416
Technical Data Sheet

SCHMOLZ + BICKENBACH
Providing special steel solutions

Chemistry

Comparable Standard:

Typical Analysis %	C	Si	Mn	P	S	Cr	Mo
Min.					0.15	12.00	
Max.	0.15	1.00	1.25	0.060		14.00	0.60

	Cu	Zr
Min.		
Max.	0.50	0.60

Description

Ugitech's 416 is free machining martensitic grade. The unique production process—developed exclusively by Ugitech—results in a product that delivers superior productivity, tool life and consistency, and improves the surface finish on all types of machined parts. Machined parts are frequently used in the annealed condition, but may be heat-treated to develop optimum mechanical properties for specific applications.

416 HT, condition T (HRc26-32), is the popular heat-treated version of **416**. This condition is specified for numerous engineering applications, and represents the optimum condition for both machinability and corrosion resistance. No further heat treatment of machined parts is required.

These grades deliver heat to heat consistency that is unsurpassed in the industry. Once an optimum set-up has been established, machinists can take advantage of increased machine efficiency rates (run "lights out production"). Also, crashes due to hard spots are a thing of the past. **416** and **416 HT** can both provide a significant competitive advantage for shops that demand efficient, high volume and reliable production.

Classification

Free Machining Martensitic stainless steel. Oxidation resistance in continuous service to 1200°F (650°C).

Characteristics

- AISI Type 416
- UNS S41600
- ASTM A314
- ASTM A473
- ASTM A484
- ASTM A581-Chemistry
- ASTM A582
- ASTM F899
- AMS 5610 Type 2
- QQ-S-763
- QQ-S-764
- MIL-W-52263
- SAE J405 No. 51416
- EN 10088-3
  1.4401/1.4005
  X12CrS13

Available Forms

Cold drawn bars, Turned bars, Ground bars, Wire, SMQ™
Please inquire for additional information on available forms.

Mechanical Properties (Typical)

Annealed Properties

Cold Drawn Bars (1" and under)	
Tensile Strength	90 - 120 ksi (620 - 830 MPa)
Yield Strength(0.2)	80 - 105 ksi (550 - 725 MPa)
Elongation	10% Minimum
Reduction of Area	40% Minimum
Hardness	190 - 240 BHN

Turned Bars (Over 1")	
Tensile Strength	90 - 110 ksi (650 - 750 MPa)
Yield Strength(0.2)	65 - 85 ksi (510 - 580 MPa)
Elongation	20% Minimum
Reduction of Area	60% Minimum
Hardness	190 - 210 BHN

Heat Treat Properties (Condition T HRc 26—32)

All Sizes	
Tensile Strength	129 - 150 ksi (890 - 1035 MPa)
Yield Strength(0.2)	110 - 130ksi (760 - 895 MPa)
Elongation	40% Minimum
Reduction of Area	5% Minimum
Hardness	27 - 31 HRc (264 - 294 BHN)

Magnetic and Electrical Properties

Typical Magnetic Permeability:

Magnetic in all conditions.

Electrical Resistivity

22 μΩ - in (550 μΩ - mm) @ 68°F (20°C)

Typical Physical Properties (Typical)

Density:	0.276 lbs/in^3 (7.6 g/cm^3)
Mean Coefficient of Linear Expansion:	68-392 ºF (20-200 ºC) = 6.0 x 10^{-6} in/in/ºF (10.8 x 10^{-6}cm/cm/ºC)
Modulus of Elasticity in Tension:	29.7 x 10^{-6} psi (205,000 MPa)
Thermal Conductivity:	14.4 Btu/ft/hr/ºF (25.1 W/m/ºC) @68°F (20°C)

Forging (Hot Working)

416 is not a forging grade, but can be forged If necessary. It is not recommended for upsetting operations. The following heating and handling conditions are recommended.

- Slow heating to 1475º F (800º C), then more rapidly to 2100-2150º (1150-1180º C)
- Forge in the range of 1750-2150º F (950-1180ºC)
- After forging, slow cooling in the furnace

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Corrosion Resistance

Ugitech's **416** in the annealed and heat treated conditions offer good corrosion resistance in moderately aggressive, non-chlorinated media (e.g. soaps, solvents, and organic acids), fresh water, steam, many petroleum products, and mold atmospheres. Care should be taken when specifying **416**, as with any sulfur bearing stainless steel, for use in environments that encourage localized attack such as pitting and crevice corrosion. Therefore, competent design should avoid areas that will allow corrosive products to collect and stagnate while in service. In general **416 HT**, 416 condition T (HRc 26-32) represents the optimum condition for corrosion resistance.

Resistance to scaling for Ugitech's **416** is approximately 1200°F (650°C). This temperature can change depending upon the type of environment and application.

The corrosion resistance of a stainless steel depends on many factors related to the composition of the corrosive element, pH, temperature, velocity, agitation, cervices, deposits, dissimilar metal contact, metallurgical condition, as well as the preparation of the surface. The table here is for comparative purposes only and illustrates the performance in different environments. Consult your local SCHMOLZ + BICKENBACH USA metallurgist to discuss your application.

Optimum corrosion resistance requires that parts be smooth, and free from surface contamination such as cutting fluid and foreign particles. Under these conditions, parts will be passive in the air. Due to complexity and cost, passivation of **416** and **416 HT** should be avoided. However, if passivation is required, the following treatment is recommended (reference ASTM A380):

Solution: 20–50% nitric acid + 2-6 wt. sodium dichromate at 70-120°F (20-50°C).

Treatment: Immerse for 25-40 minutes followed by thorough rinsing to remove all residual solution.

Environment	Behavior
Nitric Acid	RESTRICTED
Humidity	⬢⬢⬡⬡
Phosphoric Acid	RESTRICTED
NaCl (Saline Mist)	RESTRICTED
Sulfuric Acid	RESTRICTED
Seawater	RESTRICTED
Acetic Acid	RESTRICTED
Petroleum	RESTRICTED
Sodium Carbonate	⬢⬢⬡⬡

It is important to note, maintaining corrosion resistance at weld zones will require cleaning and passivation.

Hardenability (Cold Working)

Hardenable by heat treatment. Strength and hardness increase slightly upon cold work such as drawing and forming.

Heat Treatment

Annealing

The heat treatment (annealing) that gives **416** its softest properties includes heating at 1650ºF (900ºC), followed by slow cooling in the furnace.

Sub-critical anneal

Heat 1200°F to 1400°F (650°C to 760°C) followed by air cooling

Heat Treatment

Hardening

Ugitech's **416** can be heat treated (hardened and tempered) to different hardness ranges for different applications. The hardening should be performed at 1750ºF (950ºC), followed by air or oil quenching. Oil quenching should be used on larger sentions. Air quenching smaller section can reduce quench hardness by one or two Rockwell points. Typical max. quench hardenability ranges from HRc 41 to HRc 43.

The tempering temperatures should be selected depending on desired final properties required - see 416 hardenability chart. below.

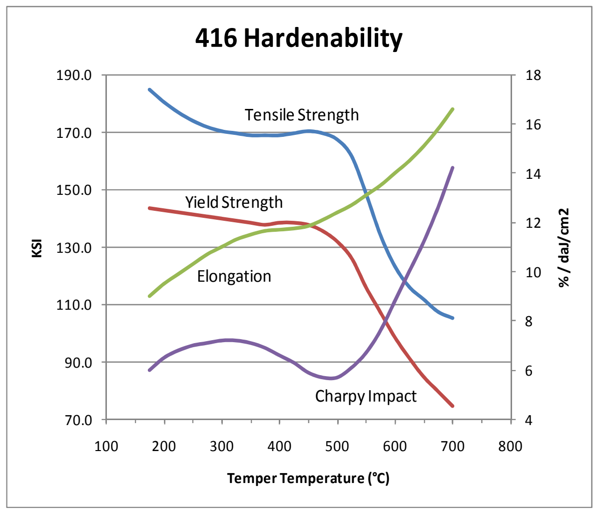
<u>Caution:</u> Tempering of **416** in the range of 750-1110ºF (400-600ºC) results in reduced corrosion resistance and decreased impact strength. However, it may be necessary to temper in this range to obtain necessary strength levels. Care should be taken in the design of parts to compensate for these reduced properties. Contact your local SCHMOLZ + BICKENBACH USA application engineer with specific concerns.

Stress Relieving

Ugitech's **416** can be stress relieved as follows:

<u>Hardened and tempered</u> - Heat and hold 50°F to 100°F (10°C to 40°C) below tempering temperature for 4-7 hours, slow cool.

<u>Annealed</u> - Heat and hold 1100°F (595°C) for 4-7 hours, slow cool.



Welding

Similar to any sulfur bearing stainless steel, the welding of 416 should be avoided since the high sulfur content can result in cracking. This is particularly true for welding processes where no filler metal is used (except for friction welding). If welding is required, AWS E309/ER309 is recommended as filler metal. A tempering heat treatment at 1200ºF (650º C) after welding may be useful in restoring ductility to the welded area. Gas welding with hydrogen or nitrogen gas should be avoided.

Machinability

The key to **416** lies in the production process. Careful control of alloy content and distribution of metallurgical phases results in better tool life, improved surface finish, and excellent chip control across a wide range of cutting conditions. **416 HT** represents the optimum condition for machinability.

The table on the following page, in conjunction with the recommendations below it, provides a useful guideline for initial set-up. To realize the optimal potential of either grade, contact your local application engineer. A review of your current set-up will allow specific recommendations adapted to **416** or **416 HT**.

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Machining Operation	Metallurgical Condition	Depth of cut Or width (inches)	HSS Tooling: Cutting Speed SFPM	HSS Tooling: Feed (ipr)	HSS Tooling: Type of Tool	Coated Carbide Tools: Cutting Speed SFPM	Coated Carbide Tools: Feed (ipr)	Coated Carbide Tools: Type of Tool
Turning	Cold Drawn	0.04 0.08 0.12	120—160 100—140 80—130	0.003—0.008 0.003—0.010 0.004—0.012	M2—M3 (T15)	460—900 425—800 375—700	0.005—0.008 0.006—0.010 0.006—0.012	C7 C6 C6
	Annealed	0.04 0.08 0.12	130—170 110—150 90—140	0.003—0.008 0.003—0.010 0.004—0.012		505—950 375—850 325—750	0.005—0.008 0.006—0.010 0.006—0.012	C7 C6 C6
Forming & Grooving	Cold Drawn	0.08 0.25 0.50 1.00 2.00	110—150 100—140 90—140 70—110 60—100	0.001—0.003 0.003—0.005 0.002—0.004 0.002—0.003 0.002—0.003	M2—M3 (T15)	360—500 295—400 210—350 175—300 150—200	0.002—0.003 0.003—0.004 0.003—0.004 0.002—0.003 0.002—0.003	C6 C6 C6 C6 C6
	Annealed	0.08 0.25 0.50 1.00 2.00	120—160 10—150 100—150 80—120 70—110	0.002—0.004 0.003—0.005 0.002—0.005 0.002—0.004 0.002—0.003		390—550 325—450 245—400 200—330 185—250	0.002—0.004 0.002—0.004 0.002—0.004 0.002—0.003 0.002—0.003	C6 C6 C6 C6 C6
Shaving & Skiving	Cold Drawn	0.08 0.25 0.50 1.00 2.00	120—150 110—140 100—140 80—110 70—100	0.001—0.003 0.001—0.0025 0.001—0.002 0.001—0.002 0.001—0.002	M2—M3 (T15)	360—500 295—400 210—350 175—300 150—200	0.002—0.003 0.003—0.004 0.002—0.004 0.002—0.003 0.002—0.003	C6 C6 C6 C6 C6
	Annealed	0.08 0.25 0.50 1.00 2.00	130—160 120—150 110—150 90—120 80—110	0.001—0.003 0.001—0.0025 0.001—0.002 0.001—0.002 0.001—0.002		390—550 325—450 245—400 200—330 185—250	0.002—0.004 0.002—0.004 0.002—0.004 0.002—0.003 0.002—0.003	C6 C6 C6 C6 C6
Cut-off or Part-Off	Cold Drawn	0.04 0.08 0.12	80—120 70—110 60—100	0.001—0.002 0.001—0.0025 0.0015—0.003	M41 (T15)	295—575 320—530 320—500	0.002—0.003 0.002—0.003 0.002—0.003	C6 C6 C6
	Annealed	0.04 0.12 0.25	80—130 70—120 60—110	0.001—0.0025 0.0015—0.003 0.002—0.004		325—600 300—575 300—550	0.002—0.003 0.002—0.003 0.003—0.004	C6 C6 C6
Drilling	All	0.063 0.125 0.250 0.500 0.750	30—115	0.0005—0.002 0.002—0.004 0.003—0.006 0.005—0.009 0.008—0.012	M2	50—250	0.0005—0.002 0.002—0.004 0.002—0.005 0.004—0.006 0.006—0.009	C5—C6 or C1—C2 TiN coated
Insert Drilling	All	0.50—0.75 0.75—1.00 1.00—2.50				150—400 200—500 250—600	0.001—0.004 0.002—0.005 0.002—0.006	C7 C6 C5
Reaming	All	0.062 0.125 0.250 0.500 0.750 1.000	30—115	0.002—0.005 0.004—0.008 0.007—0.016 0.015—0.025 0.015—0.030 0.020—0.030	M2 (M42)	50—250	0.002—0.005 0.004—0.008 0.007—0.016 0.015—0.025 0.015—0.030 0.020—0.030	C5—C6 Or C3 TiN Coated
Tapping	All	All	20—80		M2-M7 TiN Coated			

The machining data presented within all tables and graphs represent typical working ranges based on field and laboratory research. Results will vary based on parts to be produced, equipment and tooling utilized, personnel operating the equipment and customer part specifications. For additional information, contact Technical Support at the Corporate Office: (800) 323-1233.

Machinability Table Guidelines

1. For heat treated **416 HT**, the following adjustments should be made to the standard annealed condition as presented in the 416 Machinability Table:
   - On all operations except drilling, speed should be decreased 20% with HSS tooling and increased 20% when using Carbide tooling.
   - Carbide grade ANSI C6 or better is the best all-purpose choice of carbide grades for machining 416 HT.
   - For drilling, speeds and feeds should remain the same as 416R.
   - Feed rates in all cases should remain the same as 416R.
2. Grades of tooling in parenthesis indicate an alternate or second choice of tooling.
3. When using the C1-C4 grade carbides, decrease speed by 25-40%.
4. When using coated tools, speeds and feeds should be increased by 10-15%.
5. Drill speeds were developed for 118° drills. Increase speeds 10-20% with use of 130° to 140° angle drills.
6. For drilling deeper than 3x diameter, reduce speed and feed by 20-40% for straight drilling, or set decreasing pecking depth to 2x diameter max.

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