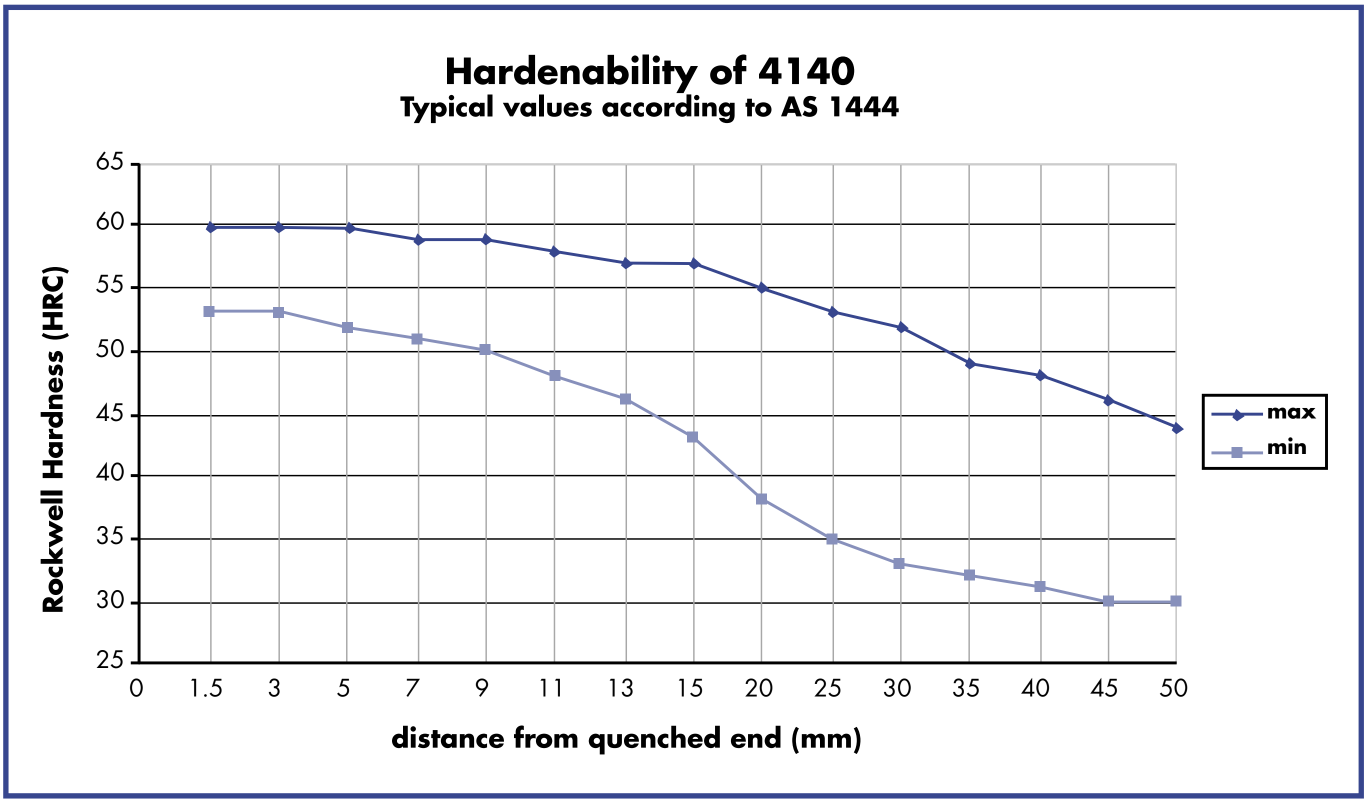
4.6.9 WELDING

Welding is not recommended because of the likelihood of quench cracking occurring. If welding must be carried out, pre-heat to 200 to 300°C and maintain this while welding. Immediately after welding stress relieve at 500 to 600°C.

4.6.10 APPLICATIONS OF 4140

Medium-high stressed shafts and components where the use of carbon steel 1045 would not be appropriate. Reasons for using 4140 are the higher yield and fatigue strength, better through hardening of the material and superior impact properties compared to plain carbon steels like 1045. These advantages are only achieved when 4140 is used in the heat treated condition. Typical components include transmission shafts, spindles and small gears, threaded fasteners such as bolts, nuts and studs.

4.6.11 HARDENABILITY DIAGRAM



4.6.12 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 4140
6582 or 4340	Higher core strength required, especially in sections larger than 100mm. These grades also have better impact properties and ductility (in all sections).

4.7 Wakefield 6582: THROUGH – HARDENING LOW ALLOY STEEL BAR

Colour coding: Jade (band) – Rose Pink

4.7.1 INTRODUCTION

Wakefield 6582 alloy bar is a high performance through-hardening steel that offers high yield and tensile strength after heat treatment whilst maintaining good toughness and ductility. This product is a close equivalent to ASTM 4340 and outperforms 4340 in its through-hardening and impact properties.

4.7.2 RELATED SPECIFICATIONS

Wakefield 6582 low-alloy steel bar complies with grade 34CrNiMo6 (Euronorm EN 10083) described under Material Number 1.6582.

4.7.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Cr	Ni	Mo
0.30-0.38	≤ 0.40	0.50-0.80	≤ 0.035	≤ 0.035	1.30-1.70	1.30-1.70	0.15-0.30

4.7.4 CONDITIONS OF SUPPLY – MECHANICAL PROPERTIES

Normally supplied in the quenched and tempered condition, with strength levels varying according to diameter in order to optimise the strength-toughness balance.

Diameter (mm)	Tensile Strength (MPa min)	Approx. mechanical Condition	0.2% proof stress (MPa)	Elongation (A%)	Reduction of area (Z%)	Impact value (ISO-V) (J) KV
≤ 40	1100 – 1300	W/X	900 min	10 min	45 min	45 min
> 40 ≤ 100	1000 – 1200	V/W	800 min	11 min	50 min	45 min
> 100 ≤ 160	900 – 1100	U/V	700 min	12 min	55 min	45 min
> 160 ≤ 250	800 – 950	T	600 min	13 min	55 min	45 min
> 250 ≤ 500	750 – 900	S	540 min	14 min	–	45 min

The third column in the table above shows the mechanical properties of Wakefield 6582 and the closest mechanical properties designation according to AS 1444-1996 for reference purposes.

4.7.5 CONDITIONS OF SUPPLY – TOLERANCES AND INSPECTION

Wakefield 6582 is supplied hot rolled (black) or cold finished in the as heat treated condition.

Wakefield 6582 Black is supplied with very tight tolerances in order to reduce machining allowances to a minimum. Dimensional tolerance better than 1/2 DIN 1013 (up to 210mm, DIN 1013 for sizes over 210mm). Depth of surface defects max. 0.50mm (all sizes). Out of straightness tolerance: 40 - 100mm diameter 2mm/m; 100 - 210mm diameter 2.5mm/m.

Wakefield 6582 Bright is supplied cold drawn with tolerance h10 for sizes up to 25mm. Bars with diameters 25 to 75mm are supplied cold drawn to h10 or peeled to k12. Bar diameters 76mm to 210mm are supplied peeled to k12 and sizes over 210mm are peeled to a -0/+2mm tolerance.

4.7.6 MACHINING ALLOWANCES FOR Wakefield 6582 ROUND BAR (MM ON DIAMETER)

Bar diameter (mm)	Black (hot rolled or forged)		Bright (drawn or peeled bar)	
	part length <120mm	part length >120mm	part length <120mm	part length <120mm
≤ 50	1.4mm	1.4 + 4mm/m	1.0mm	1.0 + 4mm/m
> 50 ≤ 100	1.7mm	1.7 + 4mm/m	1.0mm	1.0 + 4mm/m
> 100 ≤ 160	2.0mm	2.0 + 5mm/m	1.0mm	1.0 + 4mm/m
> 160 ≤ 210	2.3mm	2.3 + 5mm/m	1.5mm	1.5 + 4mm/m
> 210 ≤ 450	-	-	1.5mm	1.5 + 6mm/m

e.g. an Wakefield 6582 Black 180mm diameter bar with a length of 500mm requires a machining allowance of 2.3mm + 0.5x5mm = 4.8mm and therefore cleans up to 175.2mm.
All bars have been subject to ultrasonic inspection (to AS1065 level 2).

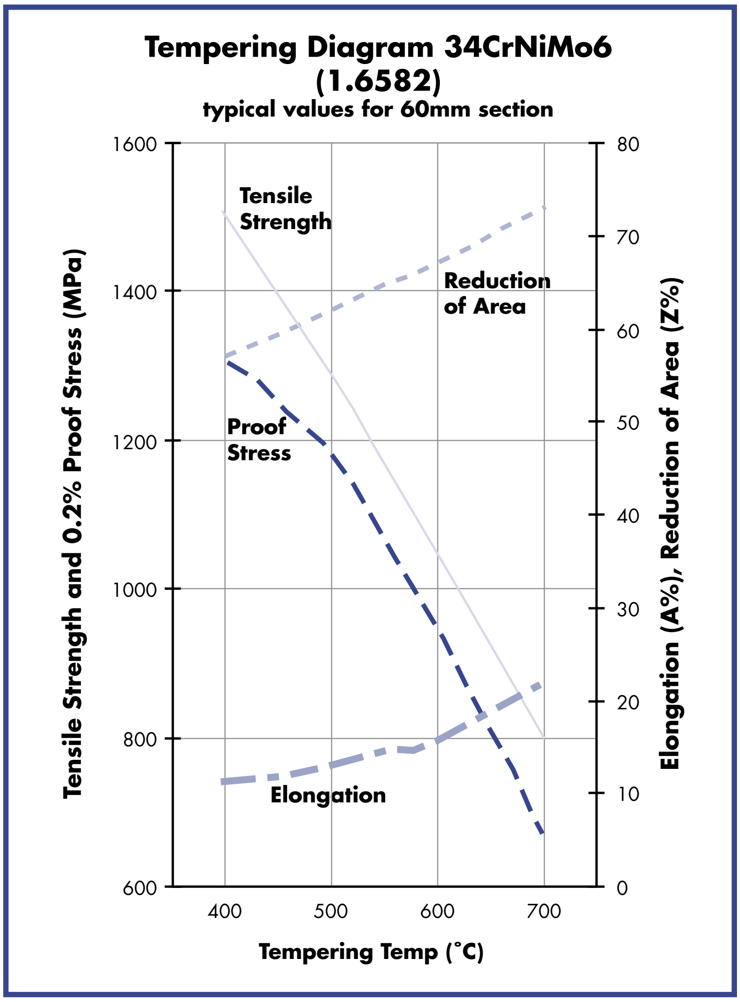
4.7.7 APPLICATIONS

Parts exposed to high permanent or fluctuating stresses. Applications where excellent fatigue and toughness properties of the material are required. Typical components include gears, planetary gears, pinions, crankshafts, eccentric shafts, axles, bushes and sleeves.

4.7.8 HEAT TREATMENT

Normalising	Hardening	Quenching medium	Tempering
850 – 880°C	830 – 860°C	Oil	540 – 660°C

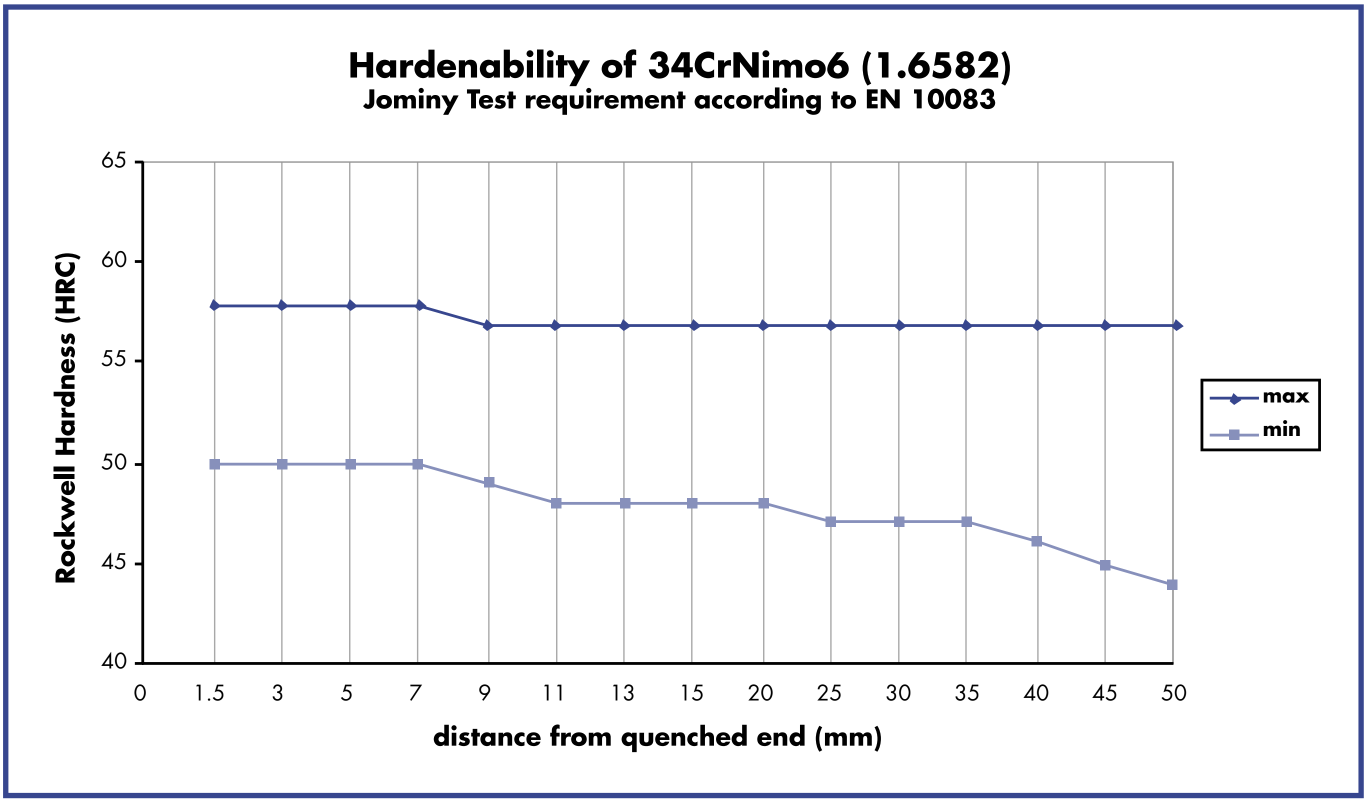
4.7.9 TEMPERING DIAGRAM



4.7.10 WELDING

Welding is not recommended because of the high hardenability of this steel and hence the likelihood of embrittlement in the heat affected zone and connected danger of quench cracking. If welding must be carried out, pre-heat to 200 to 300°C and maintain this while welding. Immediately after welding stress relieve at 550 to 650°C.

4.7.11 HARDENABILITY DIAGRAM



4.7.12 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 6582
4340	Similar strength properties as Wakefield 6582. Through-hardening response in larger sections not as good as Wakefield 6582. Impact properties of Wakefield 6582 are superior to 4340.
4140	Lower cost and good availability in a range of sizes. However, in general significantly lower impact properties characteristically apply when heat-treated to similar strength levels as 6582. Through-hardening response substantially lower in large sections than 6582.
6580	Higher yield strength and fatigue achievable, especially in larger sections, when heat treated to similar impact properties as 6582. Higher toughness is also achieved in 6580.

4.8 4340: THROUGH-HARDENING LOW ALLOY STEEL BAR

Colour Coding: Jade (band) - Marigold

4.8.1 INTRODUCTION

Wakefield 4340 is a nominally 1.8 percent Nickel Chromium Molybdenum low alloy steel of high hardenability, with high strength and toughness in relatively large sections achieved with a "quench-and-temper" heat treatment. A contemporary alternative to 4340 is Wakefield 6582 through-hardening steel that has improved through-hardening characteristics and offers superior impact properties to 4340 at equivalent strength levels.

4.8.2 RELATED SPECIFICATIONS

Wakefield 4340 low-alloy steel bar complies with grade AS1444, Grade 4340 and/or ASTM A434(A29) Grade 4340. Wakefield 4340 is an alternative to Wakefield 6582 through-hardening steel and to JIS SCNM447.

4.8.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Cr	Mo	Ni
0.37-0.44	0.10-0.35	0.55-0.90	≤ 0.040	≤ 0.040	0.65-0.95	0.20-0.35	1.55-2.00

4.8.4 CONDITIONS OF SUPPLY – MECHANICAL PROPERTIES

Wakefield 4340 is supplied in the hardened and tempered condition. The level of hardness is selected to give useful strength while still maintaining the ability to machine the material into finished

Diameter (mm)	Tensile Strength (MPa)	Approx. Mechanical condition AS1444	0.2% proof stress (MPa)	Elongation (A%)	Impact value Charpy (J)
≤ 60	1000 – 1150	V	835 min	12 min	42 min
> 60 ≤ 100	930 – 1080	U	740 min	12 min	42 min
> 100 ≤ 178	930 – 1080	U	720 min	14 min	50 min
> 178 ≤ 240	900 – 1000	T	690 min	14 min	35 min

The third column in the table above shows the mechanical properties of Wakefield 4340 and the closest mechanical properties designation according to AS 1444-1996 for reference purposes.

4.8.5 CONDITIONS OF SUPPLY – SURFACE FINISH AND MACHINING ALLOWANCE

Wakefield 4340 Black is supplied with +/– tolerance according to DIN 1013 or better. Wakefield 4340 Bright is supplied cold drawn with h10 tolerance for bars up to 25mm diameter. Bars with diameters 25 to 75mm are supplied cold drawn to h10 or peeled to k12. Bars 75 to 210mm are supplied peeled to k12 and sizes over 210mm are peeled to a -0/+2mm tolerance.

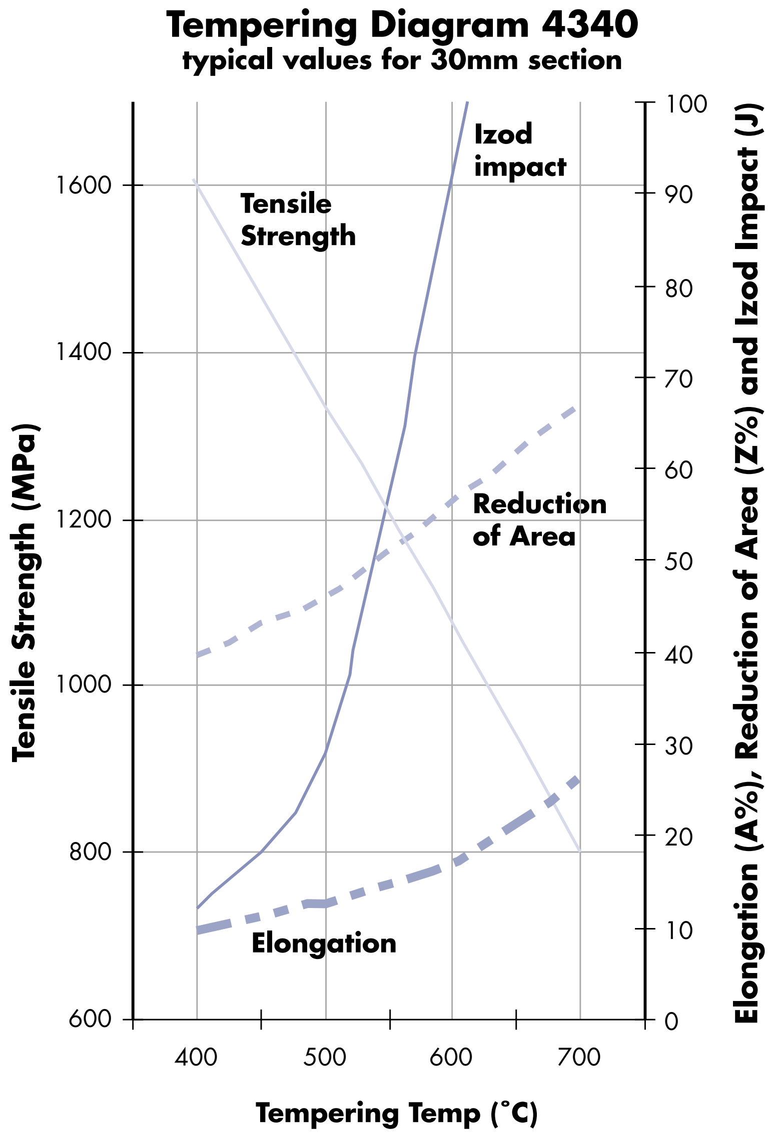
4.8.6 MACHINING ALLOWANCES FOR 4340 ROUND BAR (MM ON DIAMETER)

Bar diameter (mm)	Black (hot rolled or forged)		Bright (drawn or peeled bar)	
	part length <120mm	part length >120mm	part length <120mm	part length >120mm
0-50	1.5mm	1.5 + 6mm/m	1.0mm	1.0 + 4mm/m
50-100	2.3mm	2.3 + 6mm/m	1.0mm	1.0 + 4mm/m
100-150	4.5mm	4.5 + 6mm/m	1.0mm	1.0 + 4mm/m
150-210	6.5mm	6.5 + 6mm/m	1.5mm	1.5 + 4mm/m
210-450	-	-	1.5mm	1.5 + 6mm/m

Hot-rolling surface defects are retained in cold drawing. For bright bar in the range of cold drawing (up to 50mm) it is essential to take machining allowance into account. Peeled bar is generally free of surface defects. A certain allowance for surface defects is recommended however, as minor defects are permitted by the various national standards (AS, EN, etc.).

4.8.7 HEAT TREATMENT

Annealing	Normalising	Hardening	Quenching medium	Tempering
850°C	850 – 920°C	850 – 860°C	Oil	450 – 650°C



HARDENING

Heat components slowly to 850°C, hold until uniform then quench vigorously in oil (or polymer with an equivalent quench rate) to between 80 and 110°C.

TEMPERING

While still warm, re-heat to 450 to 650°C, hold one hour per 25mm of section (2 hours minimum) and cool in air. Select tempering temperatures according to the required mechanical properties – refer to tempering curve.

STRESS RELIEVING

For pre-hardened steel stress relieving is achieved by heating to between 500 to 550°C. Re-treated bars or forgings heat to 25°C below tempering temperature. Annealed components, heat to 600 to 650°C. Hold in this temperature range for 1 to 2 hours, furnace cool to 450°C, then air cool.

4.8.8 SURFACE HARDENING

Nitriding: Nitride at approximately 510°C for 10 to 60 hours, depending upon required case. Surface hardness achievable is 600 to 650HV.

Induction or Flame Hardening: Wakefield 4340 can be surface hardened to 58HRC (water quench) or surface hardened to between 53 to 55HRC (oil quench). Tempering at 200°C.

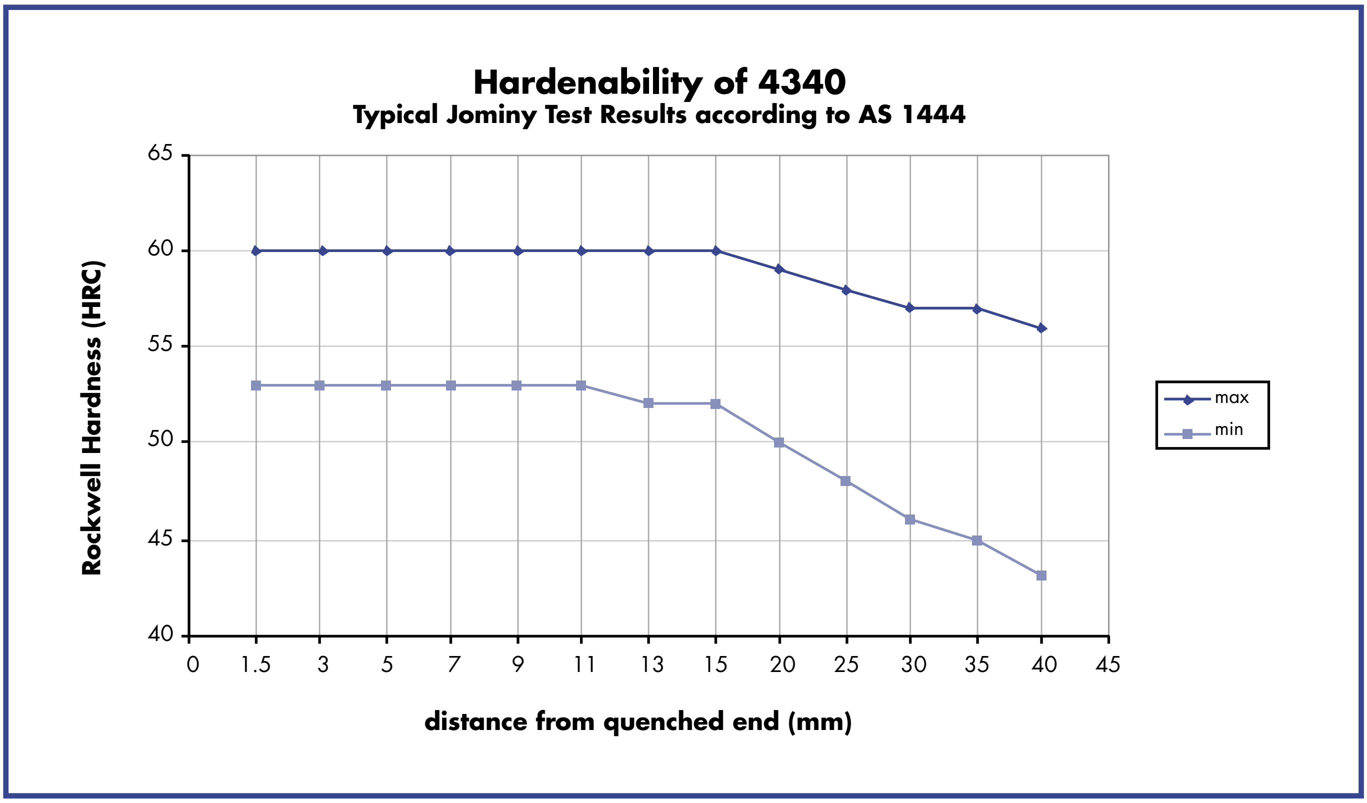
4.8.9 WELDING

Welding is not recommended because of the danger of quench cracking. If welding must be carried out, pre-heat to 200 to 300°C and maintain this while welding. Immediately after welding stress relieve at 550 to 650°C.

4.8.10 APPLICATIONS OF 4340

Parts exposed to high permanent and fluctuating stresses. Applications where excellent fatigue and toughness properties of the material are required. Typical components include gears, planetary gears, axles, pinions, shafts, bushes and sleeves.

4.8.11 HARDENABILITY DIAGRAM



4.8.12 POSSIBLE ALTERNATIVE GRADES

Grade	Why it might be chosen instead of 4340
4140	Lower cost and better availability in a range of sizes. However, in general slightly lower impact properties achieved when heat-treated to similar strength levels as 4340.
6582	Superior impact properties and through-hardening when heat-treated to similar strength levels as 4340.
6580	Substantially higher yield strength achievable, especially in larger sections, when heat treated to similar impact properties as 4340. Higher toughness is also achieved in 6580.

4.9 6580: THROUGH – HARDENING LOW ALLOY STEEL BAR

Colour code: Jade (band) - Lime

4.9.1 INTRODUCTION

Wakefield 6580 alloy bar is the ultimate through-hardening steel that offers exceptional yield and tensile strengths whilst maintaining good toughness and ductility. The grade is a contemporary alternative to En25 and En26 is and outperforms these grades in terms of achievable strength, hardenability and toughness-strength ratio. It enjoys increasing popularity due to its versatility and its price/performance ratio.

4.9.2 RELATED SPECIFICATIONS

Wakefield 6580 alloy bar complies with grade 30CrNiMo8 (Euronorm EN 10083) described under Material Number 1.6580.

4.9.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Cr	Ni	Mo
0.26-0.34	≤ 0.40	0.30-0.60	≤ 0.035	≤ 0.035	1.80-2.20	1.80-2.20	0.30-0.50

4.9.4 CONDITIONS OF SUPPLY – MECHANICAL PROPERTIES

Normally supplied in the quenched and tempered condition, with strength levels varying according to diameter in order to optimise the strength-toughness balance.

Diameter (mm)	Tensile Strength (MPa)	Approx. mechanical condition	0.2% proof stress (MPa)	Elongation (A%)	Reduction of area (Z%)	Impact value (ISO-V) (J) KV
≤ 40	1300 – 1450	Y	1100 min	9 min	40 min	30 min
> 40 ≤ 100	1200 – 1300	X	1020 min	10 min	45 min	35 min
> 100 ≤ 160	1100 – 1200	W	925 min	11 min	50 min	45 min
> 160 ≤ 250	1000 – 1100	V	820 min	12 min	50 min	45 min
> 250 ≤ 500	900 - 1000	U	700 min	12 min	–	45 min

The third column in the table above shows the mechanical properties of Wakefield 6580 and the closest mechanical properties designation according to AS 1444-1996 for reference purposes.

4.9.5 CONDITIONS OF SUPPLY – TOLERANCES AND INSPECTION

Wakefield 6580 is supplied hot rolled or forged (black) in the as heat treated condition. The product is supplied with very tight tolerances in order to reduce machining allowances to a minimum. Dimensional tolerance better than /21 DIN 1013 (up to 210mm). Depth of surface defects max. 0.50mm (up to 210mm).
Out of straightness tolerance: 40 - 100mm diameter 2mm/m; 100 - 210mm diameter 2.5mm/m.
Bars over 210mm diameter are supplied peeled to -0/+2mm tolerance.
All bars have been subject to ultrasonic inspection according to AS1065 level 2.

4.9.6 MACHINING ALLOWANCE CHART

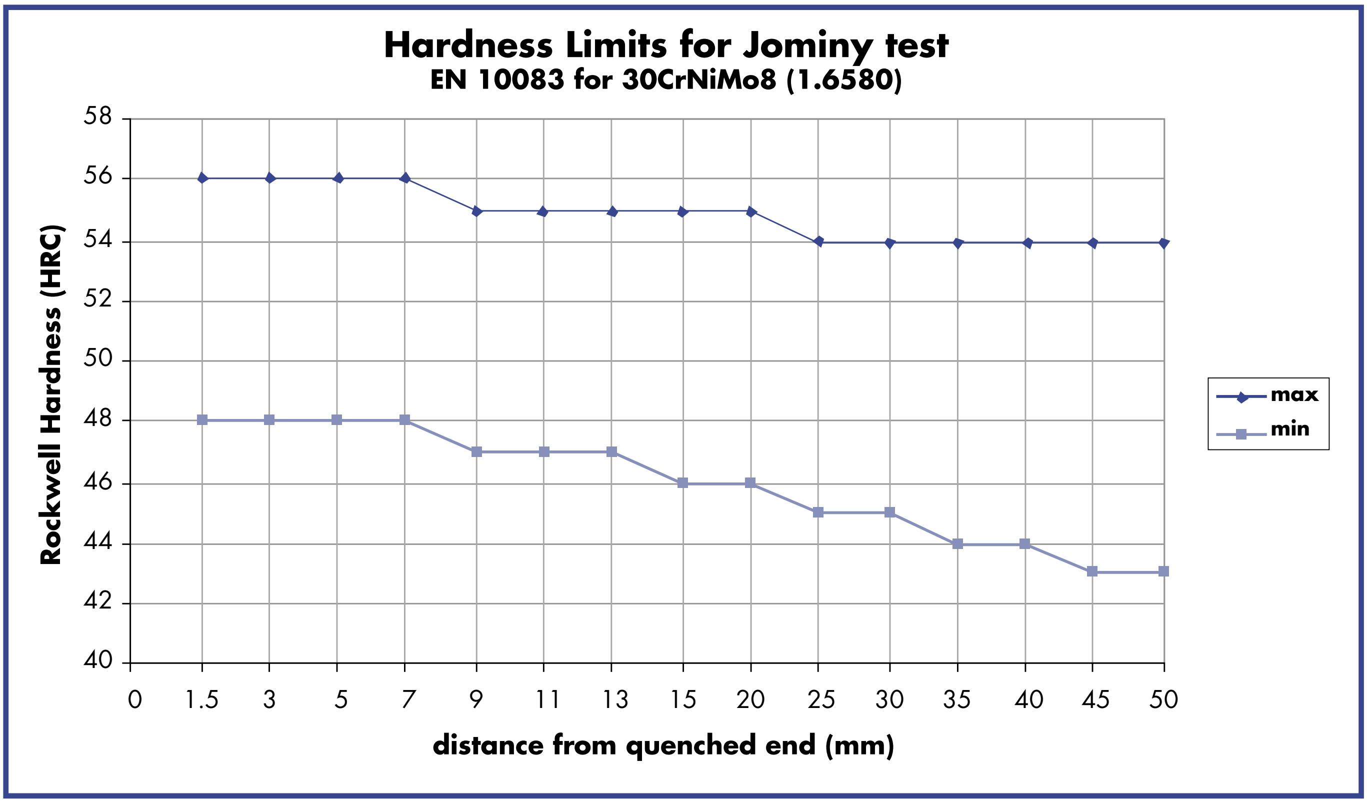
Bar diameter (mm)	Machining Allowance (mm on total diameter)	
	Part length <120mm	Part length >120mm
≤ 50	1.4mm	1.4 + 4mm/m
> 50 ≤ 100	1.7mm	1.7 + 4mm/m
> 100 ≤ 160	2.0mm	2.0 + 5mm/m
> 160 ≤ 210	2.3mm	2.3 + 5mm/m

e.g. a 180mm diameter bar with a length of 500mm requires a machining allowance of 2.3mm+0.5x5mm = 4.8mm and therefore cleans up to 175.2mm.

4.9.7 HEAT TREATMENT

Normalising	Hardening	Quenching medium	Tempering
850 – 880°C	830 – 860°C	Oil	540 – 660°C

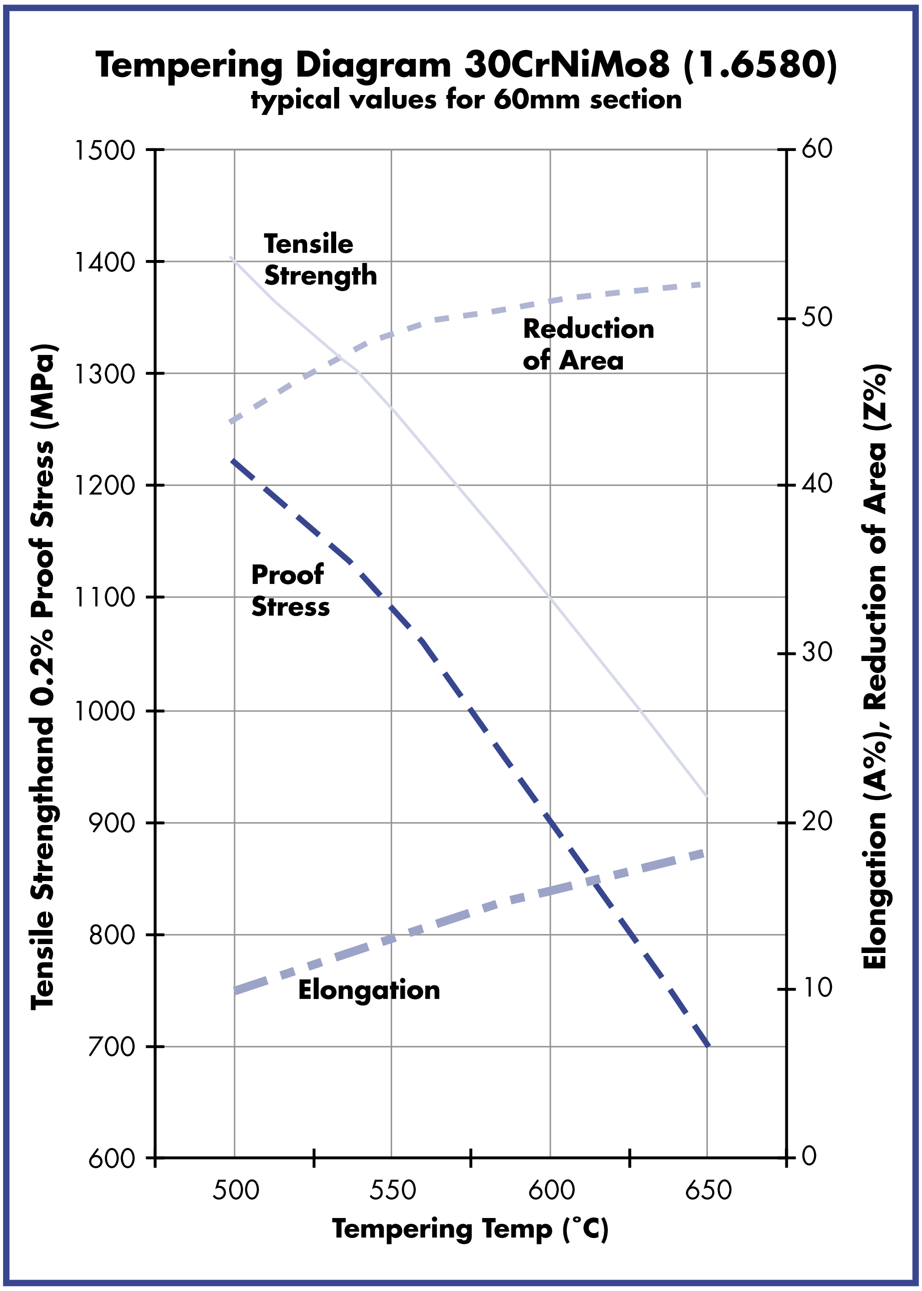
4.9.8 HARDENABILITY DIAGRAM



4.9.9 WELDING

Welding Wakefield 6580 would normally be avoided as this grade has a very high hardenability and therefore embrittlement in the heat affected zone will occur. If welding is unavoidable pre-heat to between 200 to 300°C, maintain this temperature during the welding operation and stress relieve at 550 to 600°C immediately after welding.

4.9.10 TEMPERING DIAGRAM



4.9.11 APPLICATIONS

Parts exposed to highest dynamic stresses. Applications where excellent fatigue properties of the material are required. Typical components include gears, planetary gears, drive pinions, shafts, bushes and sleeves. Bars with diameters up to 40mm have hardness of 44/45 HRC in the rim area and given the high toughness of the material Wakefield 6580 will perform well in applications where currently induction hardened components in grades 4140 or 4340 are being used.

4.10 8620H: CASE–HARDENING STEEL BAR

Colour Code: Red (Band) - White

4.10.1 INTRODUCTION

8620H is a low Nickel Chromium Molybdenum case-hardening steel of medium hardenability used principally for relatively lightly stressed components.8620H can be carburised and subsequently hardened by a quenching and tempering operation. The “H” designation of 8620H indicates guaranteed hardenability according to the hardenability diagram on the following page.

4.10.2 RELATED SPECIFICATIONS

Wakefield 8620H complies with AS1444 Grade 8620H and/or ASTM A29 Grade 8620. Alternatively Wakefield 8620H can be supplied as Euronorm grade 20NiCrMo2-2+HH (Material Number 1.6523/1.6526 under EN 10084).

4.10.3 CHEMICAL COMPOSITION

Specification values in %

Grade	C	Si	Mn	P	S	Cr	Ni	Mo
8620H	0.17-0.23	0.10-0.35	0.60-0.95	≤ 0.040	≤ 0.040	0.35-0.65	0.35-0.75	0.15-0.25
1.6523	0.17-0.23	≤ 0.40	0.65-0.95	≤ 0.035	≤ 0.035	0.35-0.70	0.40-0.70	0.15-0.25

4.10.4 CONDITIONS OF SUPPLY

Normally supplied in the annealed condition with hardness max 212 HB, with typical hardness being in the range 170-200 HB. Bars are cold finished (peeled) and supplied to k12 tolerance for all bar diameters. All bars are ultrasonically inspected to AS1065 level 2.

4.10.5 HEAT TREATMENTS

Treatment	Temperature Range (°C)	Cooling
Carburising	880 - 960	Oil (water), hot quench 160-250°C, Salt bath 580-650°C, Case-hardening box, Air*
Intermediate annealing	630 - 650	Air, Furnace
Core hardening	860 – 900	Oil (water), hot quench 160-250°C*
Case hardening	780 – 820	Oil (water), hot quench 160-250°C*
Tempering	150 - 200	Air

** the choice of cooling medium depends on the desired final properties and geometry of the section to be case hardened and the effect of the cooling medium, given the hardenability of the steel.*

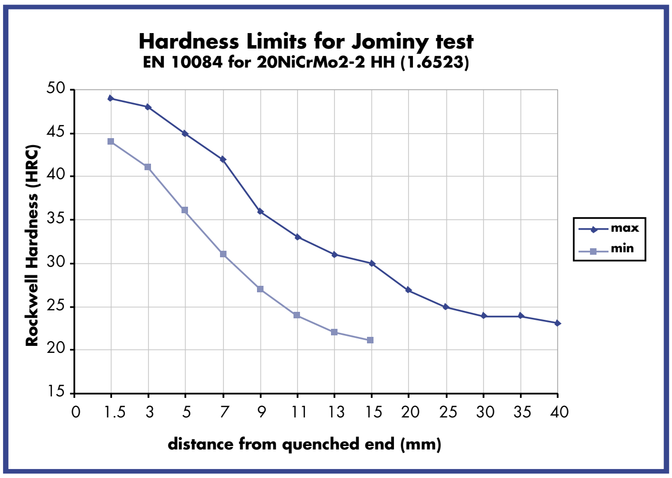
After final machining, heat in carburising atmosphere (blank carburise) to 880 to 960°C and hold for sufficient time at temperature to produce the required case depth. The time at temperature during the blank carburising process determines the depth of case achieved.
After completion of blank carburisation treatment, re-heat to 860-900°C, hold until uniform and then quench in oil as rapidly as practical.
A refining treatment is necessary to improve the structure of the case and its hardness. Heat slowly to 780-820°C, hold until uniform and then quench in oil.
Single quench treatment may also be possible where components are quenched directly from 820 to 840°C.
Minimum tempering time is 1 hour, but a tempering period of 1 hour per 25mm of section is recommended. If the steel is to be direct hardened, in general, a carburising temperature of 950°C should not be exceeded. After case hardening a typical case hardness of 61 HRC can be achieved.

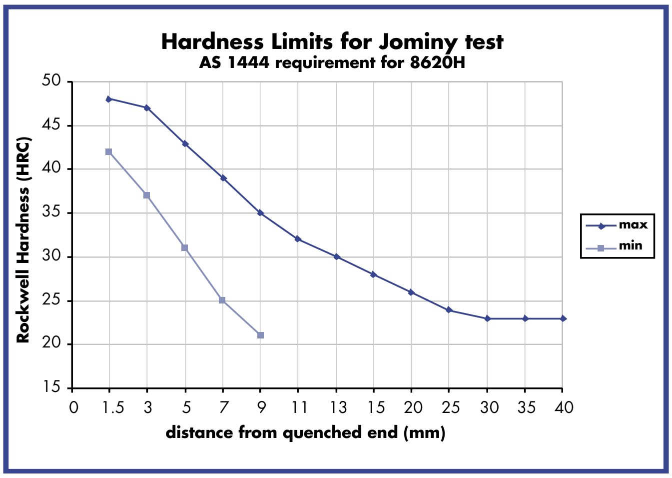
4.10.6 MECHANICAL PROPERTIES AFTER CASE HARDENING

The following table shows the typical mechanical properties achievable in the core of a test section after carburizing, hardening and tempering.

Diameter (mm)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (A%)	Impact Value DVM (J)
11	785 min	980 – 1270	9 min	41 min
30	590 min	780 – 1080	10 min	41 min
63	490 min	690 – 930	11 min	–

4.10.7 HARDENABILITY DIAGRAM





4.10.8 WELDING

Pre-heat welding area to 250-450°C and maintain this temperature while welding with a low hydrogen electrode. Cool at a maximum rate of 100°C per hour. Weld before carburising.

4.10.9 APPLICATIONS

Small diameter gear parts exposed to low-medium stress. Typical components include gears, planet wheels, drive pinions, shafts.

4.11 6587: CASE–HARDENING ALLOY STEEL BAR

Colour coding: Signal Red (band) - Black

4.11.1 INTRODUCTION

Steel grade 17CrNiMo6 was registered as a grade in 1991 and is therefore one of the most contemporary grades in the alloy bar market. It is characterised by high case hardness and depth combined with excellent core strength. Recently the grade has been developed further by slightly increasing Carbon and Manganese content and this led to the new designation 18CrNiMo7-6, which is the current official designation for this steel under Euronorm EN 10084, which supersedes DIN17210.

4.11.2 RELATED SPECIFICATIONS

6587 low-alloy steel bar complies with both 17CrNiMo6 (DIN17210) and 18CrNiMo7-6 (EN 10084) both described under Material Number 1.6587. The specification of 17CrNiMo6 is practically equivalent to grade X4317 under AS 1444.

4.11.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Cr	Ni	Mo
0.15-0.21	≤ 0.40	0.50-0.90	≤ 0.035	≤ 0.035	1.50-1.80	1.40-1.70	0.25-0.35

4.11.4 CONDITIONS OF SUPPLY

Normally supplied in the annealed condition with hardness max 229 HB, with typical hardness being in the range 170-200 HB. Bars are supplied peeled to k12 tolerance for bar diameters up to 210mm and peeled to -0/+2mm tolerance for larger diameters. All bars are ultrasonically inspected to AS1065 level 2.

4.11.5 HEAT TREATMENT

Treatment	Temperature Range (°C)	Cooling
Carburizing	880 - 980	Oil (water), hot quench 160-250°C,Salt bath 580-680°C, Case-hardening box, Air*
Intermediate annealing	630 - 650	Air, Furnace
Core hardening	830 – 870	Oil (water), hot quench 160-250°C*
Case hardening	780 – 820	Oil (water), hot quench 160-250°C*
Tempering	150 - 200	Air

** the choice of cooling medium depends on the desired final properties and geometry of the section to be case hardened and the effect of the cooling medium, given the hardenability of the steel*

The minimum tempering time is 1 hour, but a tempering period of 1 hour per 25mm of section is recommended. If the steel is to be direct hardened, then in general, a carburizing temperature of 950°C is not to be exceeded. After case hardening a typical surface (case) hardness of 62 HRC can be achieved. Gas carburizing for 2 hours at 925°C results in 0.8mm case depth, whilst carburizing for 24 hours at 925°C results in 3.1mm case depth.

4.11.6 MECHANICAL PROPERTIES AFTER CASE HARDENING

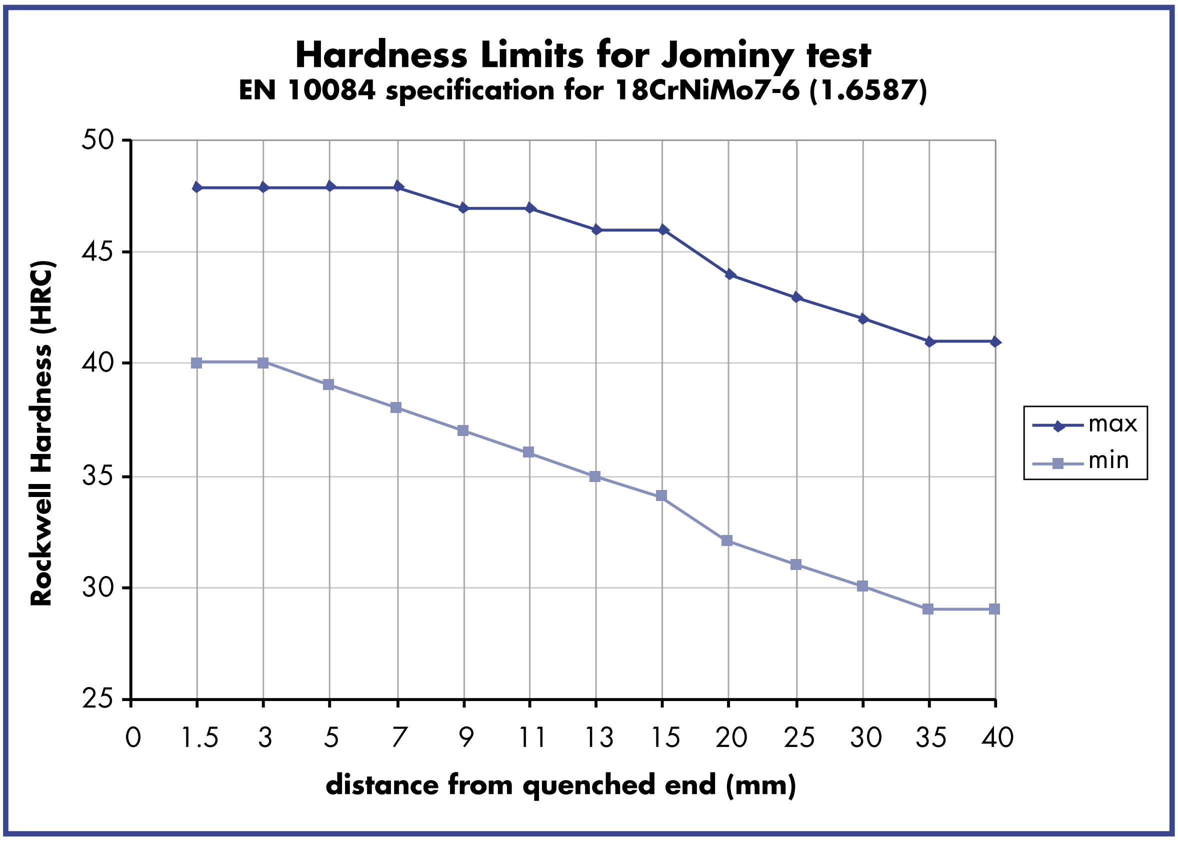
The following table shows the typical mechanical properties achievable in the core section of various diameters after carburizing, hardening and tempering.

Diameter (mm)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (A%)	Impact Value (DVM) (J) min.
11	835 min	1180 - 1420	7 min	41
30	785 min	1080 - 1320	8 min	41
63	685 min	980 - 1270	8 min	

4.11.7 WELDING

Pre-heat welding area to 250-450°C and maintain this temperature while welding with a low hydrogen electrode. Cool at a maximum rate of 100°C per hour. Weld before carburising.

4.11.8 HARDENABILITY DIAGRAM



4.11.9 APPLICATIONS

Gear parts exposed to highest stresses and wear conditions. Typical components include gears, planetary gears, plate wheels, drive pinions and shafts.

4.12 6657: CASE–HARDENING ALLOY STEEL BAR

Colour Coding: Signal Red (band) – Signal Red (White stripe)

4.12.1 INTRODUCTION

Wakefield 6657 is a 3.25% Nickel-Chromium case-hardening steel of high hardenability used principally for intermediately to highly stressed components. Wakefield 6657 can be carburised and subsequently hardened by a quenching and tempering operation. Wakefield 6657 is superior to case-hardening steel En36A due to the addition of Molybdenum to this grade, which results in higher strength and hardenability. It can also be considered as an alternative to EN39B

4.12.2 RELATED SPECIFICATIONS

Wakefield 6657 complies with Euronorm steel grade 14NiCrMo13-4 (Material Number 1.6657 under Euronorm EN 10084).

4.12.3 CHEMICAL COMPOSITION

Specification values in %

Grade	C	Si	Mn	P	S	Cr	Ni	Mo
En36A	0.10-0.16	≤ 0.35	0.35-0.60	≤ 0.040	≤ 0.040	0.70-1.00	3.00-3.75	–
6657	0.11-0.17	≤ 0.40	0.30-0.60	≤ 0.035	≤ 0.035	0.80-1.10	3.00-3.50	0.10-0.25

4.12.4 CONDITIONS OF SUPPLY

Normally supplied in the annealed condition with hardness max 241 HB, with typical hardness being in the range 190-230 HB. Bars are peeled and are supplied in k12 tolerance for bar diameters up to 210mm and peeled to -0/+2mm tolerance for larger diameters. All bars are ultrasonically inspected in accordance with AS 1065 level 2.

4.12.5 HEAT TREATMENT

Treatment	Temperature Range (°C)	Cooling
Carburising	890 - 960	Oil (water), hot quench 160-250°C, Salt bath 580-680°C, Case-hardening box, Air*
Intermediate annealing	630 - 650	Air, Furnace
Core hardening	835 – 865	Oil (water), hot quench 160-250°C*
Case hardening	780 – 810	Oil (water), hot quench 160-250°C*
Tempering	150 - 200	Air

** the choice of cooling medium depends on the desired final properties and geometry of the section to be case hardened and the effect of the cooling medium, given the hardenability of the steel*

Gas or pack carburise at 900 to 950°C to ensure the correct depth of hardening. Ideal carbon potential is 0.9%. When pack carburising, use a mixture of old and new crystals to avoid over carburising.

After carburising, cool to 830°C and direct quench or cool to ambient temperature, reheat to 830°C and quench. Components may be quenched in oil or equivalent polymer or mar-quenched into neutral salts at 150°C to 250°C, then air-cooled. There is no advantage in double quenching, but if required core refine by oil quenching from 835 to 865°C. A refining treatment is then necessary to improve the structure of the case and its hardness. Heat slowly to 780 to 810°C, hold until uniform and then quench in oil.

The minimum tempering time is 1 hour, but a tempering period of 1 hour per 25mm of section is recommended. If the steel is to be direct hardened, then in general, a carburizing temperature of 950°C should not be exceeded.

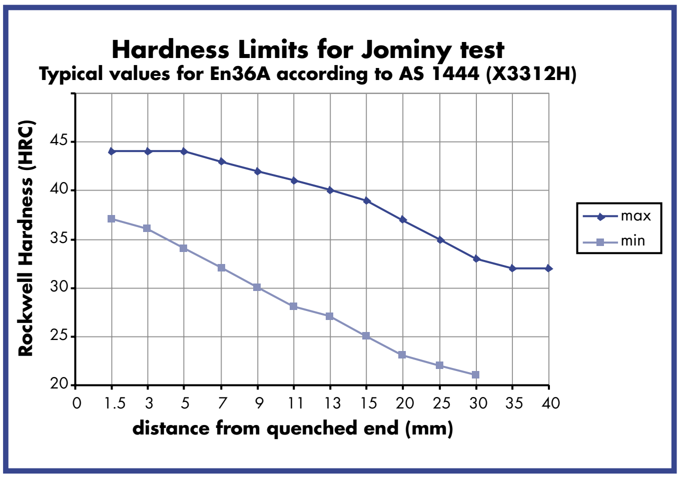
4.12.6 MECHANICAL PROPERTIES AFTER CASE HARDENING

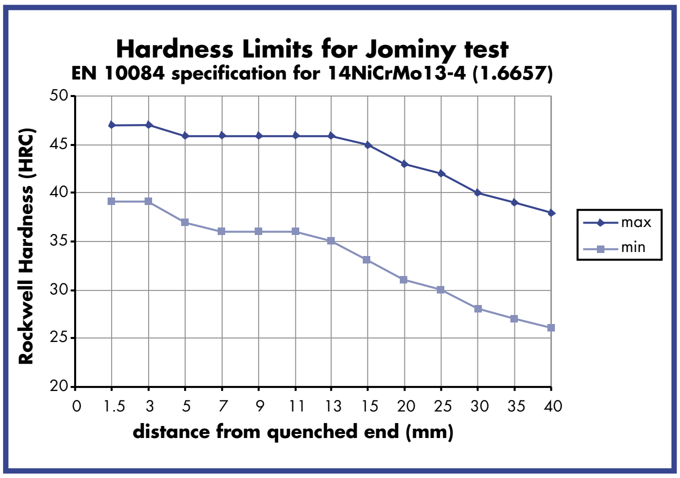
The following table shows the typical mechanical properties of Wakefield 6657 achievable in the core section of test sections after carburizing, hardening and tempering. For reference purposes they are compared to En36A.

Grade	Diameter (mm)	Tensile Strength (MPa)	Elongation (A%)	Impact value Charpy (V)
En36A	19	1000 min	9 min	35 min
6657	11	1230 -1480	9 min	35 min
6657	30	1030 -1330	10 min	35 min
6657	63	880 -1180	11 min	43 min

With 6657 a typical case hardness of 62-63 HRC can be achieved.

4.12.7 HARDENABILITY DIAGRAM





4.12.8 WELDING

Pre-heat welding area to 250-450°C and maintain this temperature while welding with a low hydrogen electrode. Cool at a maximum rate of 100°C per hour. Do not weld after carburising.

4.12.9 APPLICATIONS

Gear parts exposed to highest stresses and wear conditions. Typical components include gears, planet wheels, drive pinions, shafts, bushes and sleeves. Results in high core strength and excellent toughness in the components and is very suitable for parts with large diameter.

4.13 MICRO900: HIGH-TENSILE MICRO-ALLOY STEEL BAR

4.13.1 INTRODUCTION

Micro-alloy steels are principally carbon steels with very small additions of alloying elements such as Vanadium, Titanium and Aluminium. Micro-alloy steels have mechanical properties in the as-rolled condition similar to those of heat-treated steels (4140, 1045). Therefore they offer a cost-reducing alternative to heat treated steels.

Micro-alloy steels assume their specific properties through so called thermo-mechanical rolling. In this process the forming temperature and the cooling speed in between and after the forming process steps are designed to produce the enhancement of the mechanical properties. Involved are mainly the precipitation of V and Ti-carbides and formation of a very fine grained ferritic-pearlitic microstructure during the cooling process. In addition Mn and Si play a role in the crystalline network and optimally a pearlitic structure low in Carbon is formed during the cooling process.

Microalloy-steels are truly high-tech steels in which alloys have been partially replaced by minute process control.

4.13.2 RELATED SPECIFICATIONS

Currently only German Specification (Euronorm pre-norm) DIN EN10267 deals with precipitation-hardening ferritic-pearlitic steels. Wakefield Micro900 complies with grade 38MnSiVS5 (Material Number 1.1303) which is defined under DIN EN10267.

4.13.3 CHEMICAL COMPOSITION

Specification values in %

C	Si	Mn	P	S	Al	Ti	V
0.35-0.40	0.50-0.70	1.20-1.50	≤ 0.025	0.04-0.07	0.015-0.030	0.010-0.016	0.08-0.13

4.13.4 CONDITIONS OF SUPPLY – MECHANICAL PROPERTIES

AtlasMicro900 is supplied in the as-rolled condition. The product is thermo-mechanically rolled in order to produce the desired mechanical properties.

4.13.4.1

Diameter (mm)	Tensile Strength (MPa)	0.2% proof stress (MPa)	Elongation (%)	Impact Value K U (J)	Hardness (HB)
up to 150 incl	850 – 1000	600 min	13 min	30 min	245 – 295

On special customer request Wakefield Micro900 can be supplied in the as-rolled condition without thermo-mechanical treatment. In this case the product has no specified mechanical properties but strength and hardness are generally lower than in the thermo-mechanically treated condition. If the product is to be forged, then Wakefield Micro900 should be supplied in the plain as-rolled condition and the appropriate mechanical properties will be achieved through the forging process and subsequent controlled cooling.

4.13.5 CONDITIONS OF SUPPLY – SURFACE FINISH AND MACHINING ALLOWANCE

Wakefield Micro900 Black is supplied with +/– tolerances according to 2 DIN 1013. Wakefield Micro900 Bright is supplied cold drawn with h10 tolerance for bar diameters up to 25mm, bars with diameters 25 to 175mm are supplied as peeled with k12 tolerance.

4.13.6 MACHINING ALLOWANCES FOR MICRO900 ROUND BAR (MM ON DIAMETER)

Bar diameter (mm)	Black (hot rolled)		Bright (drawn or peeled bar)	
	part length <120mm	part length >120mm	part length <120mm	part length >120mm
0-50	1.4mm	1.4 + 4mm/m	1.0mm	1.0 + 4mm/m
50-100	1.7mm	1.7 + 4mm/m	1.0mm	1.0 + 4mm/m
100-150	2.0mm	2.0 + 5mm/m	1.0mm	1.0 + 4mm/m
150-210	2.3mm	2.3 + 5mm/m	1.5mm	1.5 + 4mm/m

Hot-rolling surface defects are retained in cold drawing. For bright bar in the range of cold drawing (up to 25mm) it is essential to take machining allowance into account. Peeled bar is generally free of surface defects. A certain allowance for surface defects is recommended however, as minor defects are permitted by the various national standards (AS, EN, etc.). A minor sulphur addition to this grade gives significantly improved machinability.

4.13.7 FORGING

Components are to be forged at 1200°C ± 30°C. Forging finish temperature of the part should be in the range of 1000 – 1100°C. Down to a temperature of 600 – 650°C a controlled cooling is to be applied depending on the weight of the part as shown in the table.

Cooling speed					
Weight of part (kg)	**≤ 1.5**	**1.5 – 3.5**	**3.5 – 7.5**	**7.5 – 15.0**	**15.0 – 25.0**
°C/min surface	120	90	70	55	46
°C/min core	90	80	60	47	40

Final cooling to room temperature should occur in a container.

4.13.8 SURFACE HARDENING

Micro900 can be induction hardened and when tempered at 150 – 200°C it achieves a surface hardness of 52-55 HRC.

4.13.9 WELDING

Under certain conditions the material can be fusion welded. It is recommended to consult a welding expert concerning the most suitable welding procedure.

4.13.10 APPLICATIONS OF MICRO900

Medium-high stressed shafts and components where the use of carbon steel 1045 would not be appropriate. Reasons for using Wakefield Micro900 are the higher yield and fatigue strength, better through hardening of the material and superior impact properties compared to plain carbon steels like 1045. Machinability of Micro900 is also significantly better than that of 1045 steel. Substitution of 1045 is particularly attractive if a 1045 steel component is to be heat treated.

Medium-high stressed components where currently 4140 steel is used. Micro900 offers mechanical properties similar to those of 4140, though its impact properties are generally not as good as those of 4140 steel. Substitution of 4140 by Wakefield Micro900 offers a significant cost saving potential both in material costs and machining cost, as the machinability of Micro900 is substantially better than that of 4140 steel.

4.14 303: FREE MACHINING STAINLESS STEEL BAR

Colour Code: Light Blue

4.14.1 INTRODUCTION

303 represents the optimum in machinability among the austenitic stainless steels. It is primarily used when production involves extensive machining.

The sulphur addition which is responsible for the improved machining and galling characteristics of 303 lowers its corrosion resistance to below that of 304. As for other austenitic grades the structure gives 303 excellent toughness, although the sulphur in 303 reduces its toughness slightly.

4.14.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
303	S30300	303S31	1.4305	X8CrNiS18-9	2346	SUS 303

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.14.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A582/A582M

Grade	C	Mn	Si	P	S	Cr	Mo	Ni
303	≤0.15	≤2.0	≤1.00	≤ 0.20	≥0.15	17.0-19.0	–	8.0-10.0

4.14.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Diameter (mm)	Tensile Strength (MPa)	Yield Strength 0.2% Proof (MPa)	Elongation (% in 50mm)	Hardness Brinell (HB)
≤ 15mm	750 – 800 typical	450 – 650 typical	34 typical	262 max
>15mm ≤25.4mm	700 typical	350 – 450 typical	44 typical	262 max
> 25.4mm	650 typical	300 typical	58 typical	262 max

Note that ASTM A582M only specifies hardness – tensile properties included above are not guaranteed and for information only. Drawn bars, generally up to 25.4mm diameter have higher strength values. Proof (yield) stress values in particular are significantly higher and the percentage elongation lower.

4.14.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m^3)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7900	193	17.3	17.8	18.4	16.3	21.5	500	720

4.14.6 CORROSION RESISTANCE

Good resistance to mildly corrosive atmospheres, but significantly less than 304 due to the sulphur addition; the sulphide inclusions act as pit initiation sites. 303 should not be exposed to marine or other similar environments, as these will result in rapid pitting corrosion. Because the sulphide inclusions in 303 are primarily aligned along the rolling direction the corrosion resistance is particularly reduced in cross-sections.

303, like other common austenitic stainless steels, is subject to stress corrosion cracking in chloride containing environments above about 50°C.

 Consult Wakefield Technical Assistance for specific environmental recommendations.

4.14.7 HEAT RESISTANCE

Good oxidation resistance in intermittent service to 760°C and in continuous service to 870°C. Continuous use in the 425-860°C range is not usually recommended due to carbide precipitation

4.14.8 PROCESSING

As well as reducing the corrosion resistance, the sulphur additions in 303 also result in poor weldability and reduced formability compared to Grade 304. Sharp bends should not be attempted in 303. A practical compromise alternative may be a 304 Ugima Improved Machinability grade - this does not machine as readily as 303, but does offer better formability (as well as excellent weldability and significantly better corrosion resistance).

4.14.9 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.14.9.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to 127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.

All hexagon bar and all square bar is cold drawn.

4.14.9.2 Diameter and A/F tolerances

Round Bar:	Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8
Square Bar:	h11; Hex Bar: h11.

4.14.9.3 Straightness – maximum deviation from a straight line

Round Bar:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Squares and Hexagon:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.14.9.4 Length Tolerance

Sizes up to 25.4mm:	Mill Lengths and Set Lengths, +50mm/-0
Sizes up from 25.4mm to 50.8mm:	Mill Lengths and Set Lengths, +100mm/-0
Sizes over 50.8mm:	Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.14.10 303 AND 303 FOR TOP PERFORMANCE IN MACHINING

A improved machinability version of grade 303 is available in round, hexagon and square bar. 303 machines significantly better than standard 303, enabling a higher rate of metal removal and lower tool wear in many operations. Surface quality and reliability of machining results will improve too when using 303. 303, is the new generation product offering further benefits of improved chip-breakability, substantially longer tool life and productivity benefits also in the low machining speed range.

For 303 and303 detailed set-up tables are available on request, specifying machining parameters (surface speed, feed rate, depth of cut and type of tool) for high-speed steel tooling and carbide insert tooling for the most common machining operations (roughing, finishing, drilling, parting-off etc.). Machinability assistance is available for optimal set-up and problem-solving for specific machining jobs.

4.14.11 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing
900 – 1200°C	1010 – 1120°C

Cool rapidly after annealing. 303 cannot be hardened by thermal treatment.

4.14.12 WELDING

Not generally recommended but, if unavoidable use Grade 308L or 309 electrodes. AS 1554.6 does not pre-qualify welding of 303. Welds must be annealed for maximum corrosion resistance, but even then poor mechanical and corrosion properties will result.

4.14.13 APPLICATIONS OF 303

Nuts and bolts. Bushings. Shafts. Electrical switchgear components. Gears. In general any component that is heavily machined and where the corrosion resistance and fabrication properties of 303 are viable.

4.14.14 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of 303
303UX	303UX offers the highest machinability for long run repetition machining.
304	Better corrosion resistance, formability or weldability are needed, at the expense of lower machinability.
316	Higher resistance to pitting and crevice corrosion is required, in chloride environments. A lower machinability can be accepted.
416	Even higher machinability than 303 is needed, and a lower corrosion resistance can be tolerated. Or hardening by thermal treatment is required, while maintaining a high machinability.

4.15 Wakefield 304: STAINLESS STEEL BAR

Colour Code: Lilac/Turquoise

4.15.1 INTRODUCTION

Grade 304 is the standard "18/8" stainless. It has excellent forming and welding characteristics. Grade 304L, the low carbon version of 304, does not require post-weld annealing and so is extensively used in heavy gauge components. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

4.15.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
304	S30400	304S31	1.4301	X5CrNi18-10	2332	SUS 304
304L	S30403	304S11	1.4306	X2CrNi19-11	2352	SUS 304L

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.15.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A276

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	N
304	≤ 0.08	≤ 2.0	≤ 1.00	≤ 0.045	≤ 0.030	18.0-20.0		8.0-11.0	
304L	≤ 0.03	≤ 2.0	≤ 1.00	≤ 0.045	≤ 0.030	18.0-20.0		8.0-12.0	

Atlas304 bar is generally stocked in "Dual Certified" form. These products have chemical and mechanical properties complying with both 304 and 304L specifications. Such dual certified product does not meet 304H specifications and may be unacceptable for high temperature (over about 500°C) applications.

4.15.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Values below are specified values according to ASTM A276, condition A, for cold finished 304 bars.

Diameter (mm)	Tensile Strength (MPa) min	0.2% proof stress (MPa) min	Elongation (% in 50mm) min	Reduction of Area (%) min
≤ 12.70	520	310	30	40
>12.70	515	205	30	40

4.15.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7900	193	17.2	17.8	18.4	16.3	21.5	500	720

4.15.6 CORROSION RESISTANCE

Excellent in a wide range of atmospheric environments and many corrosive media. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 50°C. Considered resistant to potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C. Consult Wakefield Technical Assistance for specific environmental recommendations.

4.15.7 HEAT RESISTANCE

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 304 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important, but 304L and dual certified product 304/304L does not suffer from this problem. For temperatures above 500°C specific high-temperature grades would normally be chosen such as 304H, 321H, 310 or S30815.

4.15.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.15.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to 127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.

All hexagon bar and all square bar is cold drawn.

4.15.8.2 Diameter and A/F tolerances

Round Bar: Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8

Square Bar: h11; Hex Bar: h11.

4.15.8.3 Straightness – maximum deviation from a straight line

Round Bar: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Squares and Hexagon: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Other tolerances may be supplied for more critical applications upon enquiry.

4.15.8.4 Length Tolerance

Sizes up to 25.4mm: Mill Lengths and Set Lengths, +50mm/-0
Sizes up from 25.4mm to 50.8mm: Mill Lengths and Set Lengths, +100mm/-0
Sizes over 50.8mm: Mill Lengths and Set Lengths, +300mm (varies depending on size)

4.15.9 304 FOR TOP PERFORMANCE IN MACHINING

A improved machinability version of grade 304 is available in round, hexagon and square bar. 304 machines significantly better than standard 304 or 304L, enabling a higher rate of metal removal and lower tool wear in many operations. Surface quality and reliability of machining results will improve too when using 304. For 304 detailed set-up table are available on request, specifying machining parameters (surface speed, feed rate, depth of cut and type of tool) for high-speed steel tooling and carbide insert tooling for the most common machining operations (roughing, finishing, drilling, parting-off etc.). Machinability assistance is available for optimal set-up and problem-solving for specific machining jobs.

4.15.10 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing
900 – 1200°C	1010 – 1120°C

Cool rapidly after annealing. Wakefield 304 cannot be hardened by thermal treatment.

4.15.11 WELDING

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 304 with Grade 308 and 304L with 308L rods or electrodes (and with their high silicon equivalents). Heavy welded sections in Grade 304 may require post-weld annealing for maximum corrosion resistance. This is not required for Grade 304L.

4.15.12 APPLICATIONS OF 304

Food processing equipment, particularly in beer brewing, milk processing & wine making. Kitchen appliances and equipment. Heat exchanger components. Threaded fasteners. Springs.

4.15.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of 304/L
304Cu	Lower work hardening rate is needed for cold forging of screws, bolts and rivets. Higher machinability than 304/L.
303	Higher machinability needed, and the lower corrosion resistance, formability and weldability are acceptable.
316	Higher resistance to pitting and crevice corrosion is required, in chloride environments.
430	A lower cost is required, and the reduced corrosion resistance and fabrication characteristics are acceptable.

4.16 316: STAINLESS STEEL BAR

Colour Code: Bottle Green/Marigold

4.16.1 INTRODUCTION

Wakefield 316 is the standard molybdenum-bearing stainless steel, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. Post-weld annealing is not required when welding thin sections.

Wakefield 316L is immune from sensitisation (grain boundary carbide precipitation) and so is extensively used in heavy gauge welded components (over about 6mm). The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

4.16.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
316	S31600	316S31	1.4401	X5CrNiMo17-12-2	2347	SUS 316
316L	S31603	316S11	1.4404	X2CrNiMo17-12-2	2348	SUS 316L

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.16.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A276

Grade	C	Mn	Si	P	S	Cr	Mo	Ni
316	≤ 0.08	≤ 2.0	≤ 1.00	≤ 0.045	≤ 0.030	16.0-18.0	2.0-3.0	10.0-14.0
316L	≤ 0.03	≤ 2.0	≤ 1.00	≤ 0.045	≤ 0.030	16.0-18.0	2.0-3.0	10.0-14.0

Atlas316 bar is generally stocked in "Dual Certified" form. These products have chemical and mechanical properties complying with both 316 and 316L specifications. Such dual certified product does not meet 316H specifications and may be unacceptable for high temperature (over about 500°C) applications.

4.16.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Values below are specified values according to ASTM A276, condition A, for cold finished bars.

Diameter (mm)	Tensile Strength (MPa) min	0.2% proof stress (MPa) min	Elongation (% in 50mm) min	Reduction of Area (%) min
≤ 12.70	620	310	30	40
>12.70	515	205	30	40

4.16.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
8000	193	15.9	16.2	17.5	16.3	21.5	500	740

4.16.6 CORROSION RESISTANCE

Excellent in a range of atmospheric environments and many corrosive media - generally more resistant than 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 50°C. Considered resistant to potable water with up to about 1000mg/L chlorides at ambient temperatures, reducing to about 500mg/L at 60°C.

316 is usually regarded as the standard "marine grade stainless steel", but it is not resistant to warm sea water. In many marine environments Wakefield 316 does exhibit surface corrosion, usually visible as brown staining. This is particularly associated with crevices and rough surface finish.

Consult Wakefield Technical Assistance for specific environmental recommendations.

4.16.7 HEAT RESISTANCE

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of Wakefield 316 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Wakefield 316 is reasonably resistant to carbide precipitation and can be used in the above temperature range. Grade 316H has higher strength at elevated temperatures and is sometimes used for structural and pressure-containing applications at temperatures above about 500°C, but the titanium stabilised grade 316Ti is often a more appropriate choice.

4.16.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.16.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.

All hexagon bar and all square bar is cold drawn.

4.16.8.2 Diameter and A/F tolerances

Round Bar:	Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8
Square Bar:	h11; Hex Bar: h11.

4.16.8.3 Straightness – maximum deviation from a straight line

Round Bar:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Squares and Hexagon:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.16.8.4 Length Tolerance

Sizes up to 25.4mm:	Mill Lengths and Set Lengths, +50mm/-0
Sizes up from 25.4mm to 50.8mm:	Mill Lengths and Set Lengths, +100mm/-0
Sizes over 50.8mm:	Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.16.9 316 AND 316 FOR TOP PERFORMANCE IN MACHINING

A improved machinability version of grade 316 is available in round, hexagon and square bar. 316 machines significantly better than standard 316 or 316L, enabling a higher rate of metal removal and lower tool wear in many operations. Surface quality and reliability of machining results will improve too when using 316. 316 is the new generation product offering further benefits of improved chip-breakability, substantially longer tool life and productivity benefits also in the low machining speed range.

For 316 and 316 detailed set-up tables are available on request, specifying machining parameters (surface speed, feed rate, depth of cut and type of tool) for high-speed tooling and carbide insert tooling for the most common machining operations (roughing, finishing, drilling, parting-off etc.). Machinability assistance is available for optimal set-up and problem-solving for specific machining jobs.

4.16.10 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing
900 – 1200°C	1010 – 1120°C

Cool rapidly after annealing. Wakefield 316 cannot be hardened by thermal treatment.

4.16.11 WELDING

Excellent weldability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 316 with Grade 316 and 316L with Grade 316L rods or electrodes (or their high silicon equivalents). Both can be applied for Wakefield 316. Heavy welded sections do not require post-weld annealing for maximum corrosion resistance. Grade 316Ti may also be used as an alternative to Wakefield 316 for heavy section welding.

4.16.12 APPLICATIONS OF 316

Food processing equipment. Laboratory equipment. Architectural panelling, railings & trim. Boat fittings. Heat exchangers. Components for mining, quarrying & water filtration. Threaded fasteners. Springs.

4.17 420: STAINLESS STEEL BAR

Colour Code: Rose Pink

4.17.1 INTRODUCTION

Grade 420 stainless steel is a higher carbon version of 410 which can be hardened by a quench-and-temper heat treatment. It contains a minimum of 12 per cent chromium, just sufficient to give corrosion resistance in fairly mild environment. It has good ductility in the annealed condition but is capable of being hardened up to Rockwell Hardness 50HRC, the highest hardness of the 12 per cent chromium grades. Its best corrosion resistance is achieved when the metal is hardened and surface ground or polished. This datasheet describes the standard Wakefield 420. Variants with carbon content controlled within particular ranges are also available, usually designated 420A (lowest carbon) and increasing through 420B and 420C. Consult Wakefield for details.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and usually also allow for a final harden and temper heat treatment. Corrosion resistance is lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

4.17.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
420	S42000	420S37	1.4021	X20Cr13	2303	SUS 420J1

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.17.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A276

Grade	C	Mn	Si	P	S	Cr	Mo	Ni
420	≤ 0.15	≤ 1.0	≤ 1.0	≤ 0.040	≤ 0.030	12.0-14.0	–	–

4.17.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Diameter (mm)	Condition	Tensile Strength (MPa)	0.2% proof stress (MPa) min	Elongation (% in 50mm) min	Reduction of Area (%) min	Hardness (HB 30)
all	Annealed					≤ 230
Up to 160	Hardened & Tempered	850 – 1000	600	12	50	

4.17.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7700	200	10.3	10.8	11.7	24.9	-	460	550

4.17.6 CORROSION RESISTANCE

Grade 420 has good resistance in the hardened condition to the atmosphere, foods, fresh water and mild alkalies or acids. Corrosion resistance is lower in the annealed condition.

Performance is best with a centreless ground surface finish. Less corrosion resistant than the austenitic grades and also less than 17% chromium ferritic alloys such as Grade 430; 420 also has slightly lower resistance than grade 410.

Consult Wakefield Technical Assistance for specific environmental recommendations.

4.17.7 HEAT RESISTANCE

Not recommended for use in temperatures above the relevant tempering temperature, because of reduction in mechanical properties. The scaling temperature is approximately 650°C.

4.17.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.17.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to 127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.

All hexagon bar and all square bar is cold drawn.

4.17.8.2 Diameter and A/F tolerances

Round Bar: Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8

Square Bar: h11; Hex Bar: h11.

4.17.8.3 Straightness – maximum deviation from a straight line

Round Bar: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Squares and Hexagon: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.17.8.4 Length Tolerance

Sizes up to 25.4mm: Mill Lengths and Set Lengths, +50mm/-0

Sizes up from 25.4mm to 50.8mm: Mill Lengths and Set Lengths, +100mm/-0

Sizes over 50.8mm: Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.17.9 420 FOR TOP PERFORMANCE IN MACHINING

A improved machinability version of grade 420 is available in round, hexagon and square bar. 420 machines significantly better than standard 420, enabling a higher rate of metal removal and lower tool wear in many operations. Surface quality and reliability of machining results will improve too when using 420. For 420 detailed set-up tables are available on request, specifying machining parameters (surface speed, feed rate, depth of cut and type of tool) for high-speed steel tooling and carbide insert tooling for the most common machining operations (roughing, finishing, drilling, parting-off etc.). Machinability assistance is available for optimal set-up and problem-solving for specific machining jobs.

4.17.10 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing	Hardening	Tempering
800 – 1100°C	840 – 900°C	980 – 1035°C	600 – 750°C

After annealing execute a slow furnace cool to 600°C and then air cool.
The tempering range 425 – 600°C should be avoided.

4.17.11 WELDING

Pre-heat to 150-320°C and post-heat at 610-760°C. Grade 420 coated welding rods are recommended for high strength joints, where a post-weld hardening and tempering heat treatment is to be carried out.

If parts are to be used in the "as welded" condition, a ductile joint can be achieved by using Grade 309 filler rod. AS 1554.6 pre-qualifies welding of 420 with Grade 309 rods or electrodes.

4.17.12 APPLICATIONS OF ATLAS420

Shafts and axles, pump components. Valve cones. Surgical instruments. Needle valves. Shear blades.

4.17.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of Atlas420
410	Only a lower hardened strength is needed.
416	High machinability is required, and the lower hardened strength and lower corrosion resistance of 416 is acceptable.
440C	A higher hardened strength or hardness than can be obtained from 420 is needed.
"specials"	Variations of 420 are available to special order often identified as 420A, 420B etc. These offer higher hardness, corrosion resistance and machinability for particular applications.

4.18 431: STAINLESS STEEL BAR

Colour Code: Signal Red

4.18.1 INTRODUCTION

This heat treatable martensitic, nickel-bearing grade has the best corrosion resistance properties of all the martensitic grades. It has excellent tensile and torque strength, and good toughness, making it ideally suited to shafting and bolt applications. It can be hardened to approximately 40HRC. Because of its high yield strength, this grade is not readily cold worked and is therefore not recommended for use in operations such as cold heading, bending, deep drawing or spinning.

Martensitic stainless steels are optimised for high hardness, and other properties are to some degree compromised. Fabrication must be by methods that allow for poor weldability and usually also allow for a final harden and temper heat treatment. Corrosion resistance is generally lower than the common austenitic grades, and their useful operating temperature range is limited by their loss of ductility at sub-zero temperatures and loss of strength by over-tempering at elevated temperatures.

4.18.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
431	S43100	431S29	1.4057	X17CrNi16-2	2321	SUS 431

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.18.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A276

Grade	C	Mn	Si	P	S	Cr	Mo	Ni
431	≤ 0.20	≤ 1.00	≤ 1.00	≤ 0.040	≤ 0.030	15.0 – 17.0	–	1.25 – 2.50

4.18.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Condition	Tensile Strength (MPa) min	0.2% proof stress (MPa) min	Elongation (% in 50mm) min	Hardness (HB)
Annealed	–	–	–	285 max
Hardened & Tempered	850 - 1000	665 min.	12 min.	248 - 302

431 is generally stocked and supplied in "Condition T" to AS 1444 or BS 970, with specified tensile strength of 850 - 1000MPa. Yield and elongation are typically in conformance with the limits listed above.

ASTM A276 only lists a Condition A version of Grade 431; the annealed hardness listed above is the specified maximum. 431 is only rarely stocked in annealed Condition A.

4.18.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7700	200	10.2	12.1	-	20.2	-	460	720

4.18.6 CORROSION RESISTANCE

Grade 431 has excellent resistance to a wide variety of corrosive media. It has reasonable resistance to salt water in cold southern waters but is unlikely to be successful in warmer tropical waters. Overall the corrosion resistance of 431 is approximately the same as or slightly below that of Grade 304.

Performance is best with a smooth surface finish, in the hardened and tempered condition.

Consult Wakefield Technical Assistance for specific environmental recommendations.

4.18.7 HEAT RESISTANCE

Resists scaling in intermittent service to 925°C and in continuous service to 870°C, but is generally not recommended for use in temperatures above the relevant tempering temperature, because of reduction in mechanical properties.

4.18.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.18.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.

All hexagon bar and all square bar is cold drawn.

4.18.8.2 Diameter and A/F tolerances

Round Bar:	Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8
Square Bar:	h11; Hex Bar: h11.

4.18.8.3 Straightness – maximum deviation from a straight line

Round Bar:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Squares and Hexagon:	1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.18.8.4 Length Tolerance

Sizes up to 25.4mm:	Mill Lengths and Set Lengths, +50mm/-0
Sizes up from 25.4mm to 50.8mm:	Mill Lengths and Set Lengths, +100mm/-0
Sizes over 50.8mm:	Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.18.9 431 FOR TOP PERFORMANCE IN MACHINING

A improved machinability version of grade 431 is available in round, hexagon and square bar. 431 machines significantly better than standard 431, enabling a higher rate of metal removal and lower tool wear in many operations. Surface quality and reliability of machining results will improve too when using 431. For 431 detailed set-up tables are available on request, specifying machining parameters (surface speed, feed rate, depth of cut and type of tool) for high-speed steel tooling and carbide insert tooling for the most common machining operations (roughing, finishing, drilling, parting-off etc.). Machinability assistance is available for optimal set-up and problem-solving for specific machining jobs.

4.18.10 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing	Hardening	Tempering
900 – 1200°C	620 – 660°C	980 – 1065°C	600 – 800°C

Process Anneal - heat to 620-660°C and subsequently air cool. Full annealed is not a practical option.

Hardened by heating to 980-1065°C, holding for about 1/2 hour then quenching in air or oil. Pre-heating at 760-790°C may be useful for complex parts or those already hardened. Temper to suit mechanical requirements, at temperatures as indicated in the table.

The tempering range 425-600°C should be avoided due to reduced impact toughness, although the effect is less marked than in most other martensitic grades.

Refer to the following table for mechanical properties achieved at various tempering temperatures.

Tempering Temperature (°C)	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Elongation (% in 50mm)	Hardness Brinell (HB)	Impact Izod (J)
300	1320	1020	20	380	75
400	1310	1010	22	395	80
500	1350	1030	20	395	55
600	1030	800	20	310	45
700	920	700	20	290	70

4.18.11 WELDING

Welding is difficult due to the risk of cracking. A pre-heat of 200-300°C is recommended prior to welding. Grade 410 filler rod can be used, but Grades 308L, 309 or 310 will provide more ductile welds, so long as matching properties are not required. Post-weld heat treat at 650°C.

4.18.12 APPLICATIONS OF 431

Nuts and bolts. Propeller shafting. Pump shafts. Beater bars. Marine hardware.

4.18.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of Atlas431
410	Only a lower hardened strength is needed.
416	High machinability is required, and the lower strength and lower corrosion resistance of 416 is acceptable.
440C	A higher hardened strength or hardness than can be obtained from 431 is needed.

4.19 2205: DUPLEX STAINLESS STEEL BAR

Colour Code: Lime

4.19.1 INTRODUCTION

2205 is the most widely used duplex (ferritic/austenitic) stainless steel grade. It finds applications due to both excellent corrosion resistance and high strength.

The standard S31803 composition has over the years been refined by many steel suppliers, and the resulting restricted composition range was endorsed as UNS S32205 in 1996. S32205 gives better guaranteed corrosion resistance, but much of the S31803 currently produced also complies with S32205.

Wakefield 2205 is not generally suitable for use at temperatures above 300°C as it suffers from precipitation of brittle micro-constituents, nor below -50°C because of its ductile-to-brittle-transition.

4.19.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
2205	S31803 / S32205	318S13	1.4462	X2CrNiMoN22-5-3	2377	SUS329J3L

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.19.3 CHEMICAL COMPOSITION

Specification values in %, according to ASTM A276

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	N
2205 (S31803)	≤ 0.03	≤ 2.0	≤ 1.0	≤ 0.030	≤ 0.020	21.0-23.0	2.5-3.5	4.5-6.5	0.08-0.20
2205 (S32205)	≤ 0.03	≤ 2.0	≤ 1.0	≤ 0.030	≤ 0.020	22.0-23.0	3.0-3.5	4.5-6.5	0.14-0.20

2205 complies with grade S31803 as well as grade S32205.

4.19.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Values below are specified values according to ASTM A276, condition A, for cold finished bars.

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness	
				Rockwell C (HR C)	Brinell (HB)
2205	655	450	25	31 max	293 max

4.19.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7800	200	13.7	14.7	-	19.0	-	450	850

4.19.6 CORROSION RESISTANCE

2205 possesses excellent general corrosion resistance; superior to Grade 316 in most environments. Excellent resistance to localised corrosion including intergranular, pitting and crevice corrosion; the CPT of 2205 is generally at least 35°C. The grade is also resistant to chloride stress corrosion cracking (SCC) at temperatures of up to about 150°C. Grade 2205 will often perform well in environments which cause premature failure of austenitic grades. It has better resistance to sea water than grade 316. C

4.19.7 HEAT RESISTANCE

Although Wakefield 2205 has good high temperature oxidation resistance this grade, like other duplex stainless steels, suffers from embrittlement if held for even short times at temperatures above 300°C. If embrittled this can only be rectified by a full solution annealing treatment. Duplex stainless steels are almost never used above 300°C.

4.19.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.19.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to 127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled. All hexagon bar and all square bar is cold drawn.

4.19.8.2 Diameter and A/F tolerances

Round Bar: Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8

Square Bar: h11; Hex Bar: h11.

4.19.8.3 Straightness – maximum deviation from a straight line

Round Bar: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Squares and Hexagon: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm

Other tolerances may be supplied for more critical applications upon enquiry.

4.19.8.4 Length Tolerance

Sizes up to 25.4mm: Mill Lengths and Set Lengths, +50mm/-0

Sizes up from 25.4mm to 50.8mm: Mill Lengths and Set Lengths, +100mm/-0

Sizes over 50.8mm: Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.19.9 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing
900 – 1200°C	1010 – 1120°C

Cool rapidly after annealing. Wakefield 2205 cannot be hardened by thermal treatment.

4.19.10 PROCESSING

The high strength that makes 2205 useful in many applications also reduces its machinability. The high work-hardening rate further decreases the machinability of 2205. Cutting speeds are approximately 20% slower than for a standard grade 304.

The high strength of 2205 also makes bending and forming more difficult; these operations will require larger capacity equipment than would be required for austenitic stainless steels. The ductility of 2205 is less than that of an austenitic grade (but is not low when compared to most other structural materials), so severe forming operations, such as cold heading, are not generally possible. If severe cold working is required it is recommended that intermediate annealing be carried out.

4.19.11 WELDING

Weldable by all standard methods, but should not generally be welded without filler metal as this may result in excessive ferrite. AS 1554.6 pre-qualifies welding of 2205 with 2209 rods or electrodes to ensure that deposited metal has the correctly balanced duplex structure. Nitrogen added to the shielding gas will also assist in ensuring adequate austenite in the structure. Heat input must be kept low and no pre- or post-heat should be used. The lower co-efficient of thermal expansion of all duplex stainless steels compared with austenitic grades reduces distortion and associated stresses.

4.19.12 APPLICATIONS OF 2205

Chemical processing, transport and storage. Oil and gas exploration and processing equipment. Marine and other high chloride environments. Pulp & Paper digesters, liquor tanks and paper machines.

4.19.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of 2205
904L	Better formability is needed, with similar corrosion resistance and lower strength.
UR52N+	Higher resistance to corrosion is required, eg resistance to higher temperature seawater.
6%Mo	Higher corrosion resistance is required, but with lower strength and better formability.
316L	The high corrosion resistance and strength of 2205 are not needed… 316L is lower cost.
329	Similar corrosion resistance and mechanical properties but higher machinability.

4.20 UR52N+: DUPLEX STAINLESS STEEL BAR

Colour Code: Violet

4.20.1 INTRODUCTION

Grade UR52N+ is a registered trade name of the Arcelor group, produced in a range of products, and certified as compliant with EN10088-3 Grade 1.4507. UR52N+ retains the older designation UNS S32550 for bar (in ASTM A276) despite the same grade in plate being designated (in ASTM A240M) by the more appropriate UNS S32520. It is anticipated that in the future UR52N+ bar will be re-classified as S32520.

UR52N+ is one of a group of "super duplex" grades, combining high strength with exceptional corrosion resistance. Like other duplex (ferritic/austenitic) grades the super duplex grades are not suitable for high or low temperature service. UR52N+ is not recommended for temperatures below -50°C or above +270°C, because of reduced toughness outside this range.

The addition of copper to this grade gives it greatly improved resistance to strong reducing acids, particularly sulphuric acid. UR52N+ is also very highly resistant to pitting/crevice corrosion in high chloride, hot environments. Its duplex structure also results in excellent resistance to stress corrosion cracking.

4.20.2 RELATED SPECIFICATIONS

Grade	UNS No	British BS	Euronorm		Swedish SS	Japanese JIS
			No	Name		
UR52N+	S32520 / S32550	-	1.4507	X2CrNiMoCuN25-6-3	-	-

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.20.3 CHEMICAL COMPOSITION

Specification values in %, according to EN10088-3, 1.4507

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	Cu	N
UR52N+ 1.4507	≤	≤	≤	≤	≤	24.0-26.0	2.7-4.00	5.5-7.5	1.00-2.50	0.15-0.30

4.20.4 CONDITIONS OF SUPPLY – SPECIFIED MECHANICAL PROPERTIES

Values below are specified in EN10088-3,1.4507.

Grade	Tensile Strength (MPa) min	Yield Strength 0.2% Proof (MPa) min	Elongation (% in 50mm) min	Hardness	
				Rockwell C (HR C)	Brinell (HB)
UR52N+ 1.4507	700-900	500	25	-	270

4.20.5 CONDITION OF SUPPLY – TYPICAL PHYSICAL PROPERTIES

Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion			Thermal Conductivity		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
		0-100°C (mm/m/°C)	0-315°C (mm/m/°C)	0-538°C (mm/m/°C)	at 100°C (W/m.K)	at 500°C (W/m.K)		
7800	205	13.5	14.0	14.5	17.0	-	450	850

4.20.6 CORROSION RESISTANCE

UR52N+ has excellent general corrosion resistance, superior to virtually all other stainless steels. It has high resistance to intergranular corrosion and very high resistance to stress corrosion cracking in both chloride and sulphide environments.

A PRE guaranteed to be at least 40 indicates that the material has good pitting and crevice corrosion resistance to warm sea water and other high chloride environments; it is rated as more resistant than grade 904L and approaching that of the 6% Molybdenum "super austenitic" grades. The crevice corrosion resistance of UR52N+ can be in excess of that of the 6% Mo grades in some cases. Copper adds resistance to sulphuric and other reducing acids, particularly in the very aggressive "mid concentration" range.

The grade of choice for severe high temperature marine environments and for chemical and petrochemical processing, including strong acids.

Consult Wakefield Technical Assistance for specific environmental recommendations.

4.20.7 HEAT RESISTANCE

Although super duplex grades have good high temperature oxidation resistance, like other duplex stainless steels they suffer from embrittlement if held for even short times at temperatures above 270°C. If embrittled this can only be rectified by a full solution annealing treatment.

4.20.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.20.8.1 Surface Finish

Round bar up to 25.4mm diameter is all cold drawn. Round bars over 25.4 and up to 127.00mm diameter are smooth-turned and polished. Round bars over 127.00mm diameter are all peeled.
All hexagon bar and all square bar is cold drawn.

4.20.8.2 Diameter and A/F tolerances

Round Bar: Cold drawn h9; Smooth-turned and Polished h10; Peeled up to 160mm k12; Peeled over 160mm +1.5mm/-0; Centreless ground h9 or h8
Square Bar: h11; Hex Bar: h11.

4.20.8.3 Straightness – maximum deviation from a straight line

Round Bar: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Squares and Hexagon: 1.5mm in 1500mm and may not exceed: 1.5mm x length in mm / 1500mm
Other tolerances may be supplied for more critical applications upon enquiry.

4.20.8.4 Length Tolerance

Sizes up to 25.4mm: Mill Lengths and Set Lengths, +50mm/-0
Sizes up from 25.4mm to 50.8mm: Mill Lengths and Set Lengths, +100mm/-0
Sizes over 50.8mm: Mill Lengths and Set Lengths, ± 300mm (varies depending on size)

4.20.9 HEAT TREATMENT

The following temperature ranges are applicable for the respective heat treatment operations.

Forging	Annealing
750 – 1150°C	1080 – 1120°C

Cool rapidly after annealing. UR52N+ cannot be hardened by thermal treatment.

4.20.10 PROCESSING

The high strength that makes UR52N+ useful in many applications also reduces its machinability. The high work-hardening rate further decreases the machinability of UR52N+. Cutting speeds are approximately 30% slower than for a standard grade 304. UR52N+ is a high strength steel, so high forming forces will be required. The ductility of the grade is quite adequate for most operations, but heavy deformation, such as cold forging, is not possible. If more than about 20% cold work is required an intermediate solution anneal is required.

4.20.11 WELDING

Weldable by standard methods, without pre-heat. Consumables over-alloyed with nitrogen and nickel are generally recommended. TIG (GTAW), MIG (GMAW) and all positional manual (MMAW) electrodes are available. Nickel-based consumables (eg Alloy C22) give higher corrosion resisting welds. As for other duplex stainless steels the coefficient of thermal expansion is lower than for austenitic grades, reducing distortion and residual stresses. Post weld annealing increases the corrosion resistance of welds.

4.20.12 APPLICATIONS OF UR52N+

Oil and gas exploration, processing and support systems, pollution control including flue gas desulphurisation, marine and other high chloride environments, chemical processing, transport and storage, pulp and paper processing.

4.20.13 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of UR52N+
2205	The lower cost and better availability of 2205 are required, and a lower corrosion resistance and strength can be accepted.
6% Mo	Higher ductility of this austenitic grade is needed, and the much lower strength is acceptable. Corrosion resistance is similar in many environments, but needs to be considered case by case.
Ni Alloys	A corrosion resistance even higher than UR52N+ is required, and a higher cost structure is acceptable.

4.21 2011: ALUMINIUM MACHINING BAR

4.21.1 INTRODUCTION

2011 is an aluminium alloy designed for high-speed machining with highest chipability of all aluminium alloys due to the addition of lead and bismuth. 2011 can be hard anodised but is not recommended for decorative anodising. Alloy 2011 is interchangeable with alloys 2017 and 2030. Alloy 2011 is heat treatable and has a high fatigue strength.

4.21.2 RELATED SPECIFICATIONS

Alloy	UNS No	AS 1865 / 1866	Euronorm 754 / 755		ASTM B211 / B221
			No	Name	
2011	A92011	2011	3.1655	EN AW-2011 / AlCu6BiPb	2011

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.21.3 CHEMICAL COMPOSITION

Specification values in %, according to AS1865/1866

Alloy 2011	Si	Fe	Cu	Zn	Pb	Bi	Others
min			5.0		0.2	0.2	each ≤ 0.05, total ≤ 0.15
max	0.4	0.7	6.0	0.30	0.6	0.6	each ≤ 0.05, total ≤ 0.15

4.21.4 TEMPER DESIGNATIONS AND DEFINITIONS

Product	Temper Designation	Definition
2011 Cold drawn	T3	Solution heat-treated, cold worked and naturally aged
	T8	Solution heat-treated, cold worked and artificially aged to improve mechanical properties
2011 Extruded	T6	Solution heat-treated and artificially aged

2011 is stocked cold-drawn in temper T8 for sizes 5 – 9 mm diameter.

2011 is stocked cold-drawn in temper T3 for sizes 10 – 55 mm diameter.

2011 is stocked extruded in temper T6 for sizes over 55mm diameter.

4.21.5 SPECIFIED MECHANICAL PROPERTIES

Temper	Size range	Tensile Strength (MPa) min	0.2% Proof Stress (MPa) min	Elongation (% in 50mm) min	Typical Hardness (HB)
T3	> 5 ≤ 40mm	320	270	10	115
	> 40 ≤ 50mm	300	250	10	110
	> 50 ≤ 55mm	290	210	10	110
T6	> 55 ≤ 125mm	310	230	8	110
	>125 ≤ 200mm	295	195	6	110

Tensile strength, proof stress and elongation are guaranteed values as specified by EN 754-2 for cold drawn bar, resp. EN 755-2 for extruded bar. The requirements as per AS1865/1866 are within the limits of EN 754/755. Typical hardness is quoted for indication purposes only.

4.21.6 TYPICAL PHYSICAL PROPERTIES

Temper	Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (mm/m/°C)	Thermal Conductivity (W/m·K)	Specific Heat (J/kg·K)	Electrical Resistivity (nΩ·m)
T3	2840	72.5	23	152	863	44
T6	2840	72.5	23	172	863	38

4.21.7 CORROSION RESISTANCE AND ANODISING

2011 is generally not recommended for applications involving corrosion without hard or protective anodising. Corrosion performance in rural atmosphere is acceptable. Resistance to exfoliation corrosion is acceptable for T3 and good T6.

2011 is not recommended for bright or colour anodising. The product is suitable for protective anodising and performs well with hard anodising.

4.21.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.21.8.1 Surface Finish

Bars up to 55mm diameter are cold drawn. Bars with greater diameters are extruded.

4.21.8.2 Diameter and A/F tolerances

Product	Temper	Range	Tolerance
Round bar	T3	> 6 ≤ 10mm	-0.09/+nil
		> 10 ≤ 18mm	-0.11/+nil
		> 18 ≤ 30mm	-0.13/+nil
		> 30 ≤ 50mm	-0.16/+nil
		> 50 ≤ 55mm	-0.19/+nil
	T6	> 55 ≤ 65mm	± 0.40
		> 65 ≤ 80mm	± 0.45
		> 80 ≤ 100mm	± 0.55
		>100 ≤ 120mm	± 0.65
		>120 ≤ 150mm	± 0.80
		>150 ≤ 180mm	± 1.00
		>180 ≤ 220mm	± 1.15
Hexagonal bar	T3	> 6 ≤ 10mm	-0.09/+nil
		>10 ≤ 18mm	-0.11/+nil
		>18 ≤ 30mm	-0.13/+nil
		>30 ≤ 50mm	-0.16/+nil
Square bar	T3	> 6 ≤ 10mm	-0.09/+nil
		> 10 ≤ 18mm	-0.11/+nil
		> 18 ≤ 30mm	-0.13/+nil
		> 30 ≤ 50mm	-0.16/+nil
		> 50 ≤ 55mm	-0.19/+nil
	T6	> 55 ≤ 65mm	± 0.50
		> 65 ≤ 80mm	± 0.70
		> 80 ≤ 100mm	± 0.90
		>100 ≤ 120mm	± 1.00

4.21.8.3 Straightness – maximum deviation from a straight line

Round, square and hexagonal cold-drawn bar and extruded bar up to 80mm: 0.6mm in any 300mm and may not exceed over total bar length: 2mm x length in metres.

Round, square and hexagonal extruded bar over 80mm up to 120mm: 1.0mm in any 300mm and may not exceed over total bar length: 2mm x length in metres.

Round, square and hexagonal extruded bar over 120mm up to 200mm: 1.5mm in any 300mm and may not exceed over total bar length: 3mm x length in metres.

4.21.8.4 Length Tolerance

Round, square and hexagonal bar:

Size up to 55mm (drawn): ± 7mm for bar length up to 5000mm
Size 60-100mm (extruded): + 7mm/-0 for bar length up to 5000mm
Size 100-200mm (extruded): + 9mm/-0 for bar length up to 5000mm

4.21.9 WELDING AND COLD FORMING

2011 is not suitable for welding processes such as oxy-gas welding, MIG/TIG welding or resistance welding. It cannot be brazed. It has acceptable soldering properties.
2011 is not recommended to undergo any cold forming operations.

4.21.10 APPLICATIONS OF 2011

General components such as screws, bolts, fittings, nuts, automatic lathe products. Auto fuel systems, clock parts, gears and machine parts, pipe stems, TV fittings, camera parts, meter shafts, ordnance, industrial connectors. Applications where good machinability and strength are required.

4.21.11 POSSIBLE ALTERNATIVE ALLOYS

Alloys	**Why it may be chosen instead of 2011**
2030	When free machining alloy is required and better mechanical properties are needed than 2011 offers.
6262	When alloy is needed with good machinability and similar mechanical properties as 2011, but good corrosions resistance and/or anodising properties and/or weldability are required as well.

4.22 6262: ALUMINIUM MACHINING BAR

4.22.1 INTRODUCTION

6262 is an aluminium alloy designed for offering high machinability, good mechanical properties and high corrosion resistance. Machinability of 6262 is significantly higher than that of other 6000 series alloys like 6061 or 6082 and approaches the machinability of alloys like 2011 or 2030. Machined pieces easily obtain a smooth and bright finish. The mechanical, corrosion and anodising properties are comparable to alloy 6061 and alloy 6082. 6262 can be protective or hard anodised. It is also available in the 6262-ECO version with reduced lead content.

4.22.2 RELATED SPECIFICATIONS

Alloy	UNS No	AS 1865/1866	Euronorm		ASTM B211 / B221
			No	Name	
6262	A96262	6262	EN AW-6262	AlMg1SiPb	6262

These comparisons are approximate only. The list is intended as a comparison of functionally similar materials not as a schedule of contractual equivalents. If exact equivalents are needed original specifications must be consulted.

4.22.3 CHEMICAL COMPOSITION

Specification values in %, according to AS1865/1866

Alloy 6262	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Others
Min	0.4		0.15		0.8	0.04			0.4	0.4	each ≤ 0.05, total ≤ 0.15
Max	0.8	0.7	0.40	0.15	1.2	0.14	0.25	0.15	0.7	0.7	each ≤ 0.05, total ≤ 0.15
Alloy 6262-ECO	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Pb**	**Bi**	**Others**
Min	0.6			0.2	0.6					0.4	each ≤ 0.05, total ≤ 0.15
Max	1.4	0.7	0.50	1.2	1.2	0.30	0.30	0.20	0.4	2.0	each ≤ 0.05, total ≤ 0.15

There is no difference in the mechanical properties, corrosion resistance, anodising properties and weldability of 6262 and 6262-ECO. The machinability of 6262-ECO is slightly better than that of 6262.

4.22.4 TEMPER DESIGNATIONS AND DEFINITIONS

Product	Temper Designation	Definition
6262 Cold drawn	T9	Solution heat-treated, artificially aged and cold worked
	T91	Solution heat-treated, artificially aged and cold worked
	T8	Solution heat-treated, cold worked and artificially aged
6262 Extruded	T6	Solution heat-treated and artificially aged

6262/6262-ECO is stocked in temper T9 for sizes 5 – 55mm diameter.
6262/6262-ECO is stocked in temper T6 for sizes over 55mm diameter.

4.22.5 SPECIFIED MECHANICAL PROPERTIES FOR 6262 AND 6262-ECO

Tensile strength, proof stress and elongation are guaranteed values as specified by EN 754-2 (drawn bar) and EN 755-2 (extruded bar). Typical hardness is quoted for indication purposes only. The mechanical properties as required by AS1865/1866 are within the limits of EN 754/755.

Temper	Size range	Tensile Strength (MPa) min	0.2% Proof Stress (MPa) min	Elongation (% in 50mm) min	Typical Hardness (HB)
T9	> 5 ≤ 50mm	360	330	4	110
T9	> 50 ≤ 55mm	345	310	4	
T6	> 55mm	260	240	8	

4.22.6 TYPICAL PHYSICAL PROPERTIES

Temper	Density (kg/m³)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (mm/m/°C)	Thermal Conductivity (W/m·K)	Specific Heat (J/kg·K)	Electrical Resistivity (nΩ·m)
T9	2840	69.0	23.4	172	825	39
T6	2840	69.0	23.4		825	

4.22.7 CORROSION RESISTANCE AND ANODISING

6262 is one of the most corrosion resistant aluminium alloys. Susceptibility to stress-corrosion cracking and exfoliation is negligible. Galvanic corrosion can occur in the course of direct contact with dissimilar metals and this should therefore be avoided. It has acceptable corrosion-resistance performance in marine environments too. 6262 is excellent for protective anodising, whilst it has good properties for hard and decorative anodising.

4.22.8 CONDITIONS OF SUPPLY – FINISH, DIMENSIONS AND TOLERANCES

4.22.8.1 Surface Finish

Bars up to 55mm diameter are cold drawn. Bars with greater diameters are extruded.

4.22.8.2 Diameter and A/F tolerances

Product	Temper	Range	Tolerance
Round bar	T9	> 6 ≤ 10mm	-0.09/+nil
		> 10 ≤ 18mm	-0.11/+nil
		> 18 ≤ 30mm	-0.13/+nil
		> 30 ≤ 50mm	-0.16/+nil
		> 50 ≤ 55mm	-0.19/+nil
	T6	> 55 ≤ 65mm	± 0.40
		> 65 ≤ 80mm	± 0.45
		> 80 ≤ 100mm	± 0.55
		>100 ≤ 120mm	± 0.65
		>120 ≤ 150mm	± 0.80
		>150 ≤ 180mm	± 1.00
		>180 ≤ 220mm	± 1.15
Hexagonal bar	T9	> 6 ≤ 10mm	-0.09/+nil
		> 10 ≤ 18mm	-0.11/+nil
		> 18 ≤ 30mm	-0.13/+nil
		> 30 ≤ 50mm	-0.16/+nil
Square bar	T9	> 6 ≤ 10mm	-0.09/+nil
		> 10 ≤ 18mm	-0.11/+nil
		> 18 ≤ 30mm	-0.13/+nil
		> 30 ≤ 50mm	-0.16/+nil
		> 50 ≤ 55mm	-0.19/+nil
	T6	> 55 ≤ 65mm	± 0.50
		> 65 ≤ 80mm	± 0.70
		> 80 ≤ 100mm	± 0.90
		>100 ≤ 120mm	± 1.00

4.22.8.3 Straightness – maximum deviation from a straight line

Round, square and hexagonal bar: 0.6mm in any 300mm and may not exceed over total bar length: 0.7mm x length in metres.

4.22.8.4 Length Tolerance

Round, square and hexagonal bar:

Diameter up to 55mm (drawn):	± 3mm for bar length up to 4000mm
Diameter 60-75mm (extruded):	+ 3mm/-0 for bar length up to 4000mm
Diameter over 75mm (extruded):	+ 5mm/-0 for bar length up to 4000mm

4.22.9 WELDING AND COLD FORMING

6262 has excellent weldability and is suitable for all conventional welding processes. Best results are achieved with MIG, TIG or resistance welding. It can be brazed very well.

4.22.10 APPLICATIONS OF 6262

General components for automotive industry, such as transmission valves, brake pistons or air conditioners, CATV connectors, camera parts, tripod fittings.

4.22.11 POSSIBLE ALTERNATIVE GRADES

Grade	Why it may be chosen instead of 6262
6082	When machining properties can be sacrificed in return for further improved corrosion resistance
2011	When alloy is needed with even better machinability and similar mechanical properties as 6262, and sacrifices are possible in corrosion resistance and/or anodising properties and/or weldability.

5.5NON-DNON-DESTRUCTIVE TESTING OF AESTRUCTIVE TESTING OF BAR PRODAR PRODUCTS

5.1 HOW DOES ULTRASONIC INSPECTION WORK?

Ultrasonic inspection normally involves the use of a piezo electric transducer which is both a transmitter and receiver of ultrasound. The transducer must be coupled to the item to be inspected, as ultrasound at the frequency used is not transmitted in air. Coupling of the transducer to the item under inspection may be achieved in two main ways: In the case of the contact inspection method a coupling medium (oil or wall paper paste, or similar) is used. The other common process used is immersion testing where the component or material under inspection is immersed in a water bath and ultrasound is transmitted through the water and into the component. (Corrosion inhibitors are normally added to the water bath where immersion testing is involved).

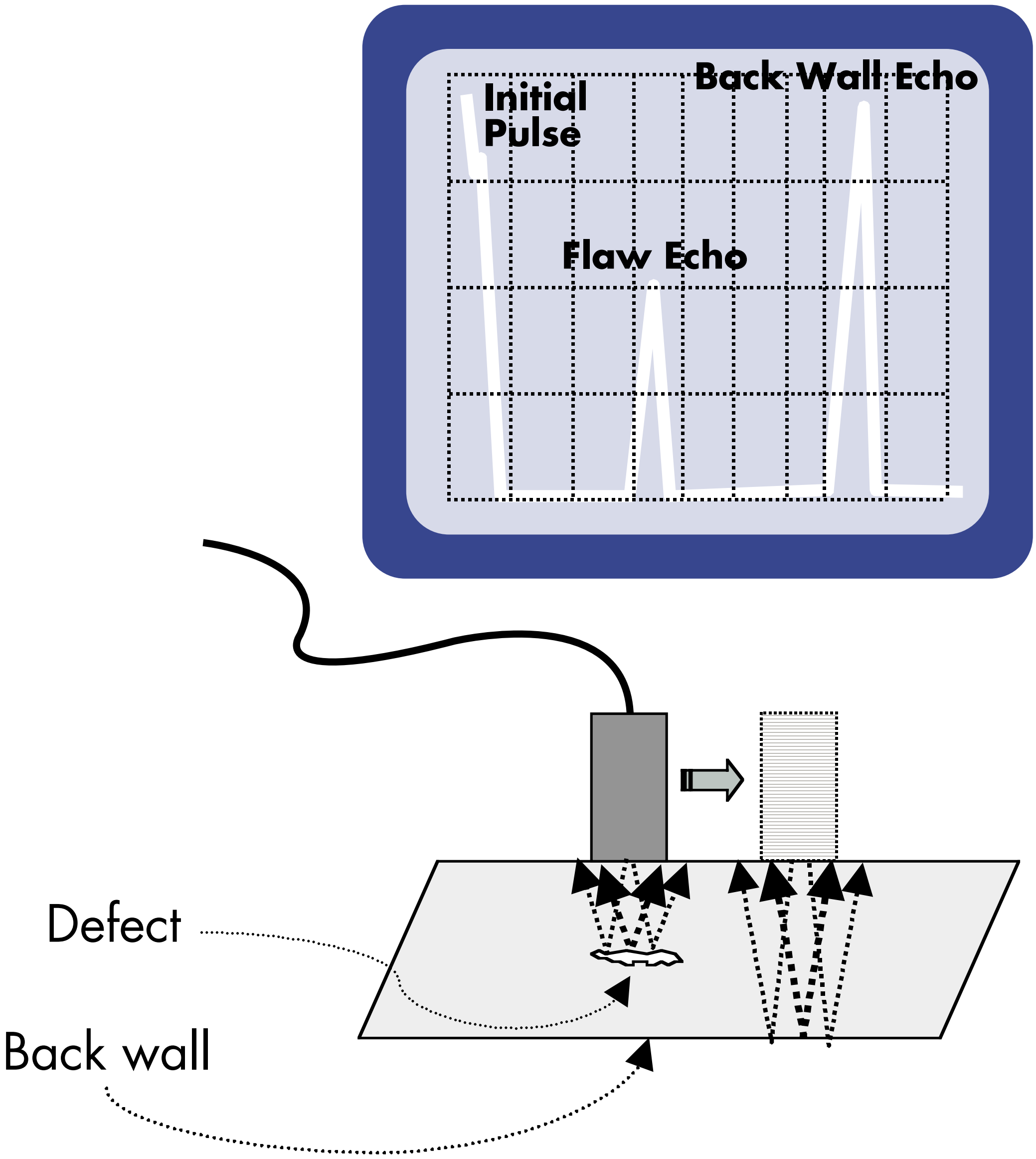


Illustration of ultrasonic detection of impurities in a steel bar

A proportion of the ultrasound is reflected back at interfaces such as the coupling medium / material interface, but the majority of the ultrasound should ideally be transmitted into the material / steel under inspection. Ultrasound is reflected from the back surface (back wall) of the item under inspection and off any planar discontinuities that may be present in the steel. (Note: to be able to detect any the discontinuities present in the steel matrix the acoustic properties of the discontinuity must be different to those of the defect free steel).

The transducer (as described above) comprises of a piezo electric crystal. Initially, the piezo crystal converts electrical energy to ultrasound which is transmitted into the item under inspection. Ultrasound reflected back to the crystal is then converted to electrical energy and this signal is amplified, and in turn the signal is monitored on a cathode ray tube or digital display screen. The time base can be calibrated providing information on the location of defects in relation to their position between the front and back wall of the item under inspection. Also using relative reflectivity (at known gain setting and beam path lengths) it is possible to determine the size of discontinuities present. An experienced ultrasonic technician can accurately map the location, size and shape of discontinuities that may be present. Based on the location, size, shape / geometry of a discontinuity it may then be categorised as a defect

An analogy is sometimes used to help describe the ultrasonic test method. Imagine being in a darkened room and a torch light producing a diverging beam of light is allowed to shine on a sheet of A4 paper. Where the sheet of paper is presented at right angles to the diverging beam of light more light energy is reflected backwards. If on the other hand the sheet of paper is placed in the light beam and placed parallel to the diverging beam of light (i.e. edge on) then very little light is reflected backwards. Similar principles apply to ultrasonic testing in that a diverging beam of ultrasound is used and discontinuities that present themselves at right angles to the ultrasonic beam may be detected (assuming a large enough reflectivity applies), while those that present themselves with their plane parallel to the ultrasonic beam are very difficult or impossible to detect.

Therefore, scanning methods may involve the use of normal and / or shear wave probes. A normal "0°" probe essentially directs ultrasound into the component under inspection normal to the surface (i.e. at right angles to the surface). A shear wave probe on the other hand directs ultrasound into the component at an angle. Common angles might be in the range 30° through to around 60°. Ultrasound may be diffracted and bent as it moves between material having differing acoustic attenuations, (this is similar to light through a prism). Also ultrasound changes velocity depending on the material through which it is travelling. The formula V=fl, where V=velocity, f = frequency and l = wavelength may be used by an ultrasonic technician. Ultrasonic probes are normally identified with the following basic information: Frequency (MHz), Diameter and Angle. Please note that the information provided above is not meant to be exhaustive, rather it is an introduction to the some of the major principles of the ultrasonic test method.

5.2 WHY IS ULTRASONIC INSPECTION AN ISSUE?

All rolled and forged steel products contain microscopic discontinuities, such as non-metallic inclusions. Volumetric discontinuities such as voids or cavities may also be present, originating from shrinkage or gas porosity. In addition, surface discontinuities or defects such as cracks or seams may be present, remnant from hot processing of billets or created during heat treatment.

The issue is: when does a discontinuity become a defect? Discontinuity size and shape, frequency of occurrence, distribution and location all need to be considered. Rejection or acceptance of discontinuities also depends on the application of the component. The loss of effective cross-section due to the presence of any discontinuity, loss of strength due to fatigue, and implications of sudden impact are all relevant considerations.

Ultrasonic inspection is a non-destructive testing method used to locate volumetric discontinuities and to determine their size, geometry and frequency of occurrence.

5.3 ULTRASONIC INSPECTION OF ALLOY BAR

Products benefiting from inspection: 4140, 4340, 6582, 6580, 6587, 6657 and 8620H.

5.3.1 WHAT DOES IT MEAN?

- All alloy steel bar products that are sold from Wakefield stock are ultrasonic inspected.
- Ultrasonic inspection has been performed in accordance with a defined standard.
- The inspection standard is explicit and transparent: AS 1065 to Level 2.
- AS1065 is the Australian Standard for "Non-Destructive Testing of Carbon and Low Alloy Steel Forgings".
- Level 2 refers to the precise inspection criteria.

5.3.2 WHY AS1065 LEVEL 2?

AS1065 defines the method of ultrasonic inspection. There are three inspection levels. The higher the level (i.e. Level 1 is higher than Level 2 which in turn is higher than Level 3), the lower the frequency and the smaller the size of the discontinuities allowed to be found by the ultrasonic inspection.

If a product meets AS1065 Level 2 it will be suitable for most general engineering applications. A small number of applications will call for an even more stringent specification regarding ultrasonic inspection; this can be carried out if requested.

5.3.3 WHAT ARE THE BENEFITS TO THE CUSTOMER?

- End user Quality of the Product is Guaranteed.
- Mill certificate based on test results is available, which can be submitted to the end user. The mill certificate will state the Ultrasonic Test Method and Acceptance Criteria used.
- Reduction in the likelihood of incurring costs and loss of time where defects are found to be present at the time of machining.
- Reduction in the likelihood of production time losses and the associated costs if a component fails in service.

6. HEAT AND SURFACE TREATMENT OF STEELS

A large variety of heat treatments can be applied to steels - this feature is one of the reasons that steels are such versatile engineering materials. The most common heat treatments are:

6.1 AS ROLLED & AS FORGED

Steel produced by hot rolling, and allowed to cool from the rolling temperature without strict control. No separate heat treatment operation is applied, but this approximates a normalised condition. Bars larger than about 250mm (it varies between steel mills) cannot be hot rolled to final size; these are hot forged in a large forging press. Again the bars are shipped without subsequent heat treatment. This condition is only used for steels destined for fairly non-critical applications.

6.2 ANNEALING

Full annealing:

- consists of heating the steel to its austenitizing temperature (approx 890°C for 0.2% carbon steel, and 840°C for 0.4% carbon), holding it until temperature uniformity is achieved, and then cooling slowly to a low temperature. The cooling rate is most critical through the transformation range (around 850°C for a 0.2% carbon steel, and 815°C for 0.4%C). Cooling is usually in the furnace and so the heat treatment cycle time is quite long.

Sub-critical annealing:

- (or stress-relief annealing) uses a lower temperature (typically 550 – 650°C) and shorter cycle time. This operation is used when the heat treated component does not have to be in softest condition. This treatment is to remove residual stresses remnant from heavy machining or other cold work.

Spheroidise annealing:

- is a treatment where the steel is held just below the lower critical temperature (around 700°C) for a prolonged period, or alternatively heated and cooled to just above and just below the lower critical temperature. This treatment is only used for steels requiring maximum ductility, such as those for cold heading to make bolts.

Solution Treatment:

- The annealing process carried out on austenitic stainless steels; solution of all phases in the material at a very high temperature (generally about 1050°C), followed by rapid cooling to prevent precipitation.

Stabilisation Treatment:

- is an optional secondary treatment of stabilised austenitic stainless steels (grades 321, 347 and 316Ti) to ensure all carbon is precipitated as titanium or niobium carbides. The temperature is about 820 – 900°C.

6.3 NORMALISING

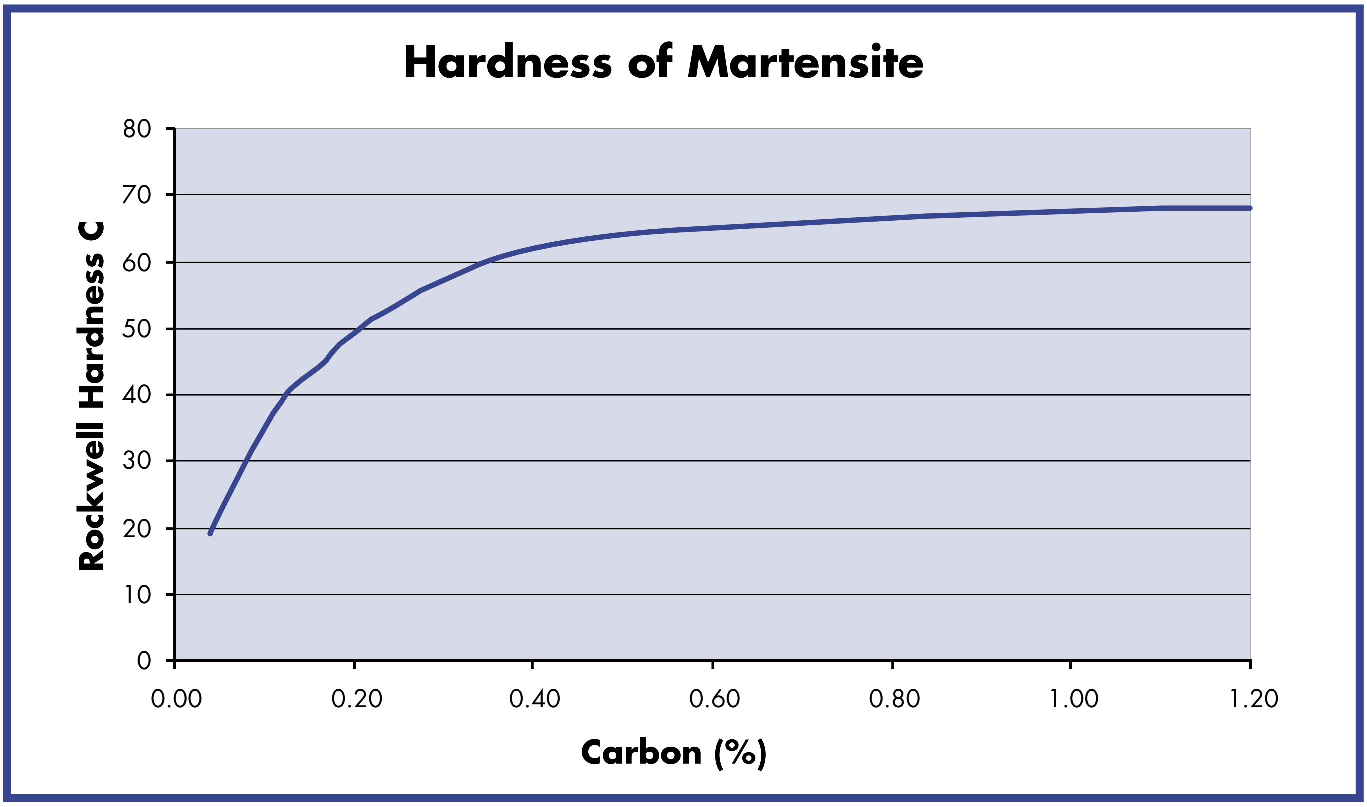
Normalising is achieved by heating to a slightly higher temperature than annealing, and then cooling a little quicker - generally in still air. The microstructure produced is a fine, fairly soft structure of pearlite, and (depending upon carbon content) probably some ferrite. The result is a slightly stronger and harder steel compared with the annealed alternative. In low carbon steels normalising also results in a better machining steel compared with annealed.

6.4 HARDENING & TEMPERING

6.4.1 HARDENING

Hardening of steel is achieved by cooling quickly from the austenitising temperature (around 850°C – 900°C). At this temperature the structure of most a steels is pure austenite. Most steels transform to some other structure (or "phase") when cooled from this temperature, depending upon the cooling rate, and it is these phase changes that generate the various heat treated conditions. Only austenitic stainless steels and austenitic manganese steels retain their austenitic structures when cooled down to room temperature. They cannot be hardened by quenching.

The result of fast quenching of low alloy steels is a metallurgical structure called martensite, a very hard but brittle phase. The hardness of a martensitic steel depends upon the alloy content – the most significant element is the carbon content, with higher carbon content steels being able to be made much harder, as shown in the graph below. Very low carbon martensites (less than about 0.1% C) are relatively low hardness and quite tough. It follows that mild steel, or other low carbon steels, cannot be hardened to high hardnesses. A medium carbon steel such as 4140 results in a hardness of up to about Rockwell C 60 (60 HRC) in the fully hardened condition. Higher carbon contents – up to about 1.0% C will result in as-quenched hardnesses of up to about 70 HRC. Cutting and metal working tools are almost always made from high carbon steels, so that the required high hardness can be achieved in heat treatment.

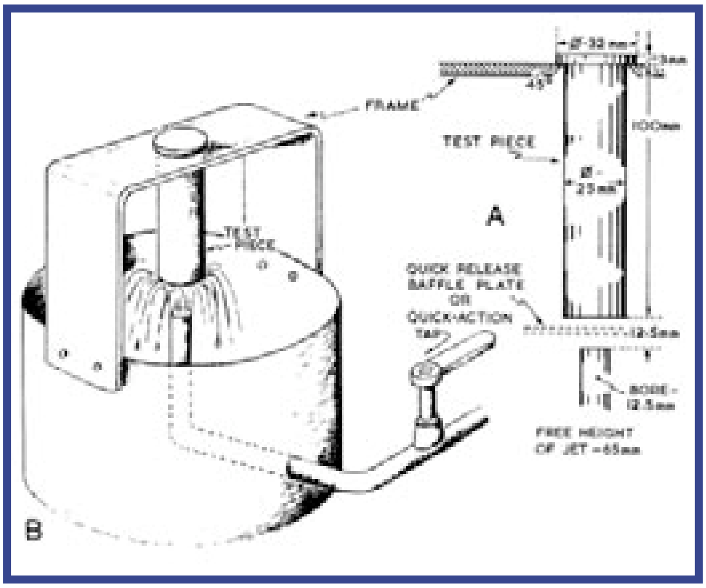


The cooling (also called "quenching") is carried out in various cooling media, with various cooling rates achievable. Quenching into brine (salty water) results in a very fast cool, plain fresh water gives a slightly slower cooling rate, and quenching into oil gives a slower rate again. Simply removing the hot steel from the furnace and cooling it by blowing air past it is slower still. A polymer quench is a synthetic water mix, with various cooling rates available.

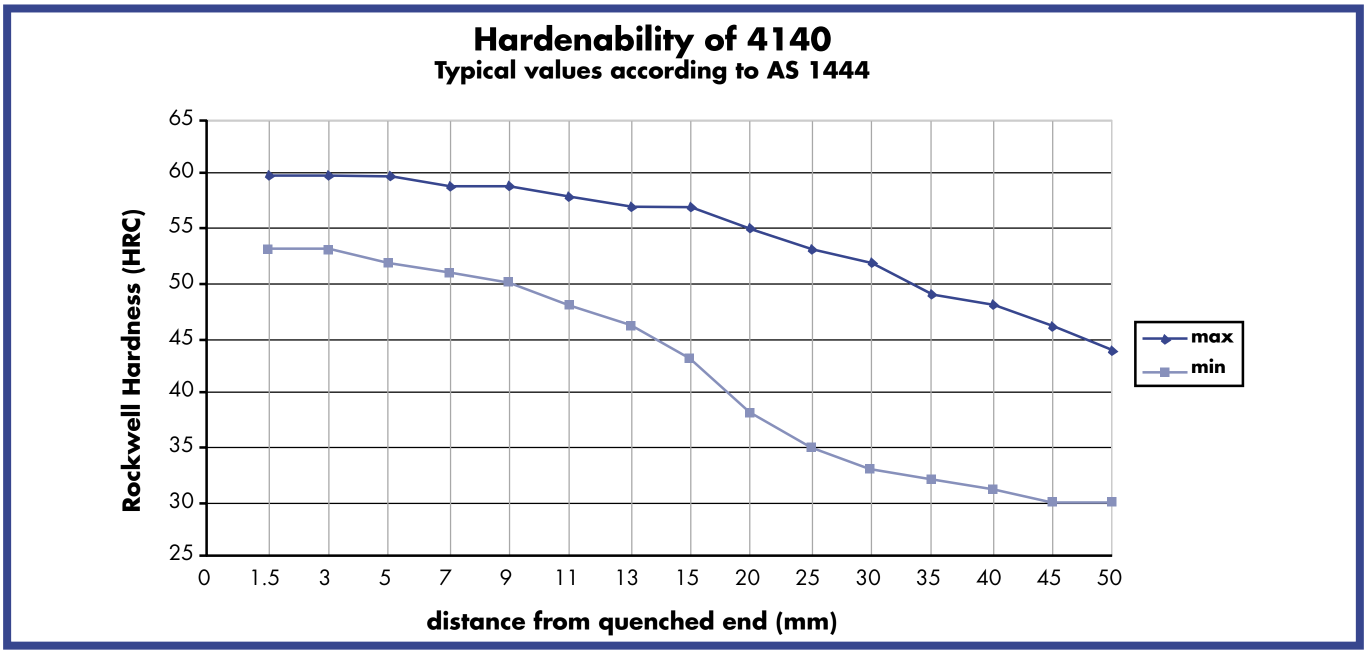
"Hardenability" is the ability of a steel to be hardened through a section thickness. The graph above assumes that the resulting microstructure is 100% martensite, but for each steel composition there is a critical cooling rate which must be achieved if the structure is to be fully martensitic.

A slower cooling rate than critical will result in a mix of transformation products, possibly including ferrite, pearlite and bainite in addition to martensite. Steels with high hardenability will transform to 100% martensite at a slower cooling rate, and hence can be hardened through heavier sections than can lower hardenability steels.

The hardenability of a steel is related primarily to its alloy content and grain size. Elements that increase hardenability are chromium, manganese, molybdenum and vanadium. Carbon plays a large part in determining hardness, but has only a minor effect on hardenability.



The standard test for measuring hardenability of a steel is the Jominy test, shown in the diagram. Drawing A shows the standard test piece – a cylinder of steel with a slightly larger diameter head at one end. The test is carried out by heating this test piece to its austenitic state, then dropping it into the apparatus shown in Drawing B. A standard jet of water directed at the bottom end of the test piece quenches it in a controlled manner. After the test piece is cooled to ambient a flat is ground along its length, and hardness determined every millimetre from the quenched end. The results can be viewed in a table or more usefully graphed to give a Jominy curve. A steel with a higher hardenability will harden further along the bar.



This test can also be used to specify hardenability of steel. Specifications for low alloy steels set down limits for hardenability by defining a maximum and minimum hardness at each distance from the quenched end, and the result is graphed as in the hardenability band for grade 4140. A Jominy test for a Heat of 4140 should give results between the two lines plotted on this graph.

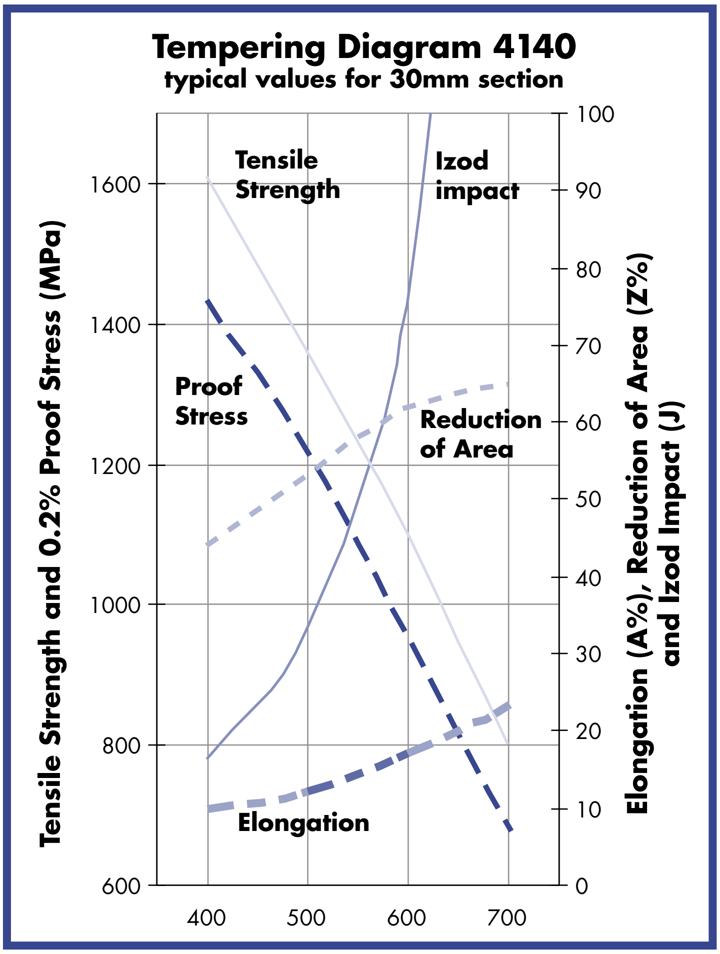
The results of this test also show what happens in the real heat treatment situation, where a bar is quenched with the intention of fully hardening it; the Jominy curves show that steels with only small alloying additions have low hardenability and so don't harden far along the Jominy sample and also do not harden through large bar diameters.

6.4.2 TEMPERING

Although as-quenched martensite is hard it is also quite brittle. The brittleness can be reduced (and toughness increased) by “tempering” - a second heat treatment involving heating the hardened steel to an intermediate temperature. This results in a trade-off between strength and toughness. Tempering is almost always an essential second step … as-quenched martensite is usually too brittle for practical service applications. The response of a quenched (fully martensitic) steel to tempering is quite predictable; the higher the tempering temperature the more the hardness, tensile strength and proof stress are reduced, and the more the toughness (impact), elongation and reduction of area properties are increased. A tempering curve for low alloy steel 4140 is shown below.

This diagram indicates the typical mechanical properties (tensile strength, yield point or proof stress, elongation, reduction of area and Izod or Charpy impact resistance) to be expected when the steel is quenched from the correct hardening temperature and then tempered at the nominated temperature. This diagram is typical for grade 4140, but compositional variations between individual heats will have some influence on the outcome. Other conditions such as hardening (austenitising) time and temperature and sample size also have an influence on the properties of the tempered product. For many steels (including 4140) there is a substantial drop in Izod impact strength in the range 200 to 450°C so this tempering range is usually avoided.

This data assumes that the steel is fully hardened, i.e. that it was quenched in the hardening heat treatment sufficiently fast that the structure was converted to martensite right through to the centre. A steel which is not cooled sufficiently fast transforms to some other products, in addition to martensite, towards the bar centre. Such a structure is said to be “slack quenched”, and although it may exhibit the same strength or hardness as a correctly hardened and tempered structure its toughness and ductility will be inferior. If the component being produced is not able to be fully hardened through the required section thickness, then another steel grade, with higher hardenability, should usually be selected.



6.5 SURFACE HARDENING OF STEELS

A good combination for many high duty engineering components is a hard outside skin (case) while still retaining a slightly softer, tougher inside (core). One of the main benefits of steel as an engineering material is its capacity for surface hardening to give this combination of desirable properties.

Induction and flame hardening of medium carbon steels are selective surface hardening processes that result in a localised harden-and-temper; heat input is restricted to just the outer layer of the steel. There is no change to the composition and no diffusion required. The processes can therefore be very rapid.

Case hardening by contrast is a group of diffusion-based operations that change the composition of the external component layer. Steels subjected to carburising, nitriding or similar processes have increased carbon or nitrogen in their surfaces, and in fact are different steels at the surface compared to the underlying core.

6.6 CASE HARDENING - CARBURISING

The hardness achievable by hardening and tempering a steel is very largely determined by its carbon content (see previous graph). One way of achieving this mixture of properties is therefore to add carbon to the case, usually by putting the steel in a furnace containing a high carbon content gas, and then to harden and temper the component. The two operations – carburising and hardening & tempering – should be seen as distinct, although in some instances the heat treatment is carried out directly from the carburising temperature. Very high surface hardnesses (in excess of 60 HRC) can be achieved by this carburising treatment.

This treatment is very widely used for gears. Steels used have low carbon content (typically 0.15 - 0.20%), and medium to high alloy content (eg 6587, 6657, 8620, En36A, En39B).

Carburising of the steel surface is most commonly carried out by pack or gas processes, although liquid (salt bath), vacuum and plasma processes are also used. In any carburisation process the aim is to drive carbon into the surface of a steel with originally a low carbon content, usually less than 0.25%, and to increase this to approximately 0.8 – 1.0% at the surface. The depth of this carburised layer will depend upon the temperature, time of carburising, type of carburising cycle, carbon concentration at the surface of the specimen and original composition of the steel. This is a diffusion process, driven by concentration differences and very much time dependent. The processes achieve a thin carburised layer very quickly, but because diffusion is the controlling mechanism it becomes increasingly slow to achieve deeper cases.

6.6.1 PACK CARBURISING

In this process, the part that is to be carburised is packed in a steel container so that it is completely surrounded by granules of charcoal. The charcoal is treated with an activating chemical such as barium carbonate that promotes the formation of carbon dioxide. This gas in turn reacts with the excess carbon in the charcoal to produce carbon monoxide, which reacts with the low-carbon steel surface to form atomic carbon, able to diffuse into the steel. This carburising process does not harden the steel, it only increases the carbon content to some depth below the surface, so that when subsequent quenching is carried out the surface will achieve a high hardness.

It is difficult to quench components directly from the pack, as the sealed container has to be opened and the parts extracted. It is more usual to slow cool the entire pack at the end of the carburisation time and remove the part for separate hardening and tempering. This technique lends itself to jobbing work, requires only basic heat treatment equipment and can carburise to a depth of up to about 1.3mm. It is unsuitable for continuous production work, or for thin or closely controlled case depths.

6.6.2 GAS CARBURISING

This process is commonly used for production carburising, and is well suited to continuous furnace lines. The components are heated above the upper critical temperature (Ac3) in a furnace with an atmosphere of carbon-containing gas such as methane, ethane, propane, natural gas, acetylene, manufactured gas or mixed hydrocarbon gases. Most carburising gases are flammable and controls are needed to keep this carburising gas at approximately 925°C from contacting oxygen. The carburising gases are often diluted with an endothermic carrier gas, mainly nitrogen and carbon monoxide along with smaller amounts of carbon dioxide, hydrogen and water vapour. The carrier gas serves to control the amount of carbon supplied to the steel surface and prevents the formation of soot residue. Control of the process is often by measurement of the dew point, related to the water vapour content of the gas mixture.

As for pack carburising, the carbon monoxide (dissociated from the carbon-containing gas such as methane) decomposes to atomic carbon which is able to diffuse into the steel.

Gas carburising allows more accurate control of the composition and depth of the case than does pack carburising, and is more suited to continuous production. The equipment required however is more sophisticated and specialised, and requires highly skilled operators. There are also safety issues associated with the carburising gases – these can be explosive mixtures.

6.6.3 CARBURISING – HEAT TREATMENT

The second step of the case hardening process is heat treatment – a harden-and-temper operation designed to produce the desired combination of properties in both the case and core.

Because the case and core have widely different carbon contents, they also have different austenitising (“Ac3”) temperatures for hardening – ideally about 880°C for the core and 760°C for the case. The ideal treatment is firstly to heat the steel to grain refine the core, followed by a water quench and then a second heating to about 760°C followed by a second quench. The result of this treatment is a case of fine-grained martensite surrounding a core of fine ferrite and bainite. A final low temperature temper (160 – 220°C) will relieve any quenching stresses in the case.

A more economical heat treatment cycle is so-called direct hardening. This is particularly appropriate for thin cases (up to 0.5mm) because the relatively short carburising time will not have produced excessive grain growth. Here the components are quenched directly from the end of the carburisation treatment, followed only by the temper.

An intermediate approach, suitable for intermediate depth cases, is to cool slowly from the carburising temperature and then to re-heat to a compromise temperature of around 820°C, followed by a water quench and then temper. This treatment results in slightly coarse-grained case and core, but the properties are satisfactory for many applications.

6.7 NITRIDING

In this process atomic nitrogen is diffused into the steel surface, similar to the carbon diffusion of carburising. The treatment temperature is much lower than for carburising, in the range 500 – 600°C, but for generally longer times – up to 100 hours, depending on the steel being treated and the desired case depth. Under these conditions very hard nitrides form at and near the steel surface. Steels suitable for nitriding contain the nitride-forming elements aluminium, chromium, molybdenum or vanadium. Steels containing aluminium will form very hard but thin cases, while those with chromium will form slightly softer and deeper nitrided cases. Plain carbon steels do not respond well to nitriding.

As the nitriding temperature is comparatively low this treatment results in less distortion, and volume changes are low because there is no phase transformation. The normal process is to harden and temper the component first to achieve the required core properties, followed by machining and finally nitriding.

Gas nitriding is usually carried out in an atmosphere of ammonia, which dissociates to nitrogen and hydrogen at the treatment temperature. Over-nitriding results in a thick layer of iron nitrides on the steel surface – called the "white layer" because of its appearance through a microscope. The white layer has a detrimental effect on fatigue life so is usually either removed or the nitriding process controlled to prevent its formation. Some proprietary nitriding processes have become available, offering precise control over case depth and hardness and freedom from white layer.

6.7.1 CARBONITRIDING

This process involves the diffusion of both carbon and nitrogen into a steel surface, so combines carburising and nitriding treatments. The process is performed in a gas furnace using a carburising gas such as propane or methane, mixed with several percent of ammonia, which is a source of nitrogen. The process is well suited to continuous furnace operation, and results in case hardnesses of 60 – 65 HRC and depths of about 0.08 – 0.8mm. Carbonitriding is performed at 700 – 800°C, followed by a quench into oil or by gas. Distortion is likely to be less than for carburisation but more than nitriding. Unlike nitriding this process can be applied to plain carbon steels.

6.8 SELECTIVE SURFACE HARDENING

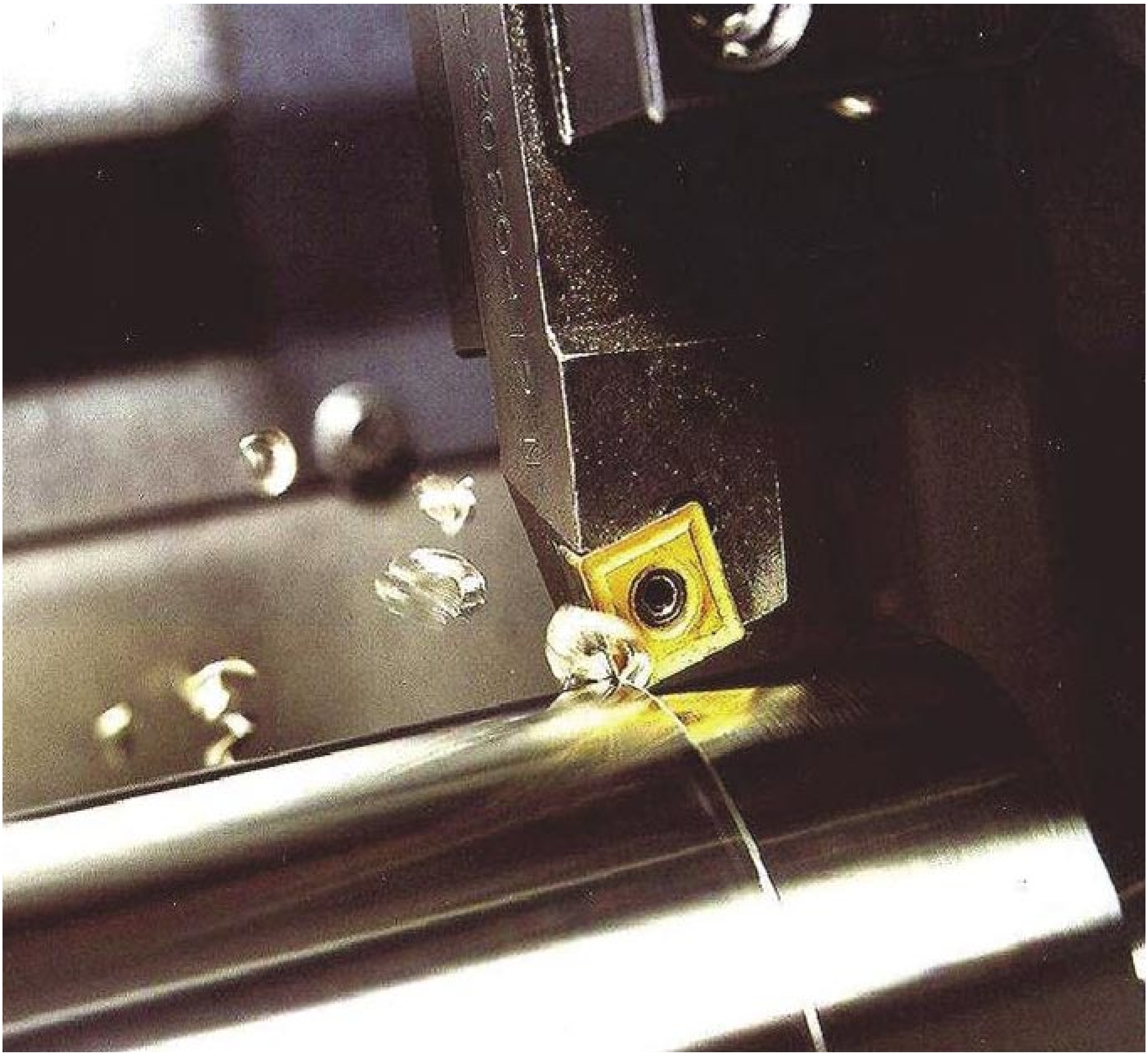
These processes do not change the surface composition but are in fact heat treatments confined to local areas of the component. The surface – and usually only a small section of the component's overall surface – is austenitised and then rapidly quenched to produce martensite. The basic requirement is that the steel have sufficient carbon and hardenability to achieve the required hardness at the surface. Medium carbon steels are usually used. The processes are classified according to heat source – the most commonly used are flame hardening and induction hardening, but there are also applications using lasers and electron beams. In addition to increased wear resistance the surface hardening also induces residual compressive stresses that result in improved bending and torsional strength as well as increased fatigue properties. The component is first hardened and tempered (or normalised) to achieve the required core properties, and the selected areas of the surface are then austenitised and quenched. The final result is a core structure of tempered martensite (or ferrite / pearlite if normalised) with a surface case of untempered martensite. The case is not as hard as in a carburised steel because the carbon content of the surface is not as high.

6.9 FLAME HARDENING

The selected surface area is quickly heated by a gas flame. When the outside layer is heated above its transformation temperature (austenitised) the component is quenched. The result is re-hardening of the outer surface. Manually operated torches are useful for small areas such as the cutting edge of a tool. The process can be automated for repetitive components, with torches arranged according to the component shape. Symmetrical parts such as gears and shafts can be spun between centres within a ring burner; the work piece rotates slowly and as soon as the surface has reached the required austenitic state it is quenched either by complete immersion or by water jets adjacent to the burner ring. Quenching of the surface layer is also assisted by "self quenching" – the inner core of the component remains cold throughout, and its mass will quickly conduct heat from the outer surface.

6.10 INDUCTION HARDENING

This process is the same as flame hardening except that an induction coil provides the heat to the steel surface. The pattern of the heated region can be very precisely controlled by the shape of the coil and also by the frequency of the alternating current in the coil; the higher the frequency the shallower is the depth of penetration of the heating. Induction heating is highly suited to large production runs of similar parts. Its advantages compared to flame hardening are rapid heating rate, less component scaling, high production rate, very precise control over hardening location and depth and low energy consumption.



7.1 MACHINING AND MACHINABILITY

In this section general guidelines are given for the machining of the bar product stocked and marketed by Wakefield Metals. This concerns carbon and alloy steels (section 7.2), stainless steels (section 7.3) and aluminium alloys (section 7.4).

The term machinability includes all those properties which are relevant for the machining and cutting process:

- the wear of tools
- the necessary cutting force
- the resulting form of the chips
- the quality of the surface produced

Machinability should not be regarded as a material property which can be expressed in a number or a single parameter. It is a very complex technological construct. The machinability depends both on the general physical and chemical properties of the material used, as well on the fabrication process used to produce the material itself, hence we talk about IM or improved machinability products that are produced in a way to make them more machinable.

The parameters influencing machinability and the outcome of the machining process are shown in the figure below.

	MACHINABILITY PARAMETERS			
MACHINING INPUT PARAMETER	**CHIP FORM**	**SURFACE**	**WEAR**	**CUTTING FORCE**
PROCESS	***	***	***	***
MATERIAL	***	**	***	**
CUTTING PARAMETERS AND TOOL GEOMETRY	**	***	***	**
MACHINE	*	***	**	*
TOOL MATERIAL	*	**	***	*

*** = NOT SIGNIFICANT, ** = SIGNIFICANT, *** = VERY SIGNIFICANT**

Process relates to the type of machining process (turning, milling, etc.) and the kinematical arrangement of the tools, this is the most important element governing the outcome of a machining operation. As mentioned, different materials vary in their machinability and the way they behave under different cutting conditions. For example, stainless steels should be machined with high feed rate and depth of cut in order to counter work-hardening that occurs. Aluminium alloys should generally be machined with maximised surface speed in order to counter the tendency for build-up on the cutting edge. Guidelines for "feeds and speeds" are given in the following sections. Tool materials should carefully selected, matching the material that is to be machined. Here again important differences exist between materials: coated carbide inserts work very well for carbon and stainless steels but are not recommended for aluminium, as titanium (coating layer usually being titanium nitride) has a chemical affinity for aluminium and will hence quickly dissipate and make the tool surface softer.

7.2 MACHINING OF CARBON AND ALLOY STEEL

The cutting parameters given in this section are recommended ranges which have to be adapted to the specific operating conditions which include factors like tool geometry, machine condition, length and stability of the workpiece and coolant.

7.2.1 SPECIFIC CUTTING FORCE

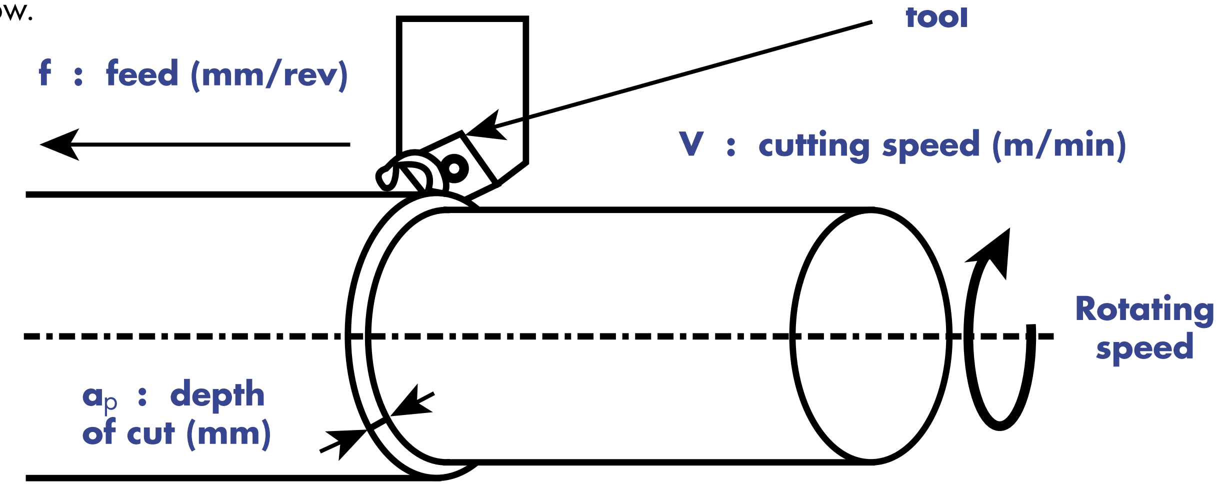
The following table gives the specific cutting force for the various Wakefield bar grades. Given the horsepower of the machining equipment, specific cutting force can be used to determine the maximum depth of cut or maximum feed rate that is achievable.

Product	Specific Cutting Force (MPa)
M1020	
M1030	2000 – 2200
1045	
1214FM	
12L14FM	1800 – 2000
4140	
6582	2600 – 2800
4340	
6580	2800 – 3000
8620H	
6587	2100 – 2300
6657	
U250	1100 – 1200
U400	1200 – 1400

7.2.2 TURNING

7.2.2.1 General Information

The main parameters of any turning operation and their interaction are shown in the diagram below.

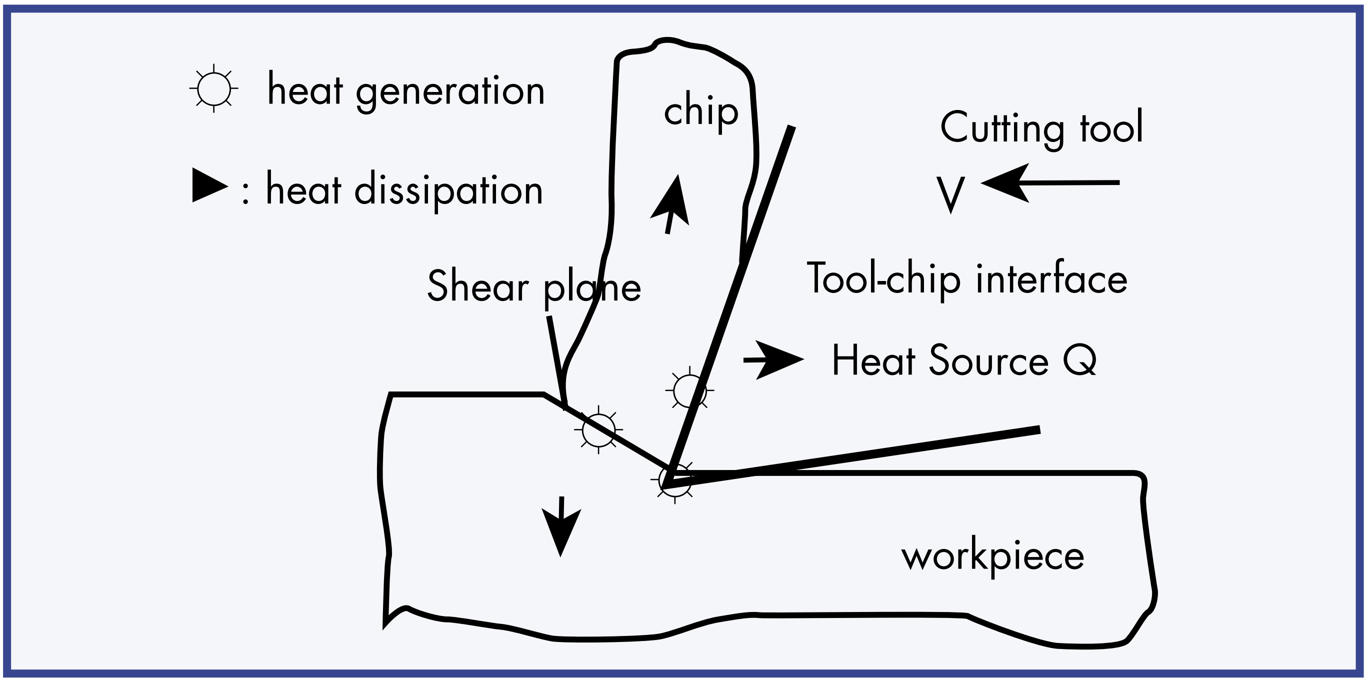


Rate of metal removal (productivity):

$$Q = V_c \cdot a_p \cdot f \qquad (mm^3/min)$$

The rate of metal removal is one of the principal variables influencing overall productivity of the turning operation.

The achievable rate of metal removal is limited by the amount of heat generated during the turning operation. Research has shown that 99% of the energy that is put into the cutter, feed and speed is transformed into the form of heat, mainly through deformation of the chip and friction between the chip and the face of the tool. Therefore, the more energy that is put into the cut, the more heat is produced. Generally coolants are used to dissipate the heat generated. Chips are cut from the material which is slightly ahead of the front of the tool and this area is the primary shear zone. The forces exerted by the cutter on to the workpiece create plastic deformation in this area, which allows the material to yield to the cutter. Then there is a secondary shear zone that forms where the chip slides up the face or front side of the cutting tool. This is the hottest area of the machining operation and temperature in this area can rise to 1,200°C. A third shear zone is located under the leading edge of the cutter. This zone is formed by springback material at the bottom of the cut that was depressed as the primary shear zone yielded. These three areas of heat generation are shown in the drawing below.



Optimising the metal removal rate therefore needs to be balanced against the negative aspects of excessive heat generation: shorter tool life and break-down of the tool. Generally, for carbon and alloy steels this is less of an issue than for stainless steels, which have a very low thermal conductivity and more heat tends to build up around the tool.

Contemporary tool making companies offer multi-layered inserts for improving its heat resistance. Usually there is a top-layer of TiN (titanium-nitride) which enhances the frictional properties of the insert surface. The second coating is made of aluminium-oxide (Al_2O_3). This coating protects against excessive thermal overload.

Nickel and Molybdenum-containing alloy steels like Wakefield 6582, 6587, 6580, 6657 and En39B, tends to show some work-hardening. This work-hardening is quite small when compared to the work-hardening of austenitic stainless steels. Still, it is seen as advantageous to select a depth of cut and feed rate to ensure that the actual cutting edge penetrates the material past the hard zone. This should especially be borne in mind when machining alloy steels with relatively high nickel content such as 6657 and En39B.

7.2.2.2 Turning-Machining Data Charts

The machining data are based on average conditions and usage of cold finished bar (esp. for sections less than 100mm diameter). They are based on a planned tool life of 30 minutes with a square insert geometry used as the reference.

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
M1030 M1020 1045	6	0.30 – 0.80	160 – 230	Roughing (P30-40)
	2.5	0.20 – 0.50	180 – 260	Medium (P20-25)
	0.5	0.05 – 0.25	230 – 380	Finishing (P10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
1214FM 12L14FM	6	0.30 – 0.80	180 – 260	Roughing (P30-40)
	2.5	0.20 – 0.50	220 – 300	Medium (P20-25)
	0.5	0.05 – 0.25	280 – 450	Finishing (P10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
4140 6582 4340	6	0.30 – 0.80	90 – 140	Roughing (P30-40)
	2.5	0.20 – 0.50	100 – 170	Medium (P20-25)
	0.5	0.05 – 0.25	150 – 210	Finishing (P10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
6580	6	0.30 – 0.80	55 – 95	Roughing (P30-40)
	2.5	0.20 – 0.50	75 – 130	Medium (P20-25)
	0.5	0.05 – 0.25	115 – 160	Finishing (P10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
8620H 6587 6657	6	0.30 – 0.80	100 – 180	Roughing (P30-40)
	2.5	0.20 – 0.50	150 – 210	Medium (P20-25)
	0.5	0.05 – 0.25	200 – 320	Finishing (P10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
U250	2	0.30 – 0.80	130 – 200	Medium (K15-25)
	0.5	0.05 – 0.4	175 – 300	Finishing (K10-15)

Product	Depth of cut (mm)	Feed rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
U400	2	0.30 – 0.80	110 – 180	Medium (K15-25)
	0.5	0.05 – 0.4	140 – 240	Finishing (K10-15)

7.2.3 MILLING

7.2.3.1 General Information:

The following formula are applicable to milling operations.

Metal removal rate

$$Q = a_e \cdot a_p \cdot v_f \qquad (mm^3/min)$$

a_e = radial depth of cut (mm)
a_p = axial depth of cut (mm)
v_f = table travel (mm/min)

Cutting speed

$$v_c = \frac{n \cdot D}{318} \qquad (m/min)$$

n = revolutions per minute (rev/min)
D = diameter of the cutter (mm)

Feed speed (or Table travel speed)

$$v_f = n \cdot z \cdot f_z \qquad (mm/min)$$

n = RPM (rev/min)
z = number of teeth
f_z = feed per tooth (mm)

Feed per revolution

$$f = z \cdot f_z \qquad (mm/rev)$$

z = number of teeth
f_z = feed per tooth (mm)

7.2.3.2 Milling - Machining Data Charts

For cutters with indexable carbide inserts.

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
M1030 M1020 1045	Roughing	0.15 – 0.5	120 – 180	Roughing (P20-35)
	Finishing	0.05 – 0.20	160 – 260	Finishing (P10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
1214FM 12L14FM	Roughing	0.15 – 0.5	140 – 220	Roughing (P20-35)
	Finishing	0.05 – 0.20	190 – 310	Finishing (P10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
4140 6582 4340	Roughing	0.15 – 0.5	90 – 140	Roughing (P20-35)
	Finishing	0.05 – 0.20	110 – 180	Finishing (P10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
6580	Roughing	0.15 – 0.5	60 – 80	Roughing (P20-35)
	Finishing	0.05 – 0.20	90 – 150	Finishing (P10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
8620H 6587 6657	Roughing	0.15 – 0.5	100 – 170	Roughing (P20-35)
	Finishing	0.05 – 0.20	150 – 240	Finishing (P10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
U250	Roughing	0.20 – 0.5	130 – 170	Roughing (K15-25)
	Finishing	0.05 – 0.20	170 – 250	Finishing (K10-15)

Product	Operation	Feed per tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
U400	Roughing	0.20 – 0.5	120 – 150	Roughing (K15-25)
	Finishing	0.05 – 0.20	140 – 220	Finishing (K10-15)

7.2.4 DRILLING

7.2.4.1 General Information

The main formulas for drilling operations are the following:

Cutting speed

$$v_c = \frac{n \cdot D}{318} \qquad (m/min)$$

n = revolutions per minute (rev/min)
D = diameter of the drill (mm)

Feed speed

$$v_f = n \cdot f \qquad (mm/min)$$

n = RPM (rev/min)
f = feed per rev. (mm/rev)

Metal Removal Rate

$$Q = 250 \cdot D \cdot f \cdot v_c \qquad (mm^3/min)$$

D = diameter of the drill (mm)
f = feed per rev. (mm/rev)
v_c = cutting speed (m/min)

7.2.4.2 Drilling – Machining Data Charts

Standard drilling parameters for **SOLID CARBIDE** drills, for drilling with internal coolant supply and P25-P40/K40 type tool. Feed rates for drill diameter 7-10mm and up represent the middle of a range.

Product	Cutting Speed (m/min)	Feed Rate (mm/rev) for various drill diameters (mm)					
		2-3	4-6	7-10	11-15	16-20	21-32
M1020 M1030 1045	70 – 90	0.03 – 0.06	0.10 – 0.15	0.20	0.30	0.35	0.40
1214FM 12L14FM	90 – 110	0.03 – 0.06	0.10 – 0.15	0.20	0.30	0.35	0.40
4140 6582 4340	50 – 60	0.03– 0.06	0.05 – 0.11	0.16	0.22	0.25	0.28
6580	35 – 45	0.03– 0.06	0.04 – 0.10	0.14	0.20	0.23	0.28
8620H 6587 6657	60 – 80	0.03– 0.06	0.06 – 0.13	0.18	0.25	0.30	0.35
U250	80 – 100	0.08– 0.12	0.18 – 0.25	0.30	0.35	0.40	0.50
U400	60 – 80	0.08– 0.12	0.18 – 0.25	0.25	0.30	0.35	0.45

Standard drilling parameters for **INDEXABLE CARBIDE INSERT** drills, for drilling with external coolant supply and P25-P40/K40 type tool.

Product	Cutting Speed (m/min)	Feed Rate (mm/rev) for various drill diameters (mm)		
		< 25	25 – 40	> 40
M1020 M1030 1045	150 – 270	0.05 – 0.10	0.08 – 0.18	0.10 – 0.20
1214FM 12L14FM	180 – 330	0.05 – 0.10	0.08 – 0.18	0.10 – 0.20
4140 6582 4340	110 – 210	0.05 – 0.10	0.08 – 0.15	0.10 – 0.20
6580	110 – 180	0.05 – 0.10	0.08 – 0.15	0.10 – 0.20
8620H 6587 6657	130 – 240	0.05 – 0.12	0.08 – 0.16	0.10 – 0.20
U250	80 – 180	0.09 – 0.15	0.14 – 0.25	0.18 – 0.30
U400	80 – 180	0.09 – 0.15	0.14 – 0.24	0.15 – 0.28

7.2.5 PARTING-OFF

Product	Surface Speed (m/min) for various feed rates (mm/rev)	
	0.05 – 0.10	0.10 – 0.25
M1020 **M1030** **1045**	140 – 180	110 – 150
1214FM **12L14FM**	160 – 220	130 - 170
4140 **6582** **4340**	90 – 120	80 – 100
6580	70 – 90	60 – 80
8620H **6587** **6657**	120 – 150	100 - 140
U250	120 – 160	100 – 140
U400	110 – 150	90 – 130

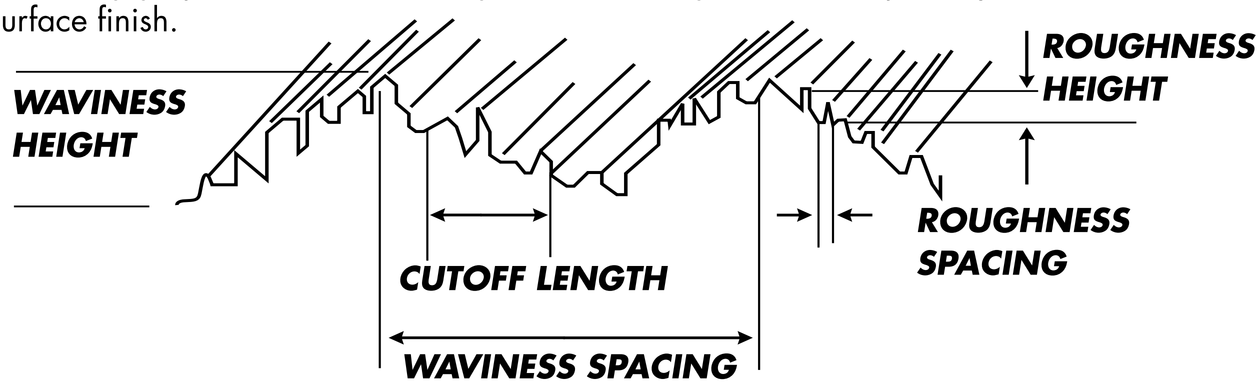
7.2.6 SURFACE FINISH

Surface finish is a characteristic of any machined surface. It is sometimes called surface texture or roughness. What the surface finish of a work piece should be, is based on what the component is supposed to do. The surface finish specification is relevant for the following considerations:

Good surface finishes achieve high efficiency. High quality surface finishes coupled with micron fit will produce less friction. For example a 75HP piston engine can loose up to 5HP to the friction of the connecting rods, crank, and piston unless high quality finishes are applied.

- Good surface finishes increase the wear resistance of two work pieces in an assembly.
- Good surface finishes reduce the friction between two work pieces in an assembly.
- Good surface finishes have a cosmetic effect and make parts "look good".
- Good surface finish permits the proper function of static and dynamic o-ring seals in hydraulic and pneumatic equipment.

The following graph shows the meaning of surface roughness as the primary, measurable indicator for surface finish.



Deviation of surface shape from a straight line can be classified into two groups:

- Waviness
- Roughness

Waviness refers to a low frequency wave-like pattern in the surface as shown in the picture above. Once the wave pattern is filtered out surface roughness is the deviation of the actual surface from a reference line. The so called cut-off length is used to discriminate between waviness and roughness, a common cut-off length for industrial purposes is 0.8mm.

Surface roughness is most commonly measured as ARITHMETIC AVERAGE ROUGHNESS or Ra. Ra is calculated by taking the average of a large number of measured distances from the reference line.

In machining the theoretically achievable surface finish is determined by the nose radius of the tool and the feed rate. In machining practice, many other factors will influence the achieved surface finish, all related to the vibrations that are generated in the workpiece and the tool during the finish machining operation. For carbon and alloy steels (low cold-work hardening), the general rules are the following:

- the larger the nose radius, the better the surface finish
- the lower the feed rate, the better the surface finish

Generally, feed rate should not be higher than ½ of the nose radius and for a very good surface finish ¼ of the nose radius is recommended. The effect of increasing feed rate is stronger than the effect of increasing nose radius. In other words, the adverse effect on surface finish of doubling the feed rate will not be offset by using a tool with a double nose radius.

The following formulas show how the theoretical surface finish can be calculated.

Theoretical surface finish for milling operations:

$$Ra = \frac{\left(r - \sqrt{r^2 - \left(\frac{f}{2}\right)^2}\right) \times 1000}{2}$$

Ra = surface roughness in μm (micrometers or microns) r = nose radius of the tool in mm f = feed rate in mm/rev

Theoretical surface finish for turning operations:

$$Ra = \frac{f^2 \times 1000}{(24 \times r)}$$

Ra = surface roughness in μm r = nose radius of the tool in mm f = feed rate in mm/rev

Note: to convert micrometer into microinch, multiply by 39.4; to convert microinch into micrometer multiply by 0.0254.

The following table gives some reference values Ra for milling and turning operations at various feed rates and nose radiuses.

Theoretical Surface Finish Ra (μm)								
Feed rate (mm/rev)	Turning Operation				Milling Operation			
	Nose radius (mm)				Nose radius (mm)			
	0.4	0.8	1.2	1.6	0.4	0.8	1.2	1.6
0.05	0.26	0.13	0.09	0.07	0.39	0.20	0.13	0.10
0.10	1.04	0.52	0.35	0.26	1.57	0.78	0.52	0.39
0.15	2.34	1.17	0.78	0.59	3.55	1.76	1.17	0.88
0.20	4.17	2.08	1.39	1.04	6.35	3.14	2.09	1.56
0.25		3.26	2.17	1.63		4.91	3.26	2.45
0.30		4.69	3.13	2.34		7.09	4.71	3.52
0.40		8.33	5.56	4.17		12.70	8.39	6.27
0.50			8.68	6.51			13.17	9.83

Feed rate (mm/rev)	Theoretical Surface Finish Ra (µinch)							
	Turning Operation				Milling Operation			
	Nose radius (mm)				Nose radius (mm)			
	0.4	0.8	1.2	1.6	0.4	0.8	1.2	1.6
0.05	10.3	5.1	3.4	2.6	15.4	7.7	5.1	3.8
0.10	41.0	20.5	13.7	10.3	61.8	30.8	20.5	15.4
0.15	92.3	46.1	30.8	23.1	139.6	69.4	46.2	34.6
0.20	164.0	82.0	54.7	41.0	250.0	123.5	82.2	61.6
0.25		128.2	85.4	64.1		193.4	128.5	96.3
0.30		184.5	123.0	92.3		279.3	185.3	138.7
0.40		328.1	218.7	164.0		500.1	330.4	247.0
0.50			341.8	256.3			518.3	386.8

7.2.7 SURFACE SPEED – RPM CONVERSION CHART

Revolutions per minute (RPM) for selected diameters and cutting speeds

Component Or Cutter Diameter (mm)	Cutting Speed (m/min)								
	40	50	75	100	150	200	300	400	500
10	1275	1595	2390	3185	4780	6370	9555	12740	15925
15	850	1065	1595	2125	3185	4250	6370	8495	10620
20	640	800	1195	1595	2390	3185	4780	6370	7965
25	510	640	960	1275	1915	2550	3825	5100	6370
30	425	535	800	1065	1595	2125	3185	4250	5310
40	320	400	600	800	1195	1595	2390	3185	3985
50	255	320	480	640	960	1275	1915	2550	3185
63	205	255	380	510	760	1015	1520	2025	2530
80	160	200	300	400	600	800	1195	1595	1995
100	130	160	240	320	480	640	960	1275	1595
125	105	130	195	255	385	510	765	1020	1275
150	85	110	160	215	320	425	640	850	1065
175	75	95	140	185	275	365	550	730	910
200	65	80	120	160	240	320	480	640	800
250	55	65	100	130	195	255	385	510	640
300	45	55	80	110	160	215	320	425	535

Related formula

$$n = \frac{318 \cdot v_c}{D}$$

v_c = cutting speed (m/min)
n = revolutions per minute (rev/min)

7.3 MACHINING OF STAINLESS STEEL

7.3.1 303

303 = NSU = 4305

C = 0.10 % max	Cr = 17.0 – 19.0 %	Ni = 8.0 – 10.0 %	Mn = 2 % max	S = 0.25 – 0.35 %

Conforms to standards: ASTM A276 Grade 303 – EN 10088–3 : 1.4305 X8CrNiS18–9 – AISI 303

7.3.1.1 Cutting parameters for classical machines, multi–spindle, single–spindle screw machine:

* Second choice possible		HSS Tools			Carbide tool		
Machining operation	**Depth of cut or width (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
Ø Bar ≤ 25.4mm	1	45.5 – 55.5	0.13–0.2	S4–S5 (S9)	145 – 215	0.13–0.2	P10-M10
	2	39.5 – 45.5	0.15–0.25		120 – 155	0.15–0.25	P20-M20
	3	33.5 – 42.5	0.17–0.30		120 – 145	0.17–0.30	P25-M20
TURNING Ø Bar > 25.4mm	1	48.5 – 57.5	0.13–0.2		160 – 275	0.13–0.2	P10-M10
	2	42.5 – 51.5	0.15–0.25		140 – 250	0.15–0.25	P20-M20
	3	36.5 – 45.5	0.17–0.30		130 – 225	0.17–0.30	P25-M20
Ø Bar ≤ 25.4mm	2	42.5 – 54.5	0.08 – 0.10	S4–S5 (S9)	130 – 140	0.08 – 0.10	P20-M20
	6	39.5 – 51.5	0.08 – 0.10		105 – 130	0.08 – 0.10	P20-M20
	12.7	39.5 – 48.5	0.07 – 0.09		105 – 130	0.07 – 0.09	P25-M20
	25	39.5 – 48.5	0.07 – 0.09		105 – 130	0.07 – 0.09	P25-M20
	51	39.5 – 48.5	0.065–0.085		105 – 120	0.065–0.085	P25-M20
FORMING–GROOVING Ø Bar > 25.4mm	2	45.5 – 57.5	0.09 – 0.11		135 –170	0.09 – 0.11	P20-M20
	6	42.5 – 54.5	0.09 – 0.11		120 – 140	0.09 – 0.11	P20-M20
	12.7	42.5 – 51.5	0.08 – 0.10		120 – 130	0.08 – 0.10	P25-M20
	25	42.5 – 51.5	0.08 – 0.10		115 – 130	0.08 – 0.10	P25-M20
	51	42.5 – 51.5	0.07 – 0.09		115 – 130	0.07 – 0.09	P25-M20
Ø Bar ≤ 25.4mm	2	42.5 – 54.5	0.03 – 0.045	S4–S5 (S9)	130 – 140	0.03 – 0.045	P20-M20
	6	39.5 – 51.5	0.04 – 0.06		105 – 130	0.04 – 0.06	P20-M20
	12.7	39.5 – 48.5	0.045–0.065		105 – 130	0.045–0.065	P25-M20
	25	39.5 – 48.5	0.045–0.065		105 – 130	0.045–0.065	P25-M20
	51	39.5 – 48.5	0.04 – 0.06		105 – 120	0.04 – 0.06	P25-M20
SHAVING–SKIVING Ø Bar > 25.4mm	2	45.5 – 57.5	0.03 – 0.045		135 –170	0.03 – 0.045	P20-M20
	6	42.5 – 54.5	0.04 – 0.06		120 – 140	0.04 – 0.06	P20-M20
	12.7	42.5 – 51.5	0.045–0.065		120 – 130	0.045–0.065	P25-M20
	25	42.5 – 51.5	0.045–0.065		115 – 130	0.045–0.065	P25-M20
	51	42.5 – 51.5	0.04 – 0.06		115 – 130	0.04 – 0.06	P25-M20
Ø Bar ≤ 25.4mm	1	39.5 – 45.6	0.04 – 0.06	S4–S9 (S11)	100 – 120	0.045–0.065	P25-M20
	2	39.5 – 45.6	0.045–0.065		95 – 120	0.065–0.085	P25-M20
	3	36.5 – 42.5	0.065–0.085		90 – 110	0.09 – 0.11	P25-M20
CUT–OFF or PART–OFF	2	42.5 – 48.5	0.045–0.065		110 – 130	0.065–0.085	P25-M20
	3	44 – 45.5	0.065–0.085		100 – 130	0.09–0.11	P25-M20
	6	36.5 – 42.5	0.09 – 0.11		90 – 110	0.10–0.15	P25-M20
DRILLING	1	25–35	0.025 – 0.05	S4	100–220	0.025 – 0.05	P20-P40 or K40 TiN coated
	3		0.12 – 0.20			0.05 – 0.15	
	6		0.19 – 0.27			0.07 – 0.2	
	12		0.25 – 0.32			0.10 – 0.25	
	15		0.28 – 0.35			0.13 – 0.27	
	20		0.32 – 0.40			0.15 – 0.30	

REMARKS ON TOOLING:

The use of coated tools (tips or insert) increases the tool life by 20% to 50% using the same cutting parameters, or it increases the cutting conditions (speed) by 10% to 15% using the same tool wear. We recommended a TiN coating (PVD or CVD).

7.3.1.2 Cutting conditions for CNC machinery:

		Brazed Carbide	Uncoated Carbide Insert	Coated Carbide Insert		
Machining Operation	**Depth of cut or Width (mm)**	**Cutting Speed (m/min)**	**Cutting Speed (m/min)**	**Cutting Speed (m/min)**	**Feed (mm/rev)**	**Type of Tool**
Ø Bar ≤ 25.4mm TURNING	1	130 - 200	165 - 245	180 - 450	0.15 - 0.2	P10-M10
	2	120 - 155	165 - 230	165 - 400	0.2 - 0.3	P20-M20
	3	100 - 135	130 - 195	165 - 355	0.3 - 0.4	P25-M25
Ø Bar > 25.4mm TURNING	1	150 - 275	210 - 395	300 - 550	0.15 - 0.2	P10-M10
	3	120 - 180	150 - 320	220 - 450	0.3 - 0.4	P20-M20
	6	100 - 150	140 - 260	180 - 335	0.4 - 0.5	P25-M25
Ø Bar ≤ 25.4mm GROOVING	1	110 - 140	130 - 170	140 - 200	0.05 - 0.07	P20-M20
	3	100 - 130	120 - 150	130 - 180	0.07 - 0.10	P20-M20
	6	90 - 120	110 - 140	130 -160	0.08 - 0.10	P25-M25
Ø Bar > 25.4mm GROOVING	2	120 - 170	120 - 180	150 - 220	0.06 - 0.08	P20-M20
	3	110 - 150	120 - 180	140 - 210	0.08 -0.10	P20-M20
	6	100 - 140	110 - 160	130 - 170	0.09 - 0.11	P25-M25
Ø Bar ≤ 25.4mm CUT-OFF or PART OFF	1	95 - 115	105 - 145	135 - 185	0.05 - 0.07	P25-M25
	2	80 - 100	95 - 130	120 - 170	0.06 - 0.08	P25-M25
	3	75 - 85	85 - 110	105 - 145	0.07 - 0.09	P25-M25
Ø Bar > 25.4mm CUT-OFF or PART OFF	2	105 - 125	120 - 160	150 - 200	0.07 - 0.09	P25-M25
	3	95 - 115	105 - 140	135 - 190	0.08 - 0.10	P25-M25
	6	85 - 95	90 - 120	120 - 160	0.09 - 0.15	P25-M25

		HSS Drill type N			Plain Carbide Drill		
Machining Operation	**Diameter (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting Speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
DRILLING	1	25-35	0.025 - 0.05	S4	100-220	0.025 - 0.05	P20-P40 or K40 TiN coated
	3		0.12 - 0.20			0.05 - 0.15	
	6		0.19 - 0.27			0.07 - 0.2	
	12		0.25 - 0.32			0.10 – 0.25	
	15		0.28 - 0.35			0.13 – 0.27	
	20		0.32 - 0.40			0.15 – 0.30	

DRILLING:

1. The quality of the cutting lubricant is important. There must be a large quantity (pressure+steady flow) coming through regularly. On the large drills, it is recommended to use drills with oil holes (internal lubrication).
2. The cutting conditions recommended are valid for a depth of drilling equal to 4 x f maximum.
3. We would advise you use drills with a pointed angle of approximately 118°.

LUBRICANT:

We recommend lubricant with extreme pressure additives.

REMARKS ON THE TOOLING:

For the type of coating of the coated carbide tips (inserts), we recommend those with a final visible layer of TiN, generally gold colour.

*7.3.2 303*XL

C = 0.07 % max	Cr = 17.0 - 18.0 %	Ni = 8.2 – 9.5 %	Mn = 1.5 – 2.0 %	S = 0.35 – 0.40%

Conforms to standards: ASTM A276 Grade 303 - AISI 303

7.3.2.1 Cutting parameters for classical machines, multi-spindle, single-spindle screw machine:

*** Second choice possible**		**HSS Tools**			**Carbide Tool**		
Machining Operation	**Depth of cut or width (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
Ø Bar ≤ 25.4mm	1	40 – 60	0.13 – 0.30	S4–S5 (S9)	140 – 160	0.13 – 0.30	P10-M10
TURNING	2	35 – 50	0.15 – 0.35		115 – 220	0.15 – 0.37	P20-M20
	3	28 – 48	0.17 – 0.40		100 – 190	0.17 – 0.45	P25-M20
Ø Bar > 25.4mm	1	48– 62	0.13 – 0.30		150 – 340	0.13 – 0.30	P10-M10
	2	37– 57	0.15 – 0.35		120 – 290	0.15 – 0.37	P20-M20
	3	34 – 52	0.17 – 0.40		100 – 260	0.17 – 0.45	P25-M20
Ø Bar ≤ 25.4mm	2	38 – 60	0.07 – 0.12	S4–S5 (S9)	100 – 170	0.07 – 0.12	P20-M20
FORMING	6	36 – 56	0.07 – 0.12		100 – 160	0.07 – 0.12	P20-M20
–GROOVING	12.7	34 – 54	0.06 – 0.11		90 – 155	0.06 – 0.11	P25-M20
	25	28 – 52	0.05 – 0.10		80 – 150	0.05 – 0.09	P25-M20
	51	26 – 52	0.04 – 0.09		70 – 145	0.04 – 0.085	P25-M20
Ø Bar > 25.4mm	2	41 – 63	0.07 – 0.12		110 – 195	0.07 – 0.12	P20-M20
	6	39 – 59	0.07 – 0.12		100 – 175	0.07 – 0.12	P20-M20
	12.7	37 – 57	0.06 – 0.11		95 – 165	0.06 – 0.11	P25-M20
	25	31 – 55	0.05 – 0.10		90 – 155	0.05 – 0.09	P25-M20
	51	29 – 55	0.04 – 0.09		75 – 150	0.04 – 0.085	P25-M20
Ø Bar ≤ 25.4mm	2	38 – 60	0.04 – 0.070	S4–S5 (S9)	100 – 170	0.04 – 0.070	P20-M20
SHAVING–	6	36 – 56	0.04 – 0.075		100 – 160	0.04 – 0.075	P20-M20
SKIVING	12.7	34 – 54	0.045 – 0.075		90 – 155	0.045 – 0.075	P25-M20
	25	28 – 52	0.045 – 0.075		80 – 150	0.045 – 0.075	P25-M20
	51	26 – 52	0.04 – 0.08		70 – 145	0.04 – 0.08	P25-M20
Ø Bar > 25.4mm	2	41 – 63	0.04 – 0.070		110 – 195	0.04 – 0.070	P20-M20
	6	39 – 59	0.04 – 0.075		100 – 175	0.04 – 0.075	P20-M20
	12.7	37 – 57	0.045 – 0.075		95 – 165	0.045 – 0.075	P25-M20
	25	31 – 55	0.045 – 0.075		90 – 155	0.045 – 0.075	P25-M20
	51	29 – 55	0.04 – 0.08		75 – 150	0.04 – 0.08	P25-M20
Ø Bar ≤ 25.4mm	1	37 – 52	0.03 – 0.065	S4–S9 (S11)	90 – 160	0.03 – 0.07	P25-M20
CUT–OFF or	2	35 – 50	0.04 – 0.08		75 – 150	0.04 – 0.09	P25-M20
PART–OFF	3	34 – 48	0.05 – 0.09		60 – 145	0.05 – 0.12	P25-M20
Ø Bar > 25.4mm	2	40 – 55	0.04– 0.07		90 – 170	0.04 – 0.09	P25-M20
	3	38 – 53	0.05– 0.085		75 – 160	0.05 – 0.12	P25-M20
	6	36 – 51	0.06 – 0.11		60 – 150	0.10 – 0.15	P25-M20
DRILLING	1	15-45	0.025 – 0.06	S4	50 – 250	0.025 – 0.055	P20–P40 or K40 TiN coated
	3		0.08 – 0.27			0.05 – 0.22	
	6		0.15 – 0.32			0.07 – 0.27	
	12		0.20 – 0.37			0.10 – 0.32	
	15		0.25 – 0.42			0.13 – 0.37	
	20		0.30 – 0.47			0.15 – 0.40	

REMARKS ON TOOLING:

The use of coated tools (tips or insert) increases the tool life by 20% to 50% using the same cutting parameters, or it increases the cutting conditions (speed) by 10% to 15% using the same tool wear. We recommended a TiN coating (PVD or CVD).

7.3.2.2 Cutting conditions for CNC machinery:

Machining Operation	Depth of cut or Width (mm)	Brazed Carbide Cutting Speed (m/min)	Uncoated Carbide Insert Cutting Speed (m/min)	Coated Carbide Insert Cutting Speed (m/min)	Feed (mm/rev)	Type of Tool
TURNING Ø Bar ≤ 25.4mm	1	110 – 240	165 – 245	180 – 490	0.13 – 0.27	P10 – M10
	2	100 – 200	165 – 230	165 – 440	0.15 – 0.37	P20 – M20
	3	80 – 170	130 – 195	155 – 390	0.17 – 0.47	P25 – M25
TURNING Ø Bar > 25.4mm	1	130 – 320	180 – 440	260 – 590	0.13 – 0.27	P10 – M10
	3	100 – 230	130 – 365	210 – 485	0.25 – 0.47	P20 – M20
	6	80 – 185	120 – 295	160 – 370	0.27 – 0.57	P25 – M25
GROOVING Ø Bar ≤ 25.4mm	1	90 – 170	110 – 200	120 – 230	0.04 – 0.12	P20 – M20
	3	75 – 160	95 – 180	105 – 210	0.06 – 0.11	P20 – M20
	6	60 – 150	80 –170	100 – 190	0.07 – 0.10	P25 – M25
GROOVING Ø Bar > 25.4mm	2	100 – 200	100 – 210	130 – 255	0.07 – 0.12	P20 – M20
	3	85 – 180	120 – 200	115 – 240	0.07 – 0.11	P20 – M20
	6	70 – 175	110 – 190	110 – 200	0.07 – 0.11	P25 – M25
CUT-OFF or PART OFF Ø Bar ≤ 25.4mm	1	75 – 145	105 – 145	115 – 215	0.04 – 0.07	P25 – M25
	2	60 – 130	95 – 130	100 – 200	0.05 – 0.085	P25 – M25
	3	55 – 155	85 – 110	85 – 175	0.06 – 0.11	P25 – M25
CUT-OFF or PART OFF Ø Bar > 25.4mm	2	85 – 155	100 – 190	130 – 230	0.04 – 0.07	P25 – M25
	3	75 – 145	85 – 170	115 – 220	0.05 – 0.085	P25 – M25
	6	65 – 125	70 – 150	100 – 190	0.06 – 0.11	P25 – M25

		HSS Drill type N			Plain Carbide Drill		
Machining Operation	**Diameter (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting Speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
DRILLING	1	15 – 45	0.025 – 0.06	S4	50 – 250	0.025 – 0.055	P20-P40 or K40 TiN coated
	3		0.08 – 0.27			0.05 – 0.22	
	6		0.15 – 0.32			0.07 – 0.27	
	12		0.20 – 0.37			0.10 – 0.32	
	15		0.25 – 0.42			0.13 – 0.37	
	20		0.30 – 0.47			0.15 – 0.40	

DRILLING:

1. The quality of the cutting lubricant is important. There must be a large quantity (pressure+steady flow) coming through regularly. On the large drills, it is recommended to use drills with oil holes (internal lubrication).
2. The cutting conditions recommended are valid for a depth of drilling equal to 4 x f maximum.
3. We would advise you use drills with a pointed angle of approximately 118°.

LUBRICANT:

We recommend lubricant with extreme pressure additives.

REMARKS ON THE TOOLING:

For the type of coating of the coated carbide tips (inserts), we recommend those with a final visible layer of TiN, generally gold colour.

7.3.3 304/304L

C = 0.03 % max	Cr = 18.0 – 20.0 %	Ni = 8 – 12 %

Conforms to standards: ASTM A276 Grade 304/304L, EN 10088-3 grade 1.4301/ 1.4307 X5CrNi18-10/X2CrNi18-9, AISI 304/304L

7.3.3.1 Cutting parameters for classical machines, multi-spindle, single-spindle screw machine:

*** Second choice possible**

		HSS Tools			Carbide Tool		
Machining Operation	**Depth of cut or width (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
Ø Bar ≤ 25.4mm TURNING	1	30 – 38	0.13 – 0.2	S4–S5 (S9)*	100 – 155	0.13 – 0.2	P10 - M10
	2	27 – 35	0.15 – 0.25		90 – 130	0.15 – 0.25	P20 - M20
	3	25 – 31	0.17 – 0.30		80 – 115	0.17 – 0.30	P25 - M20
Ø Bar > 25.4mm	1	32 – 40	0.13 – 0.2		110 – 190	0.13 – 0.2	P10 - M10
	2	29 – 38	0.15 – 0.25		100 – 160	0.15 – 0.25	P20 - M20
	3	27 – 33	0.17 – 0.30		90 – 135	0.17 – 0.30	P25 - M20
Ø Bar ≤ 25.4mm FORMING –GROOVING	2	31 – 38	0.07 – 0.08	S4–S5 (S9)	80 – 100	0.07 – 0.08	P20 - M20
	6	31 – 37	0.075 – 0.085		75 – 90	0.075 – 0.085	P20 - M20
	12.7	29 – 36	0.07 – 0.08		75 – 90	0.07 – 0.08	P25 - M20
	25	29 – 36	0.06 – 0.07		70 – 85	0.06 – 0.07	P25 - M20
	51	29 – 36	0.05 – 0.06		65 – 80	0.05 – 0.06	P25 - M20
Ø Bar > 25.4mm	2	35 – 41	0.075 – 0.085		90 –110	0.075 – 0.085	P20 - M20
	6	33 – 38	0.08 – 0.09		85 – 100	0.08 – 0.09	P20 - M20
	12.7	32 – 38	0.075 – 0.085		80 – 95	0.075 – 0.085	P25 - M20
	25	31 – 38	0.065 – 0.075		80 – 90	0.065 – 0.075	P25 - M20
	51	31 – 38	0.055 – 0.065		75 – 85	0.055 – 0.065	P25 - M20
Ø Bar ≤ 25.4mm SHAVING– SKIVING	2	31 – 38	0.045 – 0.055	S4–S5 (S9)*	80 – 100	0.045 – 0.055	P20 - M20
	6	31 – 37	0.05 – 0.06		75 – 90	0.05 – 0.06	P20 - M20
	12.7	29 – 36	0.055 – 0.065		75 – 90	0.055 – 0.065	P25 - M20
	25	29 – 36	0.06 – 0.07		70 – 85	0.06 – 0.07	P25 - M20
	51	29 – 36	0.07 – 0.08		65 – 80	0.07 – 0.08	P25 - M20
Ø Bar > 25.4mm	2	35 – 41	0.045 – 0.055		90 –110	0.045 – 0.055	P20 - M20
	6	33 – 38	0.05 – 0.06		85 – 100	0.05 – 0.06	P20 - M20
	12.7	32 – 38	0.055 – 0.065		80 – 95	0.055 – 0.065	P25 - M20
	25	31 – 38	0.06 – 0.07		80 – 90	0.06 – 0.07	P25 - M20
	51	31 – 38	0.07 – 0.08		75 – 85	0.07 – 0.08	P25 - M20
Ø Bar ≤ 25.4mm CUT–OFF or PART–OFF	1	31 – 35	0.05 – 0.06	S11 (S9)*	75 – 95	0.05 – 0.06	P25 - M20
	2	29 – 34	0.07 – 0.075		70 – 85	0.07 – 0.075	P25 - M20
	3	22 – 26	0.075 – 0.08		60 – 75	0.075 – 0.08	P25 - M20
Ø Bar > 25.4mm	2	32 – 38	0.07 – 0.075		80 – 100	0.07 – 0.075	P25 - M20
	3	29 – 33	0.075 – 0.085		70 – 90	0.075 – 0.085	P25 - M20
	6	24 – 29	0.08 – 0.09		65 – 80	0.08 – 0.09	P25 - M20
DRILLING	1	17 – 25	0.02 – 0.04	S4	30 – 65	0.02 – 0.04	P20–P40 or K40 TiN coated
	3		0.06 – 0.10			0.05 – 0.09	
	6		0.09 – 0.14			0.07 – 0.12	
	12		0.13 – 0.22			0.10 – 0.16	
	15		0.16 – 0.26			0.13 – 0.20	
	20		0.20 – 0.30			0.16 – 0.23	

REMARKS ON TOOLING:

The use of coated tools (tips or insert) increases the tool life by 20% to 50% using the same cutting parameters, or it increases the cutting conditions (speed) by 10% to 15% using the same tool wear. We recommended a TiN coating (PVD or CVD).

7.3.4 316/316L

C = 0.03 % max	Cr = 16.5 – 18.5 %	Ni = 10 – 13 %	Mo = 2.0 – 2.5 %

Conforms to standards: ASTM A276 Grade 316/316L, EN 10088-3 grade 1.4401/1.4404, X5CrNiMo17-12-2/X2CrNiMo17-12-2, AISI grade 316/316L

7.3.4.1 Cutting parameters for classical machines, multi-spindle, single-spindle screw machine:

* Second choice possible		HSS Tools			Carbide Tool		
Machining Operation	**Depth of cut or width (mm)**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**	**Cutting speed (m/min)**	**Feed (mm/rev)**	**Type of tool**
TURNING Ø Bar ≤ 25.4mm	1	28 – 36	0.13 – 0.2	S4–S5 (S9)*	90 – 140	0.13 – 0.2	P10 - M10
	2	25 – 33	0.15 – 0.25		80 – 125	0.15 – 0.25	P20 - M20
	3	24 – 29	0.17 – 0.30		75 – 105	0.17 – 0.30	P25 - M20
TURNING Ø Bar > 25.4mm	1	30 – 38	0.13 – 0.2		100 – 170	0.13 – 0.2	P10 - M10
	2	27 – 36	0.15 – 0.25		90 – 120	0.15 – 0.25	P20 - M20
	3	26 – 31	0.17 – 0.30		80 – 110	0.17 – 0.30	P25 - M20
FORMING –GROOVING Ø Bar ≤ 25.4mm	2	31 – 36	0.07 – 0.08	S4–S5 (S9)	75 – 90	0.07 – 0.08	P20 - M20
	6	30 – 35	0.07 – 0.08		70 – 85	0.07 – 0.08	P20 - M20
	12.7	29 – 34	0.065 – 0.075		70 – 85	0.065 – 0.075	P25 - M20
	25	29 – 34	0.055 – 0.065		65 – 80	0.055 – 0.065	P25 - M20
	51	29 – 34	0.045 – 0.055		60 – 70	0.045 – 0.055	P25 - M20
FORMING –GROOVING Ø Bar > 25.4mm	2	33 – 38	0.075 – 0.085		80 – 95	0.075 – 0.085	P20 - M20
	6	32 – 36	0.075 – 0.085		75 – 90	0.075 – 0.085	P20 - M20
	12.7	31 – 35	0.07 – 0.08		75 – 90	0.07 – 0.08	P25 - M20
	25	31 – 35	0.06 – 0.07		70 – 85	0.06 – 0.07	P25 - M20
	51	31 – 35	0.05 – 0.06		65 – 75	0.05 – 0.06	P25 - M20
SHAVING–SKIVING Ø Bar ≤ 25.4mm	2	31 – 36	0.04	S4–S5 (S9)*	75 – 90	0.04	P20 - M20
	6	30 – 35	0.05		70 – 85	0.05	P20 - M20
	12.7	29 – 34	0.055		70 – 85	0.055	P25 - M20
	25	29 – 34	0.055		65 – 80	0.055	P25 - M20
	51	29 – 34	0.075		60 – 70	0.075	P25 - M20
SHAVING–SKIVING Ø Bar > 25.4mm	2	33 – 38	0.04		80 – 95	0.04	P20 - M20
	6	32 – 36	0.05		75 – 90	0.05	P20 - M20
	12.7	31 – 35	0.055		75 – 90	0.055	P25 - M20
	25	31 – 35	0.055		70 – 85	0.055	P25 - M20
	51	31 – 35	0.075		65 – 75	0.075	P25 - M20
CUT–OFF or PART–OFF Ø Bar ≤ 25.4mm	1	29 – 32	0.05 – 0.06	S11 (S9)*	65 – 85	0.05 – 0.06	P25 - M20
	2	26 – 30	0.07 – 0.075		60 – 75	0.07 – 0.075	P25 - M20
	3	20 – 24	0.075 – 0.08		55 – 65	0.075 – 0.08	P25 - M20
CUT–OFF or PART–OFF Ø Bar > 25.4mm	2	30 – 36	0.055 – 0.065		70 – 90	0.055 – 0.065	P25 - M20
	3	26 – 30	0.075 – 0.085		65 – 80	0.075 – 0.085	P25 - M20
	6	22 – 26	0.08 – 0.09		60 – 70	0.08 – 0.09	P25 - M20
DRILLING	1	15 – 22	0.02 – 0.04	S4	30 – 60	0.02 – 0.04	P20 – P40 or K40 TiN coated
	3		0.06 – 0.10			0.05 – 0.09	
	6		0.09 – 0.14			0.07 – 0.12	
	12		0.13 – 0.22			0.10 – 0.16	
	15		0.16 – 0.26			0.13 – 0.20	
	20		0.20 - 0.30			0.16 – 0.23	

REMARKS ON TOOLING:

The use of coated tools (tips or insert) increases the tool life by 20% to 50% using the same cutting parameters, or it increases the cutting conditions (speed) by 10% to 15% using the same tool wear. We recommended a TiN coating (PVD or CVD).

7.4 MACHINING OF ALUMINIUM ALLOYS

7.4.1 GENERAL INFORMATION

Aluminium is generally easier to machine than steel, because it is a much softer material. The machining of aluminium, compared to a steel grade of similar strength, takes 2 to 3 times less energy. Whilst the specific cutting force of medium carbon steels like M1020 or M1030 is 2000 – 2200 MPa, the specific cutting force of aluminium alloys Atlas 2011 and Atlas 6262 is 800 – 900 MPa. The low machining costs of aluminium hence make it an attractive material.

The relative softness of aluminium also creates problems in machining, such as the low chipability – the tendency to form long stringers of chips – and the 'sticky' behaviour – the tendency of aluminium part to stick to the cutting tool.

This build-up phenomenon is mostly present at low cutting speeds, when a false cutting edge of the cutting tool is formed by material sticking on to the tool. The build-up can be reduced by:

- increasing the surface speed, aluminium is very suitable for high-speed machining due to its high thermal conductivity
- increasing the cutting angle to its maximum
- using a lubrication that is suitable for aluminium
- increase the feed rate

Ceramic cutting materials (i.e. Cermet) are not recommended for machining aluminium since the matrix of this material has a chemical affinity for the aluminium thus making it difficult to achieve a satisfactory operating life.

Whilst uncoated carbide inserts in grades K01 and K10 are recommended for machining aluminium machining bar, coated carbide inserts have proved to be unsatisfactory. Titanium compounds (TiN) are mostly used as coating material and titanium has a chemical affinity with aluminium. Therefore, titanium diffuses out of the hard coating so that this soon loses its effectiveness.

Tools made out of high-speed steels offer the following advantages: high toughness, high bending strength, ease of working, low price. Toughness is important, especially since the slim form of the cutting tool typically used for cutting aluminium has a higher tendency to break than tools with a negative geometry (as are typical for cutting steel). HSS tools suitable to be used with aluminium machining bar and an acceptable tool operating life can be achieved.

Diamond tools have substantially longer operating lives compared to carbide-tipped tools, but also higher precision and better operating stability. Currently polycrystalline diamond (PCD) tools are widely used for machining aluminium alloys. PCD tools have cutting properties which are much superior to those of carbide tools. Diamond tools also allow for extremely high machining speeds (Vc > 1000m/min).

As for machinability, aluminium alloys have been classified into four groups. The standard stock alloys marketed by Wakefield Metals – 2011 and 6262 – are all part of group 2.

Group 2 consists of hardened aluminium alloys with Silicon content lower than 10%. Generally these alloys are very machinable due to their high hardness compared to other alluminium alloys. Depending on the alloy machining speeds vary from medium to high. All the alloys of group 2 are short-chipping.

7.4.2 TURNING

The guidelines for machining with uncoated carbide inserts are shown in the table below.

Product	Depth of cut (mm)	Feed Rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
2011	3 – 4	0.75 – 1.00	220 – 250	Roughing (K10)
	1 – 2	0.40 – 0.65	300 – 350	Medium (K10)
	0.1 – 0.4	0.05 – 0.20	400 – 500	Finishing (K01-K10)

Product	Depth of cut (mm)	Feed Rate (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
6262	3 – 4	0.65 – 0.90	190 – 220	Roughing (K10)
	1 – 2	0.30 – 0.55	250 – 320	Medium (K10)
	0.1 – 0.4	0.05 – 0.20	350 – 450	Finishing (K01-K10)

7.4.3 MILLING

The machining parameters in the tables below are for use of cutters with indexable uncoated carbide inserts.

Product	Operation	Feed per Tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
2011	Roughing	0.20 – 0.35	200 – 500	Roughing (K10)
	Finishing	0.05 – 0.15	400 – 700	Finishing (K01-K10

Product	Operation	Feed per Tooth (mm/rev)	Cutting Speed Coated Carbide (m/min)	Tool
6262	Roughing	0.15 – 0.30	180 – 450	Roughing (K10)
	Finishing	0.05 – 0.15	350 – 600	Finishing (K01-K10

7.4.4 DRILLING

The type W-drills with a point angle of 140° and a helix angle between 30° and 40° are most suitable for aluminium. It is generally recommended to use drills having keen cutting edges and polished surfaces for aluminium. A high polish in the flutes minimises friction and thus reduces material buildup. Since the cutting speeds (ca. 100 m/min) used while drilling are small, the danger of material buildup is large. Aluminium can be drilled using larger feeds than for drilling steel.

Standard drilling parameters for **SOLID CARBIDE** drills, for drilling with internal coolant supply.

Product	Cutting Speed (m/min)	Feed Rate (mm/rev) for various drill diameters (mm)					
		2 - 3	**4 - 6**	**7 - 10**	**11 - 15**	**16 - 20**	**21 - 32**
2011 **6262**	90 – 110	0.12	0.22	0.30	0.40	0.50	0.55

Standard drilling parameters for **INDEXABLE CARBIDE INSERT** drills, drilling with external coolant supply.

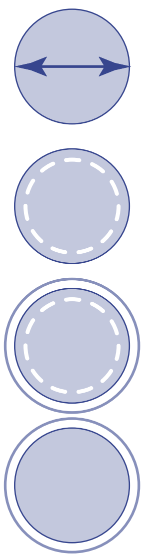
Product	Cutting Speed (m/min)	Feed Rate (mm/rev) for various drill diameters (mm)		
		< 25	**25 - 40**	**> 40**
2011 **6262**	200 – 325	0.08 – 0.12	0.11 – 0.27	0.11 – 0.27

8.1 DIMENSIONAL TOLERANCES

AS 1654 / ISO 286 nominal size tolerances for round bar (μm)

Tolerance Grade IT	Nominal Bar Diameter (mm) Up To 3	Over 3 Up To 6	Over 6 Up To 10	Over 10 Up To 18	Over 18 Up To 30	Over 30 Up To 50	Over 50 Up To 80	Over 80 Up To 120	Over 120 Up To 180	Over 180 Up To 250	Over 250 Up To 315	Over 315 Up To 400	Over 400 Up To 500
5	4	5	6	8	9	11	13	15	18	20	23	25	27
6	6	8	9	11	13	16	19	22	25	29	32	36	40
7	10	12	15	18	21	25	30	35	40	46	52	57	63
8	14	18	22	27	33	39	46	54	63	72	81	89	97
9	25	30	36	43	52	62	74	87	100	115	130	140	155
10	40	48	58	70	84	100	120	140	160	185	210	230	250
11	60	75	90	110	130	160	190	220	250	290	320	360	400
12	100	120	150	180	210	250	300	350	400	460	520	570	630
13	140	180	220	270	330	390	460	540	630	720	810	890	970
14	250	300	360	430	520	620	740	870	1000	1150	1300	1400	1550
15	400	480	580	700	840	1000	1200	1400	1600	1850	2100	2300	2500
16	600	750	900	1100	1300	1600	1900	2200	2500	2900	3200	3600	4000

Example: **Nominal Bar Diameter** = 45mm



"h" is a minus tolerance

Example 1: 45mm h8
Max. diameter = 45.000mm
Min. diameter = 44.961mm

"js" is an even tolerance

Example 2: 45mm js10
Max. diameter = 45.050mm
Min. diameter = 44.950mm

"k" is a plus tolerance

Example 3: 45mm k12
Max. diameter = 45.25mm
Min. diameter = 45.000mm

Note: k tolerances are according to the above table between k8 and k13 only.

8.2 METRIC – IMPERIAL CONVERSION CHART

INCHES		METRIC	INCHES		METRIC	INCHES		METRIC
FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm
·	0.0039	0.1000	·	0.1969	5.0000	·	0.5512	14.0000
·	0.0079	0.2000	13/64	0.2031	5.1594	9/16	0.5625	14.2875
·	0.0118	0.3000	·	0.2165	5.5000	·	0.5709	14.5000
1/64	0.0156	0.3969	7/32	0.2188	5.5563	37/64	0.5781	14.6844
·	0.0157	0.4000	15/64	0.2344	5.9531	·	0.5906	15.0000
·	0.0197	0.5000	·	0.2362	6.0000	19/32	0.5938	15.0813
·	0.0236	0.6000	·	0.2500	6.3500	39/64	0.6094	15.4781
·	0.0276	0.7000	·	0.2559	6.5000	·	0.6102	15.5000
1/32	0.0313	0.7938	17/64	0.2656	6.7469	5/8	0.6250	15.8750
·	0.0315	0.8000	·	0.2756	7.0000	·	0.6299	16.0000
·	0.0354	0.9000	9/32	0.2813	7.1438	41/64	0.6406	16.2719
·	0.0394	1.0000	·	0.2953	7.5000	·	0.6496	16.5000
·	0.0433	1.1000	19/64	0.2969	7.5406	21/32	0.6563	16.6688
3/64	0.0469	1.1906	5/16	0.3125	7.9375	·	0.6693	17.0000
·	0.0472	1.2000	·	0.3150	8.0000	43/64	0.6719	17.0656
·	0.0512	1.3000	21/64	0.3281	8.3344	11/16	0.6875	17.4625
·	0.0551	1.4000	·	0.3346	8.5000	·	0.6890	17.5000
·	0.0591	1.5000	11/32	0.3438	8.7313	45/64	0.7031	17.8594
1/16	0.0625	1.5875	·	0.3543	9.0000	·	0.7087	18.0000
·	0.0630	1.6000	23/64	0.3594	9.1281	23/32	0.7188	18.2563
·	0.0669	1.7000	·	0.3740	9.5000	·	0.7283	18.5000
·	0.0709	1.8000	3/8	0.3750	9.5250	47/64	0.7344	18.6531
·	0.0748	1.9000	25/64	0.3906	9.9219	·	0.7480	19.0000
5/64	0.0781	1.9844	·	0.3937	10.0000	3/4	0.7500	19.0500
·	0.0787	2.0000	13/32	0.4063	10.3188	49/64	0.7656	19.4469
·	0.0827	2.1000	·	0.4134	10.5000	·	0.7677	19.5000
·	0.0866	2.2000	27/64	0.4219	10.7156	25/32	0.7813	19.8438
·	0.0906	2.3000	·	0.4331	11.0000	·	0.7874	20.0000
3/32	0.0938	2.3813	7/16	0.4375	11.1125	51/64	0.7969	20.2406
·	0.0945	2.4000	·	0.4528	11.5000	·	0.8071	20.5000
·	0.0984	2.5000	29/64	0.4531	11.5094	13/16	0.8125	20.6375
7/64	0.1094	2.7781	15/32	0.4688	11.9063	·	0.8268	21.0000
·	0.1181	3.0000	·	0.4724	12.0000	53/64	0.8281	21.0344
1/8	0.1250	3.1750	31/64	0.4844	12.3031	27/32	0.8438	21.4313
·	0.1378	3.5000	·	0.4921	12.5000	·	0.8465	21.5000
9/64	0.1406	3.5719	1/2	0.5000	12.7000	55/64	0.8594	21.8281
5/32	0.1563	3.9688	·	0.5118	13.0000	.	0.8661	22.0000
·	0.1575	4.0000	33/64	0.5156	13.0969	7/8	0.8750	22.2250
11/64	0.1719	4.3656	17/32	0.5313	13.4938	·	0.8858	22.5000
·	0.1772	4.5000	·	0.5315	13.5000	57/64	0.8906	22.6219
3/16	0.1875	4.7625	35/64	0.5469	13.8906	·	0.9055	23.0000

INCHES		METRIC	INCHES		METRIC	INCHES		METRIC
FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm
29/32	0.9062	23.0188	·	1.8898	48.0000	·	3.3071	84.0000
59/64	0.9219	23.4156	·	1.9291	49.0000	·	3.3465	85.0000
·	0.9252	23.5000	·	1.9685	50.0000	·	3.3858	86.0000
15/16	0.9375	23.8125	2	2.0000	50.8000	·	3.4252	87.0000
·	0.9449	24.0000	·	2.0079	51.0000	·	3.4646	88.0000
61/64	0.9531	24.2094	·	2.0472	52.0000	3 1/2	3.5000	88.9000
·	0.9646	24.5000	·	2.0866	53.0000	·	3.5039	89.0000
31/32	0.9688	24.6063	·	2.1260	54.0000	·	3.5433	90.0000
·	0.9843	25.0000	·	2.1654	55.0000	·	3.5827	91.0000
63/64	0.9844	25.0031	·	2.2047	56.0000	·	3.6220	92.0000
1	1.0000	25.40	·	2.2441	57.0000	·	3.6614	93.0000
·	1.0039	25.5000	2 1/4	2.2500	57.1500	·	3.7008	94.0000
·	1.0236	26.0000	·	2.2835	58.0000	·	3.7402	95.0000
·	1.0433	26.5000	·	2.3228	59.0000	·	3.7795	96.0000
·	1.0630	27.0000	·	2.3622	60.0000	·	3.8189	97.0000
·	1.0827	27.5000	·	2.4016	61.0000	·	3.8583	98.0000
·	1.1024	28.0000	·	2.4409	62.0000	·	3.8976	99.0000
·	1.1220	28.5000	·	2.4803	63.0000	·	3.9370	100.0000
·	1.1417	29.0000	2 1/2	2.5000	63.5000	4	4.0000	101.6000
·	1.1614	29.5000	·	2.5197	64.0000	·	4.3307	110.0000
·	1.1811	30.0000	·	2.5591	65.0000	4 1/2	4.5000	114.3000
·	1.2205	31.0000	·	2.5984	66.0000	·	4.7244	120.0000
1 1/4	1.2500	31.7500	·	2.6378	67.0000	5	5.0000	127.0000
·	1.2598	32.0000	·	2.6772	68.0000	·	5.1181	130.0000
·	1.2992	33.0000	·	2.7165	69.0000	·	5.5118	140.0000
·	1.3386	34.0000	2 3/4	2.7500	69.8500	·	5.9055	150.0000
·	1.3780	35.0000	·	2.7559	70.0000	6	6.0000	152.4000
.	1.4173	36.0000	·	2.7953	71.0000	·	6.2992	160.0000
.	1.4567	37.0000	·	2.8346	72.0000	·	6.6929	170.0000
.	1.4961	38.0000	·	2.8740	73.0000	·	7.0866	180.0000
1 1/2	1.5000	38.1000	·	2.9134	74.0000	·	7.4803	190.0000
.	1.5354	39.0000	·	2.9528	75.0000	·	7.8740	200.0000
.	1.5748	40.0000	·	2.9921	76.0000	8	8.0000	203.2000
.	1.6142	41.0000	3	3.0000	76.2000	·	9.8425	250.0000
.	1.6535	42.0000	·	3.0315	77.0000	10	10.0000	254.0000
.	1.6929	43.0000	·	3.0709	78.0000	20	20.0000	508.0000
.	1.7323	44.0000	.	3.1102	79.0000	30	30.0000	762.0000
1 3/4	1.7500	44.4500	·	3.1496	80.0000	40	40.0000	1016.000
.	1.7717	45.0000	·	3.1890	81.0000	60	60.0000	1524.000
.	1.8110	46.0000	·	3.2283	82.0000	80	80.0000	2032.000
.	1.8504	47.0000	·	3.2677	83.0000	100	100.0000	2540.000

8.3 HARDNESS CONVERSION TABLE – CARBON & LOW ALLOY STEELS

Brinell HB	Vickers HV	Rockwell HRC	Tensile Strength MPa	Brinell HB	Vickers HV	Rockwell HRC	Tensile Strength MPa	Brinell HB	Vickers HV	Rockwell HRC	Tensile Strength MPa
100	**105**		**335**	340	357	36.3	1149	580	610	55.7	2030
105	**110**		**350**	345	362	37.0	1165	585	615	55.9	2052
110	**115**		**373**	350	367	37.5	1183	590	621	56.3	2073
115	**120**		**388**	355	373	38.1	1201	595	626	56.6	2091
120	**126**		**403**	360	378	38.7	1217	600	631	56.8	2109
125	**131**		**418**	365	384	39.2	1234	605	636	57.1	2132
130	**137**		**438**	370	389	39.7	1251	610	642	57.4	2152
135	**142**		**456**	370	389	39.7	1251	615	647	57.6	2169
140	**147**		**471**	375	394	40.2	1271		655	58.0	
145	**152**		**488**	380	400	40.8	1290		660	58.3	
150	**158**		**504**	385	405	41.3	1305		665	58.5	
155	**163**		**525**	390	410	41.8	1320		670	58.8	
160	**168**		**539**	395	415	42.3	1338		675	59.0	
165	**173**		**557**	400	421	42.8	1353		680	59.2	
170	**179**		**572**	405	426	43.3	1371		685	59.4	
175	**184**		**591**	410	431	43.7	1389		690	59.7	
180	**189**		**607**	415	436	44.2	1407		695	59.9	
185	**194**		**625**	420	442	44.7	1427		700	60.1	
190	**200**		**640**	425	447	45.1	1445		705	60.3	
195	**205**		**660**	430	452	45.4	1461		710	60.5	
200	**210**		**678**	435	457	45.9	1478		715	60.8	
205	**215**		**693**	440	463	46.4	1494		720	61.0	
210	**221**		**708**	445	468	46.7	1512		725	61.2	
215	**226**		**724**	450	473	47.1	1532		730	61.5	
220	**231**		**744**	455	478	47.6	1550		735	61.6	
225	**236**		**761**	460	484	47.9	1571		740	61.8	
230	**242**	**20.7**	**776**	465	489	48.3	1591		745	61.9	
235	**247**	**21.7**	**791**	470	494	48.6	1611		750	62.1	
240	**252**	**22.7**	**810**	475	500	49.1	1630		755	62.2	
245	**257**	**23.7**	**827**	480	505	49.5	1644		760	62.5	
250	**263**	**24.5**	**844**	485	510	49.8	1665		765	62.6	
255	**268**	**25.3**	**859**	490	515	50.2	1685		770	62.8	
260	**273**	**26.2**	**877**	495	521	50.5	1704		780	63.3	
265	**278**	**26.9**	**896**	500	526	50.8	1724		790	63.6	
270	**284**	**27.6**	**912**	505	531	51.1	1744		800	64.0	
275	**289**	**28.4**	**927**	510	536	51.5	1764		810	64.4	
280	**294**	**29.2**	**950**	515	542	51.8	1782		820	64.7	
285	**300**	**29.8**	**965**	520	547	52.0	1801		830	65.0	
290	**305**	**30.5**	**980**	525	552	52.4	1818		835	65.1	
295	**310**	**31.0**	**995**	530	557	52.8	1838		840	65.3	
300	**315**	**31.6**	**1015**	535	563	53.1	1855		850	65.6	
305	**321**	**32.3**	**1033**	540	568	53.4	1873		860	65.9	
310	**326**	**32.8**	**1048**	545	573	53.7	1893		870	66.1	
315	**331**	**33.4**	**1063**	550	578	54.0	1916		880	66.4	
320	**336**	**34.0**	**1083**	555	584	54.3	1934		890	66.6	
325	**341**	**34.6**	**1101**	560	589	54.6	1952		900	67.0	
330	**346**	**35.2**	**1116**	565	594	54.9	1973		910	67.2	
335	**352**	**35.7**	**1131**	570	600	55.2	1995		920	67.5	
340	**357**	**36.3**	**1149**	575	605	55.4	2013		930	67.7	

Note: Conversions between hardness scales and particulary conversions between hardness and tensile strength are approximate only. These conversions should not be used to determine compliance with specifications. This table does not apply to austenitic stainless steels.