416 Martensitic Stainless Steel Bar

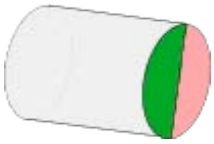
416 is a free machining basic straight chromium high hardenability martensitic stainless steel with excellent machinability, reasonable strength and corrosion resistance. Generally supplied either hardened and tempered in the tensile range 550 - 700 Mpa (condition P) Brinell range 152 - 207, or in the annealed condition with a maximum Brinell hardness of 207.

Characterised by excellent machinability, non-galling and non-seizing properties due to its higher sulphur content which has the effect of lowering its corrosion resistance. It is however resistant to mild corrosive atmospheres, fresh water, steam, organic materials, many mild acids and petroleum products, coupled with reasonable strength in the hardened and tempered condition.

416 due to its excellent hardenability is capable of being through hardened up to Rc40 depending upon carbon content and section size. Small sections can be air cooled and larger sections oil quenched for maximum through hardness.

Pre hardened and tempered 416 will also respond readily to nitriding achieving a typical surface hardness of over Rc65. The nitriding process however reduces the corrosion resistance and is therefore not generally recommended except for critical applications where the benefit outweighs all other considerations.

Material magnetic in all conditions.

Colour Code  Pink & Green (Bar end)	Stocked Sizes	12.7 to 130 mm diameter.
	Bar Finish	Peeled Bar

Related Specifications		
	Australia	AS 2837-1986 416
	Germany	W.Nr 1.4005 X12CrS13
	Great Britain	BS970 Part3 1991 416S21 BS970 1955 EN56AM
	Japan	JIS G4303 SuS 416
	USA	ASTM A582/A582M-95b 416 SAE 51416 AISI 416 UNS S41600

Chemical Composition		**Min. %**	**Max. %**
	Carbon	0.09	0.15
	Silicon	0	1.00
	Manganese	0	1.50
	*Nickel	0	1.00
	Chromium	11.50	14.00
	*Molybdenum	0	0.60
	Phosphorous	0	0.06
*Nickel & Molybdenum addition optional.	Sulphur	0.15	0.35

Mechanical Property Requirements For Material in the Annealed and Heat Treated - Condition P To AS2837 - 1986 416 and BS970 Part3 1991 416S21

Condition	Tensile Strength Mpa Min	Tensile Strength Mpa Max	0.2% Yield Strength Mpa Min	Elongation on $5.65\sqrt{S_o}$* % Min	Impact Izod J Min	Hardness HB Min	Hardness HB Max
Annealed							207
P	550	700	340	15	34	152	207

Material stocked generally in annealed condition 76.2 mm dia and larger.

Material stocked generally in condition P up to and including 63.5 mm dia.

NB. Check the mill certificate if critical for end use.

Typical Mechanical Properties At Room Temperature - Annealed and Hardened and Tempered to Condition P

Condition	Tensile Strength Mpa	0.2% Yield Strength Mpa	Elongation in 50mm %	Impact Izod J	Hardness HB
Annealed	530	290	27	75	160
*P	650	490	24	95	190

*Typical Hardening Temperatures	950 °C - 1020 °C
*Typical Tempering Temperatures	650 °C - 750 °C

Typical Mechanical Properties At Room Temperature - Hardened By Oil Quench at 980 °C and Tempered as Indicated

Tempering Temperature °C	Tensile Strength Mpa	0.2% Yield Strength Mpa	Elongation in 50mm %	Impact Izod J	Impact Charpy J	Hardness HB	Hardness RC
150	1210	950	10	27	27	360	39
250	1190	940	11	34	30	350	38
370	1180	930	14	34	30	350	38
480	1100	870	15	*22	*20	330	36
540	950	760	16	*34	*30	285	31
595	780	650	17	54	54	235	23
650	710	570	21	65	68	205	16
700	660	520	22	105	100	190	12

High tensile strength and high yield strength but low impact properties when tempered below 400 °C.

*Note drop in impact properties. Tempering within the range 400 °C - 580 °C should be avoided.

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Elevated Temperature Properties

While 416 displays a reasonable resistance to scaling in continuous service up to 650 °C, it does however experience a substantial drop in tensile strength, creep and stress rupture strength at relatively low working temperatures. It is also susceptible to hot cracking due to its high sulphur content.

NB. High temperature use is therefore not generally recommended.

Low Temperature Properties

416 is not recommended for use at sub-zero temperatures due to a substantial drop in impact properties consistent with most steels other than the austenitic steel types.

Cold Bending

416 has limited cold bending properties and it is generally not recommended.

Hot Bending

In the hardened and tempered condition, it is not recommended due to its affect on the mechanical properties within the heat affected zone. Even in the annealed condition it should also be avoided if possible due to its susceptibility to hot cracking.

Corrosion Resistance

416 due to its higher sulphur content has lower resistance to all corrosion types than grade 410, and indeed all of the 400 series martensitic stainless steels.

Its selection therefore is generally based upon its excellent machinability coupled with its lower corrosion resistance capabilities.

NB. It has optimum corrosion resistance in the hardened and tempered condition and is not therefore recommended for use in the annealed condition.

It is most important that oxygen is always allowed to circulate freely on all stainless steel surfaces to ensure that a chrome oxide film is always present to protect it. If this is not the case, rusting will occur as with other types of non stainless steels.

For optimum corrosion resistance surfaces must be free of scale and foreign particles.
Finished parts should be passivated.

Forging

Heat uniformly to 1150 °C - 1200 °C, hold until temperature is uniform throughout the section.

Do not soak but commence forging immediately.

Do not overheat as this can cause a loss of toughness and ductility.

Do not forge below 900 °C

Finished forgings should be cooled slowly in air, ashes or dry lime etc. to room temperature and annealed immediately.

NB. Severe upset forging of this grade is not recommended.

Heat Treatment

Sub-Critical Annealing

Heat uniformerly to 650 °C - 750 °C as required, hold until temperature is uniform throughout the section.

*Soak as required, cool in air.

Annealing

Heat to 820 °C - 900 °C, hold until temperature is uniform throughout the section. *Soak as required. Cool in furnace.

Hardening

Heat to 950 °C - 1020 °C, hold until temperature is uniform throughout the section. *Soak as required.

Quench in oil or air cool. Temper immediately while still hand warm.

Nitriding

Prior to nitriding, the chrome oxide film which protects the surface must be broken down by pickling or fine sand blasting.

Nitriding is carried out at 500 °C - 550 °C followed by slow cooling (no quench) reducing the problem of distortion. Parts can therefore be machined to near final size, leaving a grinding tolerance only. Always ensure that the tempering temperature employed during the initial heat treatment was higher than the nitriding temperature otherwise the core strength will be affected.

Tempering (Condition P)

Heat to 650 °C - 750 °C as required, hold until temperature is uniform throughout the section. *Soak as required. Cool in air.

416 can of course be tempered at much lower temperatures, producing much higher tensile strengths, but with subsequent lower impact properties.

NB. Tempering however within the range 400 °C - 580 °C should be avoided due to the brittleness, resulting in a considerable reduction in impact properties and loss of corrosion resistance.

*Heating temperatures, rate of heating, cooling and soaking times will vary due to factors such as work piece size/shape, also furnace type employed, quenching medium and work piece transfer facilities etc.

Please consult your heat treater for best results.

Machining

416 was developed as a free machining grade and has by far the best machinability of all the 400 series martensitic stainless steels. It also has much better machinability than grade 303 free machining austenitic stainless steel and all operations such as turning, drilling, broaching, tapping, milling, reaming and threading etc. can be readily carried out as per machine manufacturers recommendations for suitable tool type, feeds and speeds.

Welding

416 is not generally recommended for welding in either the annealed or hardened and tempered condition, due to its high sulphur content resulting in hot cracking or its hardening capability resulting in cold cracking.

If it is really necessary to weld in either condition the following procedure may be taken as a guide only.

Welding Procedure

Welding electrodes or rods should be low hydrogen types 410 or *similar when strength is required or post-weld hardening and tempering, otherwise an austenitic stainless electrode or rod such as 308 or *similar may be used to give a more ductile weld, when strength is not so critical and post-weld annealing is not possible or intended.

Pre-heat at 200 °C - 300 °C and keep heat input to a minimum to reduce dilution of sulphur and filler metal. On completion of welding cool slowly as possible until hand warm and as required:

Post-weld sub-critical anneal at 650 °C - 750 °C or full anneal and harden and temper as required.

*Please consult your welding consumables supplier.

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