INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Machining duplex stainless steels

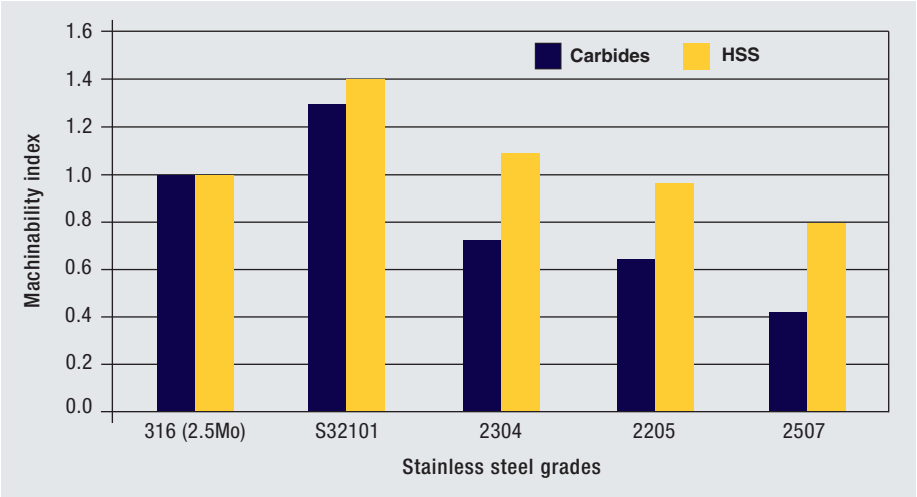
The duplex stainless steels have yield strengths typically about twice that of the non-nitrogen alloyed austenitic grades, and their initial work hardening rate is at least comparable to that of the common austenitic grades. The chip formed when machining duplex stainless steel is strong and abrasive to tooling, and especially for the more highly alloyed duplex grades. Because the duplex stainless steels are produced with as low a sulfur content as possible, there is little to aid chip breaking.

For these reasons duplex stainless steels are typically more difficult to machine than the 300 series austenitic stainless steels of similar corrosion resistance. Higher cutting forces are required and more rapid tool wear is typical of duplex stainless steel machining. The more difficult machinability compared to austenitics is most noticeable when using carbide tooling. This is illustrated in **Figure 1** with a relative machinability index comparison for some duplex stainless steels and Type 316. Note, the higher machinability rating of the lean duplex stainless steel S32101 compared to Type 316 stainless steel.

Guidelines for machining duplex stainless steels

The guidelines for machining below are generally applicable to all stainless steels, but following them is especially important for duplex stainless steels.

- **Use powerful, rigid machines with extremely strong, rigid mounting of the tools and work piece. (Cutting forces for similar cuts will typically be much higher for duplex stainless steels than for corresponding austenitic stainless steels.)**
- **Minimize vibration by keeping the tool extension as short as possible.**
- **Use a nose radius on the tool no larger than necessary.**
- **Favor an edge geometry for carbide tooling that provides a “sharp” edge while still providing adequate strength.**
- **Design machining sequences to always provide for a depth of cut below the work hardened layer resulting from prior passes.**
- **Use adequate but not excessive speed to avoid built-up edge and rapid wear.**
- **Change tooling inserts or re-grind at scheduled intervals to ensure sharp cutting edges.**
- **Use generous flows of coolant/lubricant using cutting oils or emulsions with extreme pressure (EP) additives.**
- **Use coated carbide inserts with positive chip-breaker geometry.**

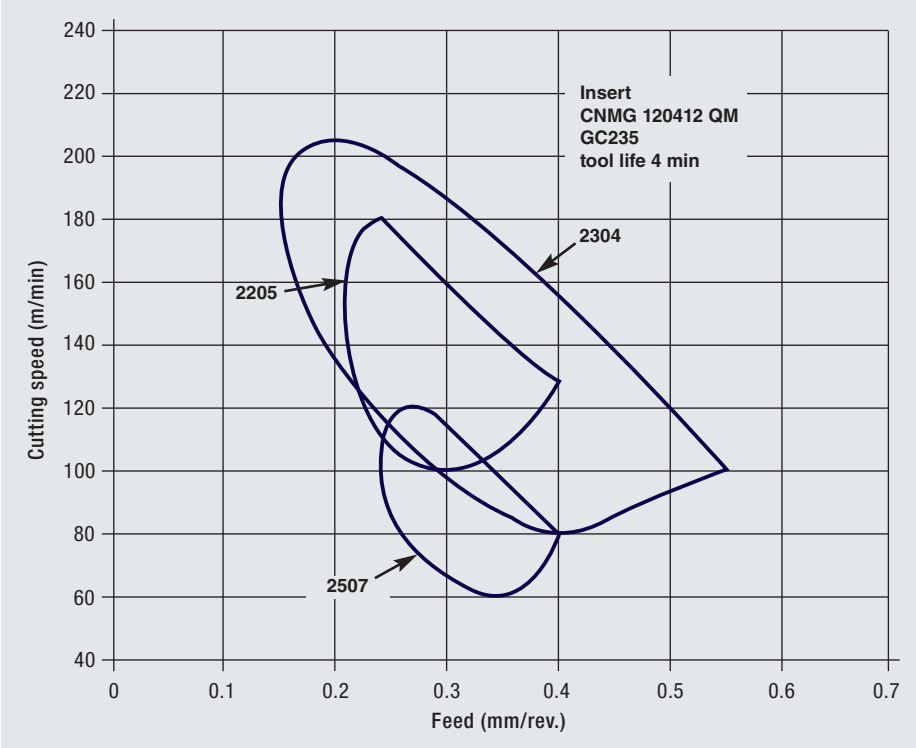


Source: Outokumpu

Figure 1:
Relative machinability of duplex stainless steels compared with Type 316 (2.5Mo) for cemented carbide tooling and for high-speed steel tooling.

Turning with high-speed steel and cemented carbides

Guidelines for face turning duplex stainless steels are provided in **Table 1** and a comparison of the turning parameters for different duplex stainless steel grades is shown in **Figure 2**.



Source: Sandvik

Figure 2:
Comparison of machining parameters for turning duplex stainless steels with a cemented carbide insert with a tool life of four minutes.

Table 1: Machining guidelines for face turning duplex stainless steels.

Stainless steel (or machining data)	Carbides				High-speed steel	
	Roughing		Finishing			
	Speed (m/min)	Speed (sfm)	Speed (m/min)	Speed (sfm)	Speed (m/min)	Speed (sfm)
S32101	170–240	560–790	200–280	660–925	20–30	65–100
2304	120–160	400–525	150–210	500–680	18–25	60–85
2205	90–120	300–400	120–160	400–525	15–20	50–65
2507	50–70	165–230	70–105	230–350	10–15	35–50
Feed (per turn)	0.3–0.6mm	0.012–0.024 in.	0.05–0.3mm	0.002–0.012 in.	0.05–0.2mm	0.002–0.008
Depth of cut	2–5 mm	0.080–0.200 in.	0.5–2 mm	0.020–0.080	0.5–2 mm	0.020–0.080
Grade	S32101, 2304, 2205: ISO P20-P35 (C5) Superduplex: ISO P30-P50		S32101, 2304,2205: ISO P10-P15 (C6-C7) Superduplex: ISO P25-P35		High quality	

Source: Outokumpu

Twist drilling with high-speed steel drills

Guidelines for twist drilling duplex stainless steels with high-speed steel drills are provided in **Tables 2** and **3**.

- Drill geometry: point angle 130°; self-centering drill point geometry is recommended; web thinning for large diameter drills is recommended.
- Coolant: 10% emulsion with ample flow to tool point; for depth greater than 2x diameter, remove chips by periodic withdrawal with flooding of coolant in hole.
- Increased speeds: TiN coating permits 10% increase; through drill coolant permits 10–20% increase.

Table 2: High-speed steel twist drilling parameters for duplex stainless steels in SI units.

Drill diameter (mm)	Speed (m/min)				Feed (mm/rev)	
	S32101	2304	2205	2507	S32101, 2304, 2205	2507
1–3	12–37	6–10	6–8	5–8	0.05	0.04
5	12–37	10–12	10–12	9–11	0.10	0.08
10	12–37	12–15	10–12	9–11	0.20	0.15
15	12–37	12–15	10–12	9–11	0.25	0.20
20	12–37	12–15	10–12	9–11	0.30	0.25
30	12–37	12–15	10–12	9–11	0.35	0.30
40	12–37	12–15	10–12	9–11	0.41	0.35

Source: Outokumpu

Table 3: High-speed steel twist drilling parameters for duplex stainless steels in English units.

Drill diameter (in.)	Speed (sfm)				Feed (in./rev)	
	S32101	2304	2205	2507	S32101, 2304, 2205	2507
0.040–0.120	40–120	20–33	20–25	16–25	0.002	0.0015
0.20	40–120	33–40	33–40	30–36	0.004	0.003
0.40	40–120	40–50	33–40	30–36	0.008	0.006
0.60	40–120	40–50	33–40	30–36	0.010	0.008
0.80	40–120	40–50	33–40	30–36	0.012	0.010
1.20	40–120	40–50	33–40	30–36	0.014	0.012
1.60	40–120	40–50	33–40	30–36	0.016	0.014

Source: Outokumpu

Face milling with cemented carbides

Guidelines for face milling duplex stainless steels with cemented carbides are provided in **Table 4**.

- Use coated inserts or a tough grade of insert for roughing. A harder insert may be used for finishing when finer finish is required.
- Use climb milling with an average chip thickness of at least 0.1 mm (0.004 inch). Adjust feed by a proportional factor of 1.0 to 0.7 as the entering angle is increased from 45° to 90°.
- Use no coolant, particularly during roughing, to obtain good chip ejection from the tool.

Table 4: Machining guidelines for face milling duplex stainless steels with cemented carbides.

Stainless steel (or machining data)	Roughing		Finishing	
	Speed (m/min)	Speed (sfm)	Speed (m/min)	Speed (sfm)
S32101	180–230	595–760	200–250	660–825
2304	100–130	330–425	130–150	425–525
2205	50–80	165–260	80–110	260–360
2507	30–50	100–165	50–70	165–230
Feed (per tooth)	0.2–0.4 mm	0.008–0.016 in.	0.1–0.2 mm	0.004–0.008 in.
Depth of cut	2–5 mm	0.080–0.200 in.	1–2 mm	0.040–0.080 in.
Carbide grade	S32101, 2304, 2205: ISO P20-P40 Superduplex: ISO P25-P40		S32101, 2304, 2205: ISO P10-P25 Superduplex: P20-P30	

Source: Outokumpu