

**HARDOX®**  
WEAR PLATE

# MACHINING RECOMMENDATIONS FOR HARDOX®



# TABLE OF CONTENTS

Drilling recommendations	4
Countersinking and counterboring recommendations	10
Tapping recommendations	12
Thread milling recommendations	13
Milling recommendations	14
Troubleshooting for drilling	20
Troubleshooting for milling	21
Turning recommendations	22
Results from our own tests	23
Tool recommendations for Hardox®	24
Tool suppliers we recommend and have collaborated with	31

All Hardox® wear plate steel grades can be machined with high speed steel (HSS) or cemented carbide (CC) tools. This brochure contains 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. Our recommendations are based on our own tests on tools of various makes and in consultation with leading tool manufacturers.

## TYPICAL PROPERTIES FOR HARDOX®

Steel grade	Hardness in Brinell (HBW) Min - Max	Typical hardness in Rockwell-C (HRC)	Typical yield strength (MPa), not guaranteed
Hardox® HiTemp	375 – 425	-	≈1100
Hardox® HiAce	425 – 475	-	≈1250
Hardox® HiTuf	310 – 370	-	≈850
Hardox® 400	370 – 430	-	≈1100
Hardox® 450	410 – 475	-	≈1250
Hardox® 500	450 – 540	-	≈1400
Hardox® 500 Tuf	475 – 505	-	≈1250 - 1400
Hardox® 550	525 – 575	-	-
Hardox® 600	550 – 640	-	-
Hardox® Extreme	-	57 – 63	-

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## DRILLING RECOMMENDATIONS

### HSS DRILL

Use HSS drills only when you have unstable machine conditions. HSS drills are only suitable up to 500 Brinell. If the machine conditions are good, you can choose among solid cemented carbide drills, drills with exchangeable heads or indexable insert drills.

### ADVICE FOR REDUCING VIBRATIONS AND INCREASING THE LIFETIME OF THE DRILL

- Minimize the distance to the column and between the drill tip and the workpiece.
- Don't use a longer drill than necessary.
- Always use metal supports and clamp the workpiece securely.
- Solid and firm table.
- Always use coolant.
- Coolant mix 8-12%.
- Just before the drill breaks through, disengage the feed rate for about a second, play/springback can otherwise snap the drill tip. Re-engage the feed rate when the play/springback has ceased.



Steel grade	Cutting speed (Vc), m/min	Drill diameter, (Dc), mm				
		Feed per revolution, (fn) mm/rev				
		Ø 10 mm	Ø 15 mm	Ø 20 mm	Ø 25 mm	Ø 30 mm
Hardox® HiTemp	7 – 9	0.11	0.16	0.23	0.29	0.35
Hardox® HiAce	5 – 7	0.10	0.15	0.20	0.25	0.30
Hardox® HiTuf	10 – 12	0.10	0.16	0.23	0.29	0.35
Hardox® 400	7 – 9	0.11	0.16	0.23	0.29	0.35
Hardox® 450	5 – 7	0.10	0.15	0.20	0.25	0.30
Hardox® 500	3 – 5	0.08	0.12	0.16	0.20	0.24
Hardox® 500 Tuf	3 – 5	0.08	0.12	0.16	0.20	0.24



**HSS, HSS-E, HSS-Co**  
Individual holes can be drilled with an ordinary HSS drill. For rational production, a microalloyed (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.

## FORMULAS AND DEFINITIONS, DRILLING

$$V_c = \pi \times D_c \times n / 1000$$

$$n = V_c \times 1000 / (\pi \times D_c)$$

$$V_f = f_n \times n$$

$$\pi = 3.142$$

$$V_c = \text{Cutting speed (m/min)}$$

$$n = \text{Spindle speed (rpm)}$$

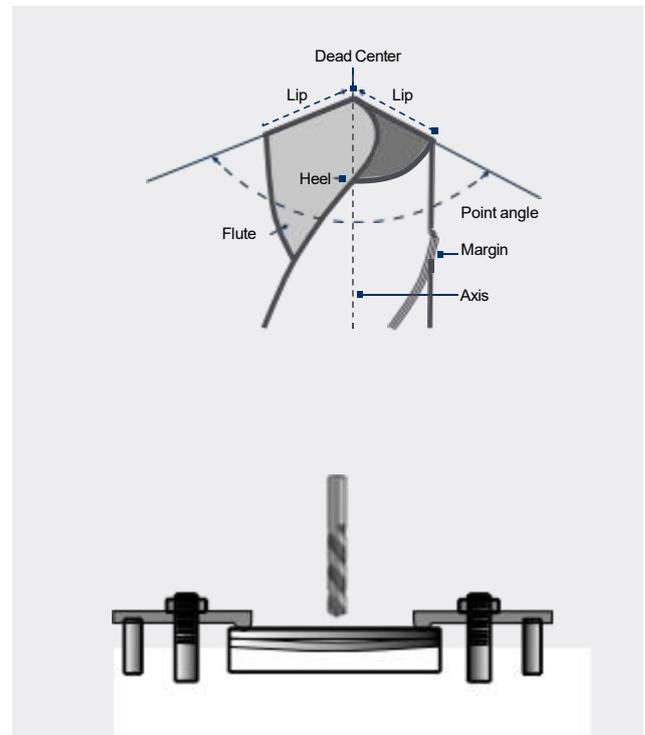
$$f_n = \text{Feed per revolution (mm/r)}$$

$$V_f = \text{Penetration rate (mm/min)}$$

$$D_c = \text{Drill diameter (mm)}$$

## ADVICE FOR DRILLING IN THIN PLATE BELOW 8 MM

1. Important to have good support under the plate to avoid deflection.
2. An indexable drill is recommended, because it begins cutting at the periphery, and does not build up the high pressure a solid carbide drill would do.
3. With a drill diameter over Ø 10 mm and a point angle of 118-140°, it is very important to support the plate that is drilled. If the drill tip breaks through the bottom surface without a supporting plate to guide the tip, it may result in an oval and undersized hole (see picture).
4. Reduce feed rate and increase cutting speed Vc, especially when using an indexable drill.



## SOLID CEMENTED CARBIDE DRILL

For stable machine conditions and with internal coolant.  
This is the only type of drill suitable for drilling Hardox® Extreme.

Steel grade	Cutting speed (Vc), m/min	Drill diameter, (Dc), mm			
		Feed per revolution, (fn) mm/rev			
		Ø 3,0 – 5,0 mm	Ø 5,01 – 10,0 mm	Ø 10,01 – 15,0 mm	Ø 15,01 – 20,0 mm
Hardox® HiTemp	50 – 70	0.03 – 0.06	0.06 – 0.12	0.12 – 0.16	0.16 – 0.21
Hardox® HiAce	40 – 60	0.03 – 0.05	0.05 – 0.11	0.11 – 0.15	0.15 – 0.20
Hardox® HiTuf	60 – 80	0.03 – 0.06	0.06 – 0.12	0.12 – 0.17	0.17 – 0.22
Hardox® 400	50 – 70	0.03 – 0.06	0.06 – 0.12	0.12 – 0.16	0.16 – 0.21
Hardox® 450	40 – 60	0.03 – 0.05	0.05 – 0.11	0.11 – 0.15	0.15 – 0.20
Hardox® 500	35 – 50	0.03 – 0.05	0.05 – 0.10	0.10 – 0.14	0.14 – 0.18
Hardox® 500 Tuf	35 – 50	0.03 – 0.05	0.05 – 0.10	0.10 – 0.14	0.14 – 0.18
Hardox® 550	30 – 40	0.03 – 0.05	0.05 – 0.09	0.09 – 0.13	0.13 – 0.17
Hardox® 600	25 – 35	0.02 – 0.04	0.04 – 0.08	0.08 – 0.13	0.13 – 0.16
Hardox® Extreme	18 – 25	0.02 – 0.04	0.04 – 0.08	0.08 – 0.12	0.12 – 0.15



- Drilling 7x Dc, reduce the feed rate by 20%
- Drilling with external coolant, reduce the spindle speed and feed rate by 20%

## INDEXABLE INSERT DRILL

For stable machine conditions and with internal coolant.  
Important: Use as short a drill as possible. The recommendations are for 2xØ.

Steel grade	Cutting speed (Vc), m/min	Drill diameter, (Dc), mm			
		Feed per revolution, (fn) mm/rev			
		Ø 12,0 – 20,0 mm	Ø 20,01 – 30,0 mm	Ø 30,01 – 44,0 mm	Ø 44,01 – 63,5 mm
Hardox® HiTemp	60 – 120	0.04 – 0.10	0.06 – 0.12	0.06 – 0.14	0.08 – 0.16
Hardox® HiAce	50 – 90	0.04 – 0.10	0.06 – 0.12	0.06 – 0.14	0.08 – 0.16
Hardox® HiTuf	70 – 130	0.04 – 0.10	0.06 – 0.12	0.06 – 0.14	0.08 – 0.16
Hardox® 400	60 – 120	0.04 – 0.10	0.06 – 0.12	0.06 – 0.14	0.08 – 0.16
Hardox® 450	50 – 90	0.04 – 0.10	0.06 – 0.12	0.06 – 0.14	0.08 – 0.16
Hardox® 500	40 – 70	0.04 – 0.08	0.04 – 0.10	0.06 – 0.12	0.08 – 0.14
Hardox® 500 Tuf	40 – 70	0.04 – 0.08	0.04 – 0.10	0.06 – 0.12	0.08 – 0.14
Hardox® 550	35 – 55	0.04 – 0.08	0.04 – 0.10	0.06 – 0.12	0.08 – 0.14
Hardox® 600	30 – 50	0.04 – 0.06	0.04 – 0.08	0.06 – 0.10	0.06 – 0.12

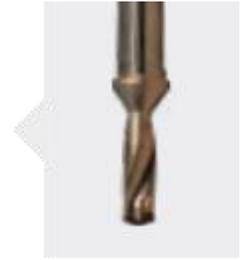


- The cutting data for indexable drills has been formulated in co-operation with Sandvik Coromant.
- Not suitable for Hardox® Extreme.

## DRILLS WITH EXCHANGEABLE DRILL TIP

For stable machine conditions and with internal coolant.

Steel grade	Cutting speed (Vc), m/min	Drill diameter, (Dc), mm			
		Feed per revolution, (fn) mm/rev			
		Ø 7,5 – 12,0 mm	Ø 12,01 – 20,0 mm	Ø 20,01 – 25,0 mm	Ø 25,01 – 33,0 mm
Hardox® HiTemp	50 – 70	0.08 – 0.12	0.12 – 0.20	0.20 – 0.25	0.25 – 0.33
Hardox® HiAce	40 – 60	0.07 – 0.11	0.11 – 0.15	0.15 – 0.20	0.20 – 0.28
Hardox® HiTuf	60 – 80	0.08 – 0.13	0.13 – 0.22	0.22 – 0.27	0.27 – 0.36
Hardox® 400	50 – 70	0.08 – 0.12	0.12 – 0.20	0.20 – 0.25	0.25 – 0.33
Hardox® 450	40 – 60	0.07 – 0.11	0.11 – 0.15	0.15 – 0.20	0.20 – 0.28
Hardox® 500	35 – 50	0.06 – 0.10	0.10 – 0.14	0.14 – 0.18	0.18 – 0.24
Hardox® 500 Tuf	35 – 50	0.06 – 0.10	0.10 – 0.14	0.14 – 0.18	0.18 – 0.24
Hardox® 550	30 – 40	0.05 – 0.08	0.08 – 0.12	0.12 – 0.16	0.16 – 0.22
Hardox® 600	25 – 35	0.04 – 0.07	0.07 – 0.11	0.11 – 0.14	0.14 – 0.18



## CUTTING SPEED RECOMMENDATIONS FOR CHAMDRILL/SUMOCHAM IN UNSTABLE MACHINES

With this tool and with machine conditions that are not optimal, using these drills is a good solution when many holes need to be drilled. The drilling operation can be done almost 3 times faster compared to our recommendations for HSS drills.

All recommendations for the cutting data are based on tests we have performed in our own radial drilling machine.

CHAMDRILL with exchangeable drill tip (see specific tool recommendations at the end of this brochure).

- If the drill centers badly in the start, we recommend that you center the drill manually. Otherwise the drill head may break (especially with drill Ø over 15 mm).



### 4 RESULTS FROM OUR OWN TEST

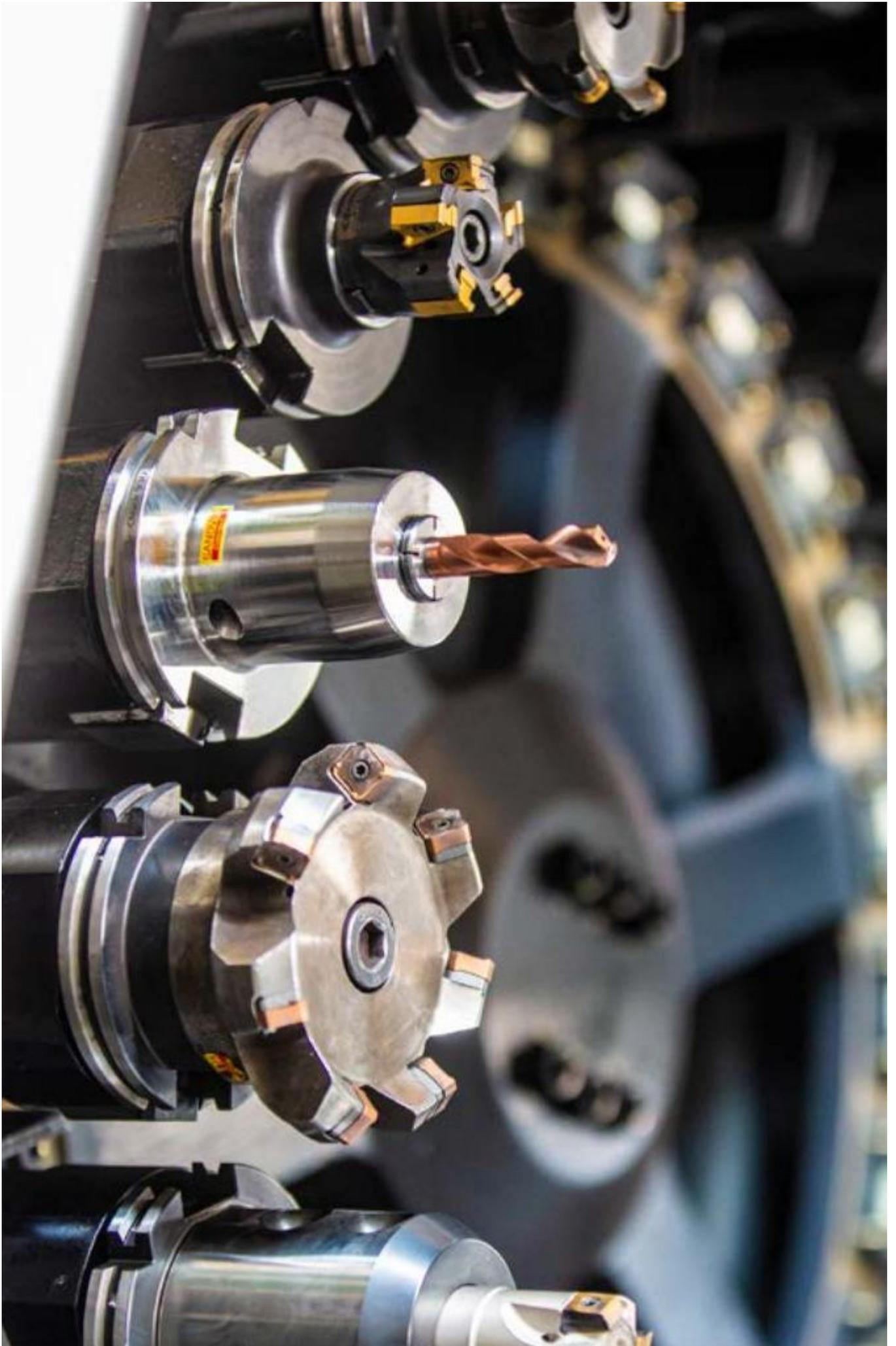
Thickness of Hardox® 450	Ø Drill	Vc, m/min	fn, mm/r	Nr of holes	Chamdrill vs HSS
16 mm	8.5	13.3	0.11	400	2.6 times faster
25 mm	14.2	15.8	0.17	270	2.6 times faster
Thickness of Hardox® 500	Ø Drill	Vc, m/min	fn, mm/r	Nr of holes	Chamdrill vs HSS
12 mm	14.2	11.1	0.11	300	2.5 times faster
30 mm	25	9.8	0.17	107	1.9 times faster



Steel grade	Cutting speed (Vc), m/min	Drill diameter, (Dc), mm		
		Feed per revolution, (fn) mm/rev		
		Ø 7.5 – 11.5 mm	Ø 12.0 – 17.5 mm	Ø 18.0 – 25.9 mm
Hardox® HiTemp	12 – 22	0.08 – 0.12	0.12 – 0.18	0.13 – 0.24
Hardox® HiAce	10 – 18	0.08 – 0.12	0.12 – 0.18	0.11 – 0.20
Hardox® HiTuf	14 – 25	0.08 – 0.12	0.12 – 0.18	0.13 – 0.24
Hardox® 400	12 – 22	0.08 – 0.12	0.12 – 0.18	0.13 – 0.24
Hardox® 450	10 – 18	0.08 – 0.12	0.12 – 0.18	0.11 – 0.20
Hardox® 500	8 – 14	0.06 – 0.12	0.11 – 0.16	0.10 – 0.18
Hardox® 500 Tuf	8 – 14	0.06 – 0.12	0.11 – 0.16	0.10 – 0.18



- Type of tool holder we recommend and used during the test, see the image to the right.





# COUNTERSINKING AND COUNTERBORING RECOMMENDATIONS

Countersinking and counterboring are best performed using tools with replaceable inserts, which are available from the tool supplier Granlund. Always use a revolving pilot and use coolant. See the table on page 11 for screw and article number for the tools.

Calculation of spindle speed uses the same formula as for drilling.

## REDUCE THE CUTTING DATA BY ABOUT 30% FOR COUNTERSINKING

Steel grade	Cutting speed (Vc), m/min	Counterbore diameter, (Dc), mm			
		Feed per revolution, (fn) mm/rev			
		Ø 18.0 – 26.0 mm	Ø 26.0 – 38.0 mm	Ø 38.0 – 47.0 mm	Ø 47.0 – 60.0 mm
Hardox® HiTemp	25 – 70	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® HiAce	20 – 50	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® HiTuf	30 – 80	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 400	25 – 70	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 450	20 – 50	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 500	15 – 45	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 500 Tuf	15 – 45	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 550	12 – 40	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20
Hardox® 600	10 – 35	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20	0.10 – 0.20



Image: Granlund Tools AB



Image: Granlund Tools AB

## COUNTERSINKING AND COUNTERBORING TABLE FOR SCREWS

Size	Article number	Ø Screw head
M8	0KV9-18.0	16 mm
M10	0KV9- 20.5 / 1KV9- 20.0	20 mm
M12	0KV9- 25.0 / 1KV9- 26.0	24 mm
M14	1KV9- 30.0	27 mm
M16	1KV9- 30.0 / 2KV9- 32.0	30 mm
M20	2KV9- 38.0	36 mm
M24	2KV9- 40.0	39 mm



Size	Article number	Ø Screw head
M10	0WHV- 18.0	16 mm
M12	0WHV- 20.0 / 1WHV- 20.0	18 mm
M14	0WHV- 23.0 / 1WHV- 23.0	21 mm
M16	1WHV- 26.0	24 mm
M20	1WHV- 32.0	30 mm
M24	1WHV- 38.0 / 2WHV- 38.0	36 mm
M30	2WHV-47.0	45 mm



KV9

Image: Granlund Tools AB



WHV

Image: Granlund Tools AB



# TAPPING RECOMMENDATIONS

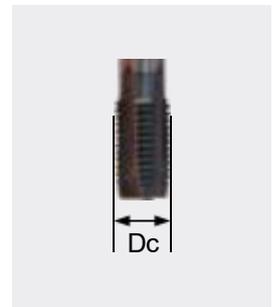
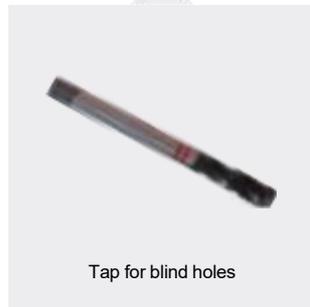
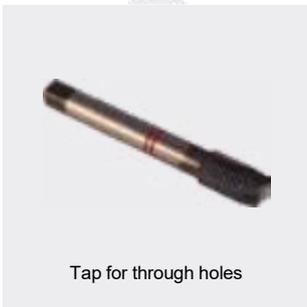
Steel grade	Cutting speed (Vc), m/min	Size from - to
Hardox® HiTemp	4 – 8	M6 – M30
Hardox® HiAce	1 - 3	M8 – M30
Hardox® HiTuf	6 – 10	M6 – M30
Hardox® 400	4 – 8	M6 – M30
Hardox® 450	1 – 5	M6 – M30
Hardox® 500	1 – 3	M8 – M30
Hardox® 500 Tuf	1 – 3	M8 – M30

With correct tools and tool holders, we recommend tapping up to 500 Brinell with four-flute taps that can withstand the very high torque occurring during tapping in hard materials. If diameter is not critical, the drilled hole can be 3% larger than standard. This will increase the lifetime of the tap.

## CALCULATION OF SPINDLE SPEED

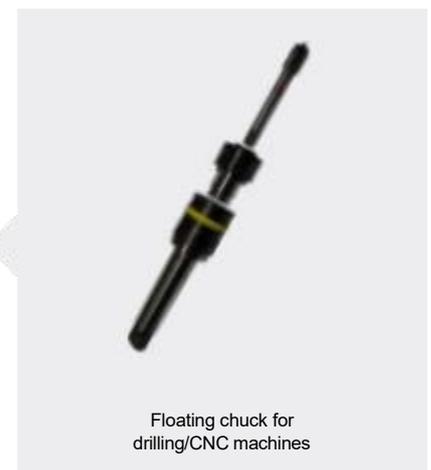
$$n = \frac{Vc \times 1000}{\pi \times Dc}$$

n = Spindle speed (rpm)  
 Vc = Cutting speed (m/min)  
 Dc = Tool diameter (Ø mm)  
 $\pi$  = 3.142



The tool supplier Emuge-Franken provides the type of tool holders we recommend for tapping. See the image to the right.

Size	Pitch	Drill Ø min - max
M6	1	5.0 – 5.1
M8	1.25	6.8 – 6.9
M10	1.5	8.5 – 8.7
M12	1.75	10.25 – 10.5
M14	2	12 – 12.3
M16	2	14 – 14.3
M20	2.5	17.5 – 18
M24	3	21 – 21.5
M27	3	24 – 24.5
M30	3.5	26.5 – 27.0





## THREAD MILLING RECOMMENDATIONS

A CNC machine is necessary for thread milling. The tool supplier can provide programming support for the CNC machines.

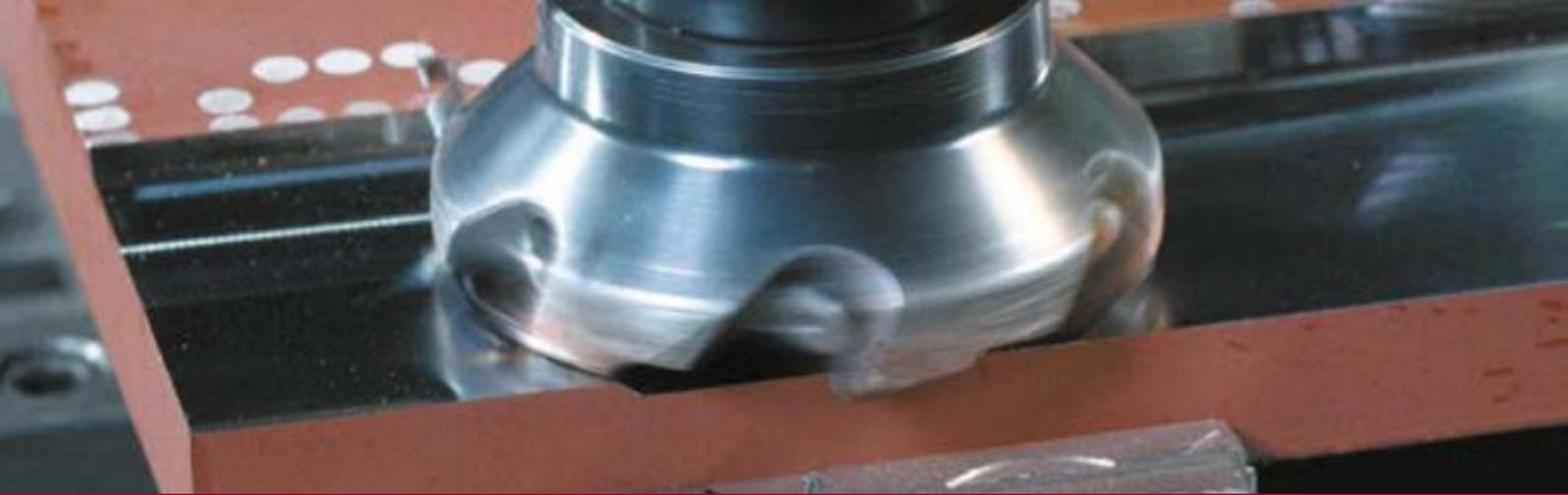
Steel grade	Cutting speed (Vc), m/min	Feed per tooth (fz), mm/tooth
Hardox® HiTemp	60 – 80	0.02 – 0.05
Hardox® HiAce	40 – 60	0.02 – 0.04
Hardox® HiTuf	70 – 100	0.03 – 0.06
Hardox® 400	60 – 80	0.02 – 0.05
Hardox® 450	50 – 70	0.02 – 0.05
Hardox® 500	40 – 60	0.02 – 0.05
Hardox® 500 Tuf	40 – 60	0.02 – 0.05
Hardox® 550	35 – 55	0.02 – 0.04
Hardox® 600	30 – 40	0.01 – 0.03
Hardox® Extreme	25 – 35	0.01 – 0.03



### TAPPING AND THREAD MILLING ADVICE

- Taps for blind holes have a shorter lifetime due to the smaller core diameter.
- Before tapping, make sure that the predrilled hole is in good condition (do not use worn out drills).
- Always use coated taps.
- Requires thread milling from Hardox® 550 to Hardox® Extreme.
- Do the thread milling in two passes.
- Make sure that the coolant mix is between 8-12%.
- We recommend climb milling.

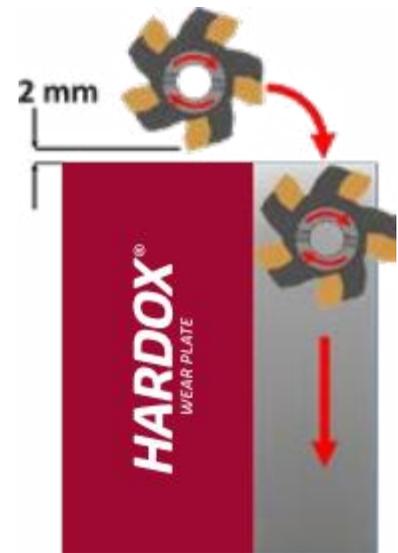




# MILLING RECOMMENDATIONS

## MILLING ADVICE

- Position the cutter off-center (to the left) to achieve a thicker chip at the entry and to avoid a thick chip at the exit.
- Avoid cutting through the center line of the cutter, as this could generate vibration.
- Always use down milling (climb milling).
- We recommend that the width of the cut (ae) is 25 or 75-80% of the cutter diameter.
- Use rolling into cut method.
- Dry milling is recommended if an insert is used.
- If the machine power is low use a coarse pitch cutter.
- Always use a vise or good clamping equipment.
- The depth of cut with milling gas-cut edges should be at least 2 mm, to avoid the hard surface layer of the cut edge.
- If you enter the workpiece with the rolling into cut method the chip thickness on the exit is always zero, and it will help to give a longer tool life.



Roll in to cut

## FORMULAS AND DEFINITIONS

$$n = \frac{Vc \times 1000}{\pi \times DC}$$

$$Vc = \frac{\pi \times DC \times n}{1000}$$

$$Vf = fz \times n \times Zc$$

$$fz = \frac{Vf}{n \times Zc}$$

$$\pi = 3.142$$

Vc= Cutting speed (m/min)

n = Spindle speed (rpm)

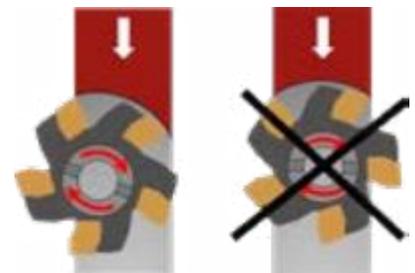
fz = Feed per tooth (mm/t)

Vf = Table feed (mm/min)

Zc= Number of effective teeth (pcs)

DC= Cutting diameter (mm)

ap = Axial depth of cut (mm)



## INSERT GRADES FOR MILLING

	ISO	ANSI	
P	01	C8	▲
	10	C7	
	20		
	30	C6	
	40		
	50	C5	▼
M	10		▲
	20		
	30		
	40		▼
K	01	C4	▲
	10	C3	
	20	C2	
	30	C1	
	40		▼
H	01	C4	▲
	10	C3	
	20	C2	
	30	C1	▼

## WORKPIECE MATERIAL

P	ISO P= Steel
M	ISO M = Stainless steel
K	ISO K = Cast iron
H	ISO H = Hardened steel

▲ = Wear resistance

▼ = Toughness

\* Example insert grade 1030.

The last 2 numbers in the insert grade indicate the position of the insert in this scale, if the insert has wear or toughness resistance.

## INSERT GEOMETRY

The macro geometry affects many parameters in the cutting process. An insert with a strong cutting edge can work at higher loads, but it will also generate higher cutting forces, consume more power and generate more heat.

Parameter	L	M	H
Edge strength			
Cutting forces			
Power consumption			
Max chip thickness			
Heat generated			

Use inserts grade P30-50 with light cutting geometry and a coarse-pitch cutter if the machine power is low and with unstable machine conditions.

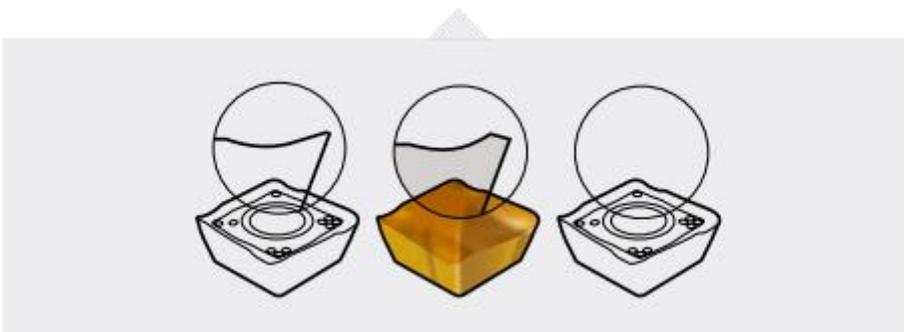


Image: Sandvik Coromant AB

## FACE MILLING RECOMMENDATION WITH A 45° SETTING ANGLE

In very stable machine conditions and with rigid set-up the insert grade P10 is more suitable in all milling operations with inserts, especially in Hardox® 600 and Hardox® Extreme.

Then the cutting speed can be increased by approximately 80-100%.

Recommendations are for average machine conditions.

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t	
		min	max
		Insert grade P30	Insert grade P30
Hardox® HiTemp	120 – 160	0.10	0.25
Hardox® HiAce	100 – 140	* 0.10	* 0.25
Hardox® HiTuf	140 – 180	0.10	0.25
Hardox® 400	120 – 160	0.10	0.25
Hardox® 450	110 – 150	0.10	0.25
Hardox® 500	100 – 140	0.10	0.25
Hardox® 500 Tuf	100 – 140	0.10	0.25
Hardox® 550	70 – 90	0.10	0.20
Hardox® 600	50 – 70	0.10	0.20
Hardox® Extreme	30 – 50	0.10	0.20



\*Hardox® HiAce has proven to be very abrasive when performing milling. An insert with a high hardness (range P10-P20) is recommended. The insert should have an easy cutting geometry (L).

## FACE MILLING RECOMMENDATION WITH ROUND INSERTS

Round inserts have strong cutting edges and are good to use when the surface has holes and cavities.

Recommendations are for average machine conditions.

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t	
		min	max
		Insert grade P30	Insert grade P30
Hardox® HiTemp	120 – 160	0.10	0.25
Hardox® HiAce	100 – 140	* 0.10	* 0.25
Hardox® HiTuf	140 – 180	0.10	0.25
Hardox® 400	120 – 160	0.10	0.25
Hardox® 450	110 – 150	0.10	0.25
Hardox® 500	100 – 140	0.10	0.25
Hardox® 500 Tuf	100 – 140	0.10	0.25
Hardox® 550	70 – 90	0.10	0.25
Hardox® 600	50 – 70	0.10	0.20
Hardox® Extreme	30 – 50	0.10	0.20



\*Hardox® HiAce has proven to be very abrasive when performing milling. An insert with a high hardness (range P10-P20) is recommended. The insert should have an easy cutting geometry (L).

## SHOULDER MILLING RECOMMENDATION WITH A 90° SETTING ANGLE

Recommendations are for average machine conditions.

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t	
		min	max
		Insert grade P30	sert grade P30
Hardox® HiTemp	120 – 160	0.12	0.25
Hardox® HiAce	100 – 140	* 0.12	* 0.25
Hardox® HiTuf	140 – 180	0.12	0.25
Hardox® 400	120 – 160	0.12	0.25
Hardox® 450	110 – 150	0.12	0.25
Hardox® 500	100 – 140	0.12	0.25
Hardox® 500 Tuf	100 – 140	0.12	0.25
Hardox® 550	70 – 90	0.10	0.20
Hardox® 600	50 – 70	0.10	0.20
Hardox® Extreme	30 – 50	0.10	0.20



\*Hardox® HiAce has proven to be very abrasive when performing milling. An insert with a high hardness (range P10-P20) is recommended. The insert should have an easy cutting geometry (L).

## HIGH FEED MILLING WITH COROMILL 210 10° SETTING ANGLE

Recommendations are for average machine conditions.

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t			
		Min Insert grade P30	Max Insert grade P30	Min Insert grade P30	Max Insert grade P30
		Insert size 09	Insert size 09	Insert size 14	Insert size 14
Hardox® HiTemp	120 – 160	0.4	2.0	0.5	3.0
Hardox® HiAce	90 – 130	* 0.4	* 2.0	* 0.5	* 3.0
Hardox® HiTuf	140 – 180	0.4	2.0	0.5	3.0
Hardox® 400	120 – 160	0.4	2.0	0.5	3.0
Hardox® 450	110 – 150	0.4	2.0	0.5	3.0
Hardox® 500	90 – 130	0.4	2.0	0.5	3.0
Hardox® 500 Tuf	90 – 130	0.4	2.0	0.5	3.0
Hardox® 550	70 – 90	0.4	2.0	0.5	3.0
Hardox® 600	50 – 70	0.4	2.0	0.5	3.0
Hardox® Extreme	35 – 50	0.4	2.0	0.5	3.0



• The fz and pitch/rev are recommendations for Coromill 210 from Sandvik Coromant.

\*Hardox® HiAce has proven to be very abrasive when performing milling. An insert with a high hardness (range P10-P20) is recommended. The insert should have an easy cutting geometry (L).

## HOLE MAKING WITH HIGH FEED MILLING (CIRCULAR RAMPING)

Circular ramping, also called helical interpolation, or spiral interpolation is a simultaneous movement in a circular path (X and Y) together with an axial feed (Z) with a defined pitch (P). It can be used as an alternative to drilling. To manage circular ramping a CNC machine is necessary.

### ADVICE

- Use compressed air to remove metal chips.
- Always use down-milling/climb milling.
- $P = \text{pitch mm/rev.}$
- Max pitch with insert size 09 is 1.2 mm.
- Max pitch with insert size 14 is 2.0 mm.

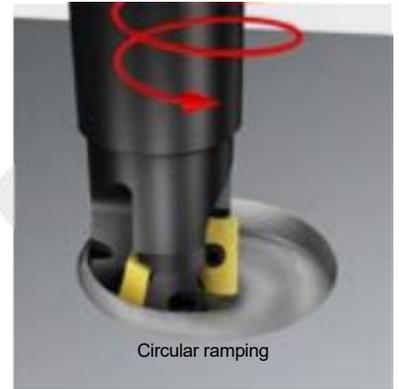


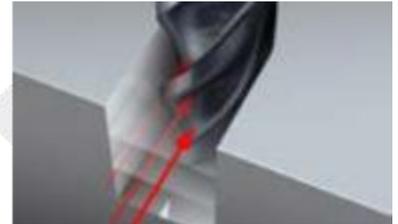
Image: Sandvik Coromant AB



## END MILLING RECOMMENDATION FOR SOLID CEMENTED CARBIDE TOOL

Slot milling recommendation.

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t		
		Min – Max		
		Ø Diameter 3.0 – 6.0	Ø Diameter 8.0 – 12.0	Ø Diameter 14.0 – 20.0
Hardox® HiTemp	75 – 100	0.01 – 0.03	0.03 – 0.06	0.06 – 0.09
Hardox® HiAce	65 – 90	0.01 – 0.03	0.03 – 0.05	0.05 – 0.07
Hardox® HiTuf	80 – 105	0.01 – 0.03	0.04 – 0.07	0.07 – 0.10
Hardox® 400	75 – 100	0.01 – 0.03	0.03 – 0.06	0.06 – 0.09
Hardox® 450	70 – 95	0.01 – 0.03	0.03 – 0.06	0.06 – 0.08
Hardox® 500	45 – 70	0.01 – 0.025	0.03 – 0.05	0.05 – 0.07
Hardox® 500 Tuf	45 – 70	0.01 – 0.025	0.03 – 0.05	0.05 – 0.07
Hardox® 550	40 – 65	0.01 – 0.02	0.03 – 0.045	0.05 – 0.065
Hardox® 600	30 – 40	0.005 – 0.015	0.02 – 0.03	0.03 – 0.04
Hardox® Extreme	20 – 30	0.005 – 0.01	0.015 – 0.025	0.025 – 0.035



Slot milling advice  
ap (depth of cut)  
Max 0.5 x Diameter

Image: Sandvik Coromant AB

## SHOULDER MILLING RECOMMENDATION

Steel grade	Cutting speed (Vc), m/min	Feed per tooth, (fz) mm/t		
		Min – Max		
		Ø Diameter 3.0 – 6.0	Ø Diameter 8.0 – 12.0	Ø Diameter 14.0 – 20.0
Hardox® HiTemp	180 – 210	0.02 – 0.04	0.06 – 0.09	0.10 – 0.13
Hardox® HiAce	120 – 150	0.015 – 0.35	0.05 – 0.07	0.08 – 0.10
Hardox® HiTuf	190 – 220	0.02 – 0.05	0.06 – 0.10	0.10 – 0.13
Hardox® 400	180 – 210	0.02 – 0.04	0.06 – 0.09	0.10 – 0.13
Hardox® 450	160 – 190	0.02 – 0.04	0.06 – 0.09	0.10 – 0.12
Hardox® 500	120 – 150	0.015 – 0.35	0.05 – 0.07	0.08 – 0.10
Hardox® 500 Tuf	120 – 150	0.015 – 0.35	0.05 – 0.07	0.08 – 0.10
Hardox® 550	80 – 110	0.01 – 0.035	0.045 – 0.07	0.08 – 0.10
Hardox® 600	70 – 100	0.01 – 0.035	0.04 – 0.07	0.08 – 0.10
Hardox® Extreme	60 – 90	0.01 – 0.03	0.04 – 0.06	0.06 – 0.08



Shoulder milling advice  
ap (use the whole cutting length)  
ae (radial depth of cut) max 0.1 x D

Image: Sandvik Coromant AB

- If possible, use only compressed air to remove the chip and use weldon chuck for tool over Ø 10 mm.



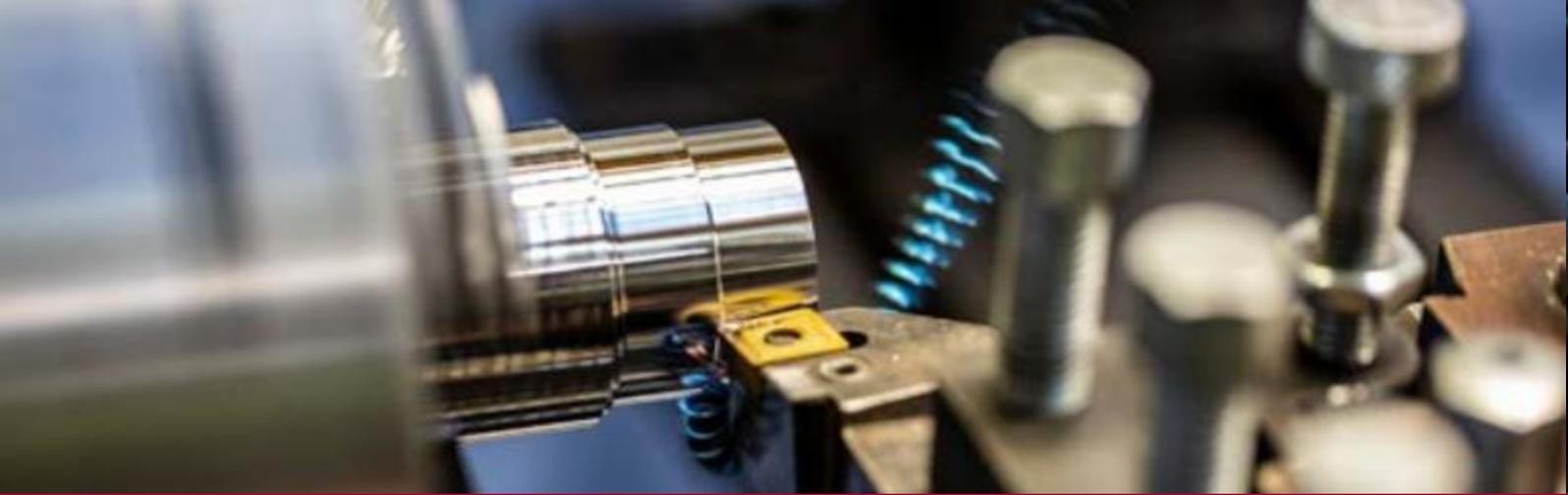
# TROUBLESHOOTING FOR DRILLING

Short lifetime of cemented carbide tool		●	●	●	●	●				
Short lifetime of HSS tool			●	●		●		●	●	
Vibrations	●			●		●				●
Wear on the cutting edge/margin				●	●			●		
Wear on the chisel edge/drill center				●			●			●
Asymmetrical holes			●	●		●				●
Small chipping on the cutting edges	●		●				●			
Chip build-up in the drill flutes		●		●			●			●
Chipping on the corner of the cutting edges		●		●	●	●				
Holes oversize/undersize				●		●				●
	Choose a tougher cemented carbide grade.	Increase the coolant flow rate and clean the coolant holes of the drill.	Check that the right HSS or cemented carbide grade is used.	Check the guideline for the cutting data.	Check the toolholders and the total indicated run-out.	Improve the set-up of the workpiece /reduce long tool set-up.	Increase the cutting speed.	Reduce the cutting speed.	Increase the feed rate.	Reduce the feed rate.



# TROUBLESHOOTING FOR MILLING

Flank wear		●			●				●		●
Cratering wear		●					●				●
Plastic deformation		●		●							●
Cutting edge build-up			●		●		●				
Chip jamming				●		●		●			
Small chipping on the cutting edges			●				●		●	●	
Short lifetime on the cutter/inserts		●			●				●		●
Vibrations	●	●			●	●	●	●	●		
Not enough horsepower/torque		●				●	●	●			
		Position the cutter off-center. See page 14.									
		Reduce the cutting speed.									
		Increase the cutting speed.									
		Reduce the feed rate.									
		Increase the feed rate.									
		Use a coarse-pitch cutter.									
		Use smaller cutter and inserts with positive light cutting geometry. See page 15.									
		Reduce the cutting depth.									
		Check the set-up of the cutter.									
		Use a tougher inserts grade.									
		Use a more wear resistant inserts grade.									



## TURNING RECOMMENDATIONS

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

Insert grade	P25 / C6	P35 / C6-C7	K20 / C2
Feed per revolution (mm/rev)	0.1 – 0.4 – 0.8	0.1 – 0.4 – 0.8	0.1 – 0.3
Steel grade	Cutting speed Vc (m/min)		
Hardox® HiTemp	130 – 90 – 70	105 – 65 – 45	
Hardox® HIAce			100 – 80
Hardox® HiTuf	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
Hardox® 500 Tuf	-		100 – 80

At higher feed rate, reduce the cutting speed.

### FORMULAS AND DEFINITIONS

$$Vc = \frac{Dm \times \pi \times n}{1000}$$

$$n = \frac{Vc \times 1000}{\pi \times Dm}$$

$$vf = n \times fn$$

$$\pi = 3.142$$

Vc = Cutting speed (m/min)

n = Spindle speed (rpm)

fn = Feed per revolution (mm/rev)

vf = Feed rate (mm/min)

Dm = Machined diameter (mm)

ap = Cutting depth (mm)



## RESULTS FROM OUR OWN TESTS

### MACHINES USED DURING THE TESTS

#### VMC FADAL 4020 HT modell 1997

- Spindle type ISO 40 taper
- Through spindle coolant
- Spindle speed max 10,000 rpm
- Effect spindle motor 16.8 kW
- Torque 303 Nm

#### CSEPEL RF 50 modell 1970

- Radial drilling machine
- Spindle type morse taper 4
- Spindle speed 45-2000
- Effect on the spindle motor 4 kW

* Hardox® 500	Tool	drill Ø	Ø	Vc	Thread depth	Total
Tapping/through holes	Manigley 105/4 DUO	21.5	M24	3.4	40 mm	48

* Hardox® 500	Tool	Ø	Vc	fn	Drill depth	Total
Drilling/through holes	HSS Co 5% X-Alcr	18	5	0.17	30 mm	33

Hardox® 500	Tool	Ø	Vc	fn	Drill depth	Total
Drilling/through holes	EF drill	10.4	40	0.1	30 mm	875

Hardox® 500	Tool	drill Ø	Ø	Vc	Thread depth	Total
Tapping/through holes	Manigley 105/4 DUO	10.4	M12	3	30 mm	161

Hardox® 600	Tool	Ø	Vc	fn	Drill depth	Total
Drilling/through holes	ChamDrill	18	30	0.1	30 mm	180

Hardox® Extreme	Tool	Ø	Vc	fn	Drill depth	Total
Drilling/through holes	MPS1 (DP 1021)	12	25	0.1	25 mm	403

\* Tests carried out on the drilling machine.



# TOOL RECOMMENDATIONS FOR HARDOX® WEAR PLATE

## HIGH SPEED STEEL DRILL

Description:	High speed steel drill alloyed with 8% cobalt (HSS-Co 8%)
Supplier:	MayKestag, Austria
Tool name:	HSS-E Co 8 Taper Shank Drills, WN 103
Article nr:	832xxxx
Web:	<a href="https://www.maykestag.com/en/">https://www.maykestag.com/en/</a>



Description:	High speed steel drill alloyed with 8% cobalt (HSS-Co 8%)
Supplier:	Witec, Germany
Tool name:	TYPE WITEC MN
Article nr:	2-135 15 VAP
Web:	<a href="http://www.witec-tools.de/">http://www.witec-tools.de/</a>

Description:	High speed steel drill alloyed with 8% cobalt (HSS-Co 8%)
Supplier:	Somta, South Africa
Tool name:	MTS Armour Piercing drill
Article nr:	261xxxx
Web:	<a href="https://www.somta.co.za/">https://www.somta.co.za/</a>

Description:	High speed steel drill alloyed with cobalt (DRILL BIT COBALT™S+X-ALCR DIN1897N Hardox® STUB)
Supplier:	Izar, Spain
Tool name:	Ref 1054
Article nr:	32xxx
Web:	<a href="https://www.izartool.com/">https://www.izartool.com/</a>

## HIGH SPEED STEEL DRILL

Description:	High speed steel drill alloyed with cobalt (DRILL BIT COBALT'S"+X-ALCR TAPER STUB)
Supplier:	Izar, Spain
Tool name:	Ref 1154
Article nr:	xxxxx
Web:	<a href="https://www.izartool.com/">https://www.izartool.com/</a>



Description:	High speed steel drill alloyed with 8% cobalt (HSCo - 8%)
Supplier:	Presto tools, England
Tool name:	Armour Piercing drill (APX)
Article nr:	11211xxx
Web:	<a href="https://www.presto-tools.co.uk/">https://www.presto-tools.co.uk/</a>

## SOLID CEMENTED CARBIDE DRILL

Description:	Solid cemented carbide drill
Supplier:	Emuge Franken, Germany
Tool name:	EF-Drill-STEEL
Article nr:	TA203344xx.xx
Web:	<a href="https://www.emuge-franken-group.com">https://www.emuge-franken-group.com</a>



Description:	Solid cemented carbide drill
Supplier:	Sandvik Coromant AB, Sweden
Tool name:	Corodril R840 Delta C
Article nr:	R840-xxxx-30-A1A
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>

Description:	Solid cemented carbide drill
Supplier:	Granlund Tool AB, Sweden
Tool name:	Tunder / T80
Article nr:	T80-xx.x
Web:	<a href="http://www.granlund.com/">http://www.granlund.com/</a>

Description:	Solid cemented carbide drill
Supplier:	Mitsubishi, Japan
Tool name:	MPS1 (DP 1021)
Article nr:	MPS1-xxxxS
Web:	<a href="http://www.mitsubishicarbide.com/">http://www.mitsubishicarbide.com/</a>

## SOLID CEMENTED CARBIDE DRILL

Description:	Solid cemented carbide drill
Supplier:	Seco, Sweden
Tool name:	Seco Feedmax
Article nr:	SD203A-xx.x-xx-xxxx-M
Web:	<a href="https://www.secotools.com/">https://www.secotools.com/</a>



Description:	Solid cemented carbide drill
Supplier:	WNT, Germany
Tool name:	WTX-UNI
Article nr:	11780
Web:	<a href="https://cuttingtools.ceratzit.com/gb/en.html">https://cuttingtools.ceratzit.com/gb/en.html</a>

Description:	Solid cemented carbide drill
Supplier:	Hoffman-Group, Germany
Tool name:	Garant 122500
Article nr:	122500
Web:	<a href="https://www.hoffmann-group.com/">https://www.hoffmann-group.com/</a>

## DRILL WITH EXCHANGEABLE DRILL TIP

Description:	Drill with exchangeable drill tip (Drill tip grade: IDI SG IC908)
Supplier:	Iscar, Israel
Tool name:	Chamdrill
Article nr:	DCM xxx-xxx-xxA-3D
Web:	<a href="https://www.iscar.com">https://www.iscar.com</a>



Description:	Drill with exchangeable drill tip (Drill tip grade: ICP IC908)
Supplier:	Iscar, Israel
Tool name:	SumoCham
Article nr:	DCN xxx-xxx-xxA-3D
Web:	<a href="https://www.iscar.com">https://www.iscar.com</a>

Description:	Drill with exchangeable drill tip (Drill tip grade: P-geometry HB7530)
Supplier:	Hoffman-Group, Germany
Tool name:	HiPer-Drill
Article nr:	23 1605 -xx.x
Web:	<a href="https://www.hoffmann-group.com/">https://www.hoffmann-group.com/</a>

## DRILL WITH EXCHANGEABLE DRILL TIP

Description:	Drill with exchangeable drill tip (Drill tip grade: P-geometry PM 4334) (Drill tip grade: M-geometry MM 2234, for Hardox 600)
Supplier:	Sandvik Coromant, Sweden
Tool name:	CoroDrill 870
Article nr:	870-xxxx-xxxx
Web:	<a href="https://www.sandvik.coromant.com">https://www.sandvik.coromant.com</a>



## INDEXABLE INSERT DRILL

Description:	Indexable insert drill (Center insert LM 1044) (Peripheral insert LM 4044)
Supplier:	Sandvik Coromant, Sweden
Tool name:	CoroDrill 880
Article nr:	880-Dxxxxxxx-xx
Web:	<a href="https://www.sandvik.coromant.com">https://www.sandvik.coromant.com</a>



## COUNTERBORING IN HARDOX®

Description:	Counterbore
Supplier:	Granlund Tool AB, Sweden
Tool name:	WHV counterbore
Article nr:	xWHV-xx.x
Web:	<a href="http://www.granlund.com/">http://www.granlund.com/</a>



## COUNTERSINKING IN HARDOX®

Description:	Countersink
Supplier:	Granlund Tool AB, Sweden
Tool name:	KV countersink
Article nr:	xKV9-xx.x
Web:	<a href="http://www.granlund.com/">http://www.granlund.com/</a>



## TAPPING IN HARDOX® WEAR PLATE

Description:	Tap for through holes (HSSE-PM tap with TiCN coating)
Supplier:	Manigley, Switzerland
Tool name:	105/4 DUO
Article nr:	433xx
Web:	<a href="http://www.manigley.ch/de/home">http://www.manigley.ch/de/home</a>



Description:	Tap for blind holes (HSSE-PM tap with TiCN coating)
Supplier:	Manigley, Switzerland
Tool name:	131/3 DUO
Article nr:	433xx
Web:	<a href="http://www.manigley.ch/de/home">http://www.manigley.ch/de/home</a>

Description:	Tap for through holes (HSS-E-PM with TiAlN coating)
Supplier:	Sandvik Coromant, Sweden
Tool name:	CoroTap 200
Article nr:	E324 / E326
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>

Description:	Tap for through holes (HSSE-PM with TiAlN coating)
Supplier:	Hoffman-Group, Germany
Tool name:	Garant 132065
Article nr:	132065-Mxx
Web:	<a href="https://www.hoffmann-group.com/">https://www.hoffmann-group.com/</a>

Description:	Tap for through holes (HSSE-PM with TiCN coating)
Supplier:	BASS, Germany
Tool name:	VARIANT 1/2 TIH
Article nr:	1088xx
Web:	<a href="https://www.bass-tools.com/">https://www.bass-tools.com/</a>

## THREAD MILLING IN HARDOX® WEAR PLATE

Description:	Solid carbide thread milling cutter with TiCN coating
Supplier:	Emuge Franken, Germany
Tool name:	GF-VZ-VHM-R15-IKZ-HB
Article nr:	GFB35106.xxxx
Web:	<a href="https://www.emuge.de/">https://www.emuge.de/</a>



Description:	Solid carbide thread milling cutter with TiCN coating
Supplier:	Emuge Franken, Germany
Tool name:	GSF-VHM 2D IKZ-HB
Article nr:	GF333106.xxxx
Web:	<a href="https://www.emuge.de/">https://www.emuge.de/</a>

## END MILLING IN HARDOX® WEAR PLATE

Description:	Solid carbide end milling cutter with Siron-A coating
Supplier:	Seco Tool, Sweden
Tool name:	JS 554 Siron-A
Article nr:	JS554xxxx
Web:	<a href="https://www.secotools.com/">https://www.secotools.com/</a>



## MILLING WITH INSERT IN HARDOX® WEAR PLATE

Description:	Face milling with Coromill 345
Supplier:	Sandvik Coromant, Sweden
Tool name:	Coromill 345
Article nr:	345-xxxxxx-13x
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>



Description:	Face milling with Coromill 300 (Round inserts)
Supplier:	Sandvik Coromant, Sweden
Tool name:	Coromill 300
Article nr:	R300-xxxxxx-xxx
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>

Description:	Shoulder/face milling with Coromill 490
Supplier:	Sandvik Coromant, Sweden
Tool name:	Coromill 490
Article nr:	490-xxxxxx-xxx
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>

Description:	Holemaking with high feed milling
Supplier:	Sandvik Coromant, Sweden
Tool name:	Coromill 210
Article nr:	R210-xxxxxx-xxx
Web:	<a href="https://www.sandvik.coromant.com/">https://www.sandvik.coromant.com/</a>

## INSERT GRADE IN HARDOX® STEEL

Use insert grade Pxx30 for average machine conditions. In very stable machines and with a rigid set-up the insert grade Pxx10 would be more suitable, especially over 500 Brinell.

Tool name	Article nr/insert grade	Insert geomerty
Coromill 210	R210-xxxxxx-Px / xx10	M
	R210-xxxxxx-Px / xx30	M
Coromill 300	R300-xxxxxx-Px / xx10	L-M-H
	R300-xxxxxx-Px / xx30	L-M-H
Coromill 345	345R-xxxxxx-Px / xx10	L-M-H
	345R-xxxxxx-Px / xx30	L-M-H
Coromill 490	490R-xxxxxx-Px / xx10	L-M
	490R-xxxxxx-Px / xx30	L-M-H



**HARDOX<sup>®</sup>**  
WEAR PLATE

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