Selecting cutting data

Example of how to find the values when calculating spindle speed (n) and table feed (v_f):

Conditions:	Cutter-	R245-125Q40-12M	
	Insert-	R245-12 T3 M-PM	GC4030
	Workpiece material:	SS1672-08	HB =180

Formulas to be used: $n = \frac{v_c \times 1000}{\pi \times D_c}$ $v_f = z_n \times n \times f_z$ $f_z = \frac{hex}{\sin \kappa_r}$

v_c In order to get v_c, the max chip thickness (h_{ex}) for an operation and the Coromant Material Classification (CMC) code is needed.

See feed recommendations.

The cutter selected has a 45° entering angle (κ_r) and PM insert geometry will be used.

Max chip thickness (h_{ex}) for the operation is 0.17 mm

The material is SS1672-08 and corresponding CMC code is 01.2.

The cutting speed v_c is approx. 283 m/min for CMC 01.2 (between 325 and 270 m/min for h_{ex} = 0.10 and 0.20 mm respectively).

This cutting speed is valid for hardness HB150. If your hardness is HB180 a compensation factor of 0.92 for the deviation of +30 units.

The compensated cutting speed becomes 0.925 x 283 m/min ≈ 262-m/min.

D_c The cutter selected has a diameter, Dc, of 125 mm.

z_n Number of teeth is found on the same page and zn is in this case 8.

κ_r The selected cutter has a 45° entering angle.

f_z Feed per tooth for the cutter and selected insert geometry.

Feed per tooth

n Revolutions per minute

v_f Table feed per minute vf = 8 × 667 × 0.24 = 1281 mm/min

Hardness of workpiece

The cutting speeds given on the following pages are valid for a specific material hardness. If the material being machined differs in hardness from those values, the recommended cutting speed must be multiplied by a factor obtained from the table below.

Difference in hardness

CMC No.	← Reduced hardness								Increased hardness →
	Hardness Brinell (HB)								
	–80	**–60**	**–40**	**–20**	**0**	**+20**	**+40**	**+60**	**+80**
01	-	-	-	1.07	1.0	0.95	0.90	-	-
02	1.26	1.18	1.12	1.05	1.0	0.94	0.91	0.86	0.83
03	-	-	1.21	1.10	1.0	0.91	0.84	0.79	-
05	-	-	1.21	1.10	1.0	0.91	0.85	0.79	0.75
06	-	-	1.31	1.13	1.0	0.87	0.80	0.73	-
07	-	1.14	1.08	1.03	1.0	0.96	0.92	-	-
08	-	-	1.25	1.10	1.0	0.92	0.86	0.80	-
09	-	-	1.07	1.03	1.0	0.97	0.95	0.93	0.91
20	1.26	-	1.11	-	1.0	-	0.90	-	0.82
CMC No.	**Hardness Rockwell (HRC)**								
			–6	**–3**	**0**	**+3**	**+6**	**+9**	
04			1.10	1.02	1.0	0.96	0.93	0.90	

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Terminology and units for milling

D_c	= Cutting diameter	mm
l_m	= Machined length	mm
D_e	= Effective cutting diameter	mm
a_p	= Cutting depth	mm
a_e	= Working engagement	mm
v_c	= Cutting speed	m/min
Q	= Metal removal rate	cm^3/min
T_c	= Period of engagement	min
z_n	= Total number of edges in the tool	piece
f_z	= Feed per tooth	mm
f_n	= Feed per revolution	mm
v_f	= Table feed (feed speed)	mm/min
h_{ex}	= Max chip thickness	mm
h_m	= Average chip thickness	mm

z_c	= Effective number of teeth	piece
k_{c1}	= Specific cutting force (for h_{ex} =1 mm)	N/mm^2
n	= Spindle speed	rev/min
P_c	= Cutting power net	kW
η	= Efficiency	
κ_r	= Major cutting edge angle	degrees
v_{c0}	= Constant for cutting speed	
c_{vc}	= Correction factor for cutting speed	
m_c	= Rise in specific cutting force (kc) as a function of chip thickness	
iC	= inscribed circle	

General milling formulas

Cutting speed
(m/min)

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

Spindle speed
(rev/min)

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

Table feed (feed speed)
(mm/min)

$$v_f = f_z \times n \times z_n$$

Feed per tooth
(mm)

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

Feed per revolution
(mm/rev)

$$f_n = \frac{v_f}{n}$$

Removal rate
(cm^3)

$$Q = \frac{a_p \times a_e \times v_f}{1000}$$

Specific cutting force
(N/mm^2)

$$k_c = k_{c1} \times h_m^{-mc}$$

Average chip thickness (mm)
(Side and facemilling) when $a_e/D_c \leq 0.1$

$$h_m \approx f_z \sqrt{\frac{a_e}{D_c}}$$

Average chip thickness (mm)
when $a_e/D_c \geq 0.1$

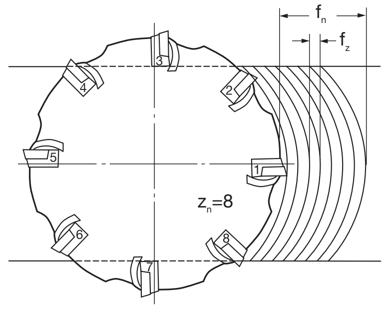
$$h_m = \frac{\sin \kappa_r \times 180 \times a_e \times f_z}{\pi \times D_c \times \arcsin\left(\frac{a_e}{D_c}\right)}$$

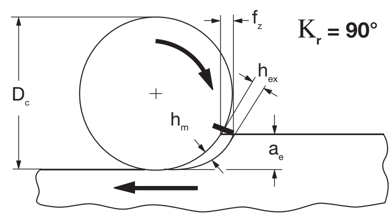
Machining time
(min)

$$T_c = \frac{l_m}{v_f}$$

Net power
(kW)

$$P_c = \frac{a_p \times a_e \times v_f \times k_c}{60 \times 10^6 \times \eta}$$

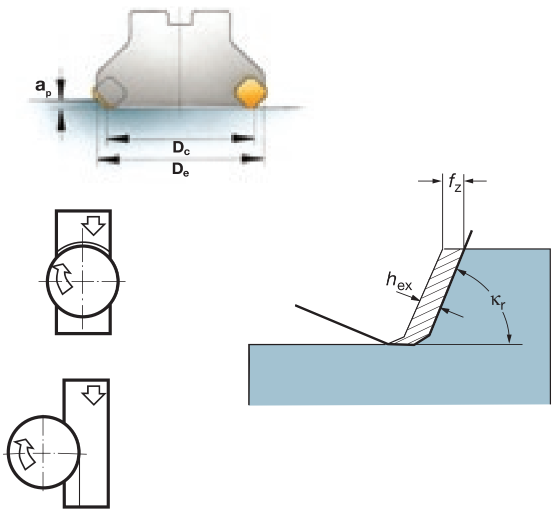




Formulas for specific milling cutters

Facemilling cutters, side and facemilling cutters and endmills

These tools are characterized by having straight cutting edges.



Max cutting diameter at a specific depth (mm)

$$D_e = D_c + \frac{2 \times a_p}{\tan \kappa_r}$$

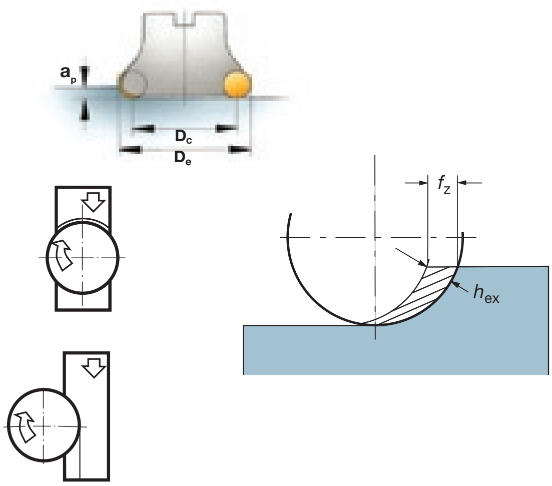
Feed per tooth (mm/tooth), cutter centered

$$f_z = \frac{h_{ex}}{\sin \kappa_r}$$

Feed per tooth (mm/tooth), side milling

$$f_z = \frac{D_e \times h_{ex}}{\sin \kappa_r \times \sqrt{D_e^2 - (D_e - 2 \times a_e)^2}}$$

Cutters with round inserts



Max cutting diameter at a specific depth (mm)

$$D_e = D_c + \sqrt{iC^2 - (iC - 2a_p)^2}$$

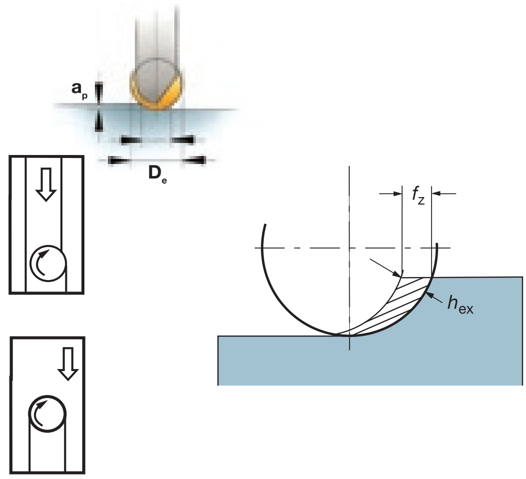
Feed per tooth (mm/ tooth), cutter centered

$$f_z = \frac{iC \times h_{ex}}{D_e - D_c}$$

Feed per tooth (mm/tooth), side milling

$$f_z = \frac{D_e \times iC \times h_{ex}}{(D_e - D_c) \times \sqrt{D_e^2 - (D_e - 2 \times a_e)^2}}$$

Ballnose endmills



Max cutting diameter at a specific depth (mm)

$$D_e = \sqrt{D_3^2 - (D_3 - 2 \times a_p)^2}$$

Feed per tooth (mm/tooth), side milling

$$f_z = \frac{D_3 \times h_{ex}}{\sqrt{D_e^2 - (D_e - 2 \times a_e)^2}}$$

Feed per tooth (mm/tooth), cutter centered

$$f_z = \frac{D_3 \times h_{ex}}{D_e}$$

Calculation of power consumption

The example is valid for 0° top rake angle. The power consumption changes 1% per degree of change in top rake. A positive top rake angle decreases the power consumption and a negative top rake increases the power consumption. A positive cutter with +15° top rake angle requires 15% less power than a cutter with 0° top rake angle.

Plunge milling

$$P_c = \frac{A \times v_f \times K}{60 \times 10^6 \times \eta}$$

$A \approx a_e \times D^3$ (slot)

$A \approx a_e \times S$ (stepover S)

Example

45° facemilling of steel, CMC 01.3

Cutter diameter, D_c=125 mm

Depth of cut, a_p=5 mm

Width of cut, a_e=100 mm

Feed per insert, f_z=0.2 mm

Table feed, v_f=1000 mm

Milling in general

$$P_c = \frac{a_p \times a_e \times v_f \times K}{100\,000}$$

For an engagement of 80% the K value is 5.4.

$$P_c = \frac{5 \times 100 \times 1000 \times 5.4}{100\,000} = 27.0 \text{ kW}$$

For different insert geometries the power consumption must be adjusted.

For each degree more positive top rake angle the power consumption will decrease with 1%.

For a CoroMill 245 facemill with M-geometry. The M-geometry has +21° top rake angle.

$$P_{c(\gamma)} = P_c \times M_\gamma$$

For a top rake angle of +21° the M_γ value is 0.79.

$P_{c(\gamma)} = 27.0 \times 0.79 = 21.3$ kW

Optimized power consumption calculation

Use multiplying factor from top rake angle to adjust P_c values.

True rake angle, γ	Multiplying factor, Mγ	True rake angle, γ	Multiplying factor, Mγ
–7°	1.07	12°	0.88
–6°	1.06	13°	0.87
–5°	1.05	14°	0.86
–4	1.04	15°	0.85
–3°	1.03	16°	0.84
–2°	1.02	17°	0.83
–1°	1.01	18°	0.82
0°	1	19°	0.81
1°	0.99	20°	0.80
2°	0.98	21°	0.79
3°	0.97	22°	0.78
4°	0.96	23°	0.77
5°	0.95	24°	0.76
6°	0.94	25°	0.75
7°	0.93	26°	0.74
8°	0.92	27°	0.73
9°	0.91	28°	0.72
10°	0.90	29°	0.71
11°	0.89	30°	0.70

When machine power is a problem

- Go from close to coarse pitch, i.e. less number of teeth.
- A positive cutter is more power efficient than a negative.
- Reduce the cutting speed before the table feed.

Warning:
Be aware of the power curve for machining centres. The machine may lose efficiency if the rpm is too low.

- Use a smaller cutter and take several passes.
- Reduce the depth of cut.

A B C D E F G H

Constant K for use in power requirement calculation[1)]

ISO	CMC No.	Description		$a_e/D_c=0.8$			$a_e/D_c=0.4$			$a_e/D_c=0.2$		
				$f_z=0.1$	$f_z=0.2$	$f_z=0.4$	$f_z=0.1$	$f_z=0.2$	$f_z=0.4$	$f_z=0.1$	$f_z=0.2$	$f_z=0.4$
P		**Steel**										
	01.1	**Unalloyed**	C = 0.10–0.25%	5.7	4.8	4.0	6.2	5.2	4.4	6.8	5.7	4.8
	01.2		C = 0.25–0.55%	6.1	5.1	4.3	6.6	5.6	4.7	7.2	6.1	5.1
	01.3		C = 0.55–0.80%	6.5	5.4	4.6	7.1	5.9	5.0	7.7	6.5	5.4
	01.4			6.9	5.8	4.8	7.5	6.3	5.3	8.2	6.9	5.8
	01.5			7.6	6.4	5.4	8.3	7.0	5.9	9.1	7.6	6.4
	02.1	**Low-alloyed (alloying elements ≤5%)**	Non-hardened	6.5	5.4	4.6	7.1	5.9	5.0	7.7	6.5	5.4
	02.2		Hardened and tempered	7.6	6.4	5.4	8.3	7.0	5.9	9.1	7.6	6.4
	03.11	**High-alloyed (alloying elements ≤5%)**	Annealed	7.4	6.2	5.3	8.1	6.8	5.7	8.8	7.4	6.2
	03.13		Hardened tool steel	8.2	6.9	5.8	8.9	7.5	6.3	9.7	8.2	6.9
	03.21			11.0	9.3	7.8	12.0	10.1	8.5	13.1	11.0	9.3
	03.22			11.8	9.9	8.4	12.9	10.8	9.1	14.0	11.8	9.9
	06.1	**Castings**	Unalloyed	5.3	4.5	3.8	5.8	4.9	4.1	6.3	5.3	4.5
	06.2		Low-alloy, alloying elements ≤5%	6.1	5.1	4.3	6.6	5.6	4.7	7.2	6.1	5.1
	06.3		High-alloy, alloying elements >5%	7.4	6.2	5.3	8.1	6.8	5.7	8.8	7.4	6.2
M		**Stainless steel**										
	05.11	Ferritic/Martensitic	Non-hardened	6.2	5.4	4.7	6.7	5.8	5.0	7.2	6.2	5.4
	05.12		PH-hardened	9.7	8.4	7.2	10.4	9.0	7.8	11.2	9.7	8.4
	05.13		Hardened	8.0	6.9	5.9	8.6	7.4	6.4	9.2	8.0	6.9
	05.21	Austenitic	Non-hardened	6.9	6.0	5.2	7.4	6.4	5.6	8.0	6.9	6.0
	05.22		PH-hardened	9.7	8.4	7.2	10.4	9.0	7.8	11.2	9.7	8.4
	05.51	Austenitic-Ferritic (Duplex)	Non-weldable ≥0.05%C	6.9	6.0	5.2	7.4	6.4	5.6	8.0	6.9	6.0
	05.52		Weldable <0.05%C	8.3	7.2	6.2	8.9	7.7	6.7	9.6	8.3	7.2
		Stainless steel – cast										
	15.11	Ferritic/Martensitic	Non-hardened	6.5	5.4	4.6	7.1	5.9	5.0	7.7	6.5	5.4
	15.12		PH-hardened	9.5	8.0	6.7	10.4	8.7	7.3	11.3	9.5	8.0
	15.13		Hardened	8.0	6.7	5.7	8.7	7.3	6.2	9.5	8.0	6.7
	15.21	Austenitic	Non-hardened	6.9	5.8	4.8	7.5	6.3	5.3	8.2	6.9	5.8
	15.22		PH-hardened	9.5	8.0	6.7	10.4	8.7	7.3	11.3	9.5	8.0
	15.51	Austenitic-Ferritic (Duplex)	Non-weldable ≥0.05%C	6.9	5.8	4.8	7.5	6.3	5.3	8.2	6.9	5.8
	15.52		Weldable <0.05%C	8.4	7.0		9.1	7.7		10.0	8.4	
S		**Heat resistant super alloys**										
	20.11	Iron base	Annealed or solution treated	9.1	7.7		10.0	8.4		10.9	9.1	
	20.12		Aged or solution treated and aged	9.5	8.0		10.4	8.7		11.3	9.5	
	20.21	NIckel base	Annealed or solution treated	10.1	8.5		11.0	9.3		12.0	10.1	
	20.22		Aged or solution treated and aged	11.0	9.3		12.0	10.1		13.1	11.0	
	20.24		Cast or cast and aged	11.4	9.6		12.5	10.5		13.6	11.4	
	20.31	Cobalt base	Annealed or solution treated	10.3	8.6		11.2	9.4		12.2	10.3	
	20.32		Solution treated and aged	11.4	9.6		12.5	10.5		13.6	11.4	
	20.33		Cast or cast and aged	11.8	9.9		12.9	10.8		14.0	11.8	
		Titanium alloys										
	23.1		Commercial pure (99.5% Ti)	4.7	4.0		5.1	4.4		5.5	4.7	
	23.21		α, near α and α+β alloys, annealed	5.1	4.3		5.5	4.7		6.0	5.1	
	23.22		α+β alloys in aged cond. β alloys, annealed or aged	5.1	4.3		5.5	4.7		6.0	5.1	
H	04.1	**Extra hard steel Hard steel**	Hardened and tempered	16.0	13.5		17.4	14.7		19.0	16.0	
	10.1	**Chilled cast iron**	Cast or cast and aged	9.0	7.4		9.9	8.2		10.9	9.0	
K	07.1	**Malleable cast iron**	Ferritic (short chipping)	3.3	2.7	2.2	3.6	3.0	2.4	4.0	3.3	2.7
	07.2		Pearlitic (long chipping)	3.7	3.0	2.5	4.1	3.3	2.8	4.5	3.7	3.0
	08.1	**Grey cast iron**	Low tensile strength	3.7	3.0	2.5	4.1	3.3	2.8	4.5	3.7	3.0
	08.2		High tensile strength	4.5	3.7	3.1	5.0	4.1	3.4	5.5	4.5	3.7
	09.1	**Nodular SG iron**	Ferritic	3.7	3.0	2.5	4.1	3.3	2.8	4.5	3.7	3.0
	09.2		Pearlitic	5.5	4.6		6.1	5.0		6.7	5.5	
N	30.11	**Aluminium alloys**	Wrought or wrought and coldworked, non-aging	1.5	1.3		1.7	1.4		1.8	1.5	
	30.12		Wrought or wrought and aged	2.5	2.1		2.7	2.3		2.9	2.5	
	30.21	**Aluminium alloys**	Cast, non-aging	2.3	1.9		2.5	2.1		2.7	2.3	
	30.22		Cast or cast and aged	2.7	2.2		2.9	2.4		3.2	2.7	
	30.3			1.3	1.1		1.5	1.2		1.6	1.3	
	30.41	**Aluminium alloys**	Cast, 13–15% Si	2.7	2.2		2.9	2.4		3.2	2.7	
	30.42		Cast, 16–22% Si	2.7	2.2		2.9	2.4		3.2	2.7	
	33.1	**Copper and copper alloys**	Free cutting alloys, ≥1% Pb	2.1	1.8		2.3	1.9		2.5	2.1	
	33.2		Brass, leaded bronzes, ≤ 1% Pb	2.1	1.8		2.3	1.9		2.5	2.1	
	33.3		Bronze and non-leaded copper incl. electrolytic copper	5.1	4.3		5.6	4.7		6.1	5.1	

[1)]Calculated with an efficiency $\eta_{mt} = 0.8$

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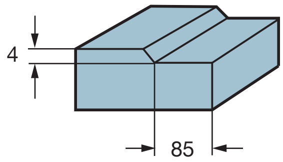
Cutting data calculations for milling operations

Facemilling

Example



Cutter:	R245-125Q40-12M	$z_n = 8$
Insert:	R245-12 T3 M-PM	GC4030
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	85 mm	
a_p:	4 mm	
κ_r	45°	

Calculate spindle speed (n)

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

$$n = \frac{283 \times 1000}{\pi \times 125} \approx 721 \text{ rpm}$$

To get v_c, first find h_{ex} value for -PM geometry.
The cutting speed v_c for h_{ex}= 0.17 mm is 283-m/min (between 325 and 270-m/min).

Calculate table feed (v_f)

$$v_f = z_n \times n \times f_z$$

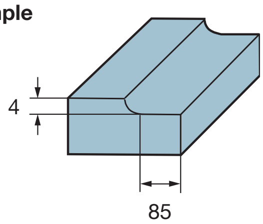
$$v_f = 8 \times 721 \times 0.24 \approx 1384 \text{ mm/min}$$

$$f_z = \frac{h_{ex}}{\sin \kappa_r}$$

$$f_z = \frac{0.17}{\sin 45°} \approx 0.24 \text{ mm/tooth}$$

Facemilling with round inserts

Example



Cutter:	R200-109Q32-16M	$z_n = 6$
Insert:	RCKT 16 06 M0-PM	GC4030
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	85 mm	
a_p:	4 mm	

Calculate spindle speed (n)

$$n = \frac{v_c \times 1000}{\pi \times D_e} = \frac{283 \times 1000}{\pi \times 123} \approx 732 \text{ rpm}$$

To get v_c, first find h_{ex} value for -PM geometry.
The cutting speed v_c for h_{ex}= 0.17 mm is 283-m/min (between 325 and 270-m/min).

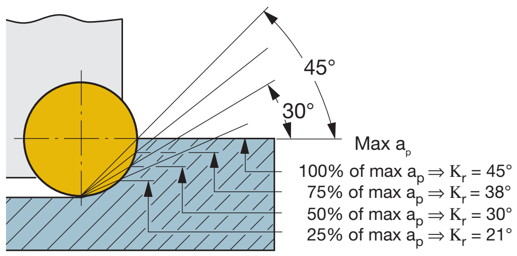
$$D_e = D_c + \sqrt{iC^2 - (iC - 2a_p)^2}$$

$$D_e = 109 + \sqrt{16^2 - (16 - 2 \times 4)^2} \approx 123 \text{ mm}$$

Calculate table feed (v_f)

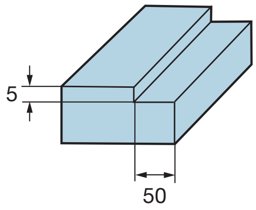
$$v_f = n \times f_z \times z_n = 732 \times 0.34 \times 6 \approx 1493 \text{ mm/min}$$

$$f_z = \frac{h_{ex}}{\sin \kappa_r} \qquad f_z = \frac{0.17}{\sin 30°} = 0.34 \text{ mm/tooth}$$



Slotting/facemilling with 90° entering angle

Example



Cutter:	R390-063Q22-17M	$z_n = 5$
Insert:	R390-17 04 08M-PM	GC1025
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	50 mm	
a_p:	5 mm	

Calculate spindle speed (n)

$$n = \frac{v_c \times 1000}{\pi \times D_c} = \frac{250 \times 1000}{\pi \times 63} \approx 1263 \quad \text{rpm}$$

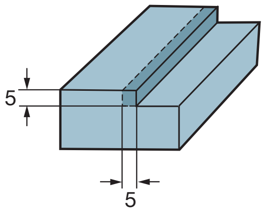
To get v_c, first find h_{ex} value for -PM geometry.
The cutting speed v_c for h_{ex} 0.15 is 250-m/min (between 280 and 230-m/min).

Calculate table feed (v_f)

$$v_f = n \times f_z \times z_n = 1263 \times 0.15 \times 5 = 947 \quad \text{mm/min}$$

Shoulder milling with 90° entering angle

Example



Cutter:	R390-063Q22-17M	$z_n = 5$
Insert:	R390-17 04 08M-PM	GC1025
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	5 mm	
a_p:	5 mm	

Calculate spindle speed (n)

$$n = \frac{v_c \times 1000}{\pi \times D_c} = \frac{318 \times 1000}{\pi \times 63} \approx 1607 \quad \text{rpm}$$

To get v_c, first find h_{ex} value for -PM geometry.
The cutting speed v_c for h_{ex} 0.15 is 318-m/min (between 325 and 310-m/min).

Calculate table feed (v_f)

For sidemilling the feed can be increased with a compensation factor.

$$v_f = k1 \times z_n \times n \times f_z \qquad v_f = 1.82 \times 5 \times 1607 \times 0.15 \approx 2193 \quad \text{mm/min}$$

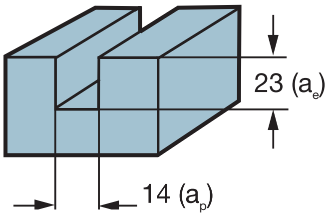
Find the compensation factor, k1, in the table below by calculating D_c/a_e

$$\frac{D_c}{a_e} = 12.6 \rightarrow k1 = 1.82$$

$\frac{D_c}{a_e}$	2	3	4	5	6	8	10	12	15	20	25	30	40	50	100
Factor k1	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	**2.8**	**3.2**	**3.6**	**5.0**

Side and facemilling

Example



Cutter:	R245-125Q40-12M	$z_n = 8$
Insert:	R245-12 T3 M-PM	GC4030
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	2 mm	
a_p:	4 mm	

Calculate spindle speed (n)

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

This gives: $n = \frac{283 \times 1000}{\pi \times 125} \approx 720$ rpm

To get v_c, first find h_{ex} value for -PM geometry. The cutting speed v_c for h_{ex} 0.17 is 283-m/min (between 325 and 270-m/min).

Calculate table feed (v_f)

$$v_f = n \times z_c \times f_z$$

This gives:

$v_f = 720 \times 5 \times 0.22 \approx 792$ mm/min

z_c = Number of effective edges = $z_n/2$

For N331.32-125S40FM $z_n = 10$ $\rightarrow z_c = 5$

f_z = factor k1 × h_{ex}

The factor k1 can be found in table below.

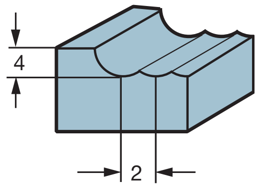
$\frac{D_c}{a_e}$	1	2	3	4	5	6	8	10	12	15	20	25	30	40	50	100
Factor k1	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8	2.0	2.2	2.5	2.8	3.2	3.6	5.0

$$\frac{D_c}{a_e} = \frac{125}{23} = 5.43 \quad \rightarrow k1 = 1.3$$

fz = 1.3 × 0.17 ≈ 0.22 mm/tooth

Profile milling

Example



Cutter:	R216-20A25-055	$z_n = 2$
Insert:	R2160-20 T3 M-M	GC4040
Workpiece material:	SS 1672-08 HB =150	CMC 01.2
a_e:	2 mm	
a_p:	4 mm	

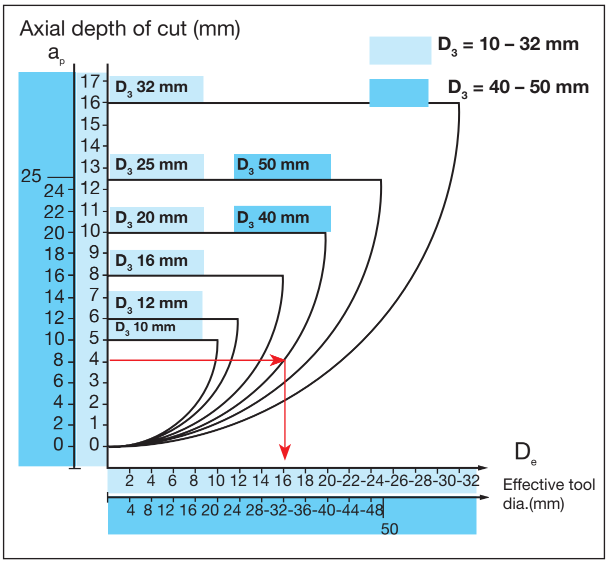
Calculate spindle speed (n)

$$n = \frac{v_c \times 1000}{\pi \times D_e} \qquad n = \frac{308 \times 1000}{\pi \times 16} \approx 6130 \text{ rpm}$$

To get v_c, first find h_{ex} value for -M geometry. The cutting speed v_c for h_{ex} 0.15 is 308-m/min (between 310 and 295-m/min).

Find effective diameter, D_e

Select axial depth of cut in this diagram. Go horizontally across the diagram to the curve representing the tool diameter. Move down vertically to the axis and read the effective diameter.



Calculate table feed (v_f)

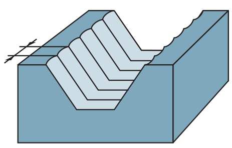
$$v_f = z_n \times n \times f_z$$

$v_f = 2 \times 6130 \times 0.1 \approx 1226$ mm/min

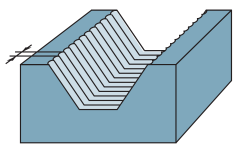
f_z according to table below. In stable conditions the feed can be increased. When working with long tools and difficult conditions the feed can be lowered.

Recommended feed, f_z mm								
Diameter, D_3	12	16	20	25	30	32	40	50
Start value	0.05	0.08	0.10	0.12	0.15	0.15	0.20	0.25
Range	0.05 – 0.10	0.08 – 0.15	0.10 – 0.20	0.12 – 0.25	0.15 – 0.35	0.15 – 0.35	0.20 – 0.40	0.25 – 0.40

Recommended radial steps and depth of cut for ball nose endmills



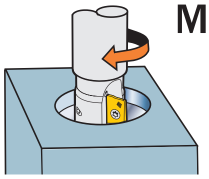
Large cuts
It is not recommended to exceed the values below for radial step and axial depth of cut.



Small cuts
With the same axial depth of cut as for large cuts, surface can be improved by decreasing the radial step.

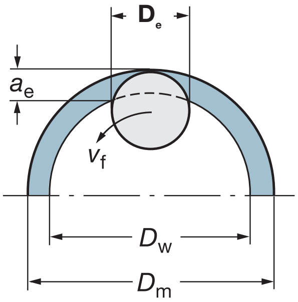
Cutter dia. D_3	**Max. recommended** Radial step	Depth of cut
12	5	6
16	6	8
20	10	10
25	12	12
30	15	12
32	16	12
40	20	15
50	20	

Cutter dia. D_3	Radial step		Radial step		Radial step	
12	1.0	0.02	1.5	0.05	2.0	0.08
16	1.0	0.02	2.0	0.06	3.0	0.14
20	2.0	0.05	3.0	0.11	4.0	0.20
25	3.0	0.09	4.0	0.16	5.0	0.25
30	3.0	0.08	4.0	0.13	5.0	0.21
32	3.0	0.07	4.0	0.13	5.0	0.20
40	4.0	0.10	6.0	0.23	8.0	0.40
50	4.0	0.08	6.0	0.18	8.0	0.32



Method for internal circular interpolation

Calculated version

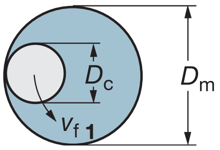


$v_f = n \times z_c \times f_z$ — Tool centre feed, mm/min

$f_z \approx \dfrac{D_e \times h_{ex}}{\sin \times K_r \sqrt{D_e^2 - (D_e - 2\,a_e)^2}}$ — Feed per insert, mm

$a_e \approx \dfrac{D_m^2 - D_w^2}{4 \times (D_m - D_e)}$ — Radial depth of cut, mm

Simplified version

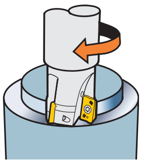


$v_f = n \times z_c \times f_z$ — Straight line feed, mm/min

$v_{f1} = v_f \times K$ — Tool centre feed, mm/min

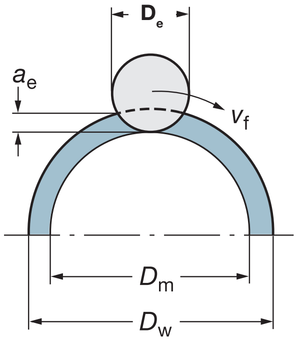
$K = \sqrt{\dfrac{D_m + D_c}{D_m}}$ — The values can be taken from the table below

Cutter diameter D_c mm	Hole diameter = D_m												
	15	20	25	30	40	50	60	75	100	125	150	200	250	300
	Factor K													
10	0.58	0.71	0.77	0.82	0.87	0.89	0.91	0.93	0.95	0.96	0.97	0.97	0.98	0.98
16		0.45	0.60	0.68	0.77	0.82	0.86	0.89	0.92	0.93	0.95	0.96	0.97	0.97
20			0.45	0.58	0.71	0.77	0.82	0.86	0.89	0.92	0.93	0.95	0.96	0.97
25				0.41	0.61	0.71	0.76	0.82	0.87	0.89	0.91	0.94	0.95	0.96
32					0.45	0.60	0.68	0.76	0.82	0.86	0.89	0.92	0.93	0.95
40						0.45	0.58	0.68	0.77	0.82	0.86	0.89	0.92	0.93
50							0.41	0.58	0.71	0.77	0.82	0.87	0.89	0.91
63								0.40	0.61	0.70	0.76	0.83	0.86	0.89
80									0.45	0.60	0.68	0.77	0.82	0.86
100										0.45	0.58	0.71	0.77	0.82
125											0.41	0.61	0.71	0.76
160												0.45	0.60	0.68
200													0.45	0.58



Method for external circular interpolation

Calculated version

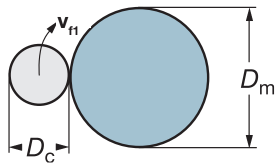


$v_f = n \times z_c \times f_z$ — Tool centre feed, mm/min

$f_z \approx \dfrac{D_e \times h_{ex}}{\sin \times K_r \sqrt{D_e^2 - (D_e - 2\,a_e)^2}}$ — Feed per insert, mm

$a_e \approx \dfrac{D_w^2 - D_m^2}{4 \times (D_m - D_e)}$ — Radial depth of cut, mm

Simplified version



$v_f = n \times z_c \times f_z$ — Straight line feed, mm/min

$v_{f1} = v_f \times K$ — Tool centre feed, mm/min

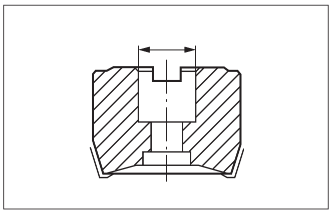
$K = \sqrt{\dfrac{D_m + D_c}{D_m}}$ — The values can be taken from the table below

Cutter diameter	Hole diameter = D_m													
	15	20	25	30	40	50	60	75	100	125	150	200	250	300
D_c mm	Factor K													
10	1.29	1.22	1.18	1.15	1.12	1.10	1.08	1.06	1.05	1.04	1.03	1.02	1.02	1.02
16	1.44	1.34	1.28	1.24	1.18	1.15	1.13	1.10	1.08	1.06	1.05	1.04	1.03	1.03
20	1.53	1.41	1.34	1.29	1.22	1.18	1.15	1.13	1.10	1.08	1.06	1.05	1.04	1.03
25	1.63	1.50	1.41	1.35	1.27	1.22	1.19	1.15	1.12	1.10	1.08	1.06	1.05	1.04
32	1.77	1.61	1.51	1.44	1.34	1.28	1.24	1.19	1.15	1.12	1.10	1.08	1.06	1.05
40	1.91	1.73	1.61	1.53	1.41	1.34	1.29	1.24	1.18	1.15	1.13	1.10	1.08	1.06
50	2.08	1.87	1.73	1.63	1.50	1.41	1.35	1.29	1.22	1.18	1.15	1.12	1.10	1.08
63	2.28	2.04	1.88	1.76	1.60	1.50	1.43	1.36	1.28	1.23	1.19	1.15	1.12	1.10
80	2.52	2.24	2.05	1.91	1.73	1.61	1.53	1.44	1.34	1.28	1.24	1.18	1.15	1.13
100	2.77	2.45	2.24	2.08	1.87	1.73	1.63	1.53	1.41	1.34	1.29	1.22	1.18	1.15
125	3.06	2.69	2.45	2.27	2.03	1.87	1.76	1.63	1.50	1.41	1.35	1.27	1.22	1.19
160	3.42	3.00	2.72	2.52	2.24	2.05	1.91	1.77	1.61	1.51	1.44	1.34	1.28	1.24
200	3.79	3.32	3.00	2.77	2.45	2.24	2.08	1.91	1.73	1.61	1.53	1.41	1.34	1.29

Mounting dimensions for milling cutters

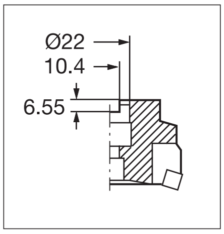
Style A

Mounting diameter (dmm)

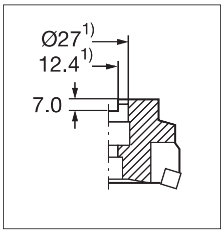


Centre bolts

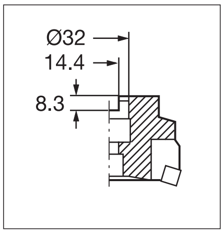
Dia. 50 – 63



Dia. 80



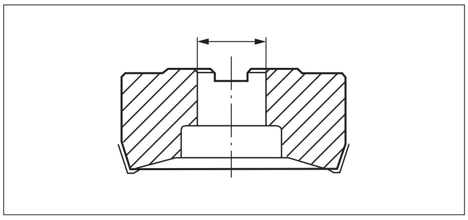
Dia. 100



1)For all Modulmill cutters and for R/L262.2AL the dimensions are 22.0 and 10.4 mm respectively.

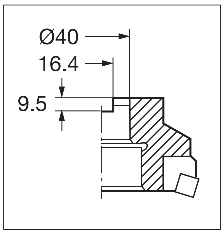
Style B

Mounting diameter (dmm)



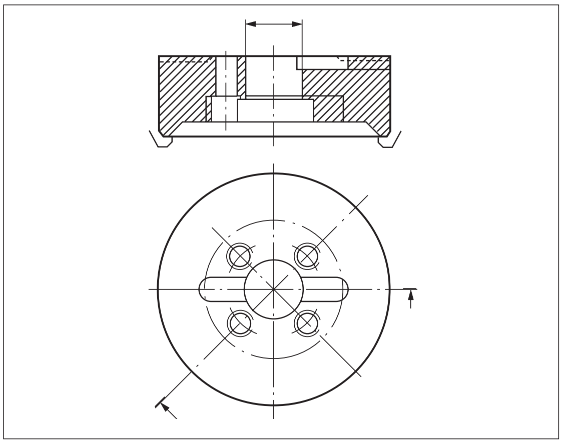
Centre bolts + washer

Dia. 125

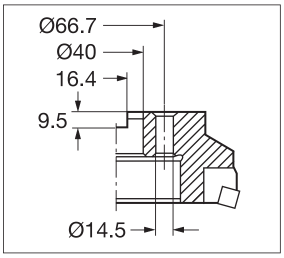


Style C

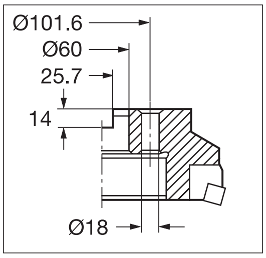
Mounting diameter (dmm)



Dia. 160

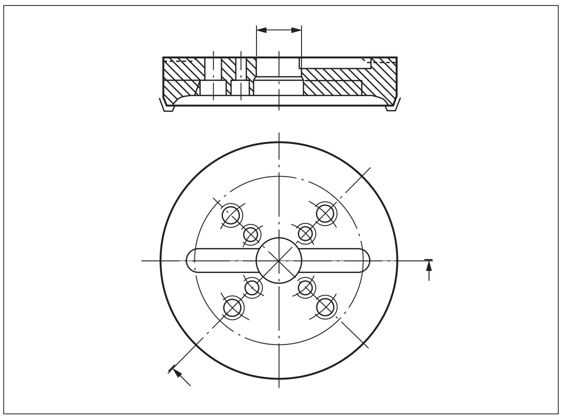


Dia. 200 – 250

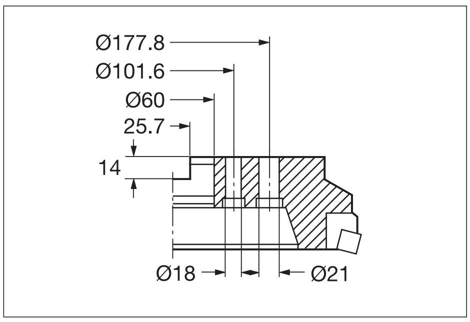


Design with single pcd (4 – bolts)

Mounting diameter (dmm)



Dia. 315 – 500



Design with double pcd (8 – bolts)

Insert mounting with Torx Plus

Sandvik Coromant has introduced the Torx Plus system on all insert screws to ensure an improved and secure clamping. The new Torx Plus screws will keep their previous codes, while the keys will change the code. All keys for insert clamping are concerned: screwdrivers, T-style keys, L-style keys, flag-style keys and combination keys (Torx Plus/hex).

Cross section

Torx Plus **Torx**

Note! Torx Plus is a registered trademark of Camcar-Textron (USA).

Torque wrench for Torx Plus screws

The torque wrench for Torx Plus screws offers a possibility to always ensure correct torque value, in the machine shop as well as in the tool-room environments.
Correct torque values are imperative especially when clamping ceramic and CBN inserts.
Always use protective goggles when using ceramic inserts.

Note!
The new Torx Plus keys and screw-drivers do NOT fit into the standard Torx screws.
However, the standard Torx keys and screw-drivers will fit the new Torx Plus screws.

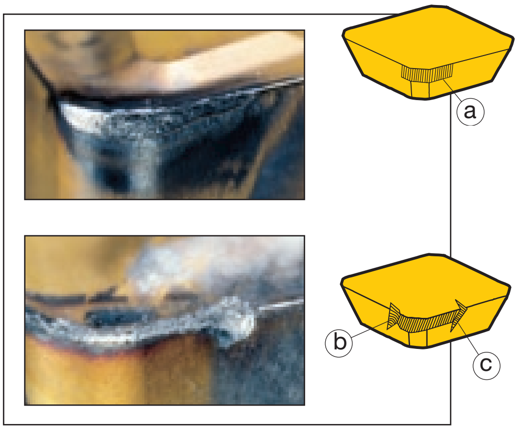
Wrench benefits:

- ergonomic handle consisting of two materials, one of which has a rubber base for best grip
- a "click" function when tightening the screws - is impossible to over tighten.
- a fixed stop in counter clockwise direction, making it easier to loosening screws
- design of blade tip has been optimised for best screw fitting
- blade material consists of a higher class of material grade

Milling cutter mountings
Coromant Capto: provides the best stability and thus basis for high productivity, reliablity and quality. Cutters are available as over-size in relation the the coupling for extended tooling. Best choice, especially for long edge milling.
Cylindrical shanks: Recommended for use with precision chucks like CoroGrip for best stability and precision. Extra long tools available.
Weldon: established tool mounting but not recommended as first choice if productivity and precision are issues.
Arbor: established tool mounting and the only solution for large-diameter cutters. Gives good stability for high productivity.
Threaded: modular system with exchangeable cutting heads. Silent tool solution and carbide shank adapters for extended tooling.

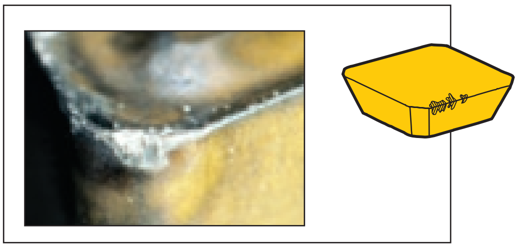
Tool wear

Flank and notch wear



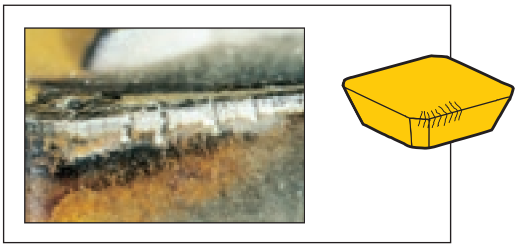
	Cause:	Remedy:
a. Rapid flank wear causing poor surface finish or out of tolerance.	a. Cutting speed too high or insufficient wear resistance.	Reduce cutting speed. Select a more wear resistant grade.
	a. Too low feed.	Increase feed.
b/c. Notch wear causing poor surface finish and risk of edge breakage.	b/c. Work hardening materials.	Reduce cutting speed. Select tougher grade.
	b/c. Skin and scale.	Increase cutting speed.

Frittering



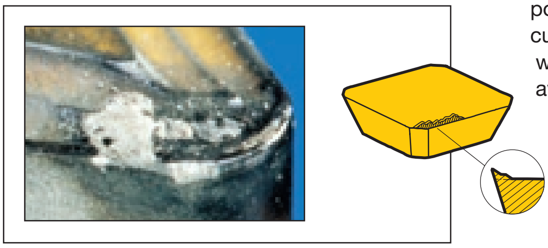
	Cause:	Remedy:
Small cutting edge fractures (frittering) causing poor surface finish and excessive flank wear.	Grade too brittle.	Select tougher grade.
	Insert geometry too weak.	Select an insert with a stronger geometry .
	Built-up edge.	Increase cutting speed or select a positive geometry. Reduce feed at beginning of cut.

Thermal cracks



	Cause:	Remedy:
Small cracks perpendicular to the cutting edge causing frittering and poor surface finish.	Thermal cracks due to temperature variations caused by:	
	- Intermittent machining.	Select a tougher grade with better resistance to thermal shocks.
	- Varying coolant supply.	Coolant should be applied copiously or not at all.

Built-up edge (B.U.E.)



	Cause:	Remedy:
Built-up edge causing poor surface finish and cutting edge frittering when the B.U.E. is torn away.	Workpiece material is welded to the insert due to:	
	Low cutting speed.	Increase cutting speed.
	Low feed.	Increase feed.
	Negative cutting geometry.	Select a positive geometry.

Poor surface finish

Cause:	Remedy:
Too high feed.	Reduce feed.
Wrong insert position.	Change position.
Deflection.	Check overhang.
Bad stability.	Better stability.

Vibrations

Cause:	Remedy:
Wrong cutting data.	Reduce cutting speed. Increase feed. Change cutting depth.
Bad stability.	Reduce overhang. Better stability.

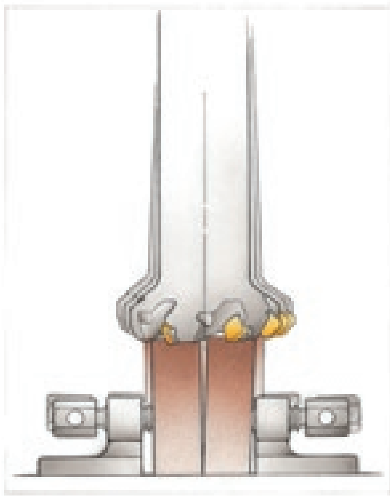
A
B
C
D
E
F
G
H

If problems should occur

Some typical problems in milling and possible solutions

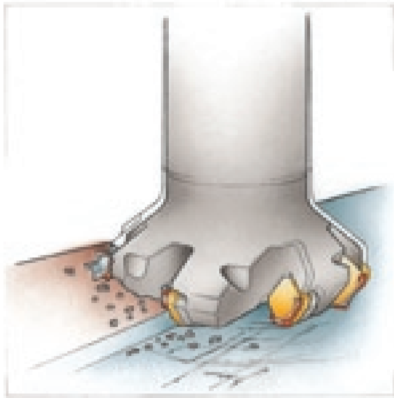
A
B
C
D
E
F
G
H

Excessive vibration



1. **Weak fixture**
   Possible solutions:
   Assess the direction of cutting forces and provide adequate support or improve the fixture.
   Reduce cutting forces by decreasing cutting depths.
   Select a coarse and differentially pitched cutter with a more positive cutting action.
   Select an L-geometry with small corner radius and small parallel land.
   Seplect a fine-grain, uncoated insert or thinner coating
2. **Weak workpiece**
   Consider a square shoulder cutter (90-degree entering angle) with positive geometry.
   Select an insert with L-geoeometry
   Decrease axial cutting force – lower depth of cut, smaller corner radius and parallel land.
   Select a coarse-pitch cutter with differential pitch.
3. **Long tool overhang**
   Minimize the overhang.
   Use coarse-pitch cutters with differential pitch.
   Balance radial and axial cutting forces – 45 degree entering angle, large corner radius or round insert cutter.
   Increase the feed per tooth
   Use a light-cutting insert geoemtry – L/M
4. **Milling square shoulder with weak spindle**
   Select smallest possible cutter diameter.
   Select positive cutter and insert.
   Try up-milling.
   Check spindle deflection to see if acceptable for machine.
5. **Irregular table feed**
   Try up-milling
   Tighten machine feed mechanism.

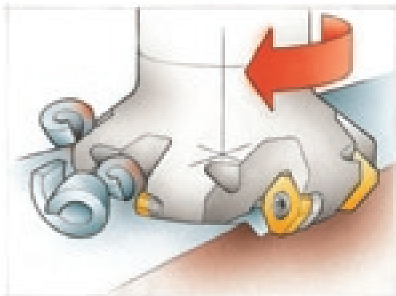
Unsatisfactory surface finish



1. **Excessive feed per revolution**
   Set cutter axially or classify inserts. Check height with indicator.
   Check the spindle run-out and the cutter mounting surfaces.
   Decrease the feed per rev to max. 70% of the width of the parallel land.
   Use wiper inserts if possible. (Finishing operations)
2. **Vibration**
   See section on vibration.
3. **Built-up edge formation on insert**
   Increase cutting speed to elevate machining temperature.
   Turn off coolant.
   Use sharp cutting edge inserts, with smooth rake side.
   Use positve insert geometry.
   Try a cermet grade with higher cutting data.

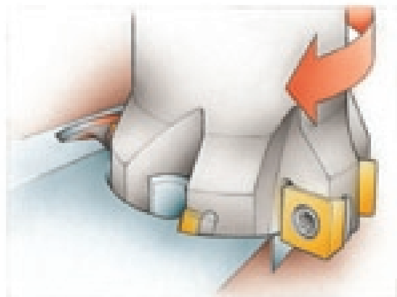
4. **Back-cutting**
   Check spindle tilt (Tilt spindle approx 0.10mm/1000 mm)
   Axial run-out of spindle should not exceed 7 microns during finishing.
   Reduce the radial cutting forces (decrease the depth of cut)
   Select a smaller cutter diameter.
   Check the parallelism on the parallel lands and on wiper insert used. (Should not be standing on ”heel or toe”)
   Make sure the cutter is not wobbling – adjust the mounting surfaces.
5. **Workpiece frittering**
   Decrease feed per tooth.
   Select a close or extra-close pitch cutter.
   Re-position the cutter to give a thinner chip at cutter exit.
   Select a more suitable entering angle (45-degrees) and lighter cutting geometry.
   Choose a sharp insert.
   Monitor flank wear to avoid excessive wear.

Insert fracture in general milling



1. **Excessive chip thickness at cutter exit**
   Minimize the chip thickness at exit by changing the cutter position in relation to workpiece.
   Use down-milling
   Decrease the feed per tooth.
   Select a smaller cutter diameter.
   Use a stronger insert geometry (H).

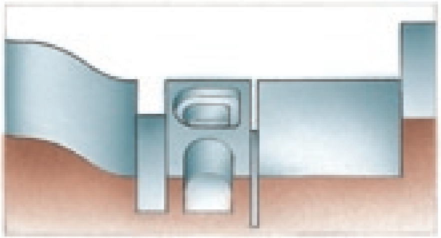
Insert fracture in square shoulder milling



1. **Swarf follows cutter in up-milling, getting stuck between shoulder and edge.**
   Change to down-milling.
   Use compressed air.
   Use a sharper insert to facilitate re-cutting of chips.
   Monitor flank wear to avoid excessive wear.
2. **Down-milling with several passes.**
   Consider performing the operation in one pass.
3. **Chip jamming between shoulder and edge.**
   Try up-milling
   Select a tougher insert grade.
   Select a horisontal milling machine.

Selection and application process

① Define the operation



Identify the type of operation:
- Facemilling
- Shoulder milling
- Profile milling
- Slot milling

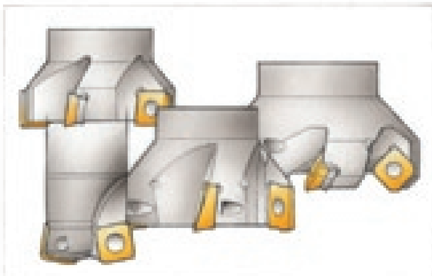
Then select the most suitable tool considering productivity, reliability and quality.

② Define the material

P M K N S H

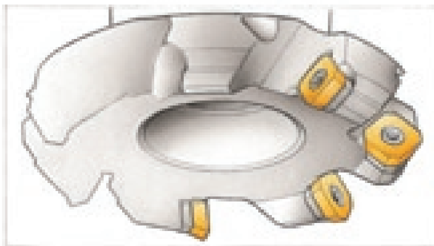
Define workpiece material according to ISO:
- Steel (P)
- Stainless steel (M)
- Cast iron (K)
- Aluminium (N)
- Heat resistant and titanium alloy (S)
- Hardened material (H)

③ Select cutter concept



Assess which concept is the most productive for the application:
CoroMill 245, CoroMill 210, CoroMill 390, CoroMill 290.

④ Select the milling cutter



Choose cutter pitch and mounting.
Use a close pitch cutter as first choice.
Use a coarse pitch cutter for long overhang and unstable conditions.
Use an extra close pitch cutter for short chipping materials and super alloys.
Choose a mounting type.

⑤ Select the insert

Choose the insert geometry for your operation:

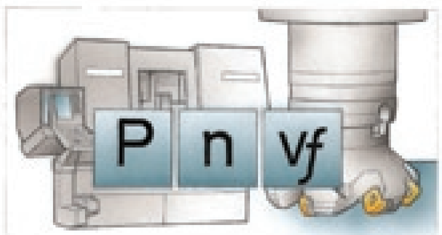
Geometry L = Light
For light cuts when low forces / power are required

Geometry M = Medium
First choice for mixed production

Geometry H = Heavy
For rough operations, forging, cast skin and vibrations

Select insert grade for optimum productivity.

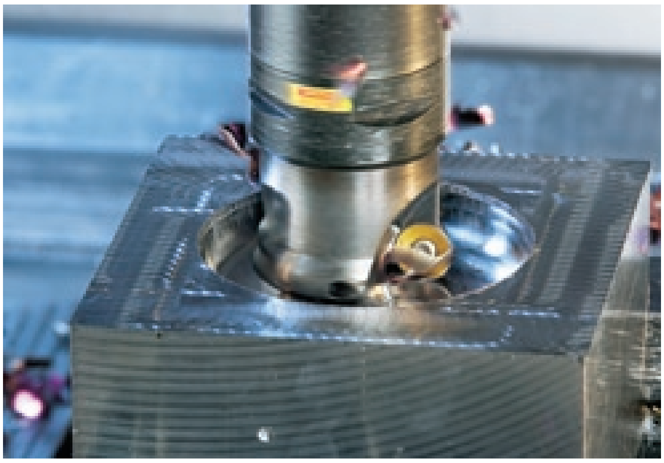
⑥ Define the start values

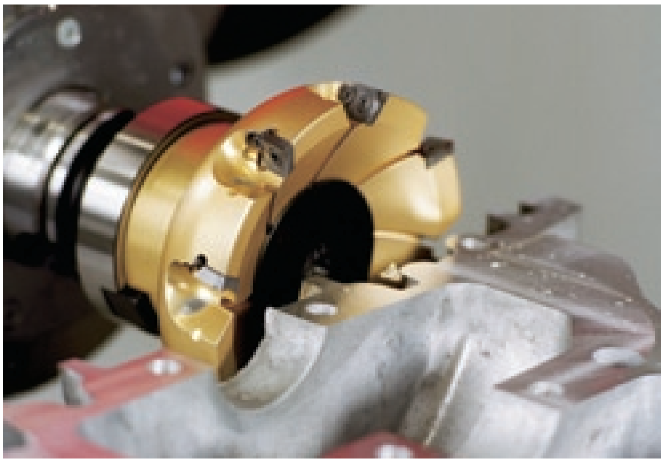


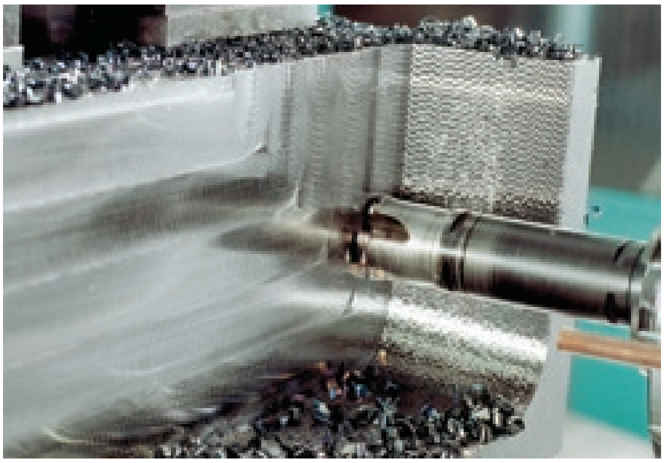
Cutting speeds and feeds for different materials are given on the insert dispensers and in the tables.
The values should be optimized according to machine and conditions!

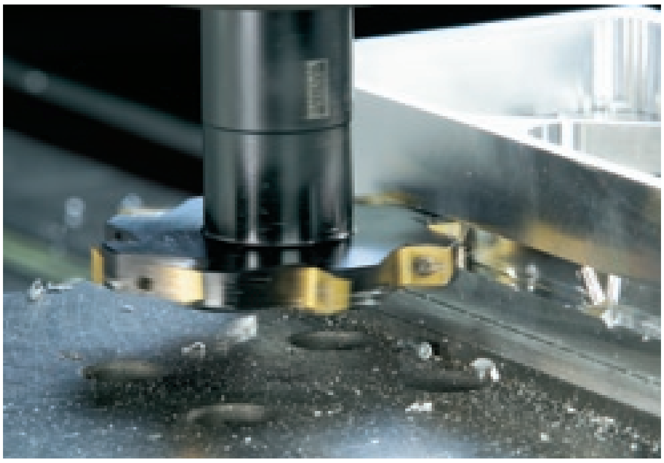
A B C D E F G H

SANDVIK Coromant









Operations – tool recommendations

General facemilling

Material/ Application	Steel P	Stainless steel M	Cast-iron K	Aluminium N	Super alloys S	Hardened steel H
Finishing	CoroMill 245	CoroMill 245	AUTO-AF*	CoroMill Century	CoroMill 245	CoroMill 245
Semi-finishing	CoroMill 245	CoroMill 245	CoroMill 245	CoroMill Century	CoroMill 300	CoroMill 245
Roughing	CoroMill 245	CoroMill 245	AUTO R	CoroMill 245	CoroMill 300	CoroMill 300
Heavy roughing	T-MAX 45	-	CoroMill 245 (18)	-	T-Max 45	CoroMill 200

* CoroMill Century

	P M K S H	N
Thin walls	CoroMill 390	CoroMill Century
Close to fixture	CoroMill 390	CoroMill Century CoroMill 390

Long overhang — P M K S N
CoroMill 210 (R)/CoroMill 245 (F)

Back facing — P M K S N H
CoroMill 331

High feed milling — P M K S H
CoroMill 210/CoroMill 300

General shoulder milling

Material/ Application	Steel P	Stainless steel M	Cast-iron K	Aluminium N	Super alloys S	Hardened steel H
Finishing	CoroMill 390	CoroMill 390	AUTO-AF	CoroMill Century	CoroMill Plura	CoroMill Plura
Semi-finishing	CoroMill 390	CoroMill 390	CoroMill 290	CoroMill 790	CoroMill 390	CoroMill 290
Roughing	CoroMill 390	CoroMill 390	CoroMill 290	CoroMill 790	CoroMill 390	CoroMill 290

	P M K S	N	H
Repeated shoulder milling	CoroMill 390	CoroMill 790	CoroMill Plura
	(Small ae (ae/Dc<…)	Large ae (ae/Dc>…..)	
Deep shoulder milling	CoroMill 390 LE-11	CoroMill 390 LE- 18	

Edging/ Contouring
CoroMill 390/CoroMill Plura

For diameters smaller than 20 mm, CoroMill Plura solid carbide endmills are first choice generally for all materials.

A B C D E F G H

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