# HARDOX®
# WELDOX®

# machining

Drilling
Countersinking
Tapping
Turning
Milling

SSAB
OXELÖSUND

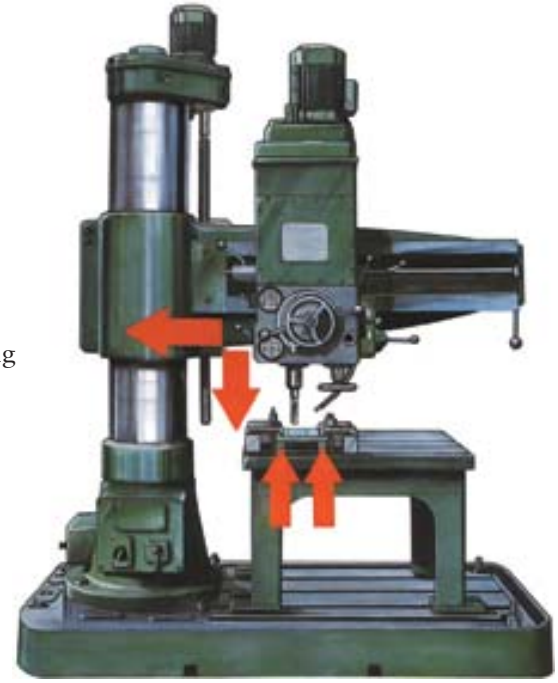
**HARDOX wear plate and WELDOX extra-high strength structural plate are steel grades that can be machined with high speed steel (HSS) or cemented carbide (CC) tools. This brochure includes our suggestions for cutting data (feeds and speeds) and the selection of tools. Other factors that should be taken into account in machining operations are also discussed. The proposals have been drawn up following our own tests on tools of various makes and in consultation with leading tool manufacturers.**

**TYPICAL PROPERTIES OF WELDOX AND HARDOX**

| | WELDOX 420 / 460 | WELDOX 500 | WELDOX 700 | WELDOX 900 / 960 | WELDOX 1100 | HARDOX 400 | HARDOX 450 | ARDOX 500 |
|---|---|---|---|---|---|---|---|---|
| Tensile strength, $R_m$ [N/mm$^2$] | ~550 | ~620 | ~860 | ~1040 | ~1350 | ~1250 | ~1400 | ~1550 |
| Hardness [HBW] | ~180 | ~200 | ~260 | ~320 | ~430 | ~400 | ~450 | ~500 |

# Drilling

Either high speed steel or cemented carbide drills can be used for drilling. The machine available and its stability determine the type of drill that should be employed. But whatever the machine type, it is vital to minimize vibrations.



## Radial or column drilling machines

Recommendations for reducing vibrations and increasing the useful life of the drill:

- Minimize the distance from the drill to the column.
- Avoid wooden spacer blocks.
- Clamp the workpiece securely, and drill as close as possible to the spacer blocks.
- Minimize the distance between the drill tip and arm by using a short spindle and short drill.
- Just before the drill breaks through, disengage the feed for about a second. Play and elasticity in the machine could otherwise snap the drill tip. Re-engage the drill feed when the play/elasticity have ceased.
- Provide an abundant supply of coolant.

**HSS**
**HSS-E**
**HSS-Co**

Individual holes can be drilled with an ordinary HSS drill. For rational production, either a micro-alloyed (HSS-E) drill or a cobalt-alloyed (HSS-Co) drill is recommended.

**HSS-Co**

Use an HSS-Co drill (8% Co) with a small helix angle and a robust core that can withstand high torques.

| | WELDOX 420 / 460 | WELDOX 500 | WELDOX 700 | WELDOX 900 / 960 | WELDOX 1100 | HARDOX 400 | HARDOX 450 | HARDOX 500 |
|---|---|---|---|---|---|---|---|---|
| *$v_c$ [m/min]* | *~26* | *~22* | *~18* | *~15* | *~7* | *~9* | *~7* | *~5* |
| **D [mm]** | **Feed rate, f [mm/rev] / Speed, n [rpm]** | | | | | | | |
| **5** | 0.14 / 1700 | 0.12 / 1520 | 0.10 / 1150 | 0.10 / 950 | 0.05 / 445 | 0.05 / 570 | 0.05 / 445 | 0.05 / 320 |
| **10** | 0.17 / 860 | 0.15 / 760 | 0.10 / 575 | 0.10 / 475 | 0.09 / 220 | 0.10 / 290 | 0.09 / 220 | 0.08 / 130 |
| **15** | 0.18 / 570 | 0.17 / 500 | 0.16 / 400 | 0.16 / 325 | 0.15 / 150 | 0.16 / 190 | 0.15 / 150 | 0.13 / 85 |
| **20** | 0.28 / 430 | 0.26 / 380 | 0.23 / 300 | 0.23 / 235 | 0.20 / 110 | 0.23 / 150 | 0.20 / 110 | 0.18 / 65 |
| **25** | 0.30 / 340 | 0.30 / 300 | 0.30 / 240 | 0.30 / 195 | 0.25 / 90 | 0.30 / 110 | 0.25 / 90 | 0.22 / 50 |
| **30** | 0.38 / 280 | 0.36 / 250 | 0.35 / 200 | 0.35 / 165 | 0.30 / 75 | 0.35 / 90 | 0.30 / 75 | 0.25 / 45 |

## More stable machine tools, such as boring mills and bed-type milling machines

For improved productivity, the benefits of cemented carbide drills should be put to use in modern and stable machines.

The choice is available between three main types of drills with cemented carbide cutting edges. The choice of drill type is dependent on the stability of the machine, the clamping of the workpiece, the hole diameter and the required tolerance. Always use the shortest possible drill.

### Coolant

- Use the type of coolant intended for drilling.
- Rule of thumb for drilling with internal coolant passages: Coolant flow [l/min] ≈ Drill diameter [mm]

### Solid cemented carbide drill

- Diameters from approx. 3 mm
- Close tolerances (high precision)
- Can be reground
- Sensitive to vibrations

### Brazed cemented carbide drill

- Diameters from approx. 10 mm
- Close tolerances (high precision)
- Can be reground
- Less sensitive to vibrations than solid carbide.

### Indexable insert drill

- Diameters from approx. 12 mm
- Offers high productivity
- Wider tolerance than the others (lower precision)
- Good economy

| | | WELDOX 420 / 460 | WELDOX 500 | WELDOX 700 | WELDOX 900 / 960 | WELDOX 1100 | HARDOX 400 | HARDOX 450 | HARDOX 500 |
|---|---|---|---|---|---|---|---|---|---|
| | | Cutting speed, $v_c$ [m/min] and Feed rate, f [mm/rev] | | | | | | | |
| Solid cemented carbide | $v_c$ | 50–70 | 50–70 | 50–70 | 40–50 | 30–40 | 35–45 | 30–40 | 25–35 |
| | f | 0.1–0.2 | 0.1–0.2 | 0.10–0.18 | 0.10–0.18 | 0.10–0.15 | 0.10–0.15 | 0.10–0.15 | 0.08–0.12 |
| Brazed cemented carbide | $v_c$ | 50–70 | 40–60 | 40–60 | 40–60 | 30–40 | 35–45 | 30–40 | 20–30 |
| | f | 0.12–0.20 | 0.12–0.20 | 0.12–0.18 | 0.12–0.18 | 0.10–0.15 | 0.10–0.15 | 0.10–0.15 | 0.08–0.12 |
| Indexable inserts | $v_c$ | 160–180 | 110–130 | 100–120 | 70–90 | 50–70 | 60–80 | 50–70 | 40–60 |
| | f | 0.1–0.2 | 0.1–0.2 | 0.10–0.18 | 0.10–0.18 | 0.06–0.14 | 0.06–0.14 | 0.06–0.14 | 0.06–0.12 |

If the drill diameter is small, select a lower feed rate within the specified range.

To calculate the speed of rotation from the recommended cutting speed:

Example for drill diameter D = 15 mm and cutting speed $v_c$ = 80 m/min

$$\text{Speed, } n = \frac{v_c \times 1000}{\pi \times D} = \frac{80 \times 1000}{3{,}14 \times 15} = 1698 = \text{approx. } 1700 \text{ rpm.}$$

### Formulas:

$$v_c = \frac{\pi \times D \times n}{1000}$$

$$n = \frac{v_c \times 1000}{\pi \times D}$$

$$v_f = f \times n$$

$v_c$ = cutting speed [m/min]
D = drill diameter [mm]
n = speed [rpm]
$\pi$ = 3.14
$v_f$ = feed rate [mm/min]
f = feed rate [mm/rev]

*Drilling contd.* ▶

# Drilling (contd.)

**If problems should arise ...**

- HSS drill tip deformed
- CC drill tip deformed
- Wear on the outside of the drill
- Holes oversize/undersize
- Chip build-up in the drill flutes
- Vibrations
- Small damage to the cut. edges (edge chipping)
- Asymmetrical holes
- Short useful life of HSS tool
- Short useful life of CC tool

**Action and solutions**

- Adjust the drill setting.
- Increase the coolant flow rate, clean the filter and the coolant holes of the drill.
- Choose a tougher grade - see the figure on page 8.
- Reduce the feed rate.
- Increase the feed rate.
- Improve the stability by more secure work-piece clamping and reduced drill overhang.
- Check the guideline values of cutting data.
- Check that the right HSS or CC grade is used.
- Increase the cutting speed.
- Reduce the cutting speed.

# Counterboring and countersinking

Spot-facing and countersinking are best done by means of countersinking tools which have replaceable cemented carbide inserts and a rotating pilot. Use coolant.

Counterbore with replaceable inserts and revolving pilot.

Conical countersink with replaceable inserts and re-volving pilot.

**NOTE**

1. Reduce the cutting data by about 30% in countersinking.
2. Always use a revolving pilot.

| | WELDOX 420 / 460 | WELDOX 500 [1] | WELDOX 700 [1] | WELDOX 900 / 960 | WELDOX 1100 | HARDOX 400 | HARDOX 450 | HARDOX 500 |
|---|---|---|---|---|---|---|---|---|
| *$v_c$ [m/min]* | *90–140* [2] | *80–120* [2] | *70–100* [2] | *40–65* [2] | *20–50* [2] | *25–70* [2] | *20–50* [2] | *17–50* [2] |
| Feed rate, f [mm / rev] | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 | 0.10–0.20 |
| **D [mm]** | **Speed, n [rpm]** | | | | | | | |
| **19** | 1510–2345 | 1340–2010 | 1175–1675 | 670–1090 | 335–840 | 420–1175 | 335–840 | 285–840 |
| **24** | 1195–1860 | 1060–1590 | 930–1325 | 530–865 | 265–665 | 330–930 | 265–665 | 225–665 |
| **34** | 845–1310 | 750–1125 | 655–935 | 375–610 | 185–470 | 235–655 | 185–470 | 160–470 |
| **42** | 680–1060 | 605–910 | 530–760 | 300–495 | 150–380 | 190–530 | 150–380 | 130–380 |
| **57** | 505–780 | 445–670 | 390–560 | 225–365 | 110–280 | 140–390 | 110–280 | 95–280 |

1) If chipbreaking problems should arise, feed in steps of 2 mm at a time.
2) If the machine power is low, select a cutting speed towards the lower end of the range.

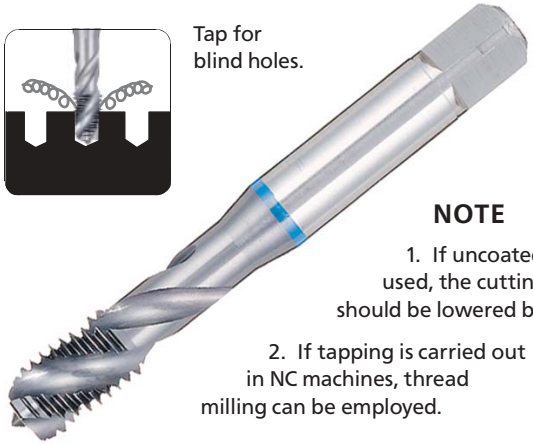
HSS countersinking cutters with three cutting edges and equipped with a pilot can be used in the WELDOX steels tabulated below. An abundant flow of coolant is necessary.

| | | WELDOX 420 / 460 | WELDOX 500 | WELDOX 700 | WELDOX 900 / 960 |
|---|---|---|---|---|---|
| $v_c$ [m/min] | | ~12 | ~10 | ~8 | ~7 |
| D [mm] | Feed rate f [mm / rev] | Speed, n [rpm] | | | |
| **15** | 0.05–0.20 | 250 | 210 | 170 | 150 |
| **19** | 0.05–0.20 | 200 | 170 | 130 | 120 |
| **24** | 0.07–0.30 | 160 | 130 | 100 | 90 |
| **34** | 0.07–0.30 | 110 | 90 | 70 | 70 |
| **42** | 0.07–0.30 | 90 | 60 | 60 | 50 |
| **57** | 0.07–0.30 | 70 | 60 | 40 | 40 |

# Tapping

If the correct type of tap is used, holes can be tapped in all HARDOX and WELDOX steels. We recommend four-flute taps which can withstand the high torques necessary for tapping holes in hard materials. When HARDOX and WELDOX materials are tapped, thread oil or thread paste is recommended as lubricant. An emulsion can also be used for the softer WELDOX 420, WELDOX 460 and WELDOX 500 steels.

In applications in which thread strength is not critical, a somewhat larger than standard hole diameter can be drilled (about 3% larger), in order to reduce the tap stresses during tapping. This will increase the useful life of the tap, above all when tapping holes in HARDOX and WELDOX 1100.

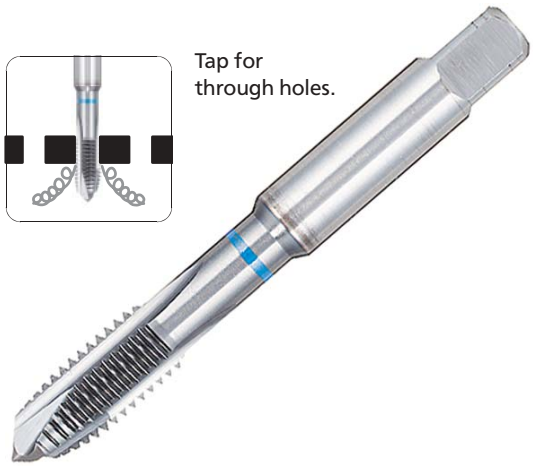


Tap for blind holes.

**NOTE**

1. If uncoated taps are used, the cutting data should be lowered by 30%.

2. If tapping is carried out in NC machines, thread milling can be employed.



Tap for through holes.

| | | HSS TiN coated | HSS-Co (HSS-E) TiN or TiCN coated | | HSS-Co (HSS-E) TiCN coated | | | |
|---|---|---|---|---|---|---|---|---|
| | | WELDOX 420/460/500 | WELDOX 700 | WELDOX 900 / 960 | WELDOX 1100 | HARDOX 400 | HARDOX 450 | HARDOX 500 |
| $v_c$ [m/min] | | 15 | 10 | 8 | 3 | 5 | 3 | 2.5 |
| **Size** | | Speed, n [rpm] | | | | | | |
| **M10** | | 475 | 320 | 255 | 95 | 160 | 95 | 80 |
| **M12** | | 395 | 265 | 210 | 80 | 130 | 80 | 65 |
| **M16** | | 300 | 200 | 160 | 60 | 100 | 60 | 50 |
| **M20** | | 235 | 160 | 125 | 45 | 80 | 45 | 40 |
| **M24** | | 200 | 130 | 105 | 40 | 65 | 40 | 30 |
| **M30** | | 160 | 105 | 85 | 32 | 50 | 32 | 25 |
| **M42** | | 110 | 75 | 60 | 22 | 35 | 22 | 20 |

# Milling

## SELECTION OF MILLING METHOD AND CUTTERS

To ensure rational production, milling cutters with cemented carbide inserts are recommended.

**FACE MILLING**

- Roughing
  - Select a cutter with round inserts, particularly for machining HARDOX

- Finishing
  - Select a cutter with 45° setting angle

**SQUARE SHOULDER MILLING**

- Select a milling cutter with 90° setting angle


**END MILLING**

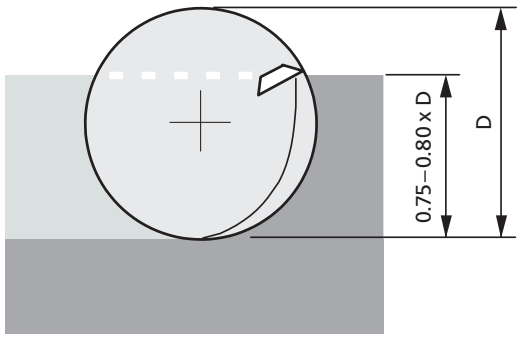
- Unstable machine
  - Select a coated HSS-Co end mill *

*) Avoid using an HSS end mill when machining a gas-cut edge.

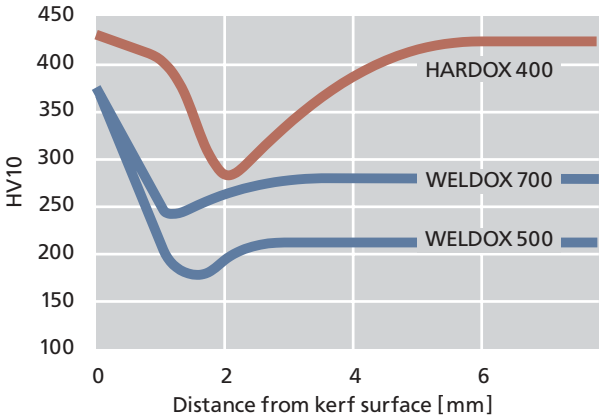
- Stable machine
  - Select a CC end mill – solid or with indexable inserts

**The following factors should be borne in mind when milling:**

- Make certain that the workpiece is securely clamped.
- If the machine power is low, use a coarse-pitch cutter.
- If possible, avoid a universal head, since this weakens the tool mounting and power transmission.
- The width of cut in face milling should be about 75–80% of the cutter diameter (see figure to the right).
- When milling surfaces which are narrower than the diameter of the milling head, the milling cutter should be located eccentrically, so that as many teeth as possible will be in engagement.
- When milling a gas-cut edge, the depth of cut should be at least 2 mm, in order to avoid the hard surface layer of the cut edge (see graph).




Recommended cutting width in face milling




Hardness profile of gas-cut edge, cut in air

| | FACE MILLING | | | | END MILLING | | | |
|---|---|---|---|---|---|---|---|---|
| | Coated CC | | Cermet | Coated CC | CC | | | HSS-Co |
| Grade | P40 / C5 | P25 / C6 | P20 / C6-C7 | K20 / C2 | K10 / C3-uncoated | K10 / C3-coated | P10 / C7-indexable insert | TiCN-coated |
| Conditions | unstable | average | stable | stable | stable | stable | stable | unstable |
| Feed rate ($f_z$) | 0.1 – 0.2 – 0.3 | 0.1 – 0.2 – 0.3 | 0.1 – 0.2 | 0.1 – 0.2 | 0.02 – 0.10 | 0.02 – 0.20 | 0.05 – 0.15 | 0.03 – 0.09 |
| Plate grade | Cutting speed, $v_c$ [m / min] | | | | | | | |
| **WELDOX 420 / 460** | 220–180–120 | 250–210–180 | 350 – 280 | – | 130 | 210 | 220 –180 | 60 |
| **WELDOX 500** | 220–180–120 | 250–210–180 | 350 – 280 | – | 125 | 210 | 220 –180 | 50 |
| **WELDOX 700** | 195–150–95 | 220–180–150 | 240 – 200 | – | 100 | 180 | 195 –150 | 40 |
| **WELDOX 900 / 960** | 95–75–50 | 200–160–130 | 220 – 170 | – | 90 | 130 | 140 –120 | 18 |
| **WELDOX 1100** | – | 150–120 –110 | 150 – 120 | – | 90 | 100 | 110 –90 | 18 |
| **HARDOX 400** | – | 150–120 –110 | 150 – 120 | – | 90 | 100 | 110 –90 | 18 |
| **HARDOX 450** | – | 150–120 –110 | 150 – 120 | – | 90 | 100 | 110 –90 | 18 |
| **HARDOX 500** | – | 120–100 | 120 – 100 | 120 – 100 | 50 | 80 | 90–70 | – |

At higher feed rates, lower the cutting speed.

## Formulas:

$$v_c = \frac{\pi \times D \times n}{1000}$$

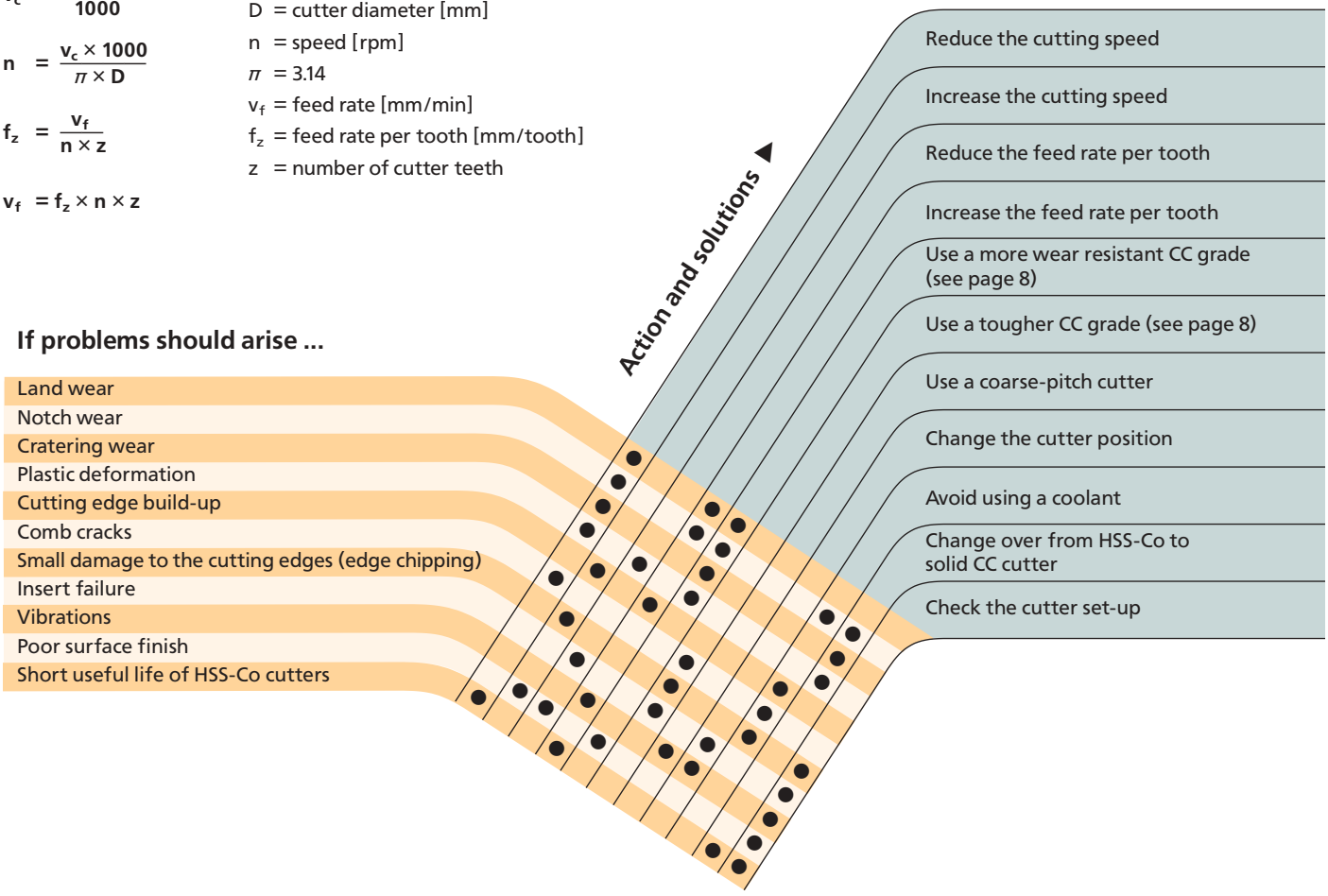
$$n = \frac{v_c \times 1000}{\pi \times D}$$

$$f_z = \frac{v_f}{n \times z}$$

$$v_f = f_z \times n \times z$$

$v_c$ = cutting speed [m/min]
D = cutter diameter [mm]
n = speed [rpm]
$\pi$ = 3.14
$v_f$ = feed rate [mm/min]
$f_z$ = feed rate per tooth [mm/tooth]
z = number of cutter teeth

## If problems should arise ...



# Turning

The cutting data recommendations below are applicable to tough cemented carbide grades. These are necessary for operations in which impact may occur, such as when turning plate with gas-cut edges.

| Carbide grade | P25 / C6 | P35 / C6-C5 | K20 / C2 |
|---|---|---|---|
| feed rate, $f_n$ [mm / rev] | 0.1 – 0.4 – 0.8 | 0.1 – 0.4 – 0.8 | 0.1 – 0.3 |
| | Cutting speed, $v_c$ [m / min] | | |
| **WELDOX 420 / 460** | 450 – 300 – 210 | 285 – 175 – 130 | – |
| **WELDOX 500** | 450 – 300 – 210 | 285 – 175 – 130 | – |
| **WELDOX 700** | 285 – 195 – 145 | 230 – 150 – 100 | – |
| **WELDOX 900 / 960** | 130 – 90 – 70 | 105 – 65 – 45 | – |
| **WELDOX 1100** | 130 – 90 – 70 | 105 – 65 – 45 | – |
| **HARDOX 400** | 130 – 90 – 70 | 105 – 65 – 45 | – |
| **HARDOX 450** | 130 – 90 – 70 | 105 – 65 – 45 | – |
| **HARDOX 500** | – | – | 100 – 80 |

At higher feed rates, lower the cutting speed.

**Formulas:**

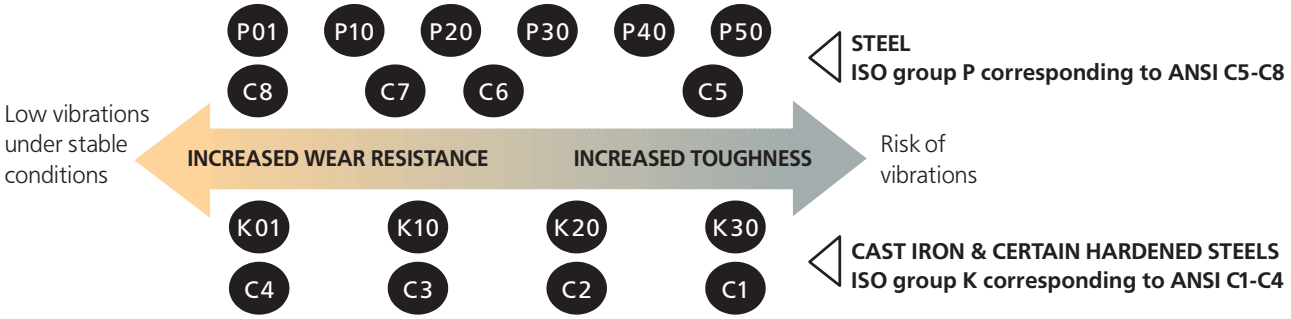
$$v_c = \frac{\pi \times D \times n}{1000}$$

$$n = \frac{v_c \times 1000}{\pi \times D}$$

$$v_f = f_n \times n$$

$v_c$ = cutting speed [m/min]
D = workpiece dia. [mm]
n = speed [rpm]
$\pi$ = 3.14
$v_f$ = feed rate [mm/min]
$f_n$ = feed rate [mm/rev]

# Tool materials / Cemented carbide grades




This brochure has been written in cooperation with Sandvik Coromant AB and Dormer Tools AB. Granlund Tools AB has contributed pictures and cutting data for the section dealing with countersinking.

For further information, please get in touch with our Technical Customer Service Department.

The *Machining* brochure is included in a series of publications that offer advice and instructions for working on HARDOX and WELDOX plate. The other brochures in the series are *Welding*, *Bending / shearing* and *Cutting*. Place your order for them with our Market Communication Department.

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