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Stainless made Painless

Guidelines for turning stainless steels.

When deciding the best way to turn stainless steels, users have a wide assortment of cutting tool geometries to choose from and an array of machining parameters they could apply. Making the right choices depends on what type of stainless steel is being turned.

AISI (American Iron and Steel Institute) divides all standard stainless steels into four groups: austenitic, ferritic, martensitic and precipitation-hardened.

Austenitic types are the 200 series (three grades) and 300 series (34 grades). They contain chromium, from 15 to 26 percent, and nickel, up to approximately 35 percent, as the major alloying elements. Carbon content varies from 0.03 to 0.25 percent.

Ferritic types are the 400 series (12 grades), which contain chromium, from 10.5 to 27 percent, as the major alloying element. Carbon content varies from 0.03 to 0.20 percent.

Martensitic types—the 400 series (12 grades)—have chromium, from 11.5 to 18 percent, as their major alloying element. Carbon content varies from 0.15 to 1.20 percent. Only three grades contain nickel: 414 and 431 (2.5 percent maximum) and 422 (1.0 percent maximum).

Precipitation-hardened types are the PH series (four grades), which contain chromium, from 12 to 18 percent, and nickel, from 3 to 8.5 percent, as the major alloying elements. Carbon content varies from 0.05 to 0.09 percent. These PH types may be either austenitic or martensitic in the annealed condition.

Machinability

Because of the variety of stainless steels, their machinability ratings vary from low to high. Machinability is a quality characterized by the degree of difficulty in machining a metallic work material under specified conditions. The machinability rating is expressed in percentages, with the assumption that the machinability rating of AISI 1212 free-machining carbon steel is 100 percent. If machinability ratings of work materials are less than 100 percent, such work materials are more difficult to machine than AISI 1212 steel.

Low machinability is attributed to austenitic steels, including 302B, 309, 309S, 314, 329, 330 and 384. Machinability ratings for these steels are only about 40 percent of that for AISI 1212 free-machining carbon steel. Low machinability is characterized by high tensile strength, a large spread between yield strength and ultimate tensile strength, high ductility and toughness, a high workhardening rate and low thermal conductivity.

The same low machinability ratings are attributed to some martensitic steels, such as 422 (low in nickel, but containing up to 1.25 percent of molybdenum and tungsten and up to 0.30 percent of vanadium); 414 and 431 (both grades contain nickel from 1.25 to 2.5 percent); and 440A, 440B and 440C (no nickel, 0.75 percent molybdenum and from 0.60 to 1.20 percent carbon). Machining difficulty is influenced by hardness level, carbon content and nickel content.

High machinability is attributed to 430F and 430F(Se) ferritic steels, as well as to 416 and 416Se martensitic steels. Machinability ratings for these steels are about 90 percent of that for AISI 1212 free-machining carbon steel.

In general, austenitic steels are more difficult to machine. When machining austenitic steels, several factors should be considered:

■ The cutting tool absorbs more heat, which may cause a built-up edge; users should increase the cutting speed, select positive insert geometry or use coated cermet grades to combat BUE.

■ Chips are stringy and have a tendency to tangle, which makes their removal difficult; possible solutions are a higher feed rate, chipbreaker geometry based on the nose radius of insert, different lead angle or smaller nose radius of insert.

■ Chatter occurs if the cutting tool's rigidity is inadequate.

■ Cut surfaces might be workhardened and more difficult to machine if cutting is interrupted or if the feed rate is too low.

Table 1. Austenitic grades: 302B, 309, 309S, 310, 310S, 314, 316, 316L, 317 and 330

Brinell hardness (HB) range	DOC	Feed rate (ipr)	Cutting speed (sfm)*	Cutting tool material grade, C/ISO
135 to 185	0.040"	0.007	500	CC-3/CM10
	0.150"	0.015	425	CC-3/CM10
	0.300"	0.020	325	CC-2/CM10
225 to 275	0.040"	0.007	425	CC-3/CM10
	0.150"	0.015	350	CC-3/CM10
	0.300"	0.020	275	CC-2/CM10

CC is industrial code for coated, cemented carbides. *Cutting speeds should be increased 30 to 35 percent to achieve higher productivity due to modern cutting tool materials and geometries.

All tables: Machining Data Handbook

Table 2. Martensitic grades: 440A, 440B, 440C and 440F

Brinell hardness (HB) range	DOC	Feed rate (ipr)	Cutting speed (sfm)*	Cutting tool material grade, C/ISO
225 to 275	0.040"	0.007	525	CC-7/CM10
	0.150"	0.015	400	CC-6/CM10
	0.300"	0.020	325	CC-6/CM10
275 to 325	0.040"	0.007	400	CC-7/CM10
	0.150"	0.015	325	CC-6/CM10
	0.300"	0.020	250	CC-6/CM10

CC is industrial code for coated, cemented carbides. *Cutting speeds should be increased 25 to 30 percent to achieve higher productivity due to modern cutting tool materials and geometries.

Table 3. Ferritic grades: 430F and 430F(Se)

Brinell hardness (HB) range	DOC	Feed rate (ipr)	Cutting speed (sfm)*	Cutting tool material grade, C/ISO
135 to 185	0.040"	0.007	875	CC-7/CP10
	0.150"	0.015	775	CC-6/CP10
	0.300"	0.020	600	CC-6/CP20

CC is industrial code for coated, cemented carbides. *Cutting speeds should be increased by 15 to 20 percent to achieve higher productivity due to modern cutting tool materials and geometries.

Machining Data

The effectiveness of turning stainless steels depends on the machining parameters applied, along with the cutting tool material and cutting tool geometry.

Machining parameters are DOC (inches), feed rate (ipr) and cutting speed (sfm). Usually, DOC and feed rate are conservative parameters predetermined by the type of operation—roughing, semifinishing and finishing. Range of typical machining data is:

■ roughing: DOC = 0.20" to 0.50", feed rate = 0.02 to 0.06 ipr;

■ semifinishing: DOC = 0.08" to 0.20", feed rate = 0.008 to 0.02 ipr; and

■ finishing: DOC = 0.02" to 0.08", feed rate = 0.004 to 0.01 ipr.

Cutting speed is a variable that depends on mechanical properties of the workpiece, DOC, feed rate and cutting tool material. Selecting the cutting speed is always a challenge.

For almost three decades, the *Machining Data Handbook* has remained a reliable source of technical information on metalworking. The machining parameters for turning stainless steels listed in Tables 1-3 were adopted from the handbook. The tables contain those grades of austenitic, martensitic and ferritic stainless steels that are normally machined at lower cutting speeds than other grades from the same series. These parameters are starting recommendations. The cutting speed should always be increased. The reason is because during the last decade, more effective cutting tool materials, such as physical-vapor-deposition-coated carbides, and improved cutting tool geometries have been developed.

Ceramic and cermet cutting tools perform at significantly higher cutting speeds when DOCs are similar to those for coated carbide cutting tools. This is because ceramics and cermets have much higher hot hardness and resistance to wear than coated carbides, but have less toughness and, thus, lower mechanical strength. Therefore, lower feed rates are recommended (from 0.007 to 0.005 ipr, 0.015 to 0.010 ipr and 0.020 to 0.015 ipr for finishing, semifinishing and roughing, respectively). Ceramic cutting tool materials for stainless steels are alumina-based grades. Cermet grades are made of mostly TiC with a nickel or cobalt binder.

Some austenitic steels can be machined at significantly higher cutting speeds than those recommended by *Machining Data Handbook* (Table 1): 1,400, 850 and 550 sfm, respectively, compared to 500, 425 and 325 sfm; hardness of 135 to 185 HB, inserts made of cold-pressed alumina (CPA), and 1,200, 750 and 450 sfm, respectively, compared to 425, 350 and 275 sfm; hardness of 225 to 275 HB, inserts made of hot-pressed cermet (HPC).

Cutting speeds for the some martensitic steels (Table 2) are: 1,400, 850 and 650 sfm, respectively, compared to 525, 400 and 325 sfm; hardness of 225 to 275 HB, inserts made of HPC, and 1,150, 600 and 400 sfm, respectively, compared to 400, 325 and 250 sfm; hardness of 275 to 325 HB, inserts made of HPC.

Cutting speeds for some ferritic steels (Table 3) are: 1,700, 1,300 and 1,000 sfm, respectively, compared to 875, 775 and 600 sfm; hardness of 135 to 185 HB, inserts made of CPA.

Principal cutting angles of indexable inserts are back rake, side rake and relief, or clearance, angles. The most common angles are:

Turning austenitic steel with a hardness of 135 to 275 HB: back rake is 0°, side rake is 5° and relief is 5°.

Turning martensitic steel with a hardness of 135 to 325 HB: back rake is 0°, side rake is 5° and relief is 5°.

Turning martensitic steel with a hardness of 325 to 425 HB: back rake is –5°, side rake is –5° and relief is 5°.

Turning ferritic steel with a hardness of 135 to 185 HB: back rake is 0°, side rake is 5° and relief is 5°.

The most common type of indexable insert is CNMG (rhombic with 80° nose angle) used for roughing, semifinishing and finishing. The other types are: TNMG (triangular, 60° nose angle) for semifinishing; TCGT for finishing; and VCEX (rhombic with 35° nose angle) for semifinishing and finishing.

Starting Off

The recommendations given for cutting parameters are nominal and should be considered only as starting points. The optimal performance or efficiency when turning stainless steels includes many other variables, such as part configuration, condition of the lathe, type of workholding components, dimensional tolerance and surface finish specification. △

About the Author

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