Silent Tools™ Application Guide

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coromant

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Introduction

In turning, milling and boring operations, difficult-to-reach features can be very sensitive to vibration and chatter as the length-to-diameter ratio increases for component and tool assembly. When vibrations resonate within cutting tool assemblies, the result is chatter with noise, damaged cutting edges and ruined workpiece surfaces. This chatter leads to excessive wear to all mechanical elements involved — from the inserts to the cutting unit, adaptors, spindle interface, bearings and main structural parts of the machine tool.

Silent Tools™ is the Sandvik Coromant trademark for damped cutting tools and adaptors. A damping system inside the tool body minimizes vibration and eliminates chatter.

Use this guide to identify the best solutions for existing or future slender tool assembly applications. If your application requires a tool assembly beyond our standard Silent Tools™ products, you can request an engineered solution (special tools) quotation.

Start minimizing vibrations, eliminating chatter, and maximizing your productivity and profit margins with Silent Tools™ today.

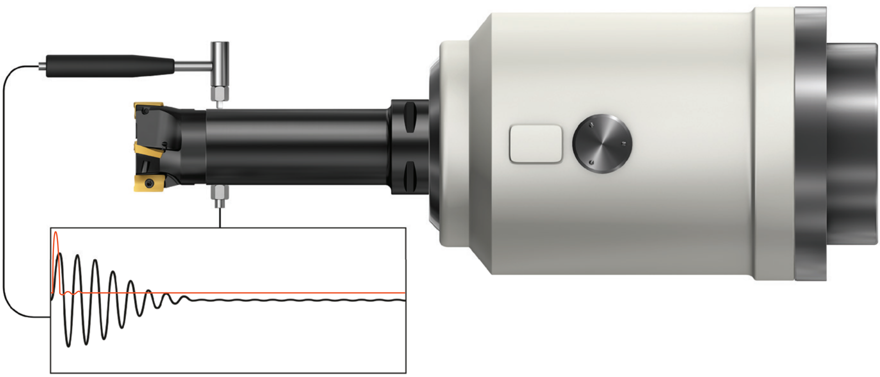
Content

1 Vibration and chatter

Vibration in a tool assembly refers to the repetitive motion of the cutting unit. This motion can occur in an up-and-down direction or from side to side.

The distance from the initial position to the endpoints of this movement is called the **amplitude** of the vibration.

The number of full movements from the initial position via both endpoints and back within a second is the **frequency** of the vibration.

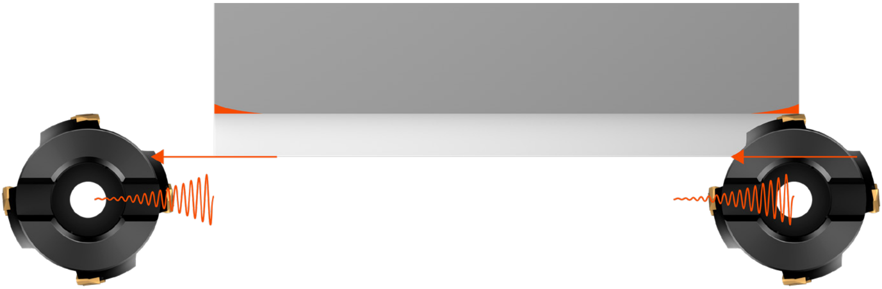


If a sudden impact (red curve) at the end of a tool assembly is big enough to alter the tool deflection, the tool assembly will go into a **free vibration** (black curve) at the lowest natural frequency for the assembly.

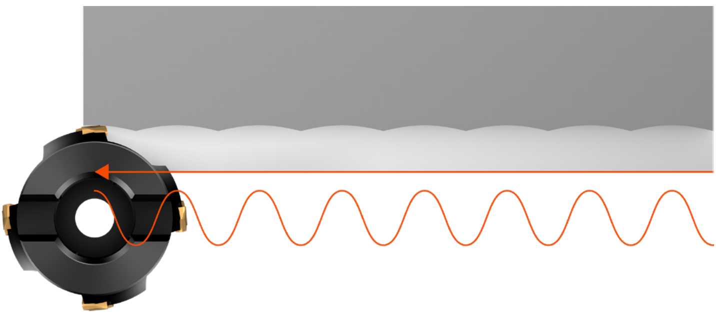
Every physical structure has multiple natural frequencies. These are the specific frequencies at which the structure is most likely to vibrate. It takes less energy to trigger the lowest natural frequency and more to trigger a higher natural frequency.

Consequently, assembly-free vibrations and possible resonance and chatter are most likely to come at the lowest natural frequency.

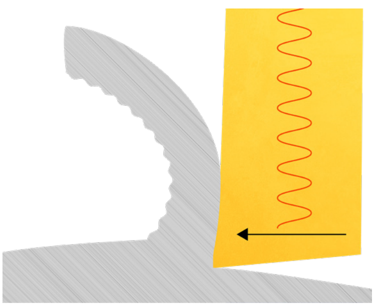
A free vibration caused by a load increase at the workpiece entry or a load release at the workpiece exit can potentially break the cutting edge or damage the machined surface. Free vibrations will eventually fade away, how quickly they diminish depends on the damping properties in the tool assembly materials.



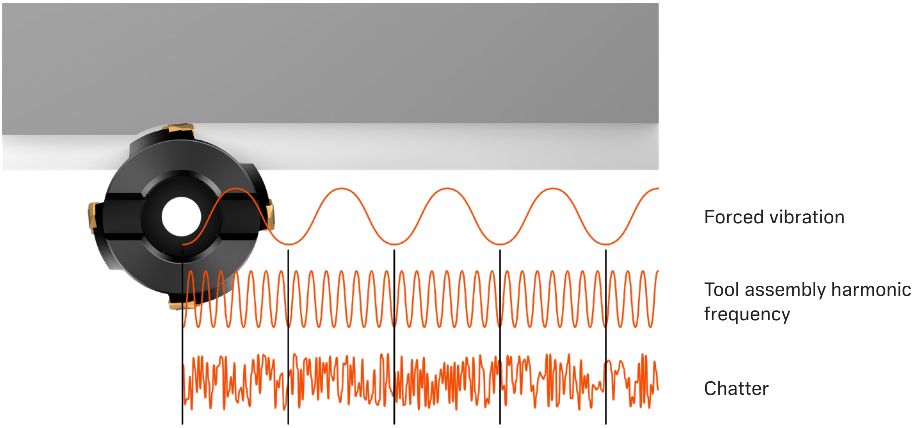
A repeating force load variation may be able to maintain a **forced vibration** in the tool assembly over the entire metal cutting operation.



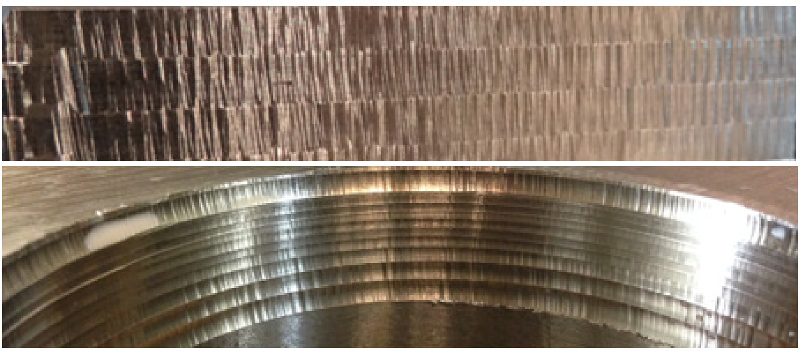
Small but continuous force variations in chip forming and chip breaking may cause small cutting speed variations and a resulting **stick-slip vibration** in the tool assembly.



If a series of forced or stick-slip vibrations comes close to a fraction of the **harmonic** frequency for the assembly, they will find resonance in the assembly. When the tool enters resonance, even a small force variation can produce a dramatic vibration response with large amplitudes. This self-exciting vibration, known as **chatter**, can severely damage the machined surfaces.



Harmonic frequencies for an assembly are the natural frequencies multiplied by whole numbers (integers). For instance, if the natural frequency is (f), the harmonic frequencies would be (2f), (3f), (4f), and so forth.



2 Tool assembly, static and dynamic stiffness

Static stiffness

When a static load is applied to a stationary structure, the structure will deflect a given distance away from the load.

The size of the attacking load divided by the deflection it causes, expresses the static stiffness of the structure in the direction of the attacking load. If the attacking load is big and the deflection is small, the static stiffness is high in that direction.

High static stiffness, K

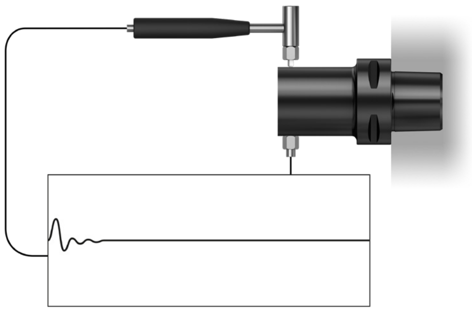
Low static stiffness, K

$$\frac{\text{Attacking load, } F}{\text{Deflection, } \delta} = \text{Stiffness, } K$$

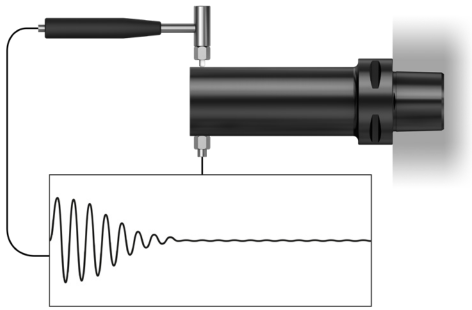
Slender tool assemblies are weak in the radial direction, and deflection can be big even for small radial forces. Consequently, the stiffness in the radial direction is generally low. But, altering the length of tool assemblies requires considerable force, which means stiffness in the axial direction is generally high.

Dynamic stiffness

Dynamic stiffness determines how a structure responds to dynamic forces. While static stiffness decides how big the deflection will be under a given force, dynamic stiffness decides the time it takes for the structure to return to its original position after being impacted by a force significant enough to cause deflection.



High dynamic stiffness



Low dynamic stiffness

The connection between static and dynamic stiffness

The ultimate dynamic stiffness is achieved through the best possible combination of high static stiffness, low kinetic energy in vibrating elements and high structural damping.

High static stiffness reduces deflection caused by force impacts, while high levels of structural damping relative to the energy in vibrating elements quickly reduce vibrations in the structure by absorbing oscillation energy.

Without deflection, vibrations cannot occur. High damping levels, compared to the kinetic energy of the vibration, ensure that any potential vibrations are quickly stopped.

Improving static stiffness and reducing the deflection

A round bar with shank diameter (D) and assembly length (L) clamped on the shank end and attacked by a load (F) on the working end, will experience a deflection (δ) as described by the formulas below.

In vibration and deflection, (EI) refers to the stiffness of a structural member given the material it's made of and the larger the GPa (Gigapascals) the smaller the deflection.

We can do three things to improve static stiffness in a tool assembly:

1. Reduce assembly length
2. Increase shank diameter
3. Change to a bar material with higher stiffness (higher modulus of elasticity) in areas where attacking loads cause high levels of stress and deflection

$\delta = FL^3/3EI$	$I = \pi D^4/64$	$\delta = FL^3/3EI$
Increased length **L** multiplies to increase deflection	Increased diameter **D** multiplies to decrease deflection	100% increase in modulus of elasticity **E** will reduce deflection by 50%
L = 100 mm: δ = 1 000 000F/3EI L = 200 mm: δ = 8 000 000F/3EI	D = 100 mm: $\delta = FL^3/3E(\pi/64)/100\,000\,000$ D = 200 mm: $\delta = FL^3/3E(\pi/64)/16\,000\,000\,000$	Carbide: E ≈ 600 GPa Tungsten Alloy E ≈ 400 GPa Steel: E ≈ 200 GPa Aluminum: E ≈ 70 GPa
L200 -> L100 = 8 times higher stiffness 8 times lower deflection δ	D100 -> D200 = 16 times higher stiffness 16 times lower deflection δ	Steel bar -> carbide bar: 3 times higher stiffness 3 times lower deflection δ

Improving dynamic stiffness by reducing energy in possible vibrations

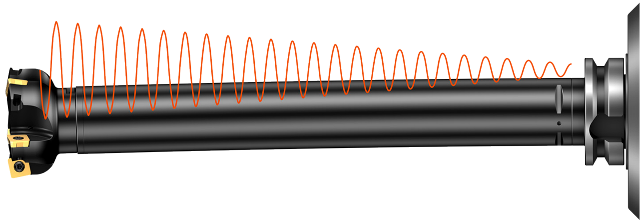
When an object vibrates, energy continuously shifts between kinetic energy and potential energy.

At the maximum amplitude for the vibrating tool assembly, all energy is stored as potential energy in the elastic stress, causing the tool shank to act as a spring, working to return the assembly to its initial position.

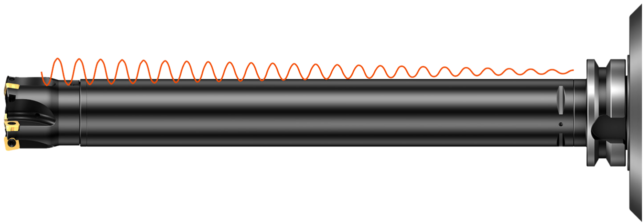
Each time the vibrating mass passes through the initial position, there is no stress in the tool shank material, and all the energy is stored as kinetic energy in the moving mass.

The kinetic energy in a vibration is proportional to the mass in motion ($E = mv^2$). By reducing the mass (weight) at the free end of the assembly, we reduce the energy in the vibration and increase the effect of the available damping.

Free end,
bigger mass



Free end,
smaller mass



Improving dynamic stiffness by increasing structural damping

Damping transforms the mechanical energy of vibrations into thermal energy (heat) within the material, taking the elastic deformations away as the vibration continues. In conventional tool assemblies, damping relies on the tool shank's ability to absorb elastic strain energy from the vibration.

Different materials exhibit different damping capacities. Generally, lower stiffness and higher porosity result in higher internal friction and better damping.

Rubber	**Carbide**
High structural damping Low static stiffness	Low structural damping High static stiffness

Cast iron, known for its high internal damping capacity, is commonly used in machine tool beds where this property is vital. On the other hand, tungsten carbide, with its high stiffness and density, has very poor material damping. Tungsten alloy has better damping capacity than tungsten carbide, while steels exhibit better damping than tungsten alloy.

Since better material damping means less material stiffness and strength — both crucial for dynamic stiffness — the options to increase dynamic stiffness by changing materials in stressed parts of the tool assembly are limited.

Increase dynamic stiffness with tuned mass dampers

A perfectly tuned mass damper inside the tool shank provides the necessary damping to achieve high dynamic stiffness, even for extremely slender tools. We can improve the static stiffness by optimizing dimensions, shapes and materials, while relying on the tuned mass damper for the damping.

Still, it is important to reduce the weight and length ahead of the damper at the tool assembly's free end.

The mass in the damper must be enough to provide sufficient kinetic energy to effectively stop tool vibrations before chatter starts. Therefore, the damper should be positioned as close as possible to the action if the tool starts to vibrate. This is the essence of the Silent Tools™ technology.

3 Turning tools

Internal turning can be challenging because the machining process is naturally unstable. While the axial cutting force (along the boring bar) remains stable, the radial cutting force bends the tool outward, affecting the hole's diameter. Meanwhile, the tangential cutting force bends the tool downward, impacting the clearance angle and causing poor contact with the material. This bending and continuous stock removal leads to vibrations that degrade the surface finish.

To address these issues, using tuned or dampened tools is highly beneficial. These tools enhance productivity, improve surface finish, extend tool life, and ensure better tolerances. Additionally, with increasing environmental regulations, these tools help reduce noise levels caused by machining vibrations.

3.1 Product overview

Silent Tools™ CoroTurn® 107 and 111 boring bars
Cylindrical shank tools with EasyFix groove is used with positive single-sided ISO inserts. Typical for smaller boring operations.

— Minimum bore: 13 and 16 mm (0.512–0.63 inch)
— Overhang: 6–10×DC
— Machine side connection: 10–12 mm (0.375–0.5 inch)
— Insert type: T- or D-
— Coolant: None

Silent Tools™ CoroTurn® SL for stationary adaptors
Cylindrical shank to CoroTurn® SL system of adaptors and cutting heads for internal turning, grooving, threading and boring in turning centers and multi-task machines.

— Minimum bore: 20 mm (0.787 inch)
— Overhang: 4–10×DC
— Machine side connection: 16–60 mm (0.63–2.362 inch)
— Workpiece side connection: SL16–40 mm (0.63–1.575 inch)
— Insert type: CoroTurn® SL heads
— Coolant: Axial concentric entry/exit

Silent Tools™ Coromant Capto® to CoroTurn® SL adaptors
Coromant Capto® to CoroTurn® SL system of adaptors and cutting heads for internal turning, grooving, threading and boring in turning centers and multi-task machines. As well as some niche applications like cylinder and bottle boring profiling.

- Machine side connection: Coromant Capto® C3–C10
- Minimum bore: 20 mm (0.787 inch)
- Overhang: 6–12×DC
- Workpiece side connection: SL16–40 mm (0.63–1.575 inch)
- Insert type: CoroTurn® SL heads
- Coolant: Axial concentric entry/exit
- Carbide reinforced available above 10×DC

Silent Tools™ HSK-T to CoroTurn® SL adaptors
HSK-T to CoroTurn® SL system of adaptors and cutting heads for internal turning, grooving, threading and boring in turning centers and multi-task machines. As well as some niche applications like cylinder and bottle boring profiling.

- Machine side connection: HSK-T 63 and 100
- Workpiece side connection: SL40 mm (1.575 inch)
- Overhang: 6×DC, 268–328 mm (10.551–12.913 inch)
- Insert type: CoroTurn® SL heads
- Coolant: Axial concentric entry/exit

Silent Tools™ Coromant Capto® or cylindrical shank to CoroTurn® SL for threading

Coromant Capto® or cylindrical shank to CoroTurn® SL system of adaptors and cutting heads for heavy internal grooving and threading in turning centers and multi-task machines.

— Machine side connection: Coromant Capto® C4–C6 or Cylindrical shank 40–60 mm (1.5–2.5 inch)
— Workpiece side connection: SL40 mm (1.575 inch)
— Overhang: 3–4×DC
— Insert type: CoroTurn® SL heads
— Coolant: Axial concentric entry/exit

CoroTurn® SL cutting heads

CoroTurn® SL system of cutting heads for internal turning, grooving, threading and boring in turning centers and multi-task machines.

— Workpiece side connection: SL16–40 mm (0.625–1.575 inch)
— Hand: RH/LH, Neutral, Back-boring RH/LH
— Coolant: Axial concentric entry/exit
— Insert family: minimum bore diameter

- CoroTurn® 107: 16–40 mm (0.625–1.57 inch)
- CoroTurn® 111: 16–25 mm (0.625–0.98 inch)
- CoroTurn® TR: 25–40 mm (0.984–1.57 inch)
- T-Max® P: 25–40 mm (0.984–1.57 inch)
- PrimeTurning™: 32–40 mm (1.26–1.57 inch)
- CoroThread®: 16–40 mm (0.625–1.57 inch)
- CoroCut®: 16–40 mm (0.625–1.57 inch)

Silent Tools™ CoroTurn® SL-QC adaptors with quick change cutting heads
CoroTurn® SL-QC system of adaptors and cutting heads with adjustable functional width (WF) for internal turning, grooving, threading and profiling, as well as cylinders and bottle boring with adaptor diameters from 80–250 mm (3.0–10.0 inch).

- Machine side connection: 80 and 100 mm (3.0 and 4.0 inch), overhang: 4–14×DC
- Machine side connection: 120, 150, 200 and 250 mm (5.0, 6.0, 8.0 and 10.0 inch), overhang: 7–10×DC
- Carbide reinforced available above 10×DC
- Workpiece side connection: SL-QC head 80 mm (3.15 inch)
- Hand: -RH/LH, Neutral, Back-boring RH/LH
- Coolant: Axial concentric entry/exit
- Insert family: CoroTurn® 107, T-Max® P and CoroThread®

Silent Tools™ Coromant Capto® to CoroTurn® SL-QC adaptors with quick change cutting heads
Coromant Capto® to CoroTurn® SL-QC system of adaptors and cutting heads with adjustable functional width (WF) internal for internal turning, grooving, threading and profiling, as well as cylinders and bottle boring with adaptor diameters from 80 and 100 mm (3.0 and 8.0 inch).

- Machine side connection: 80 and 100 mm (3.0 and 4.0 inch)
- Overhang: 6, 8 and 10×DC
- Workpiece side connection: SL-QC head 80 mm (3.15 inch)
- Hand: -RH/LH, Neutral, Back-boring RH/LH
- Coolant: Axial concentric entry/exit
- Insert family: CoroTurn® 107, T-Max® P and CoroThread®

Silent Tools™ Coromant Capto® to CoroTurn® SL-Elliptical adaptors for extended reach with quick change cutting heads

Coromant Capto® to CoroTurn® SL-Elliptical system of adaptors and cutting heads for back boring and facing operations, mainly in valve seat pockets.

- Machine side connection: Coromant Capto® C6 and C8
- Workpiece side connection: 16–40 mm (0.625–1.57 inch)
- Overhang: 9–10.5×DC
- Coolant: Axial concentric entry/exit
- Cutting head radial cutting depth: 16–26 mm (0.625–1.02 inch)
- Preferred Insert type: C-type for back boring

Silent Tools™ Plus, sensor-equipped turning adaptors

The connectivity of Silent Tools™ Plus is available for operators through a digital dashboard with data directly from inside your component through Silent Tools™ Plus, sensor-equipped turning adaptors. A tablet device enables data-driven decisions based on real-time information. The traceability and report function enables cutting data to be stored, documented and analyzed. A tool for making decision based on formalized knowledge.

- Machine side connection: Cylindrical, 60–160 mm (2.36–6.3 inch)
- Coolant: Axial concentric entry/exit
- Wedge Lock interface for cutting heads

Standard turning products charts

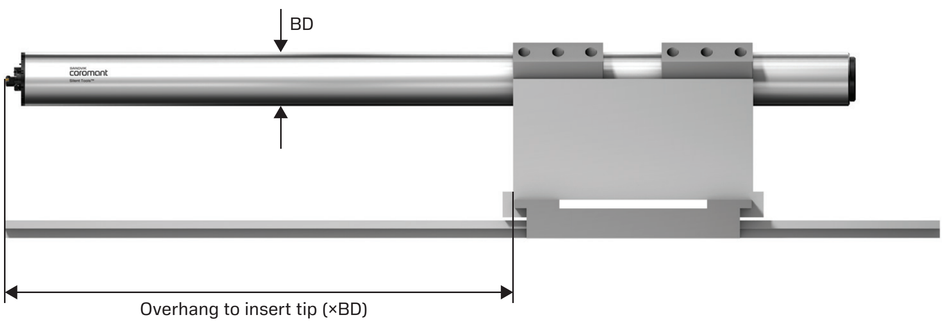
The chart below shows Silent Tools™ standard turning products with cylindrical and Coromant Capto® machine interfaces. In addition, a few standard products are available with HSK machine interface. Note: If standard adaptors do not cover your needs, it is possible to order engineered adaptors.

Cylindrical adaptors

Within functional area | Possible functional area, must be analyzed | CR = Carbide reinforced bar

	Dia, mm (inch)																
	600 (23.6)																
Cylindrical boring bars	120 (4.72)									CR	CR	CR	CR	CR	CR	CR	CR
	100 (3.94)									CR	CR	CR	CR	CR	CR	CR	CR
	80 (3.15)									CR	CR	CR	CR	CR	CR	CR	
	60 (2.36)									CR	CR	CR	CR	CR	CR		
	50 (1.97)									CR	CR	CR	CR	CR			
	40 (1.58)									CR	CR	CR	CR	CR			
	32 (1.26)									CR	CR	CR	CR	CR			
	25 (0.98)									CR	CR	CR	CR	CR			
	20 (0.79)						CR	CR	CR	CR	CR	CR	CR				
	16 (0.63)						CR	CR	CR	CR	CR						
Fine boring bars	12 (0.47)					CR	CR	CR	CR								
	10 (0.39)					CR	CR	CR	CR								
	8 (0.31)																
	BD×	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Note: Overhang is from clamping of the bar to the insert tip.

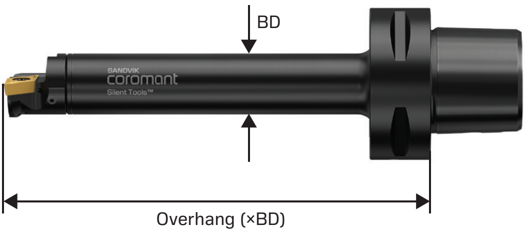


Coromant Capto® adaptors

Standard adaptors | Possible functional area, must be analyzed | CR = Carbide reinforced bar

	Body dia, mm (inch)														
C10	100 (3.94)									CR	CR	CR	CR	CR	CR
C6/C8/C10	80 (3.15)									CR	CR	CR	CR	CR	
C6/C8	60 (2.36)									CR	CR	CR	CR	CR	
C5/C6/C8	50 (1.97)									CR	CR	CR	CR	CR	
C4/C5/C6/C8	40 (1.58)									CR	CR	CR	CR	CR	
C3/C4/C5/C6	32 (1.26)									CR	CR	CR	CR		
C3/C4/C5/C6	25 (0.98)									CR	CR	CR			
C3/C4/C5/C6	20 (0.79)								CR	CR	CR				
C3/C4/C5/C6	16 (0.63)							CR	CR	CR					
	BD×	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Note: Overhang is from Coromant Capto® clamping of the bar to the insert tip.

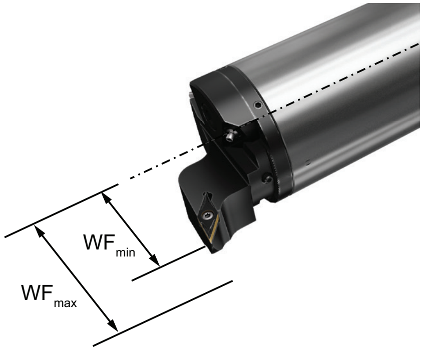


WF (functional width) dimension on SL-QC adaptors

Adaptor dia, mm (inch)	80 (3.15)	100 (3.94)	120 (4.72)	130 (5.12)	150 (5.91)	160 (6.30)	200 (7.97)	250 (9.84)
Cutting heads	WF_{min}/WF_{max}, mm (inch)							
570-SDUCR/L-80-11 570-DDUNR/L-80-15 570-DDUNR/L-80-15X 570-DCLNR/L-80-12 570-DCLNR/L-80-16	55/74 (2.17/ 2.91)	65/84 (2.56/3.31	75/94 (2.95/ 3.70)	80/99 (3.15/ 3.90)	90/109 (3.54/ 4.29)	95/114 (3.74/ 4.49)	115/134 (4.53/ 5.28)	140/159 (5.51/ 6.26)
570-DVUNR/L-80-16X	62/81 (2.44/ 3.19)	72/91 (2.83/ 3.58)	82/101 (3.23/ 3.98)	87/106 (3.43/ 4.17)	97/116 (3.82/ 4.57)	102/121 (4.02/ 4.76)	122/141 (4.80/ 5.55)	147/166 (5.79/ 6.54)

WF dimension on SL-QC mini adaptors

Adaptor dia, mm (inch)	32 (1.26)	40 (1.58)
Cutting heads	WF_{min}/WF_{max}, mm (inch)	
SL-SCLCR-32-09-QC SL-SDUCR-32-11-QC	20/27 (0.79/ 1.06)	23/31 (0.91/ 1.22)
SL-SDUCR-32-11X-QC SL-SDXCR-32-11-QC SL-SVLBR-32-16-QC	26/30 (1.02/ 1.81)	
SL-SVLBR-32-16X-QC	25/32 (0.98/ 1.26)	25/33 (0.98/ 1.30)



Engineered solutions

The standard off-the-shelf boring bar offer represents a good platform for optimized solutions and high productivity. When a tailor-made solution is needed, engineered versions of damped boring bars are available for order.

— The engineered damped boring bars are often tapered, elliptical and/or curved, with the mounting adapted to the machine
— Turning adaptors can be engineered with most of the common back and front-end couplings
— Engineered adaptors come with diameters ranging from 10 mm (0.375 inch) to 600 mm (23 inch)
— For best performance and highest possible static stiffness in the bar body and a damping system, the tools are designed for defined applications

3.2 Most suitable tool for the turning operation

The selection of boring bar material significantly impacts the production economy and should be made with the appropriate length-to-diameter ratio in mind. Carbide bars have higher static stiffness compared to steel bars, enabling longer overhangs. (A carbide-reinforced bar improves static stiffness by approximately 2.5 times compared to a steel bar with the same overhang).

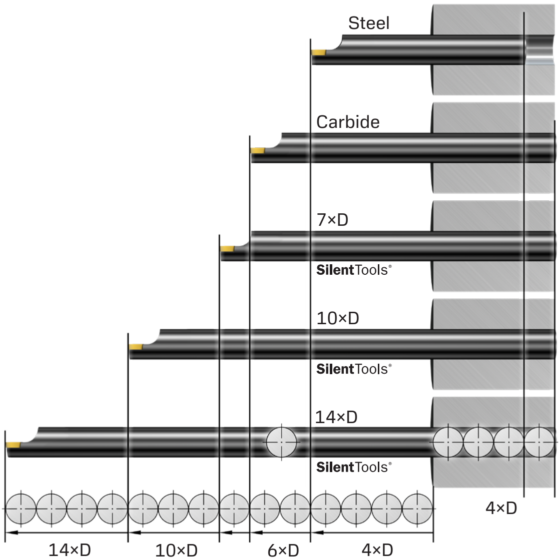
Steel bar (up to 4×D)

Carbide bar (up to 6×D)

Short, damped bar (up to 7×D)

Long, damped bar (up to 10×D)

Carbide-reinforced damped boring bar (up to 14×D)



Threading and grooving result in higher radial cutting forces than turning, which limits the recommended maximum overhang. A damping mechanism increases the dynamic stiffness and allows even longer overhangs.

To minimize bending stress and deflection, keep the tool assembly length as short as possible. With less deflection comes increased stability and higher productivity. Every millimetre counts.

Another effective method to reduce bending stress and deflection is to increase the body diameter, especially near the machine clamping interface, where the stress levels are the highest.

The following example illustrates this by comparing a standard bar with a special bar. By slightly increasing the diameter at the back end and shortening the bar, deflection is reduced by 50% when a 100 kg (220.5 lb) load is applied, corresponding to an a_p of 1.5 mm (0.059 inch) and an f_n of 0.2 mm/rev (0.008 in/rev). This reduction in deflection allows for much higher productivity with a lower deflection, and most likely with a better surface finish.

S-C6-570-3C-50/55-375-40L
Total length: 407 mm (16.02 inch)
Deflection: 0.367 mm (0.014 inch)

C6-570-3C-50-468-40L
Total length: 500 mm (19.69 inch)
Deflection: 0.725 mm (0.029 inch)

3.3 Choice of tools

There are several factors to consider when choosing cutting heads and inserts to achieve a stable process and productive turning operation.

Cutting unit length and diameter

Reduce the length and diameter of the cutting unit for two key reasons:

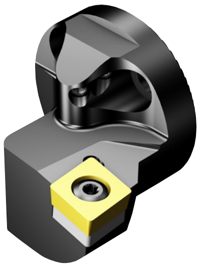
1. **Lower mass:** A smaller diameter and length decrease the mass of the cutting unit, resulting in less energy involved in possible vibrations. This makes the damper more effective in stopping vibrations.
2. **Damper closer to the cutting edge:** The damper is much more efficient when positioned close to the cutting edge. When the distance between the cutting edge and the damper is too great, the damper's effectiveness is significantly reduced.

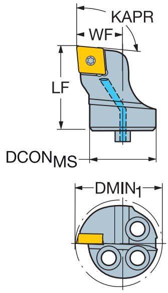
Example: CoroTurn® 107 cutting head for turning, short, compact and low weight.

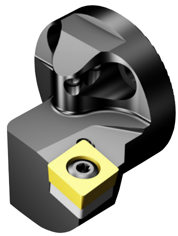
SL-SCLCR-40-12HP
- Connection diameter (DCONMS): 40 mm (1.575 inch)
- Functional length (LF): 38 mm (1.496 inch)
- Functional width (WF): 27 mm (1.063 inch)
- Weight of item (WT): 0.24 kg (0.437 lbs)

Example: CoroTurn® 107 cutting head for turning, short, compact and low weight, but a better choice due to (LF), (WF) and (WT).

SL-SCLCR-25-09HP
- Connection diameter (DCONMS): 25 mm (0.984 inch)
- Functional length (LF): 20 mm (0.787 inch)
- Functional width (WF): 17 mm (0.669 inch)
- Weight of item (WT): 0.07 kg (0.1323 lbs)



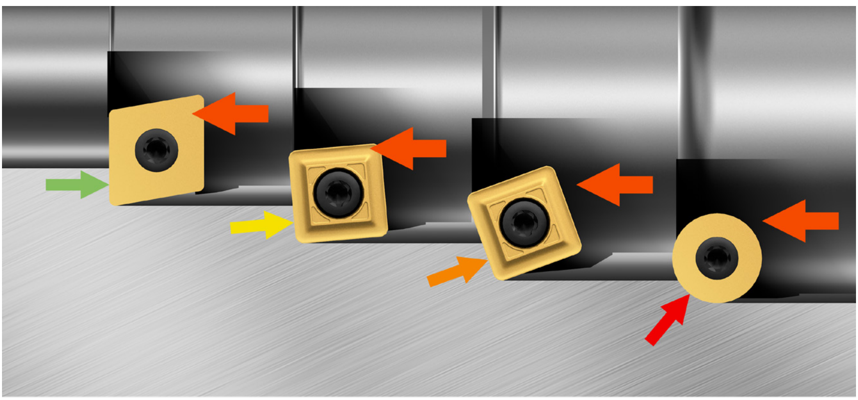




Entering angle

An entering angle close to 90° is the most stable configuration in boring, as it directs the cutting forces axially toward the insert.

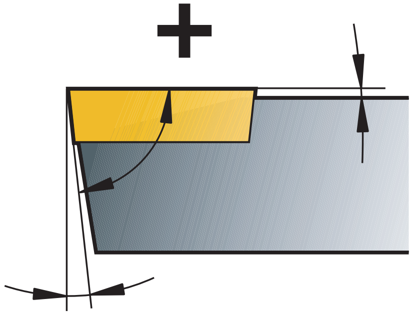
If the setup is stable enough to allow a larger chip load, the entering angle can be reduced. Then the cutting forces are increasingly directed in the radial direction, pushing the cutting edge radially. A reduced entering angle will strengthen the insert and reduce notch wear.



Rake angle

A positive rake angle reduces radial deflection, providing optimal process stability. If the setup is stable enough to allow a larger chip load, a negative rake angle can be used. Then the cutting forces are increasingly directed in the radial direction, pushing the cutting edge radially. A negative rake angle will strengthen the insert and reduce notch wear.

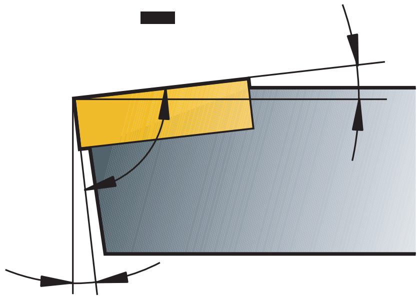
Positive rake angle
A tool has a positive rake angle when the face of the cutting tool slopes away from the cutting edge at the inner side.



- Makes the tool sharper and more pointed
- Reduces cutting forces and power requirements
- Helps in the formation of the continuous chip
- Can help to avoid built-up edge formation

Note: A positive insert geometry provides the same effect as for the positive rake angle.

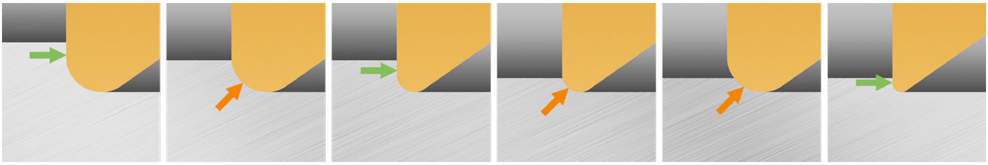
Negative rake angle
A tool has a negative rake angle when the face of the cutting tool slopes away from the cutting edge at the outer side.



- Increases the strength of the cutting edge
- The tool is more blunt
- Increases cutting force and power requirements

Insert radius

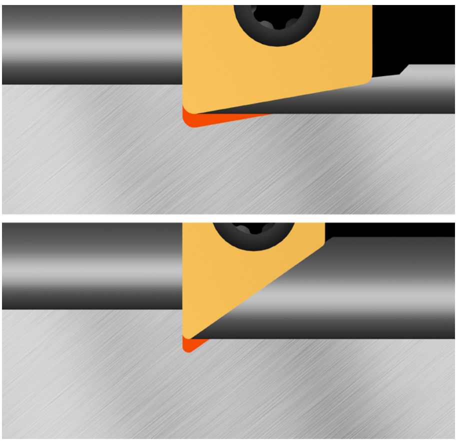
If you have the stability to take a bigger chip load, the nose radius can be increased. Then the cutting forces are increasingly directed in the radial direction, pushing the cutting edge radially. An increased nose radius will strengthen the insert and reduce notch wear.



Insert point

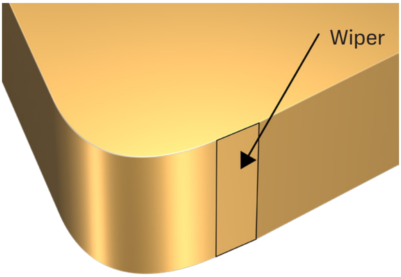
Generally, a large insert point angle should be used to maximize insert strength. However, it requires more machining power and tends to vibrate more due to larger cutting-edge engagement. A smaller insert point angle can improve tool stability by reducing variations in the chip area and cutting force caused by potential radial movements.

A smaller insert point angle can enhance tool stability by reducing variations in the chip area and cutting force caused by potential radial movements.

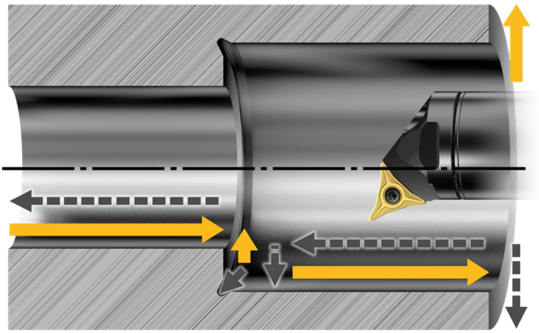


Wiper geometry and PrimeTurning™

Wiper geometry is often the preferred option thanks to its superior surface finish and increased cutting data. It is recommended to use a small nose radius to minimize radial deflection of the tool. Wiper inserts are particularly suitable for short and medium overhangs and for very stable processes.

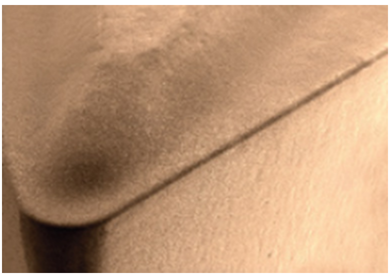


With PrimeTurning™ you can do turning in all directions, with higher metal removal rates and maximized productivity. CoroTurn® Prime A-type inserts are suitable for short and medium overhangs and for very stable processes.



Edge rounding

A small edge rounding is generally recommended to reduce radial deflection of the tool.

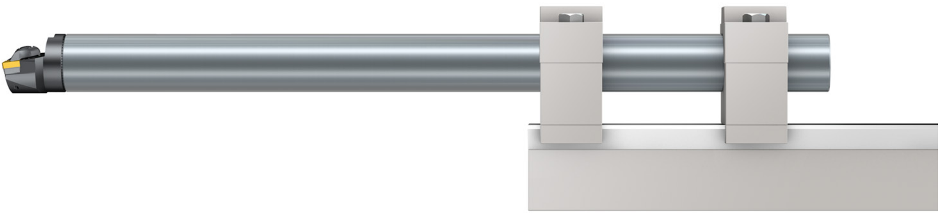


Clamping of turning tools

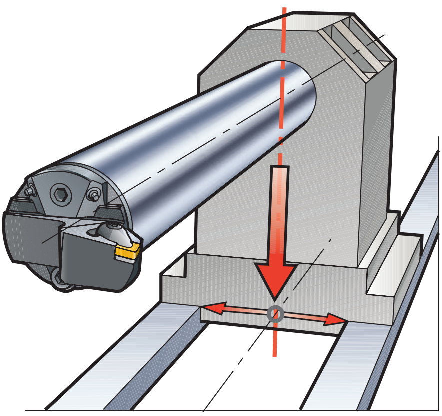
Clamping is essential to prevent movement during machining. It is crucial to ensure that both the component and tool are clamped rigidly and accurately with sufficient stability. Without stability, achieving precision is impossible.

Tool clamping and machine tool stability

Big lathes for internal turning will have a strong tool post, to hold the longest boring bars that can fit into the machine tool. The choice of machine and tool set-up must correspond with the size of the tool. Unfortunately, the importance of a stable cutting tool interface often seems to be a lower priority for many machine tool builders.

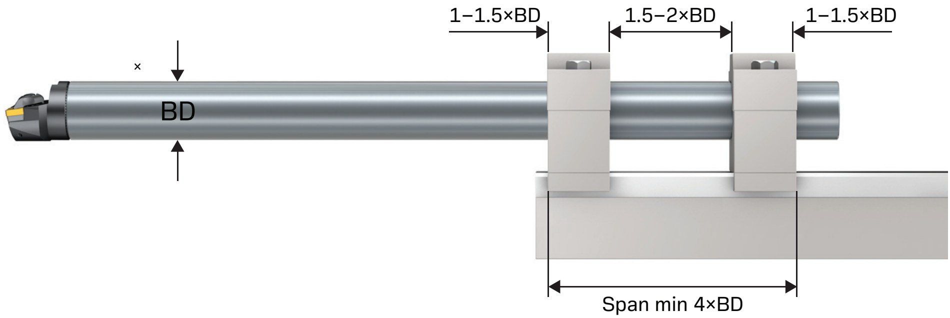


The best choice is a flatbed lathe with tool post, which can provide a rigid tool set-up with very good stability. The best tool post design is an A-frame where the bar is mounted directly over and in between the slides of the machine.

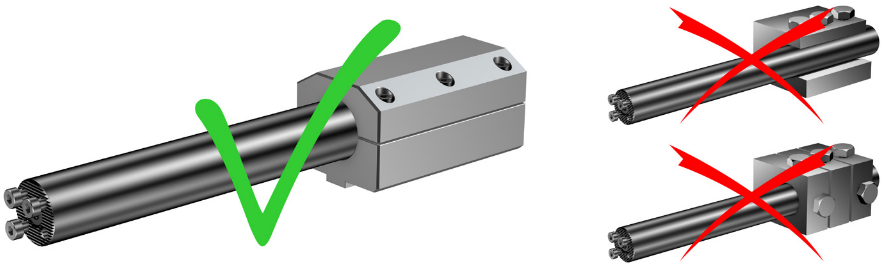


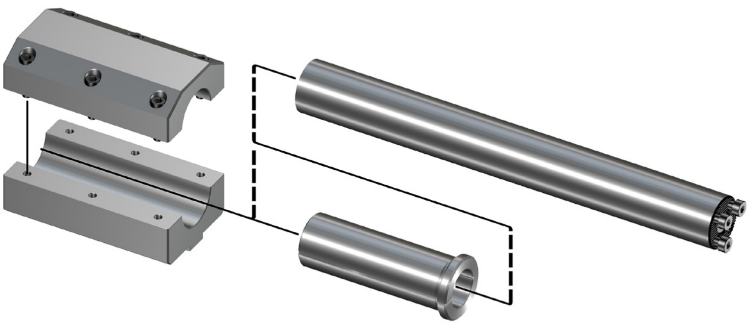
For tool post clamping, it is recommended to use large gibs positioned at least 4×BD apart and aligned with the clamping of the boring bar.

To ensure a minimum of two main contact areas for clamping, the best option is to use separate split holders with recommended clamping tolerance of ISO H7 where possible. The hardness of the clamping parts should be at least HRC 45 to avoid mechanical wear, and the surface finish should be a minimum of 1 µm to ensure sufficient clamping contact.

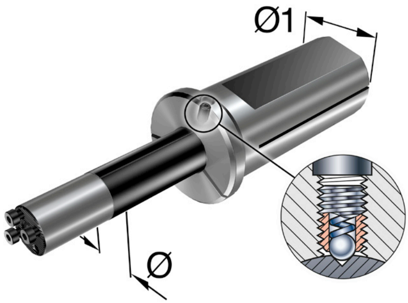


For best performance and stability, use a holder that completely encases the bar. Clamping screws should not be in direct contact with the boring bar.



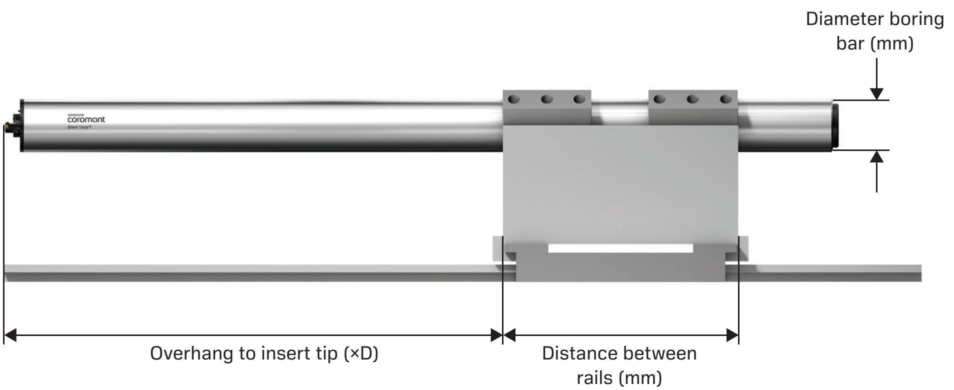


When using an EasyFix™ sleeve in a clamping set-up, tighten the screw closest to the bar first to achieve optimal rigidity and clamping effect.



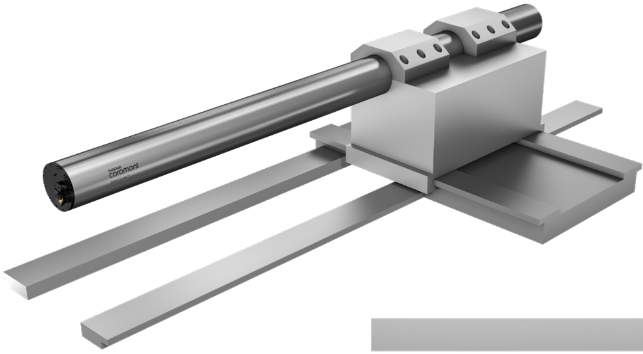
When using damped boring bars with diameters 10 and 12 mm (0.394 and 0.472 inch), an EasyFix™ (EFF) sleeve with a coolant outlet on the side is recommended.

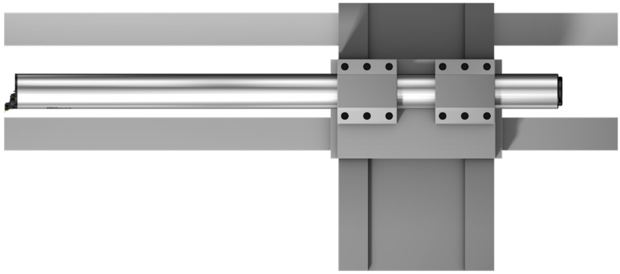
Clamping of big boring bars (diameter 120 mm (4.72 inch) and above)

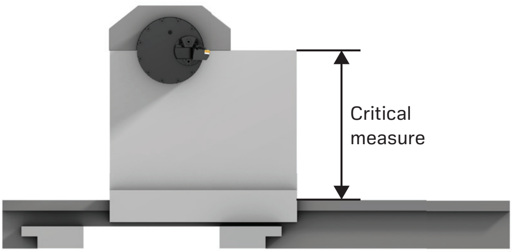


Dia. boring bar, mm (inch)	Overhang to insert tip ×D	Distance between cross slides/rails, mm (inch)
600 (24)	10	2400 (94.5)
500 (20)	10	2000 (78.7)
500 (20	12	2400 (94.5)
450 (18)	10	1800 (70.9)
450 (18)	12	2100 (82.3)
400 (16)	10	1600 (63)
400 (16)	12	1900 (74.8)
350 (14)	10	1400 (55)
350 (14)	12	1700 (67)
300 (12)	10	1200 (47.5)
300 (12)	12	1400 (55)
250 (10)	10	1000 (39.4)
250 (10)	12	1200 (47.5)
200 (8)	10	800 (31.5)
200 (8)	12	900 (35.4)
150 (6)	10	600 (23.6)
150 (6)	12	700 (27.6)
120 (5)	10	500 (19.7)
120 (5)	12	600 (23.6)

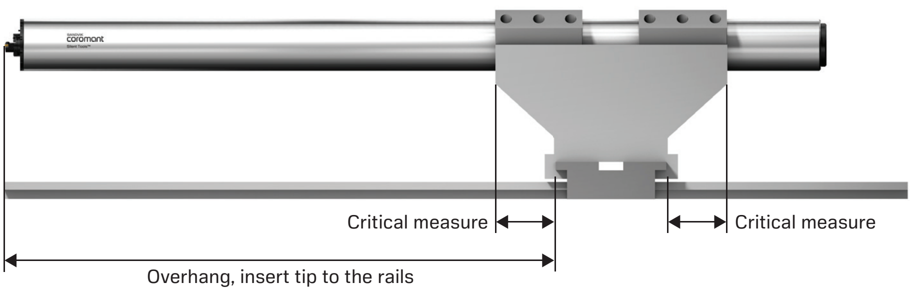
Ideal set-up:

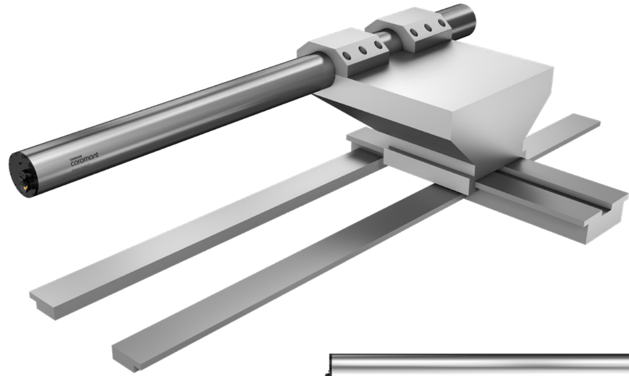


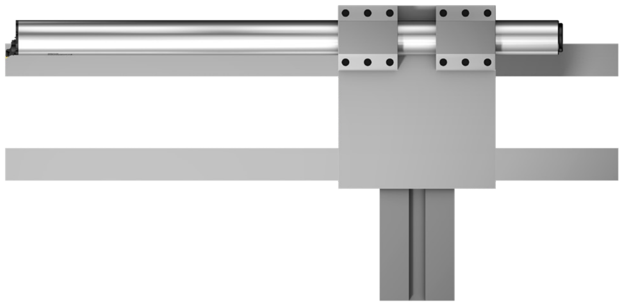


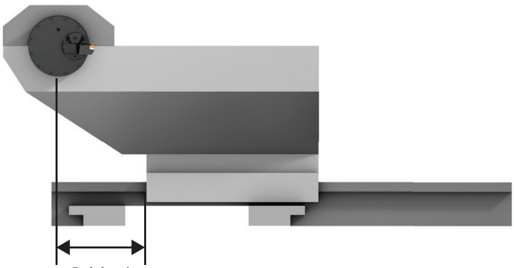


Overhang of clamping unit with respect to rails should be avoided.



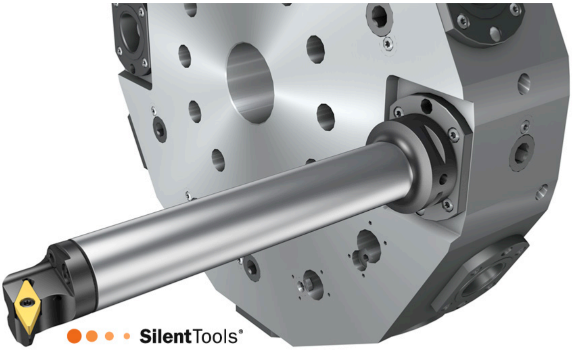




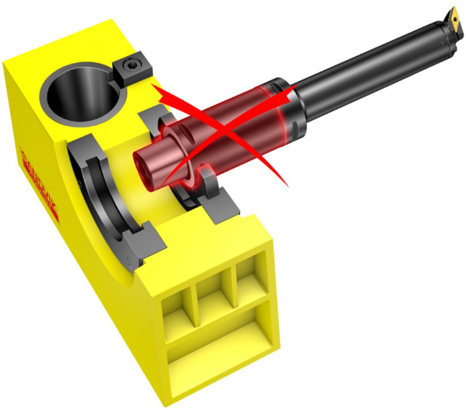


- The machine supplier is responsible for dimensioning the clamping unit and rails to withstand the bending moment caused by a large boring bar with a long overhang, as well as the applied cutting forces.
- The machine tool and the clamping should exhibit high static and dynamic stiffness.
- The clamping unit should preferably be light but rigid.
- The clamping length has been standardized to 40% of the maximum overhang length, and the overhang is defined from insert tip to the front rail

When cylindrical clamping is not feasible, modular system Coromant Capto® offers stiff clamping in a very rigid turret solution, as shown below.



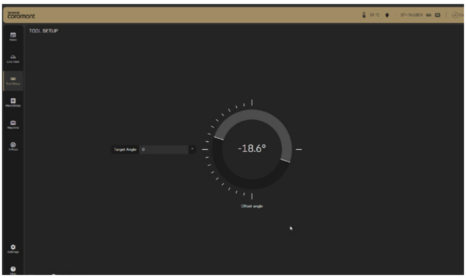
Extensions or long basic holders are not recommended. For best performance, use the adaptor directly in the tool holder.

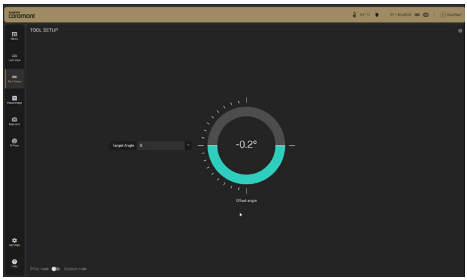


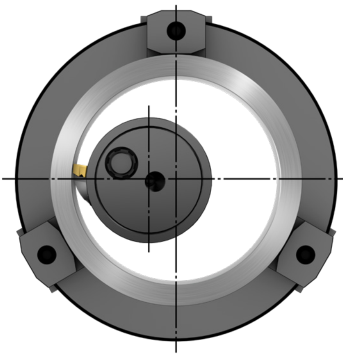
Centre height setting

Improve set-up accuracy and ensure optimal tool health with the Tool Status Checker digital device, designed for seamless monitoring of Silent Tools™ turning adaptors on a Windows tablet or computer. Download the Silent Tools™ Plus app for free from the Sandvik Coromant website.

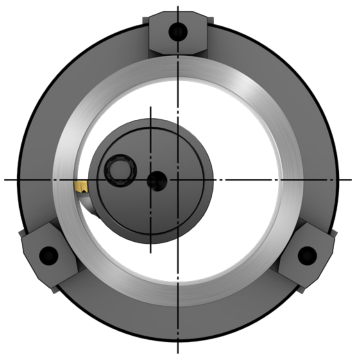
To ensure repeatability and accuracy in all machining situations, attach the Tool Status Checker to the Silent Tools™ turning adaptor. Utilize the centre height setting feature to achieve close dimensional tolerances and excellent surface finish.





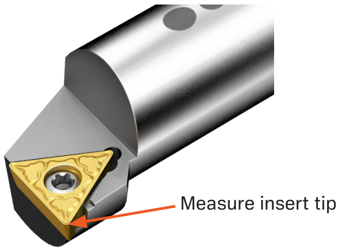


Out of center position



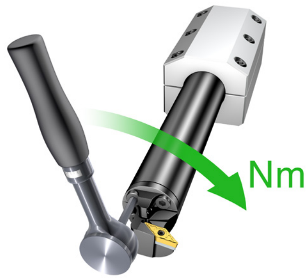
In center position

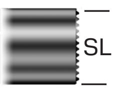
For F-bars or if the alternatives above are not possible, use an EasyFix™ sleeve or height gauge for measuring the insert tip.



Tightening of cutting head screws

Torque values for tightening the cutting unit screws are shown in the tables below for SL- and SL-QC couplings.



		**Nm (Lbs)**		**Torx Plus IP**
SL16	3212 012-156	2.0 (2.1)	5680 084-06	10
SL20	3212 012-206	3.0 (2.2)	5680 084-02	15
SL25	3212 012-257	5.0 (3.7)	5680 084-07	20
SL32	3212 012-307	7.0 (5.2)	5680 084-24	25
SL40	3212 012-358	15.0 (11.1)	5680 084-14	30
SL-QC 80	5512 046-02	50.0 (37.0)	5680 035-15	40

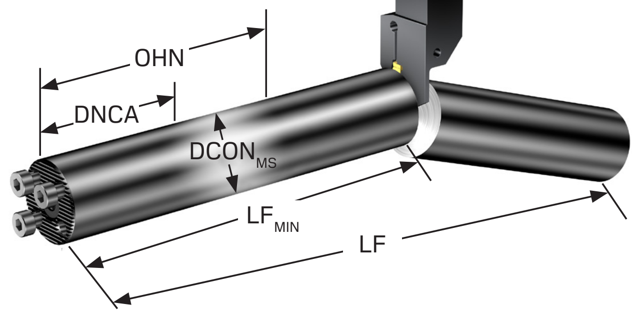
Modification of length

The tables below show the minimum required lengths after cut-off.

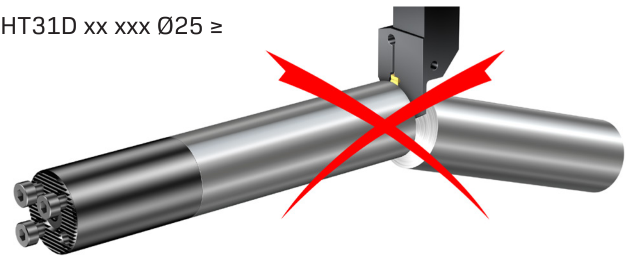
Note:

- After cut-off the standard BSP (British standard for threads) connection to coolant is no longer available
- For bigger boring bars, DCON MS ≥ 120 mm (4.72 inch), contact your Sandvik Coromant sales representative
- Cut-off is not possible for -CR boring bars from DCON MS ≥ 25 mm (0.98 inch)
- Cut-off is not possible for Silent Tools™ Plus products

HT30D xx xxx



HT31D xx xxx Ø25 ≥



Note: Min. clamping length = 4×DCONMS

- DCONMS: Connection diameter
- LF: Functional length before cut-off
- LF min: Functional length after cut-off
- OHN: Minimum overhang
- DNCA: Do not clamp area

HT30D-CY xxx, metric								
DCONMS	Functional length (LF)		Length after cut off (LFmin)		Min overhang (OHN)		DNCA	
	Short design	Long design	Short design	Long design	Short design	Long design	Short design	Long design
16	156	204	120	160	55	96	45	52
20	200	260	150	200	70	120	62	80
25	255	330	190	255	88	155	66	107
32	320	416	230	320	100	192	85	125
40	408	528	290	410	128	248	98	146
50	518	668	370	520	168	318	126	186
60	628	808	450	630	208	388	154	226
80	835	1075	595	835	275	515	202	284
100	1055	1355	755	1055	355	655	283	376

HT40D-CY xxx, metric				
DCON MS	Functional length (LF)	Length after cut off (LFmin)	Min overhang (OHN)	DNCA
40	288	250	86	85
50	368	300	98	95
60	448	350	109	105

HT30D-CY xxx, inch								
	Functional length (LF)		Length after cut off (LFmin)		Min overhang (OHN)		DNCA	
DCON MS	Short design	Long design	Short design	Long design	Short design	Long design	Short design	Long design
0.625	6.1	8.0	4.7	6.3	2.2	3.8	1.8	2.1
0.750	7.5	9.8	5.8	7.7	2.8	4.7	2.4	3.2
1.000	10.2	13.2	7.5	10.1	3.5	6.1	2.6	4.2
1.250	12.5	16.2	8.7	12.5	3.7	7.5	3.4	4.9
1.500	15.2	19.7	10.8	15.3	4.8	9.3	3.6	5.4
1.750	18.0	23.2	12.8	18.0	5.8	11.0	3.9	5.8
2.000	20.7	26.7	14.8	20.8	6.8	12.8	5.0	7.3
2.500	26.3	33.7	18.8	26.3	8.8	16.3	6.1	8.9
3.000	31.2	40.2	22.2	31.3	10.2	19.3	8.0	11.2
4.000	42.2	54.2	30.3	42.2	14.3	26.2	11.1	14.8

HT40D-CY xxx, inch				
DCON MS	Functional length (LF)	Length after cut off (LFmin)	Min overhang (OHN)	DNCA
1.500	10.7	9.4	3.4	3.2
1.750	12.8	10.4	3.4	3.2
2.000	14.8	11.9	3.9	3.7
2.500	18.7	14.3	4.3	4.0

3.4 Turning applications

Internal threading with long overhangs

For internal threading operations, where radial forces are higher than in external threading, the recommended bar type is HT40D, available as standard.

HT40D bars are developed primarily for internal threading applications. The combination of a Silent Tools™ adaptor and flank infeed is recommended for overhangs up to 4×D, to combat axial and radial cutting forces.

— Dampening system reduces unique threading vibrations
— Coromant Capto® and cylindrical machine interfaces
— Flexible CoroTurn® SL cutting head system
— Handles multi-directional cutting forces
— Improves surface finish

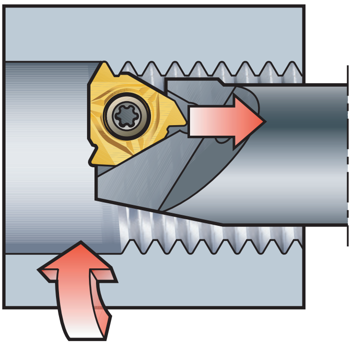
The HT40D system with the SL coupling at the front end enables a large number of cutting tool combinations from a small inventory but is primarily used with CoroThread® 266 cutting heads.

To reduce the risk of vibration, use the following tips:

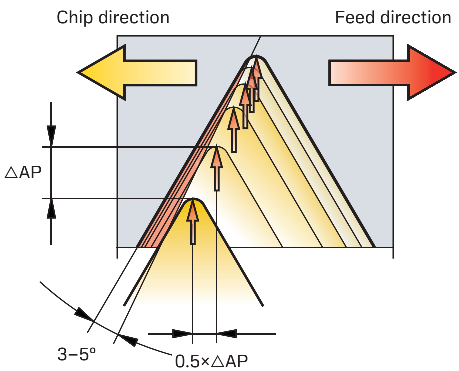
- Use modified flank feed
- Infeed per pass should not exceed 0.2 mm (0.008 inch) and never be less than 0.06 mm (0.002 inch)
- Final pass, always with reduced infeed rate
- Try to avoid zero pass. Leave some material
- Use a sharp geometry for the lowest cutting forces

For best chip evacuation:

- Use modified flank feed to lead the spiral chips toward the opening of the hole
- Use inside-out feed direction in stable conditions. Choose left or right flank to steer the chip flow
- Use coolant for the best possible chip evacuation



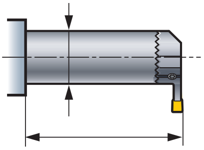
Feed direction from inside out.



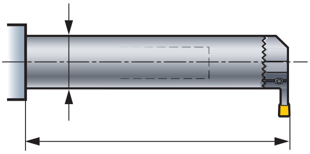
Modified flank infeed directs the chips out from the hole.

It is recommended to minimize the tool overhang and select the largest possible tool diameter for the best possible stability and accuracy.

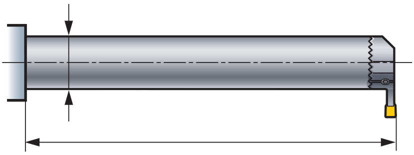
The overhang should not exceed 3×D for solid steel and 5×D for solid carbide boring bars. With damped boring bars it is possible to cut with overhangs up to 5×D, while a carbide reinforced damped bar allows overhangs up to 7×D.



L ≤ 3×BD
Solid steel bars



L ≤ 3–5×BD
Carbide bars or damped steel bars

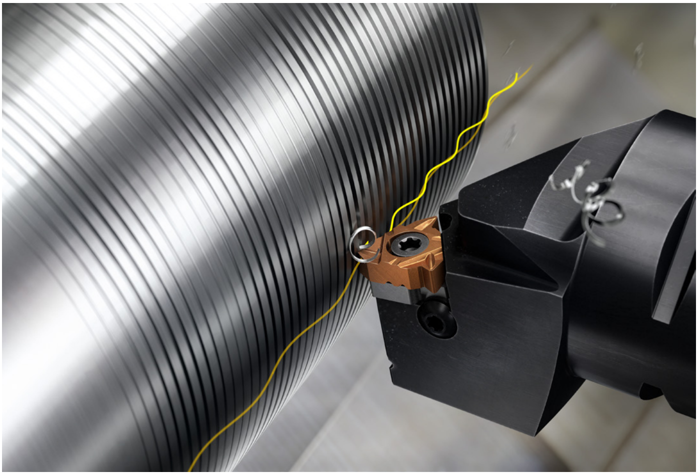


L > 5×BD
Carbide reinforced damped bars

OptiThreading™

Thread turning is a common application in turning that requires special attention to stability and chip control. Bending forces are common on slender long threads and internal threading components. Effective chip control can be achieved by selecting the appropriate geometry, cutting speed, number of passes, and by programming with the OptiThreading™ method.

CoroPlus® Tool Path with OptiThreading ™ is the software and programming method using oscillating tool movements that makes it possible to control the chip breaking in thread turning applications. This unique method gives repeated interrupted cuts on all passes except the last one.



This method generates high cutting forces when entering and exiting the engagement and for this CoroThread® 266 is an optimal system as it can withstand these high and varying cutting forces. Using OptiThreading™ together with CoroThread® 266 unlocks the following features and benefits:

- iLock ™ interface that provides excellent stability when indexing inserts
- OptiThreading™ increases the benefits of using tough insert grades
- Less work removing wrapped chips from the tool, component and/or chip conveyor
- Improved thread surface finish, because of decreased chip wrapping
- Decreased machine stops for increased productivity and automation
- Reduces vibrations when potential tool overhang increases

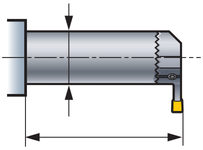
Internal grooving at long overhangs

Many components feature internal grooves, typically produced by radial grooving, multiple grooving or plunge turning.

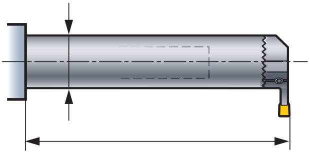
During chip evacuation, there is a large risk of chip jamming resulting in tool breakage, especially when grooving into small holes. Chips must be removed from the groove, redirected 90°, passed along the side of the tool holder, and finally extracted from the hole. To ensure secure chip evacuation, a large deviation between the hole diameter and the bar diameter is necessary, making a small diameter bar ideal. Unfortunately, small diameter bars are prone to vibration.

Stability is the key to avoid vibration, and this is related to the tool overhang and how far into the hole the groove is machined. Using the largest bar size possible minimizes vibration risk, but this conflicts with the need to avoid chip jamming.

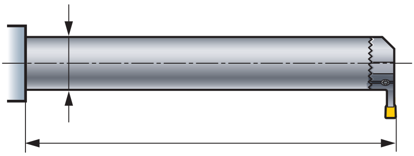
The overhang should not exceed 3×D for solid steel and 5×D for solid carbide boring bars. With damped boring bars it is possible to cut with overhangs up to 5×D, while a carbide reinforced damped bar allows overhangs up to 7×D.



L ≤ 3×BD
Solid steel bars

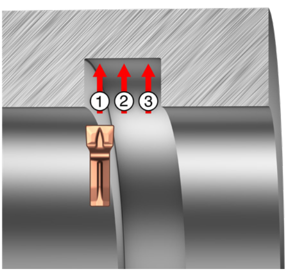


L ≤ 3–5×BD
Carbide bars or damped steel bars

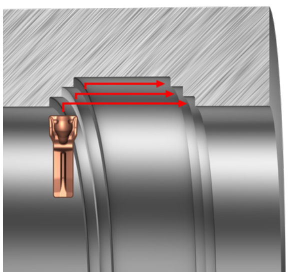


L > 5×BD
Carbide reinforced damped bars

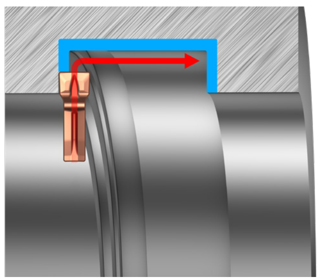
- Ensure that the set-up has the shortest possible overhang and the lightest possible cutting geometry
- Use a sharp, positive and narrow insert. Make several cuts instead of one (A)
- Start from the outside and make overlapping cuts inwards for optimal chip evacuation
- Consider side turning for a more stable process, as it might reduce vibrations and improve chip control (B)
- For a finishing operation, a side turning motion can be used. Start from the inside and turn outwards (C)
- Use right-hand or left-hand style inserts to direct the chips when roughing



A



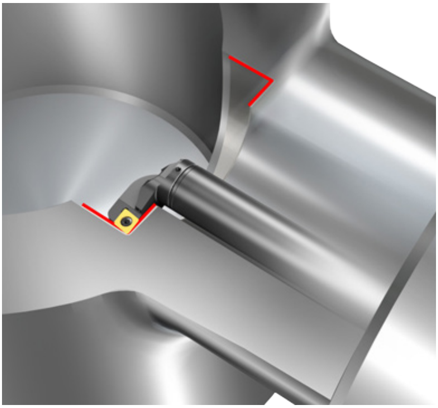
B



C

Internal turning of valve seat pocket

The Silent Tools™ elliptical adaptors are made to reach deep areas. When combined with CoroTurn® SL cutting heads, which are lightweight and have an extended radial length, they form a tool perfect for machining tough spots like valve seat pockets. This tool is optimized to handle challenges like narrow openings and long extensions, ensuring a stable machining process.



3.5 Working conditions

Load, temperature and coolant pressure

All Silent Tools™ turning adaptors are marked with their maximum load capacity, temperature tolerance and coolant pressure limits.

Keep below the load limit to avoid damage on the tool, especially the modular coupling on the machine tool side of the adaptor and the front coupling. For the load calculation, use this formula to calculate the force.

Tangential force, F_t:

$$F_t = k_{C,D,A} \times (0.4/f_n)^{0.29} \times f_n \times AP$$

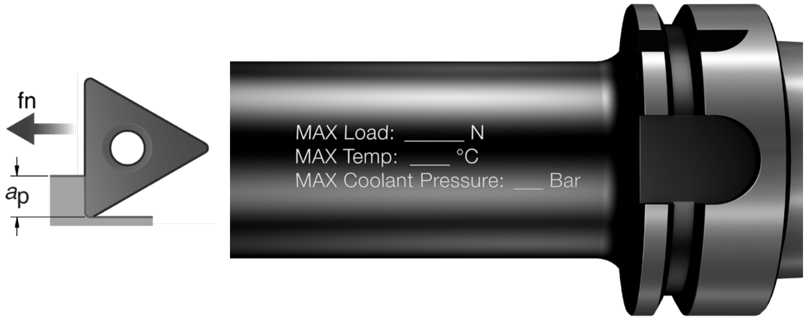
k_c 0.4 = Specific cutting force at feed 0.4 mm/r
mc = Constant, depending on material. Use 0.29 as a general value.

Tangential force, simplified formula:

$$F_t = k_{C,D,A} \times (0.4/(f_n \times \sin KAPR))^{mc} \times f_n \times AP$$

When the entering angle (KAPR) is 75 degrees or above, sin KAPR is ~1 and the simplified formula can be used. Rule of thumb: Ft should not exceed 90% of the maximum load stated for the bar used.

Keep below the maximum temperature and coolant pressure to ensure the damping mechanism is not damaged.



Chip breaking and evacuation using coolant

If experiencing poor chip breaking and evacuation, increase the coolant flow, change the insert geometry or increase the cutting speed to get shorter chips. For the best tool life and results, use coolant directed to the cutting-edge zone. All Silent Tools™ from Ø16 mm (0.63 inch) provide internal coolant directed to the cutting zone.

Coolant can be applied through the rear of the Silent Tool™ adaptor using common-size connectors with British Standard Pipe (BSP) threaded fittings. Most Silent Tools™ adaptors are designed for 80 bar (1160 psi) coolant pressure.

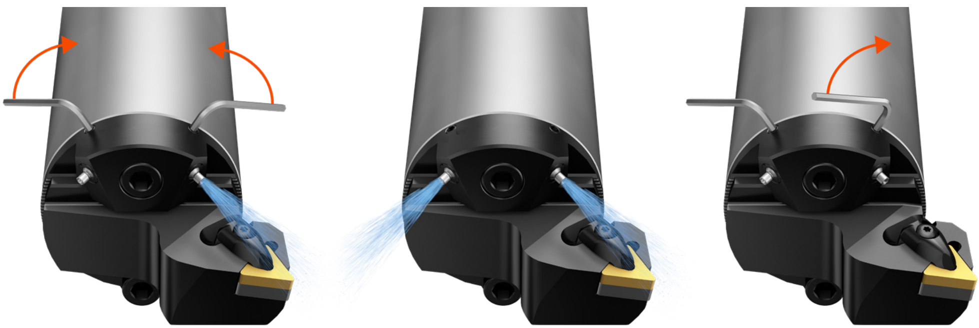
Coolant is recommended to control the heat in the cutting zone and lubricate the cutting edge and workpiece. This helps to improve tool life for a more predictable machining process. The more precise the coolant is directed to the cutting-edge zone, the more effectively it removes generated heat, thereby improving chip breaking as well.

High-pressure coolant (HPC)

Using high-pressure coolant results in shorter chips, which can be easily evacuated. The unique coolant nozzles designed for 70 bar (1000 psi) enable the coolant to be directed precisely at the cutting edge. Due to the precise direction of the coolant flow, the HPC cutting units can be utilized for benefits even at lower pressure.

Adjustment of coolant nozzles

CoroTurn® SL Quick Change units provide flexibility by allowing adjustment of the coolant nozzles to ensure that the coolant hits the cutting zone. To turn the coolant flow on and off, use a hexagon key.



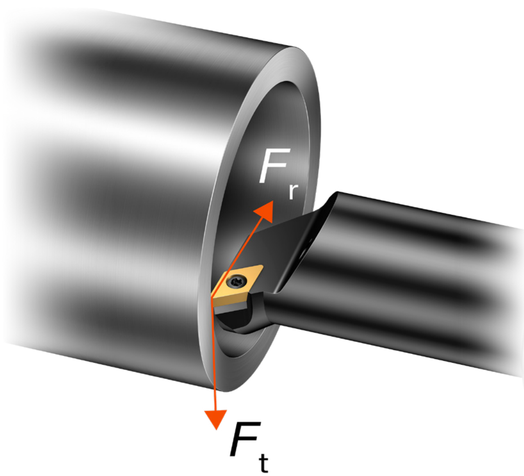
Coolant pressure versus flow

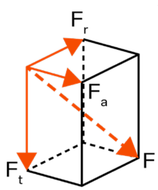
Chip breaking depends on the insert type, coolant pressure/flow and accurate direction of coolant to the cutting zone. Chip evacuation, on the other hand, depends on chip quality and clearance between the tool and the workpiece.

Sufficient chip breaking facilitates chip evacuation and reduces the risk of damaging the tool and the workpiece. This is especially important when the clearance is small. Longer chips may damage the tool and component. To improve chip breaking, increase the coolant pressure. To improve chip evacuation, increase the coolant flow or add/use coolant through the spindle.

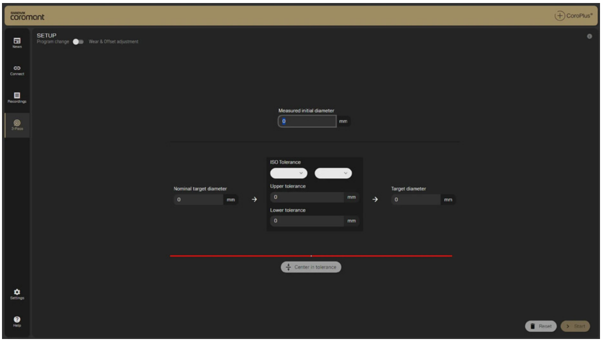
Cutting force and the 3-pass method

Tangential and radial cutting forces are part of the cutting process. These forces vary with cutting data, insert type, coolant, chip area, etc. The cutting forces create radial (Fr) and tangential (Ft) deflection of the tool. A general rule of thumb is to keep the cutting forces as low as possible, especially the radial forces, as they can affect the end diameter.





Use the 3-pass method to achieve high-accuracy diameters where radial deflection normally affects the result. The Silent Tools™ 3-pass calculator is included in our sensorized tools application. Use the QR code to download the app from the Sandvik Coromant website.



Cutting data, starting values

When selecting cutting data, it is essential to start with reliable sources to ensure optimal performance and tool longevity. CoroPlus® Tool Guide should be your first choice for determining cutting data starting values, as it provides comprehensive recommendations. Alternatively, use the insert box data or the Ifind app for quick access to the CoroPlus® Tool Guide and insert start values.

CoroPlus® Tool Guide
sandvik.coromant.com/toolguide

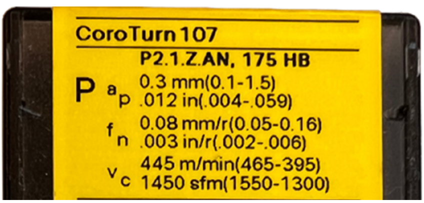
CoroPlus® Tool Guide for internal turning operations
Make sure to select an insert geometry with a starting depth of cut value, that closely matches the radial depth of cut you plan to achieve.

Launch CoroPlus® Tool Guide and find cutting data using these features:

— Find a cutting tool based on your workpiece material
— Find a cutting tool based on a given task
— Find machining process and cutting data
— Find recommended cutting data for your specific tool

Note: Becoming an expert user is easy! Just view the films online to get started with CoroPlus® Tool Guide. Learn useful tips and tricks to become an expert.

Working from the insert box recommendations

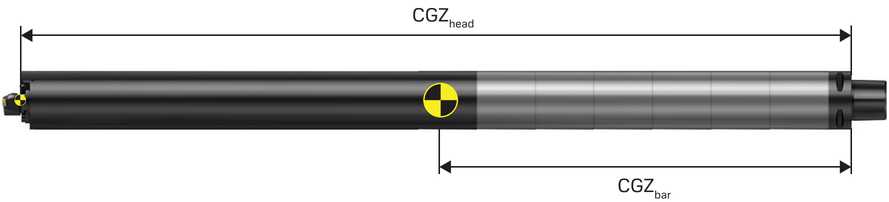


As a rule of thumb, start with the recommended values on the insert box. However, for boring bars with smaller diameters, start at the lower end.

— For bars with diameters 10 mm (0.375 inch) and 12 mm (0.5 inch), the typical depth of cut is around 0.5 mm (0.02 inch) and the feed rate is 0.15 mm/rev (0.006 in/rev)
— For diameters 16 mm (0.625 inch) up to 32 mm (1.25 inch), use the starting values on the insert box and begin at the medium/lower end
— For diameters 32 mm (1.25 inch) and above, use the starting values on the insert box

Moment calculation

When using Silent Tools™ bars in an automatic tool change (ATC) machining solution, it is important to ensure that the moment given by the tool is within the specifications that can be found on the machine or in the machine documentation.



For a bar with a cutting head mounted, the moment M can be calculated as:

$$M = g \times ((m_{bar} \times CGZ_{bar}) + (m_{head} \times CGZ_{head}))$$

CGZ = center of gravity
g = the gravity constant (≈9.8 m/s2 or 32.2 ft/s2)
m_{bar}/m_{head} = the weight of the bar and the head, respectively

For the weight and CGZ of a specific bar, see the product pages on the Sandvik Coromant website.

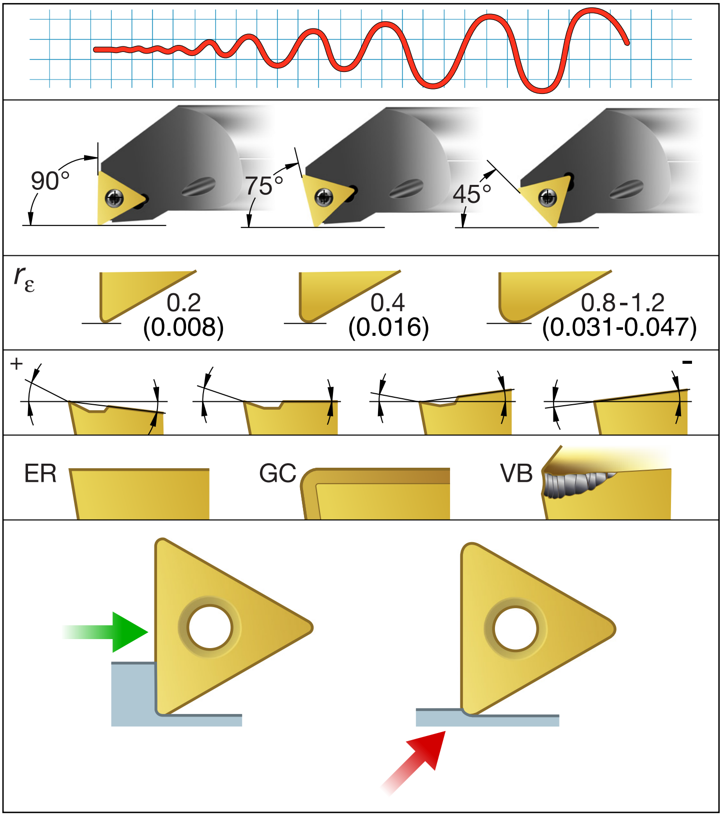
Note: Even if the weight of the head is small, the additional moment is not negligible due to the long overhang.

During tool change, the tool acceleration will add extra force. It is strongly recommended to slow down the tool changing process if the tool weight or moment is close to the machine limits, or consider performing a manual tool change.

3.6 Troubleshooting

Reducing vibration

Use the chart below to identify factors that positively and negatively affect vibration tendencies. Vibration tendencies increase towards the right side of the chart.



A lower radial force results in less radial deflection and fewer vibration-related problems. For best results, use a radial depth of cut that is larger than the nose radius when using a 90° entering angle (0° lead angle). If the radial depth of cut is smaller, a 45° entering angle will yield equal results.

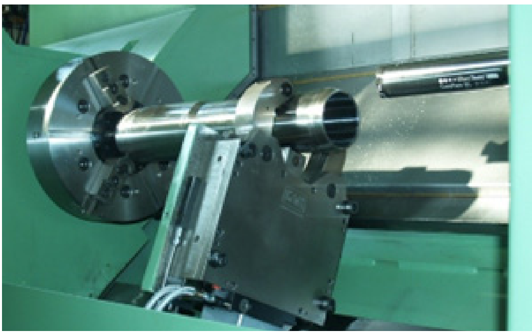
To minimize vibration tendencies, optimize the following factors:
— Entering (lead) angle
— Insert shape
— Nose radius
— Geometry
— Chip control
— Depth of cut
— Cutting data

Note that the redirecting of forces can reduce deflection.
— An entering angle as close to 90° as possible (lead angle 0°) will maximize the portion of feed force coming back from the workpiece in the axial direction. A force in the axial direction will result in less tool deflection than an equal amount of force in the radial direction
— Less force in the radial direction means less radial deflection
— The more positive the rake angle, the less cutting force is needed to machine the component. Less cutting force means less deflection

Vibrations passing the steady rest

If vibration occur in the steady rest, try the following:

— Move the steady rest to a more stable position to make the component more rigid
— Check if the steady rest needs maintenance, as bearings can cause vibrations



Back boring

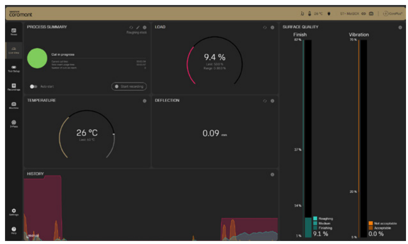
If there is a problem with chip evacuation, back boring can be a solution, as it leaves the chips in the component.

3.7 Silent Tools™ Plus

The Silent Tools™ Plus solution enhances the existing Silent Tools™ products by adding process monitoring and groundbreaking process insights. Real-time performance insights facilitate informed decision-making and allow for early mitigations, reducing scrap, rework and downtime.

By providing operators with real-time "eyes and ears" inside the process and presenting engineers with data and facts, Silent Tools™ Plus enables data-backed decision-making. The Silent Tools™ Plus solution consists of:

- Sensor-enabled Silent Tools™ Plus adaptor
- Electronic kit with the required accessories, including batteries and charger
- Software application with a license to connect to and monitor the process
- CoroPlus® Connected machine integration platform (optional)

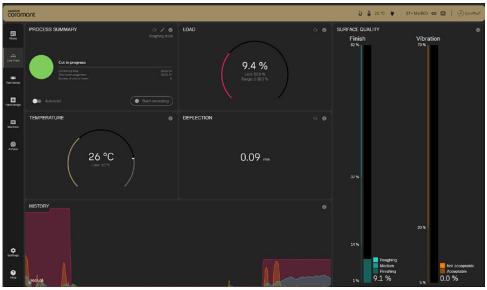


Traceable data allows for targeted quality control, supporting process development work and further analysis. Integration with the CoroPlus® Connected machine platform enables optional machine tool integration, allowing for unmanned operation and automated process monitoring.

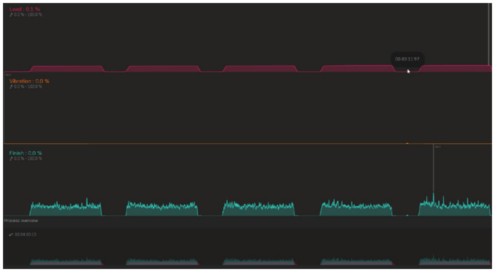
Silent Tools™ Plus software

Monitoring of several critical process parameters, including:

— Tool set-up angle
— In-cut detection
— Chatter vibrations
— Surface finish indication
— Damping system temperature
— Load
— Tool deflection



The data can be viewed live by the operator but also stored to be analyzed and reviewed after machining by the operator or engineers.



Additional features with machine integration:

— Automatic tool connection/disconnection
— Monitoring limits — configurable in software or automated through NC program — and initiating interrupts when the following limits are exceeded:
  - Vibration
  - Temperature
  - Load
  - Deflection

Silent Tools™ Plus is highly attractive for industry segments such as aerospace, oil and gas and defense, but is also suitable for challenging internal turning operations in the production of advanced or high-value components.

Silent Tools™ Plus adaptors

Silent Tools™ Plus adaptors are available as:

— Standard tools with 10× diameter overhang in sizes Ø60, Ø80 and Ø100 mm, including inch equivalents
— Engineered special tools, with several overhang lengths in diameters Ø60–160 mm, including inch equivalents

The recommended cutting head interface made for optimal use with Silent Tools™ Plus adaptors is the Wedge Lock system. They are precise, time-saving, and easy to use. Others can be provided upon request.

		**Nm (Lbs)**		**Torx Plus IP**
Wedge Lock (WL)	5516 014-09	6.0 (4.4)	5680 100-10	20

For more information about the Silent Tools™ Plus solution, and the CoroPlus® Connected machine integration platform, please visit the Sandvik Coromant website, or speak to your local Sandvik Coromant representative.

Silent Tools™ Plus
sandvik.coromant.com/ silenttoolsplus

4 Rotating tools

Working with rotating tools differs from turning, where you have a boring bar in a rigid tool post, but most of the conditions for successful operations are the same:

— Rigid clamping
— Shortest possible tool length
— Largest possible shank diameter
— Minimum weight of the cutter to reduce the kinetic energy in a potential vibration

4.1 Product overview

Milling

Silent Tools™ CoroMill® 390
Small-diameter end mill with built-in damper can be applied for most milling applications e.g. face, shoulder, cavity and slot milling.

— Machine side connection: Cylindrical or Coromant Capto® C5 and C6
— Insert type: 390-11 on (L) pitch cutters for full cut and roughing operations, 390-07 on (H) pitch cutters for ultra finishing
— Cutting diameter: 20–32 mm (0.79–1.26 inch)
— Usable length: 6×DCX

Silent Tools™ adaptors with arbor interface
Possible to build high-productive slender milling assemblies with different CoroMill® cutter concepts. Can be applied to most milling applications e.g. face, shoulder, cavity, profiling and slot milling, as well as front facing, back facing and groove milling.

— Machine side connection: Coromant Capto® or HSK-A/C
— Workpiece side connection: Arbor (metric/inch)
— Undersized body diameters available to provide side clearance
— Nominal body diameters only accept oversize cutters

Silent Tools™ adaptors for CoroMill® QD (groove and slitting cutters)
High-security groove milling and parting off for internal and external groove milling, slitting and parting off.

- Machine side connection: Coromant Capto®
- Workpiece side connection: CoroMill® QD (metric/inch)
- Cutting diameter: 80–315 mm (3.0–12.0 inch)
- Cutting width: 2–6 mm (0.079–0.250 inch)

Silent Tools™ adaptors for Coromant® EH milling cutters
Adaptors for 5-axis machining with the ability to angle the assembly away from sidewalls for high-feed cavity and profile milling to remove material in die and mold, impellers, turbine runners and wheel-type applications.

- Machine side connection: Coromant Capto®
- Workpiece side connection: Coromant® EH
- Largest adaptors usable length: 455 mm (17.9 inch), supports cutter diameter up to 32 mm (1.26 inch)
- Oversized cutters are required to provide side clearance along the tapered shank

Boring

Silent Tools™ CoroBore® BR20D for rough boring
For twin-edge boring, step boring, single edge front or back boring.

- Machine side connection: Coromant Capto®
- Workpiece side connection: CoroBore® BR20 (BR10) interface for insert cartridges
- Cutting diameter: 23–150 mm (0.90–5.90 inch) increases for back boring
- Insert type: CCMT/TCMT at 90° entering angle and SPMT at 84° entering angle, for single edge back boring CCMT using BR10 slides

Silent Tools™ CoroBore® 825D adaptors
For single-edge fine boring.

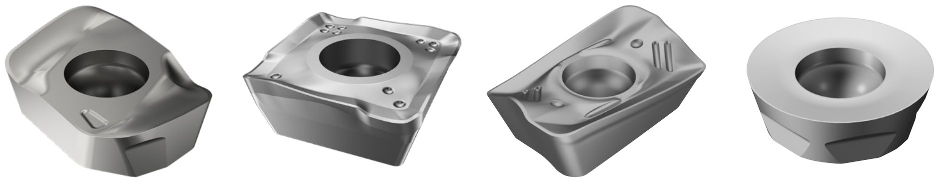
- Machine side connection: Coromant Capto®
- Workpiece side connection: CoroBore® 825 fine boring head
- Cutting diameter: 19–167 mm (0.75–6.58 inch) increases for back boring
- Insert type: TCMT / TPMT at 92° entering angle or CCMT at 95° entering angle for front and back boring
- Optimized left hand back boring cartridges available for back boring with clockwise spindle rotation

Silent Tools™ CoroBore® XL adaptors
For rough or fine boring in larger machine tools with high stability.

- Machine side connection: Coromant Capto® C8 and C10
- Flange connection with high torque capacity, driving keys in front for lightweight aluminium bridges carrying standard slides and cartrid-ges
- Cutting diameter:
  - Rough boring: 148–300 mm (5.83–11.81 inch)
  - Fine boring: 148–315 mm (5.83–12.40 inch)
- Twin-edge boring with different inserts and entering angles for high penetration rate
- Step-boring configuration (90° entering angle) to take out bigger radial depths per rough boring operation
- Single-edge fine boring for finishing at tight tolerances and high-quality surface finish

4.2 Choice of milling tools and inserts

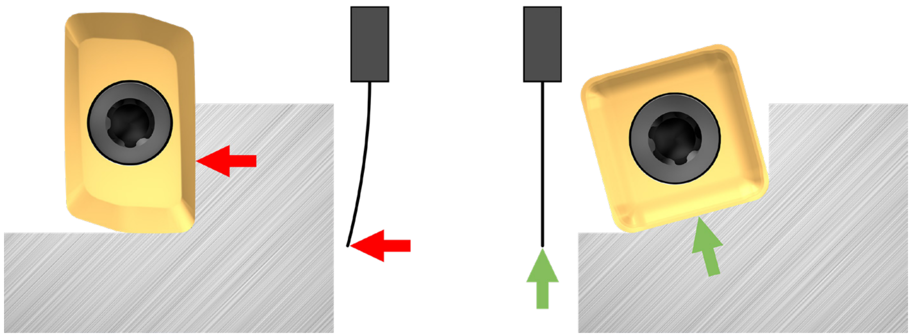
Look for light-cutting concepts. Positive geometries and good flank clearance enable larger chip volumes with less cutting force and minimal force variations, which helps to avoid vibrations. Negative concepts made for cast iron or long-edge milling cutters will increase cutting forces, force variations and vibrations.



Positive insert concepts: CoroMill® MH20, CoroMill® 490, CoroMill 390® and CoroMill® 300

It is important to consider the entering angle. Shoulder milling cutters with an entering angle of 90 degrees generate significant cutting forces in the radial direction, which can cause radial deflection, leading to vibration and/or chatter.

In contrast, high-feed milling cutters with an entering angle of 10 to 15 degrees generate significant cutting forces in the axial direction. This configuration decreases radial forces and offers the highest metal removal rate for slender tool assemblies.



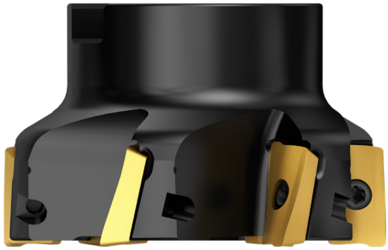
KAPR=90°

KAPR=15°

Cutter diameter comparison

When using a smaller diameter cutter versus a larger one at equal cutting speed, the smaller diameter cutter can achieve the same metal removal rate with reduced maximum chip thickness and lower torque. This means less vibrations and higher metal removal potential for the tool assembly when using the smaller diameter cutter.

DCX = 50 mm (2 inch)
Q = 100 cm³/min (6.10 in³/min)
Cutting speed, v_c = 250 m/min (820 ft/min)
Net power, P_c = 5 kW (6.7 HP)
Max. chip thickness, h_{ex} = 0.18 mm (0.007 inch)
Cutter torque, M_c = 32 Nm (23.6 lbf-ft)

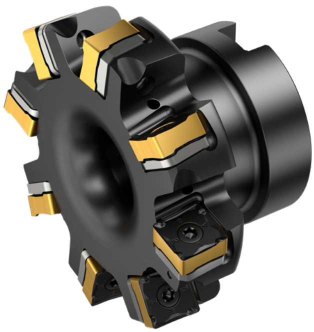


DCX = 63 mm (2.5 inch)
Q = 100 cm³/min (6.10 in³/min)
Cutting speed, v_c = 250 m/min (820 ft/min)
Net power, P_c = 5 kW (6.7 HP)
Max. chip thickness, h_{ex} = 0.22 mm (0.009 inch)
Cutter torque, M_c = 38 Nm (28.0 lbf-ft) (+20 %)

Cutter weight comparison

Reducing the mass (weight) of the cutter reduces the kinetic energy in radial movements caused by changes in cutting force. With less energy in these vibrations, it is easier for damping in tool shank and dampers to control them. As a result, a lighter cutter improves stability and allows for more metal to be removed.

DCX = 80 mm (3.15 inch)
W = 0.74 kg (1.6 lbs)
Kinetic energy in radial movements:
KE = 0.55 v^2 (v = speed in radial movements)



DCX = 100 mm (3.94 inch
W = 1.0 kg (2.2 lbs)
Kinetic energy in radial movements: KE = ½ mv^2
KE = 1.0 v^2 (v = speed in radial movements)

Consider the cutter pitch

In operations with big radial cutter engagement, a coarse pitch (L) cutter can take the biggest axial depth of cut and is potentially the most productive cutter.

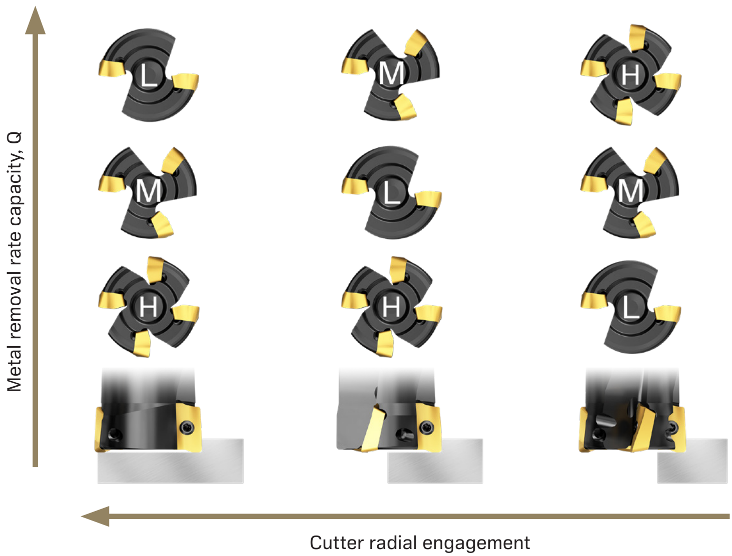
In operations with medium radial engagements, a close pitch (M) cutter can take nearly the same axial depth of cut as a coarse pitch cutter. It is potentially the most productive choice because the feed rate at the same chip thickness will be higher due to the extra insert.

In operations with small radial engagements, an extra close pitch (H) cutter can take the same axial depth of cut as a coarse and close pitch cutter. It is potentially the most productive choice because the feed rate at the same chip thickness will be higher due to the extra teeth.

The rule of thumb for selecting cutter pitch to achieve maximum stability is to choose a cutter with only 2–3 inserts actively in cut taking chip load. (Cavity milling cutters may have more than 3 inserts as only the inserts on feed direction side takes the full load).

To achieve maximum metal removal rates with slender milling tool assemblies, use:

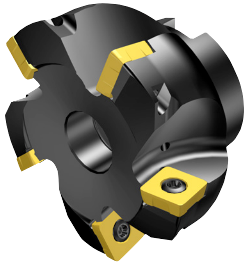
— Moderate cutting speed to ensure spindle stability
— Low axial depth of cut to limit radial deflection and vibrations
— Moderate to big radial engagement to reduce the size of force variations and vibrations caused by insert entrance and exit
— High feed to maximize chip volume



Choose correct milling concept

High-feed milling concepts

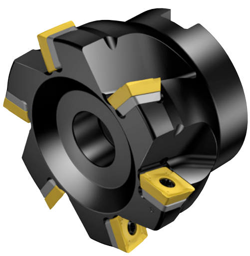
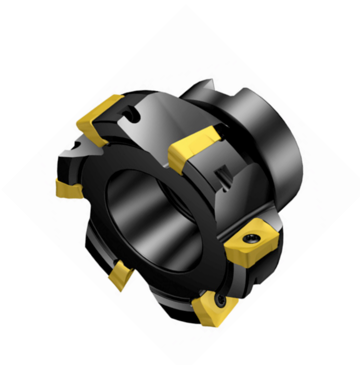
CoroMill® MH20, CoroMill® 210 and CoroMill® 415 are high-feed cutters with small entering angles and good side clearance. They are first-choice concepts for face milling and roughing out material from cavities.


Shoulder milling concepts

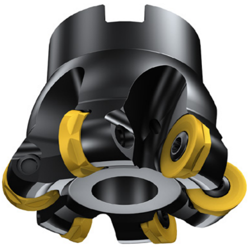
CoroMill® 490 is the first-choice cutter for true 90-degree shoulder milling applications, ensuring minimum mismatch in repeated side milling. CoroMill® MS20 and CoroMill® 390 are the most versatile cutters for face and shoulder milling, with ramping capabilities for slotting and cavity milling operations.

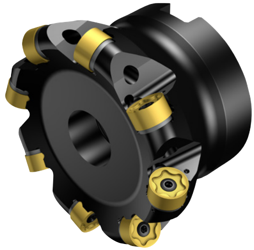
For slender tool assemblies, 390-11 and 390-17 inserts are recommended. 390-07 inserts have insufficient chip load capacity, while 390-18 inserts have a negative cutting action and are not recommended for slender tools.


Profile milling concepts

CoroMill® 300 has the most positive cutting action and is the first choice for profile milling with slender tool assemblies – even in HRSA. CoroMill® 600 and CoroMill® MR80 are good alternatives for small cutting depths. CoroMill® 216 is the most difficult cutter concept for slender tools and should only be used when required.

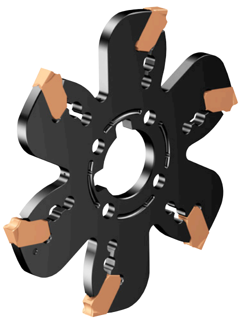




Groove milling concepts

CoroMill® QD is an excellent concept for radial and tangential feed grooving, cylinder slitting and component parting off. The low-mass cutter and light-cutting inserts make it very powerful for slender tool assemblies. It is ideal for creating locking ring grooves, O-ring grooves, segment slitting and parting off small parts. However, CoroMill® QD is not designed for front-facing or back-facing, as side forces on the inserts will bend them out of their insert seats.

CoroMill® 331 is a versatile concept for radial and tangential feed grooving, shoulder milling, side face milling, front face milling, back face milling, as well as slitting and parting off. To ensure success with Silent Tools™ assemblies, avoid using cutters significantly heavier than a standard shoulder mill suitable for the Silent Tools™ adaptor. For optimal tool assembly stability, reduce insert size and/or axial depth of cut to minimize radial forces and tool assembly deflection.

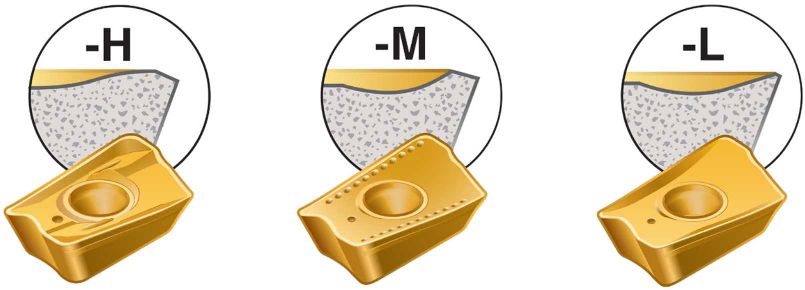


Choose a suitable geometry

Medium-geometry inserts are the first choice for general-purpose machining and mass production.

Light-geometry inserts are best suited for light-cutting operations, generating a good surface finish. Their sharp edges also minimize cutting forces and tool deflection.

Heavy-geometry inserts have strong edges, making them suitable for interrupted cuts and abrasive materials. However, they require good tool stability due to higher cutting forces and more variable cutting forces. Generally, heavy geometries are not recommended for slender tool assemblies.



Choose a suitable insert grade

Choose a grade and coating suitable for the operation and the workpiece material. Keep in mind that PVD-coated grades usually have sharper edge lines than CVD-coated grades, creating less cutting force and torque. The latest information about all-round and complementary grades can be found on our website.

4.3 Choice of boring tools and inserts

Rough boring head configuration

Rough boring heads on Silent Tools™ adaptors can be configured with one or two insert cartridges.

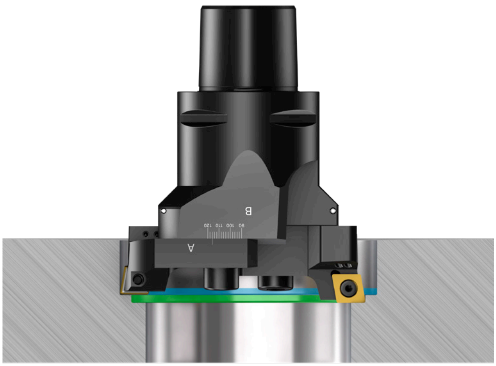
Productive, twin-edge boring

— Double penetration rate
— Vibration sensitive
— Not for the most extreme assembly lengths

In a twin-edged boring tool, both inserts are positioned on the same diameter and the same distance from the spindle gauge line. The chip thickness for each insert is half the tool feed, so the tool feed must be doubled to achieve the recommended chip thickness for the insert. This configuration is the most productive, but also the most demanding with regards to tool stability, machine tool power and torque capacity.

Step boring

— Single penetration rate
— Double radial depth of cut
— Good stability



A step-boring tool is the best solution for larger radial depths of cut. The insert on the smaller diameter is positioned slightly ahead of the second insert. The total radial depth of cut for the operation is the sum of the radial cuts taken by each insert.

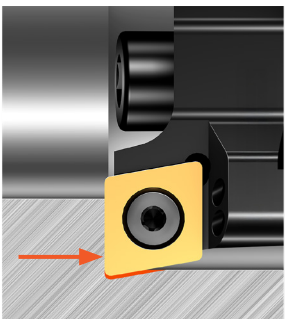
Single-edge front or back
— Single penetration rate
— Best stability
— For the most extreme assembly lengths

A single-edge boring tool provides the highest stability and is the best solution for extreme tool lengths and/or machine tools with low power and torque capacity. It is also the best choice if chip evacuation is challenging or if pre-drilled holes are off-centre.

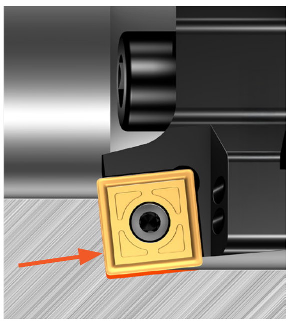
When building a tool for single-edge back boring, be aware that the choice of inserts and diameter range for the boring head might be different compared to front boring. Back boring changes the direction of axial forces from compression to stretch (tension) and will be more demanding for the spindle interface and possible modular couplings in the assembly.

How to choose boring cartridges and inserts

Minimize tool deflection and cutting force variation to achieve stable operations with slender tools. Using a 90-degree entering angle ensures that a significant portion of the **feed forces** are directed back into the tool in the **axial direction**. With smaller entering angles, more feed forces are directed back into the tool in the radial direction, resulting in greater average tool deflection for the same radial depth of cut.

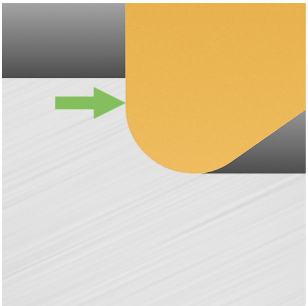


90° entering angle
+ Less radial cutting forces
+ Less tool deflection
+ Better stability – less vibration

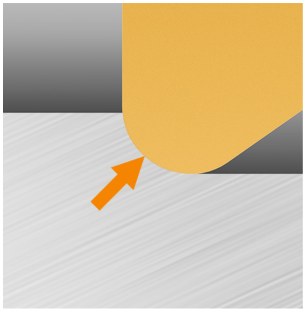


Smaller entering angle
- More radial cutting forces
- More tool deflection
- More demanding to avoid vibrations
- Less notch wear in abrasive materials

The **insert radius** must be **smaller than the radial depth of cut** to achieve the advantages of using a 90° entering angle.

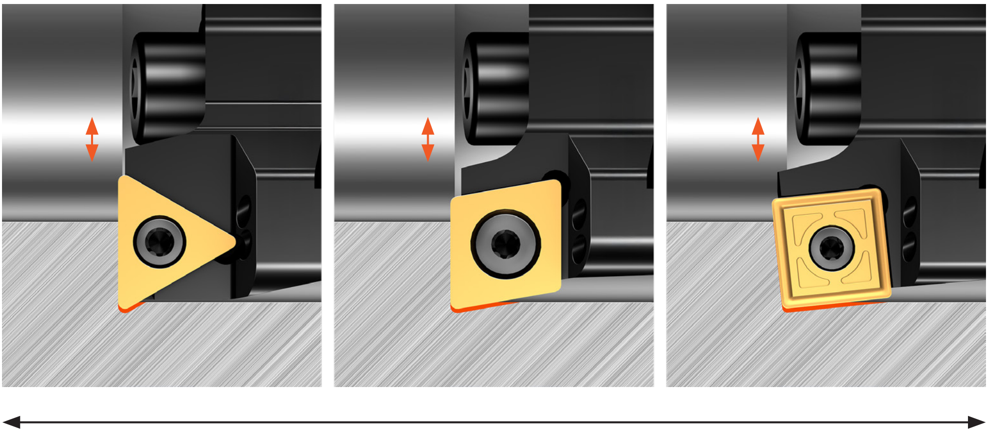


Radius smaller than radial depth of cut
— Less tool deflection
— Less vibration



Radius bigger than radial depth of cut
— More tool deflection
— More vibration

For the same small radial movement, a **smaller insert point angle** and a **bigger clearance for the secondary cutting edges** will reduce cutting force variations and vibration tendencies.

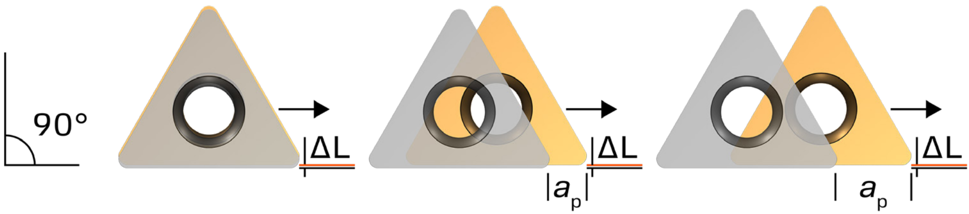


Less cutting force variation
Less vibration

More cutting force variation
More vibration

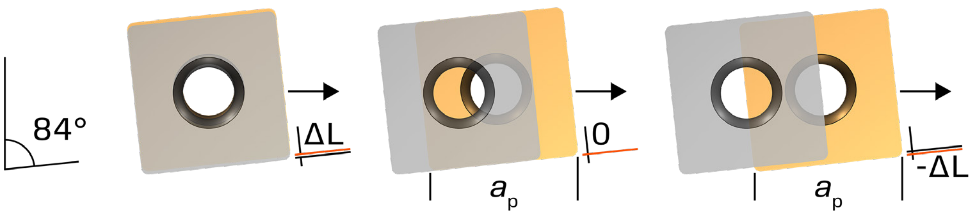
Step boring settings

Always use a 90° entering angle for step boring. With a 90° entering angle, the axial distance ΔL between each of the cutting edges in step boring will be constant as you move each of the insert's radial depth of cut outward.



ΔL is constant at initial value as the difference in diameter increases

When using insert cartridges with smaller entering angles, the axial distance (ΔL) between the two cutting edges will decrease as you move the second insert to a larger diameter. Eventually, the second insert will need to cut the entire radial depth from the pre-drilled diameter, rather than just the remaining radial depth after the first insert's cut. This situation is likely to result in a dramatic overload of the second insert.



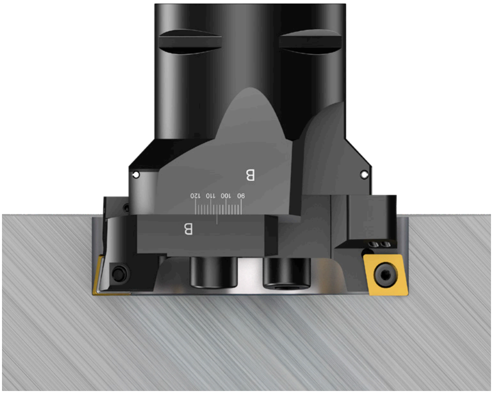
ΔL at initial value

ΔL is zero
2nd insert overload

ΔL is negative
2nd insert overload

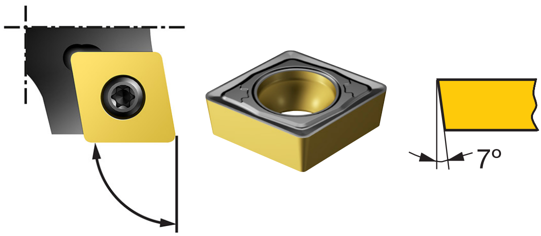
Boring of blind holes

A 90° entering angle is also the solution for rough boring of blind holes. Be aware that proper chip evacuation is demanding and there is a risk of insert overload if boring to the bottom. Our fine boring tools have a 92–95° entering angle to balance radial cutting forces, reduce deflection and vibration risks, and enable the machining of shoulders and blind holes without engaging the entire cutting edge.



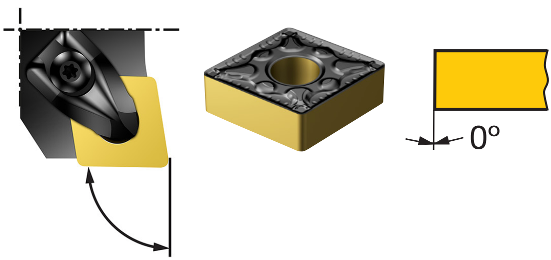
Single-sided (positive) inserts

— Softer chip forming and breaking
— Lower cutting forces
— Less tool deflection
— Less vibration



Double-sided (negative) inserts

— Harder chip forming and breaking
— Higher cutting forces
— More tool deflection
— More vibration

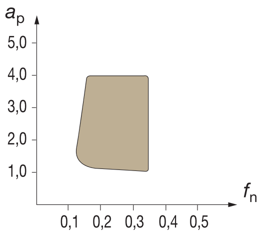


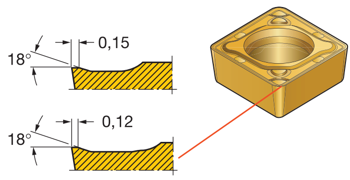
Single-sided inserts can be designed with more positive geometries and sharper edges, enhancing their light-cutting advantages compared to double-sided inserts. Double-sided inserts might be an option in stable conditions to improve insert tool life as well as in difficult operations to improve edge security.

Choose a suitable geometry with the optimized nose radius

To achieve optimal results, select a geometry that is appropriate for the operation. Ensure the chosen geometry has a starting value for the depth of cut that is close to the intended depth of cut for your operation. Additionally, matching the nose radius to that geometry.

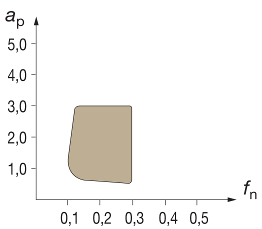
Roughing, (R) geometry

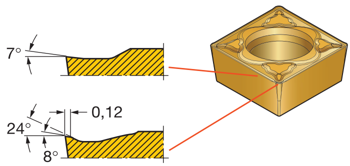




Nose radius:
1.2 mm (0.047 inch)

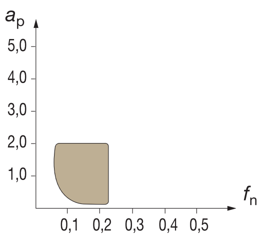
Medium, (M) geometry

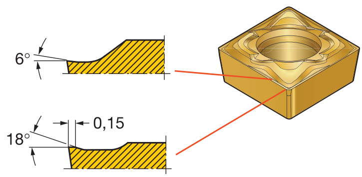




Nose radius:
0.8 mm (0.032 inch)

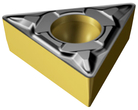
Finishing, (F) geometry





Nose radius:
0.4 mm (0.016 inch)

0.2 mm (0.008 inch) for smaller depth of cut and improved chip breaking



Example of start values for TCMT 09T3 (TCMT 3(2.5)....)

Metric

PF	PM	PR
RE=0.4 (KAPR 91°) a_p: 0.3 mm (0.1–2.0) f_n: 0.11 mm/r (0.06–0.22) v_c: 430 m/min (375–465)	RE=0.8 (KAPR 91°) a_p: 1.7 mm (0.6–3.2) f_n: 0.2 mm/r (0.10–0.30) v_c: 380 m/min (345–440)	RE=1.2 (KAPR 91°) a_p: 2.0 mm (1.2–4.0) f_n: 0.3 mm/r (0.15–0.42) v_c: 345 m/min (310–405)

Inch

PF	PM	PR
RE=0.016 (KAPR 91°) a_p: 0.012 inch (0.004–0.079) f_n: 0.004 in/r (0.002–0.009) v_c: 1410 ft/min (1230–1525)	RE=0.032 (KAPR 91°) a_p: 0.067 inch (0.024–0.126) f_n: 0.008 in/r (0.004–0.012) v_c: 1245 ft/min (1130–1445)	RE=0.047 (KAPR 91°) a_p: 0.079 inch (0.047–0.157) f_n: 0.012 in/r (0.006–0.017) v_c: 1130 ft/min (1015–1330)

Choose a suitable insert grade

Choose a grade and coating suitable for the operation and the workpiece material. Keep in mind that PVD-coated grades usually have sharper edge lines than CVD-coated grades, creating less cutting force and torque. The latest information about all-round and complementary grades can be found on our website.

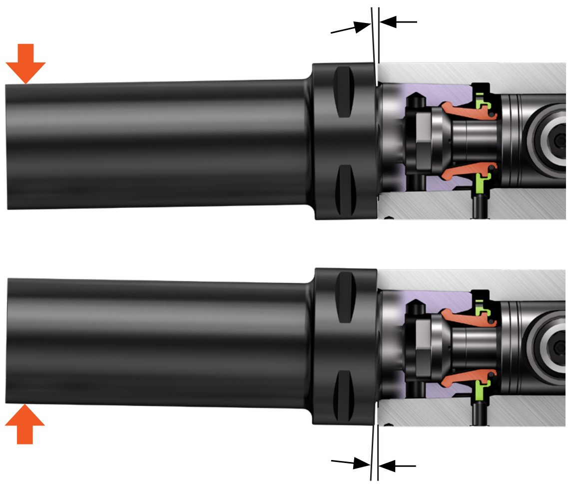
4.4 Clamping of rotating tools

Proper clamping of cutting tools is essential for achieving good machining results. For rotating tool assemblies, the stiffness and stability in the spindle interface clamping are determined by its bending moment and torque capacity.

The spindle interface includes high-precision male and female parts locked together by a defined clamping force. This coupling remains stable if the clamping force maintains pressure over the entire contact surface, ensuring no relative movement between the two coupling parts.

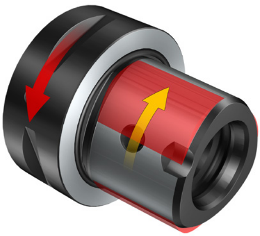
As tool assemblies increase in length and become heavier, clamping becomes more demanding. Factors such as mass (weight), bending forces, twisting forces and unbalance need to be considered.

If the bending forces exceed the clamping forces, contact pressure in the coupling surface begins to drop. This is the starting point for instability.



With even higher bending forces, a total breakdown in the male or female part of the coupling can occur.

If the tool torque exceeds the coupling capacity, drive keys or coupling polygons can be damaged.



The bending moment at the point of instability varies significantly across different spindle interfaces. This is when the flange starts to lose contact. Traditional steep taper connections have the lowest bending moment capacity due to their limited clamping force.

Spindle interface design	Size	Clamping force, N (lbf)	Bending moment at the point of instability, Nm (lb-ft)
BIG PLUS® ISO/CAT/BT 7/24 taper	40	12 000 (2 703)	40 (30)
	50	24 000 (5 405)	70 (52)
HSK-A/C	63	18 000 (4 054)	200 (148)
	100	45 000 (10 135)	1100 (811)
	125	70 000 (15 766)	1800 (1328)
Coromant Capto® (gas spring or mechanical spring clamping)	C5	32 000 (7 207)	415 (306)
	C6	41 000 (9 234)	700 (516)
	C8	50 000 (11 261)	1000 (738)
		70 000 (15 766)	1700 (1254)

From the point of instability, it is possible to put more load on the coupling before it breaks. Note that the recommended maximum loads on Coromant Capto® couplings are lower for operations with forced vibrations, such as a rotating application with interrupted cuts, compared to a turning application with continuous cuts.

Coromant Capto® size	**Recommended max torque, Nm (lb-ft)**	**Recommended maximum bending moment, Nm (lb-ft)**	
		Continuous cut	**Interrupted cut**
C3	320 (235)	400 (295)	170 (125)
C4	580 (430)	720 (530)	300 (220)
C5	1 000 (740)	1 220 (890)	600 (440)
C6	2 000 (1 475)	2 300 (1 670)	1 200 (885)
C8	4 000 (2 950)	4 500 (3 320)	2 100 (1 550)
C10	8 000 (5 900)	9 000 (6 640)	2 700 (1 990)

Maximum load limits for steep taper and HSK is hard to find, the figures below are taken from a publication by Makino.

Spindle interface design	**Size**	**Clamping force, N (lbf)**	**Maximum torque, Nm (lb-ft)**	**Maximum bending moment, Nm (lb-ft)**
ISO/CAT/BT 7/24 taper	40	12000 (2703)	510 (376)	230 (170)
	50	24000 (5405)	1500 (1106)	920 (680)
HSK	A-63	18000 (4054)	300 (221)	420 (310)
	A-100	45000 (10135)	1130 (833)	1250 (920)
		70000 (15766)	1700 (1254)	3750 (2770)

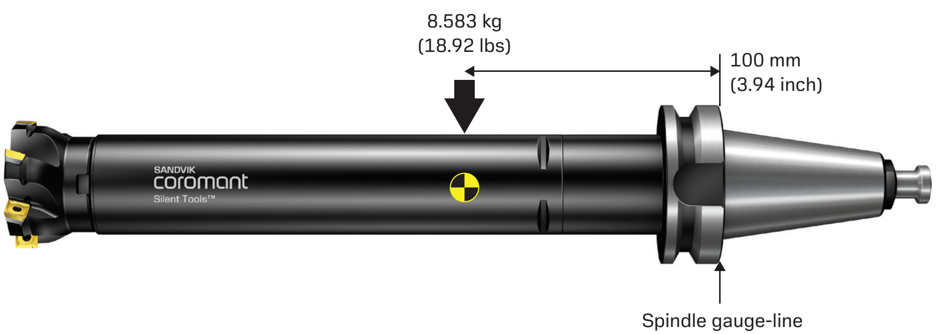
Source: Makino – Machining Titanium – Part 2 – Tool-Bending moment

Note: Spindle interface capacity may limit metal removal capacity. Estimating bending moments and torque is a planned calculation for machining operations. Be aware of the point of instability and aim to operate well below maximum load limits for the spindle interface.

How to calculate the mass moment if the machine tool spindle is not vertical

Always include the mass moment from the vertical tool assembly gauge line in the bending moment estimates. Watch the YouTube video on how to calculate mass moment.

How to calculate mass moment
https://www.youtube.com/watch?v=bLN4GxljYMA



8.583 kg × 9.81 m/s^2 ×0.100 m = 8.42 Nm
(3.94 inch × 0.0833 × 18.92 lbs = 6.2 ft-lb)

Regularly check spindle interface parts for signs of coupling overload, such as impacts, scratches or fretting (see below). If any damage is observed, replace worn parts and reduce chip load to avoid breakages.

Fretting is a type of wear that occurs as two or more materials are repeatedly moved against each other under a load. Vibration is one of the most common causes of fretting. Fretting is often accompanied by corrosion.

4.5 Building slender tool assemblies

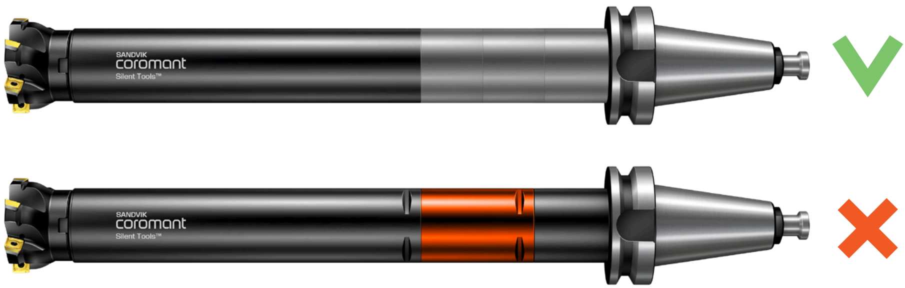
When dealing with long and heavy rotating tool assemblies, the machine tool must handle significant weights, bending moments and unbalance. Slender tools can easily deflect, which can lead to vibrations in the tool assembly. These vibrations may resonate, causing damaging chatter.

Minimizing lengths is very important. Even with the perfect solution that has the smallest possible length-to-diameter ratio, we find that extremely long, slender tool assemblies still have limited performance.

Silent Tools™ adaptors are available in various lengths, which enable building high-performance assemblies tailored to different requirements. Always choose the shortest possible assembly for the feature to be machined.

The damper in a standard Silent Tools™ adaptor is tuned to be used with one Sandvik Coromant adaptive item between the adaptor and the machine tool spindle. An additional extension will reduce or completely eliminate the effect of the tuned mass damper.

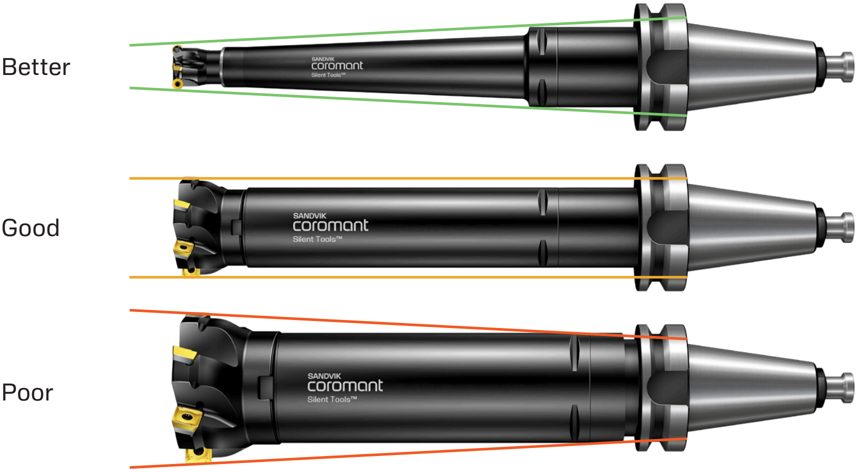
If longer assemblies are needed, ask for a special engineered Silent Tools™ adaptor optimized for the application.



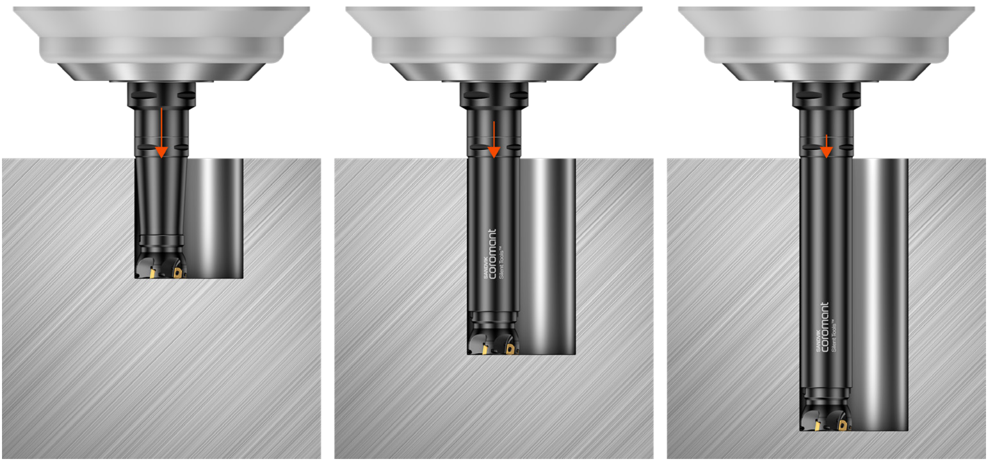
The spindle interface should limit the tool shank and cutter diameters. Typically, a normal assembly will have a cylindrical shank with a diameter smaller than the effective spindle interface diameter and carry a cutter that is only slightly oversized compared to the tool shank diameter.

Less weight at the front of the tool assembly increases stability. Additionally, a smaller cutter may have a higher productivity potential as it runs with less torque and causes less tool deflection.

Never build long tool assemblies with increasing body diameters in the workpiece direction. Such assemblies become too big and heavy for the spindle interface, with high risk of spindle overload and no potential for productivity.



To maximize productivity and profitability from start to finish, it is beneficial to use different tool assemblies. Begin with a short assembly, continue with a medium-length assembly and use an extreme-length assembly only for the final portion. Utilizing three assemblies in cavity milling can potentially reduce operation time by 40% or more. Never build the tool assembly longer than required.

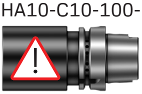


v_f= 30 mm/min (1.18 in/min) 20 mm/min (0.787 in/min) 10 mm/min (0.394 in/min)

Do not use Coromant Capto® C10 Silent Tools™ adaptors in steep taper 50 machine tool spindles. The small steep 50 spindle interface diameter is too weak to hold the C10 assemblies.

C10-390B.58-50 140 	C10-390B.140-50 140 	C10-A390.44-50 140 
C10-390B.558-50 140 (BIG-PLUS) 	C10-390.540-50 140 (BIG-PLUS) 	C10-A390.544-50 140 (BIG-PLUS) 

Do not use Coromant Capto® C10 Silent Tools® adaptors in HSK 100 machine tool spindles. The small spindle interface diameter is too weak to secure tool stability.

HA10-C10-100-155 

Do not use full-diameter Coromant Capto® C6 Silent Tools™ adaptors in steep taper 40 machine tool spindles. The assembly will be too heavy for the small spindle interface diameter.

C6-390B.55-40 075 	C6-390B.140-40 085 	C6-A390B.45-40 085 
C6-390B.555-40 075 (BIG-PLUS) 	C6-390B.540-40 085 (BIG-PLUS) 	C6-A390.45-40 090 

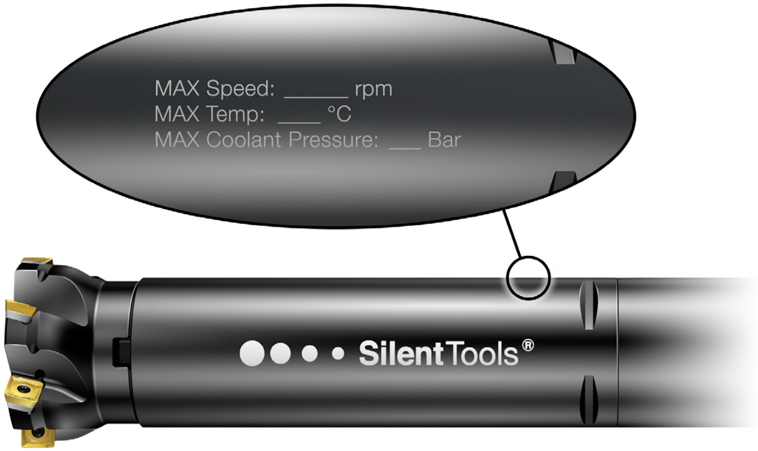
Coromant Capto® C6 Silent Tools™ adaptors with reduced body diameters may be considered for use in steep taper 40 basic holders. Check the spindle stability before starting to cut material.

C6-390B.55-40 075 	C6-390B.140-40 085 	C6-A390B.45-40 085 
C6-390B.555-40 075 (BIG-PLUS) 	C6-390B.540-40 085 (BIG-PLUS) 	C6-A390.45-40 090 

4.6 Working conditions

Operating condition limits

The operating condition limits are laser-marked on each tool or adaptor.



Exceeding the maximum **body temperature** will soften rubber elements, potentially disabling the damper temporarily or permanently. In any case, this will accelerate the aging of elastomer elements and reduce the expected lifetime of the damper.

Exceeding maximum **coolant pressure** may cause coolant fluid leakages into the damper, leading to permanent malfunction.

The damper mass inside a Silent Tools™ adaptor can move from side to side. If it moves out of the adaptor centerline, it will create unbalance in the rotating tool.

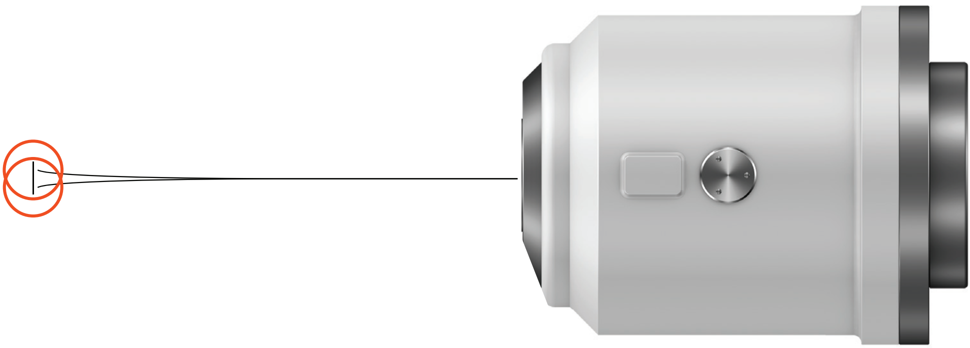
The maximum **rotational speed** specified on a Silent Tools™ product is related to the strength and stability of the product itself. This speed can only be reached if the adaptor is mounted directly into a well-maintained spindle and carries a standard cutting unit.

The maximum **speed limit** will be reduced with longer assemblies, increased run-out, and weaker spindle interfaces. Be careful not to exceed the spindle capacity of the machine tool.

Exceeding the maximum **torque** or maximum **load** marked on the product may cause permanent deformation or mechanical breakdown.

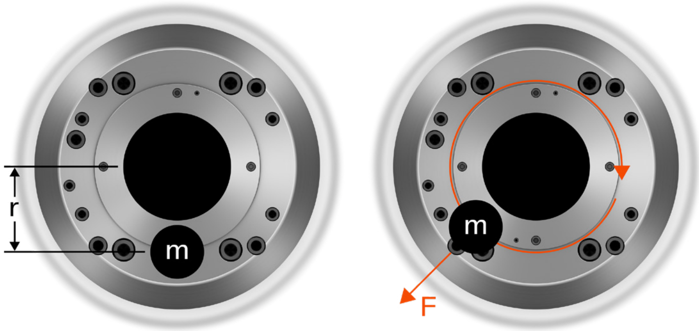
Speed limits

The speed limit for rotating tool assemblies is primarily determined by unbalance. If the mass center in the assembly is not exactly at the center of rotation, the tool assembly will experience unbalance. Unbalance is caused by uneven mass distribution, axial run-out and radial run-out.



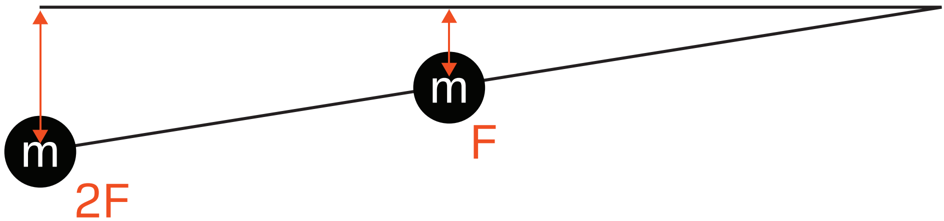
Factors increasing unbalance are:
— Longer tools
— Greater mass (weight)
— Number of modular couplings
— Higher rotational speed

Even a small mass, at a short distance from the centre of rotation, will generate a considerable centrifugal force as the speed of a rotating tool assembly increases.

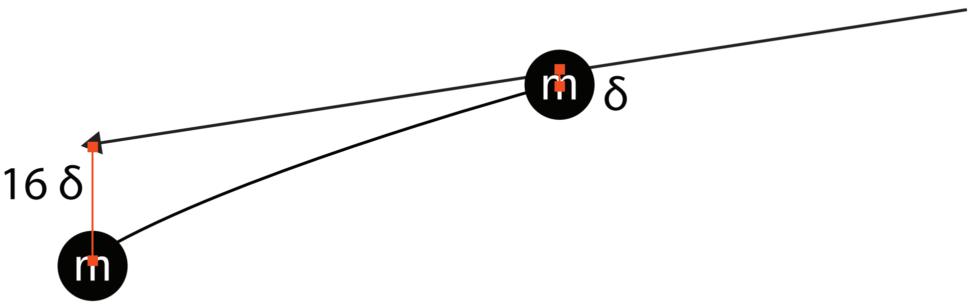


m = 0.35 kg (0.024 slugs) / r = 0.5 mm (0.02 in) / S = 3 500 RPM
$F = mr\omega^2 = mr\times(2\pi\times S/60)^2$ = 33 N (7.4 lbf)

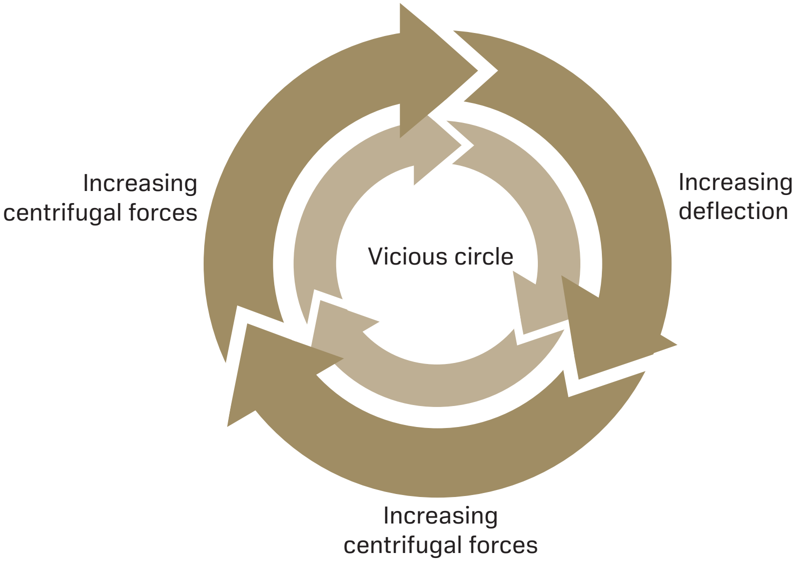
Run-out multiplies with length, and centrifugal forces multiply with run-out.



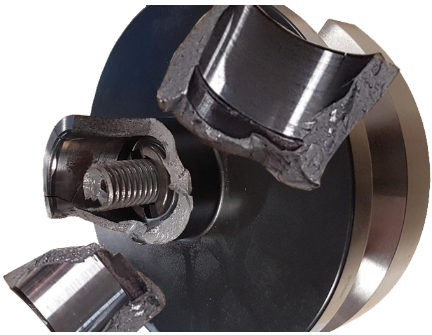
Simultaneously, stiffness decreases significantly with increased length. Doubling the length results in a 16-fold increase in deflection.



As the length of the assembly and rotational speed increase, a vicious cycle can occur where forces, deflection and run-out amplify each other, potentially leading to disintegration of the tool assembly. Avoid this scenario at all costs.



Unbalanced tool assemblies can cause disintegration.



How to determine maximum tool assembly RPM

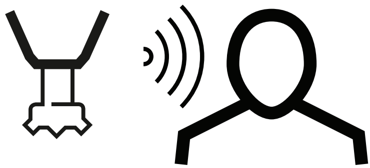
The maximum speeds specified for individual components within an assembly cannot be used to determine the maximum speed for the entire assembly. It is essential to evaluate how each machine tool handles each tool assembly at the intended speed and spindle orientation.

Example of maximum speeds for individual components.

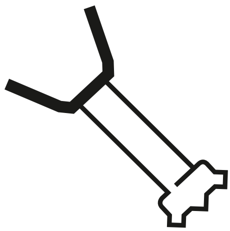
		
825D-70TC11U-C5M Max 7 000 RPM	C5-390.410-63-090C Balanced by design	Machine tool spindle Max 18 000 RPM

Follow these steps to safely find maximum RPM for each tool assembly:

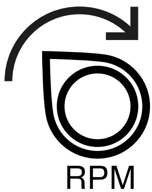
1. Run the spindle from low to the intended speed with no tool (or a short tool) to set a reference for sound and possible panel vibrations in the machine tool.



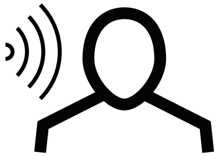
2. Mount the slender tool assembly in the machine tool spindle and turn the spindle to the intended orientation for the operation.



3. Start the spindle drive and slowly increase the spindle speed from low RPM towards the intended speed for the operation.



4. Listen carefully to the sound of the spindle drive and touch the machine tool panels. STOP immediately when vibrations can be sensed. Set maximum RPM well below the STOP point where vibrations were sensed.



Cutting data, start values and optimization

When selecting cutting data for boring and milling applications, it is essential to start with reliable sources to ensure optimal performance and tool longevity. CoroPlus® Tool Guide should be your first choice for determining cutting data starting values, as it provides comprehensive recommendations. Alternatively, use the insert box data or the Ifind app for quick access to the CoroPlus® Tool Guide and insert start values.

CoroPlus® Tool Guide
sandvik.coromant.com/toolguide

Launch CoroPlus® Tool Guide and find cutting data using these features:

— Find a cutting tool based on your workpiece material
— Find a cutting tool based on a given task
— Find machining process and cutting data
— Find recommended cutting data for your specific tool

Note: Becoming an expert user is easy! Just view the films online to get started with CoroPlus® Tool Guide. Learn useful tips and tricks to become an expert.

Milling

CoroPlus® Tool Guide for milling operations
Make sure to select a good milling concept for slender tools and a medium to light geometry insert.

1. After obtaining your results in CoroPlus® Tool Guide, ensure that the recommended spindle speed is well below the maximum RPM for your tool assembly in the actual machine tool.
2. Reduce the axial depth of cut (a_p) starting value to 30–50% of the recommendation to minimize deflection, especially with a slender tool assembly.
3. Understand the different parameters in milling, such as whether the feed is table feed or feed at the cutting diameter.
4. Keep the feed, speed and power within the machine tool's capacity limits.
5. Run your modified starting values and find the maximum axial depth of cut without causing vibrations at the chosen feed and speed.
6. Check if reducing the speed improves stability; if not, consider increasing the speed.
7. Increase the chip thickness (tool path feed rate) until you reach the maximum for the insert or meet your surface finish requirements.

Working from the insert box recommendations

1. Adopt the recommended chip thickness for your starting feed value. Refer to the material specifications and adjust the cutting speed to maintain a good insert lifespan, especially if the workpiece material has a different hardness or is more abrasive.
2. If the recommended speed results in high RPM for the tool, ensure that this speed is within the maximum safe RPM for the tool assembly before increasing it.
3. Start with a low axial depth of cut when using a slender tool assembly to limit deflection, aiming for 30–50% of what you would use with a short solid tool assembly.

Guidelines for highest productivity with slender milling tools
— Use a moderate cutting speed to ensure spindle stability
— Maintain a low axial feed to limit radial tool deflection and vibrations
— Choose medium to large radial engagement to reduce cutting force variations
— Increase the toolpath feed to maximize the metal removal rate

Boring

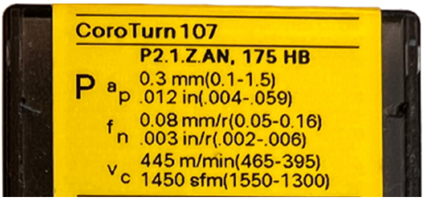
CoroPlus® Tool Guide for internal boring operations

Make sure to select an insert geometry with a starting depth of cut value that closely matches the radial depth of cut you plan to achieve. Keep in mind that the radial depth of cut capacity is limited for small-diameter boring heads and slender tool assemblies.

1. After obtaining your results in CoroPlus® Tool Guide, ensure that:
   - The radial depth of cut is within the tool's capacity
   - The spindle speed is appropriate for the tool assembly
   - The power and torque are within the machine tool's capacity limits

2. Use the recommended speed and feed as your start values.

Working from the insert box recommendations



1. Ensure to stay within the recommended values for radial depth of cut and feed. Refer to the material specifications and adjust the cutting speed to maintain a good insert lifespan, especially if the workpiece material has a different hardness or is more abrasive.
2. If the recommended speed results in high RPM for the tool, verify that this speed is within the maximum safe RPM for the tool assembly before applying or increasing the speed.

Optimizing starting values

If you are successful with the starting value data but want to increase the penetration rate:

— Consider how increased speed and feed affect tool stability, surface finish, and chip breaking

— Monitor the calculations to see how power and torque develop with higher penetration rates

Issues with chip breaking

— Try using a more closed geometry or a geometry with more negative cutting action
— Dry machining and/or higher cutting speeds can introduce more heat into the chip, improving breakage
— Note that materials vary, lower cutting speeds in aluminium can cause built-up edge, while higher speeds make the material more ductile and harder to break

Issues with chip evacuation

Directed high pressure coolant or increased coolant flow (volume) might me the solution. Alwasy check the working condition limits for tool assembly and machine tool, and how possible coolant solutions may react with the workpiece material.

For more information about how to apply boring, visit our knowledge pages.

How to apply boring
sandvik.coromant.com/how-to-apply-boring

4.7 Troubleshooting

There are several factors to avoid vibration and chatter in your boring and milling applications. Ensuring the tool assembly, spindle interface, and machine tool structures are rigid and have sufficient stiffness and additionally, the cutting edge should cut with less force and minimal force variations to minimize vibrations and chatter.

Factors to consider are:

— Static and dynamic stiffness
— Spindle stability
— Cutter (diameter, concept, entering angle, pitch)
— Tool orientation
— Milling method and cutter path
— Spindle speed variation system
— Highest MRR potential
— Silent Tools™ technology

Static and dynamic stiffness

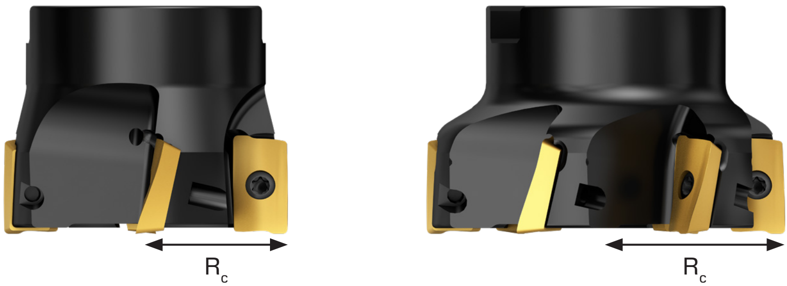
Increase static and dynamic stiffness to keep vibrations to a minimum. Static stiffness is increased by reducing the assembly length and increasing the body diameter. Dynamic stiffness is increased by reducing the weight in the front of the tool to raise harmonic frequencies and reduce kinetic energy in possible vibrations. Also, use smaller diameter cutters when possible and look for cutters, boring heads and bridges made of lighter-weight aluminium or titanium materials.

Spindle stability

To ensure spindle stability at the intended rotational speed, address any unbalance that may cause vibrations due to centrifugal forces exceeding the spindle's capacity. Replace assembly components with excessive run-out and adjust counterweights on boring bridges. Run the assembly without cutting material to ensure it is not operating near critical speeds. Note that products with tuned mass dampers inside the tool body cannot be dynamically balanced.

Cutter diameter

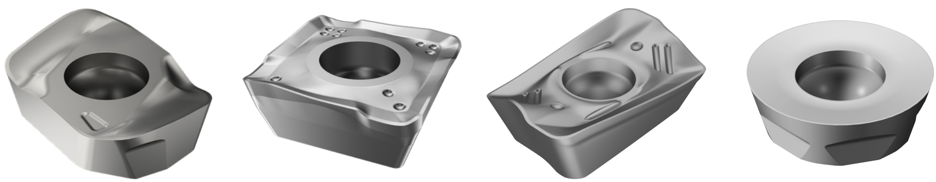
Reducing the milling cutter diameter can reduce torque, maximum chip thickness, bending moments, and tool deflection while maintaining the same metal removal rates.



$$T = F \times R_c$$

Cutter concept

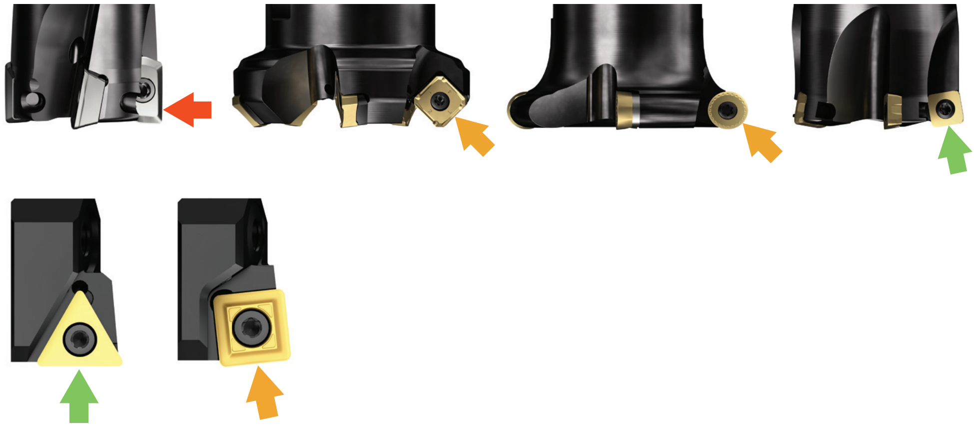
Further reduction of cutting forces and tool deflection can be achieved by choosing positive light-cutting insert concepts.



Positive insert concepts: CoroMill® MH20, CoroMill® 490, CoroMill 390® and CoroMill® 300.

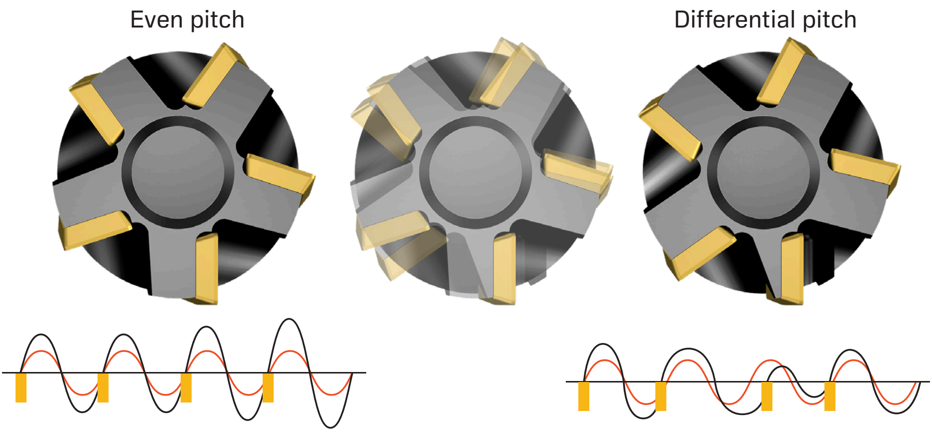
Cutter entering angle

Also, consider changing entering angles and insert radii to reduce radial portion of the cutting forces and tool deflection in milling and boring applications.



Cutter pitch

It is recommended to use a cutter with a differential pitch rather than an equal pitch if possible. Differential pitch cutters have uneven distances between the inserts, which will break the rhythm in cutting-edge entrances and exits, thereby reducing the chance for resonance.



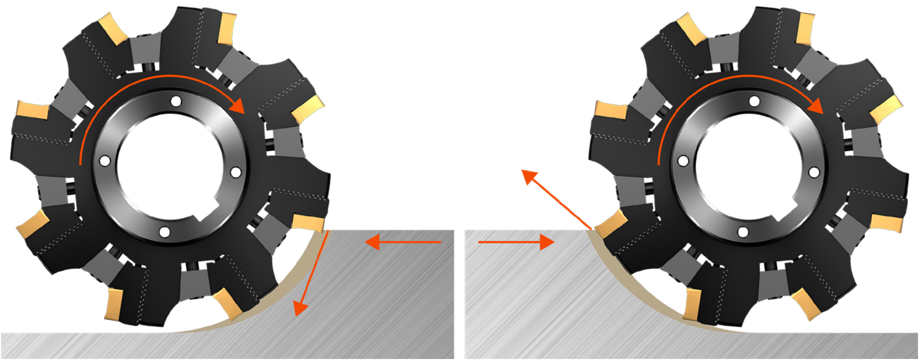
The black curve is the resulting amplitude.
The red curve is the tool assembly's natural vibration.
Yellow boxes are cutting edge entrance into workpiece material.

Tool orientation

Consider changing tool orientation to alter cutting forces into the axial direction and reduce tool deflection.

Milling method and cutter path

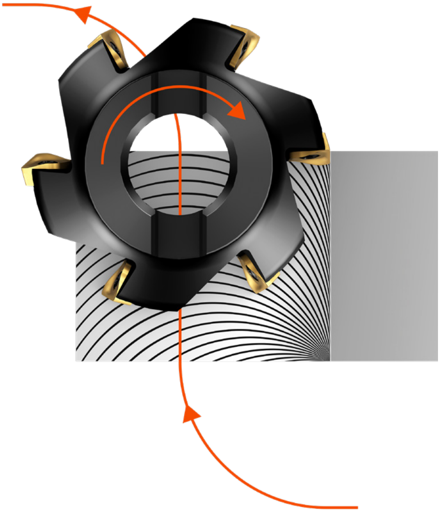
Down (climb) milling is always recommended when using carbide inserts, as it ensures a “thick to thin” chip formation and a soft workpiece exit. Up (conventional) milling creates a thick chip on exit, increasing the risk of free vibration on the workpiece exit, followed by a reverse impact on the insert flank. This can lead to increased insert wear and reduced tool life.

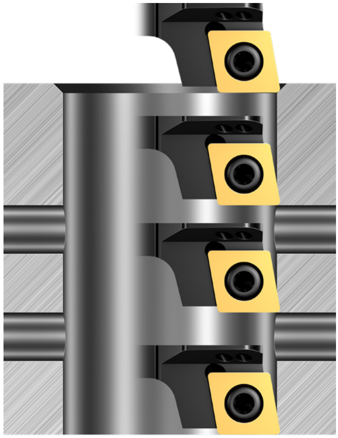


Down (climb) milling

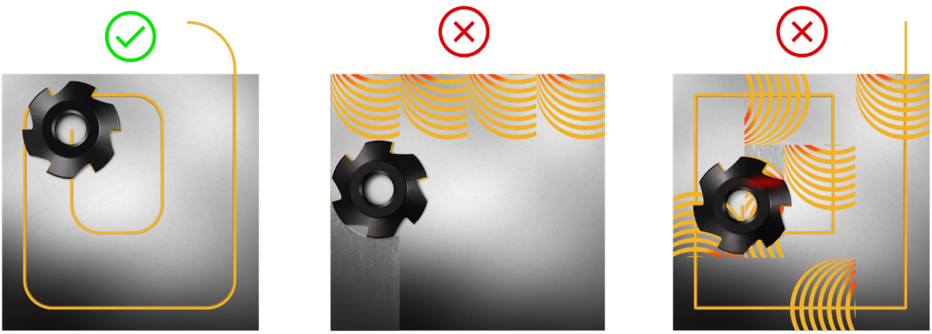
Up (conventional) milling

Rolling in and out of cut when milling reduces the impact and risk of tool breakage, surface damage and vibrations. Form entering and exit chamfers or reduce the boring tool feed when entering a bore and passing through cross-holes or bores.

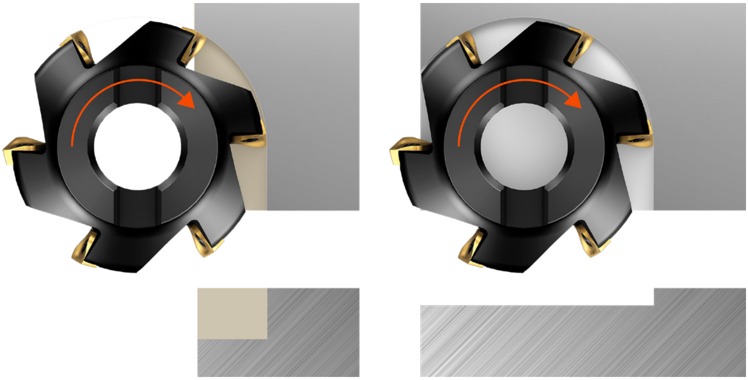




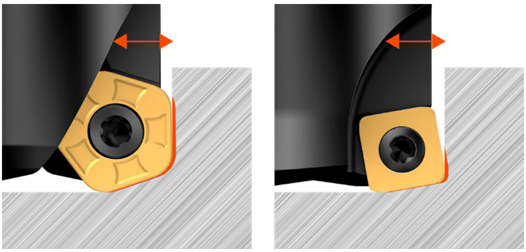
Keeping the milling cutter constantly in cut and rolling around corners avoids repeated entrances and exits.



Smaller axial depth of cut and more inserts in engagement (bigger radial engagement) may cut the same volume with less cutting force variation and less vibrations.

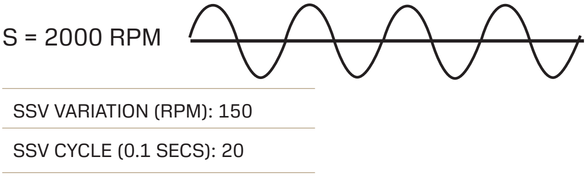


Ensuring clearance for secondary insert edges reduces variations in chip load and cutting force from possible vibrations in the tool assembly.



Spindle speed variation

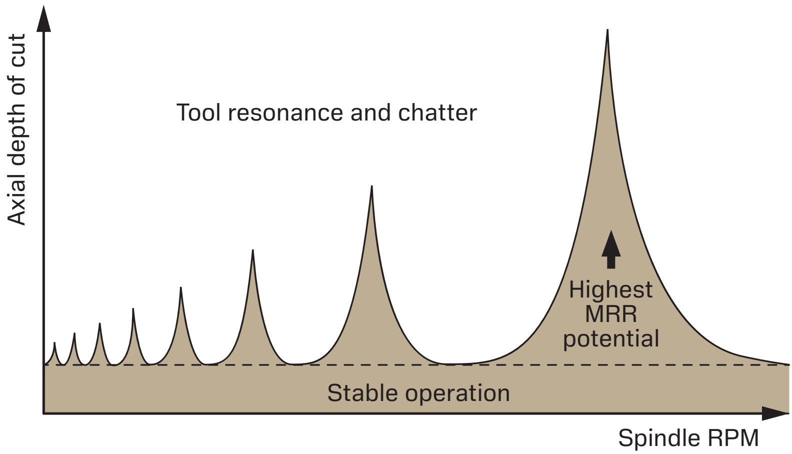
Most machine tool control systems have an optional function called SSV (Spindle Speed Variation). SSV enables the setting of a small but continuous variation in spindle speed, which breaks up the rhythm in forced vibrations. This helps reduce the chance of resonance building up and causing serious chatter.



Highest MRR (Metal Removal Rate) potential

Unbalance in the spindle and tool assembly varies with the rotational speed. Instead of selecting conservative cutting data to avoid chatter, you can identify specific rotational speeds where the tool assembly and spindle system exhibit higher stability, allowing for more aggressive cutting data without chatter.

This can be done experimentally through extensive testing at different cutting data, or by using vibration sensors to analyze the individual assembly behaviour in the machine tool. The results can then be used as input into software (e.g. CutPro / Harmonizer) to predict a stability lobe diagram. Optimization based on data from a stability lobe diagram can give significant rewards, especially for high-speed machining of aluminium.

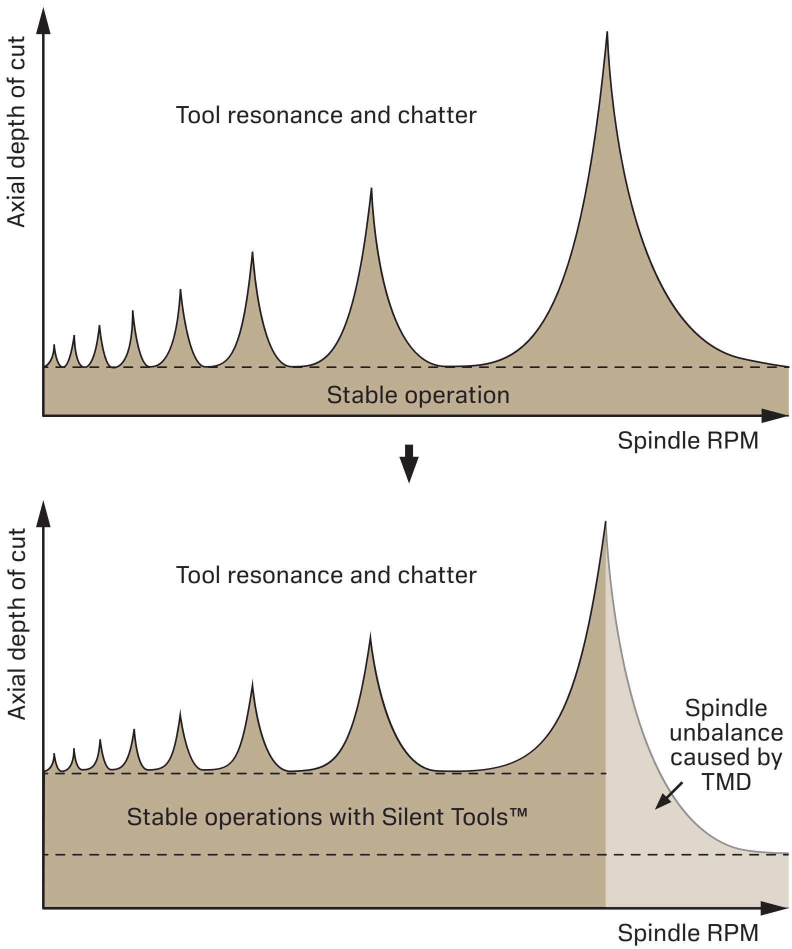


The Silent Tools™ technology is a powerful feature to overcome vibration. The perfectly tuned mass damper inside the tool shank allows the baseline for a stable operation to be elevated to a much higher level.

Finding certain RPMs for higher stability

Even for the individual Silent Tools™ assemblies in different machine tool spindles, you may find certain RPMs have higher stability. However, be aware that with the tuned mass damper inside, there is a first critical speed determined by the damper's natural frequency, which you must not exceed. See chapter "How to determine maximum tool assembly RPM" on page 80 on how to find maximum speed.

Some modular concepts are not suited for TMD (tuned mass dampers). Even the heaviest and most perfectly tuned damper will have little or no effect if it is located too far behind the cutting edges. The mass (weight) involved will be too much for the damper, and the damper will be too far from where the action is. The figure below indicates that the potential effect of the damper drops dramatically as the TMD is moved away from the cutting edges.

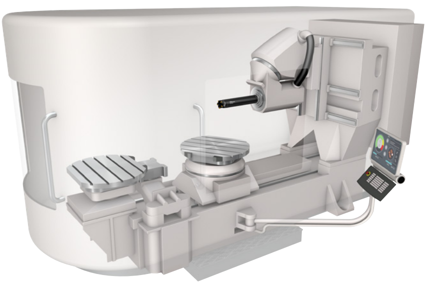


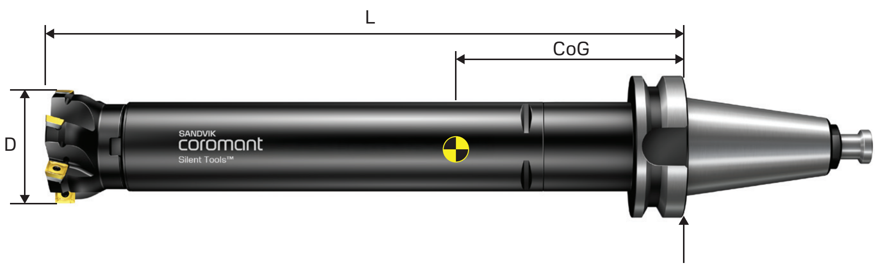
This is why some modular concepts cannot be used with TMDs, they add too much length and mass in front of the damper. The TMD will not be effective in these concepts; it would be like trying to dampen a fishing rod with a damper located close to the reel.

Four keys to sustainable operations with rotating tools

Key 1: Keep tool assembly within limits for the machine tool

— Find assembly length, vital diameters, mass (weight), and center of gravity
— Calculate assembly mass moment for ATC (automatic tool change) operations
— Do not exceed the limits for tool assembly dimensions, weight, and mass moment





Horizontal orientation	Vertical orientation
Horizontal distance to CoG is maximum. Assembly mass moment is maximum. MM = W (weight) × L (length) Nm (ft-lb)	Horizontal distance to CoG = 0 Assembly mass moment = 0

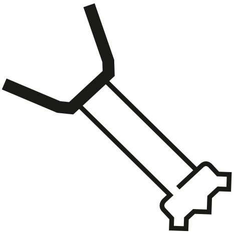
Key 2: Do not overload the spindle interface with the intended application

— Calculate the maximum torque and bending moment in the spindle interface from the intended application. Torque = Tangential cutting forces × Cutting tool radius
— If you do not have a machining calculator available, you can do your estimates
  - Torque ≈ $K_c \times a_p \times f_n \times r_C$ Nm (lb-ft)
  - Bending moment ≈ $F_t \times L + W \times CoG$ Nm (lb-ft)
— Ensure that your estimated bending moment at gauge line is below the spindle interface capacity given for the machine tool. If it exceeds this liming, reduce the intended cutting data

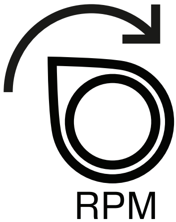
Key 3: Ensure no unbalance at intended rotational speed

— When running the machine tool spindle at the intended RPM. Listen to the sound and touch the machine tool panels. This is now your reference
— Make sure operational speeds are kept below the point of spindle unbalance

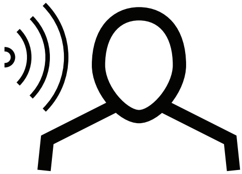
Review chapter "How to determine maximum tool assembly RPM" on page 80 for additional information.



Clamp assembly in spindle and rotate spindle to intended orientation.



Slowly increase spindle from zero toward intended speed with assembly in free air.



Listen carefully, touch machine panels and STOP when vibrations are sensed.

Key 4: Ensure chatter-free machining at all times

— Build short assemblies to increase assembly stiffness
— Choose positive inserts with sharp edges to cut with less force, and redirect cutting forces to reduce deflection

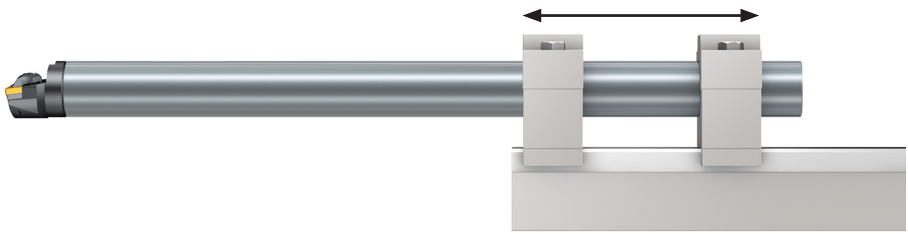
When you have all four keys in place, your operation will run for a long time and yield the best possible long-term profit.

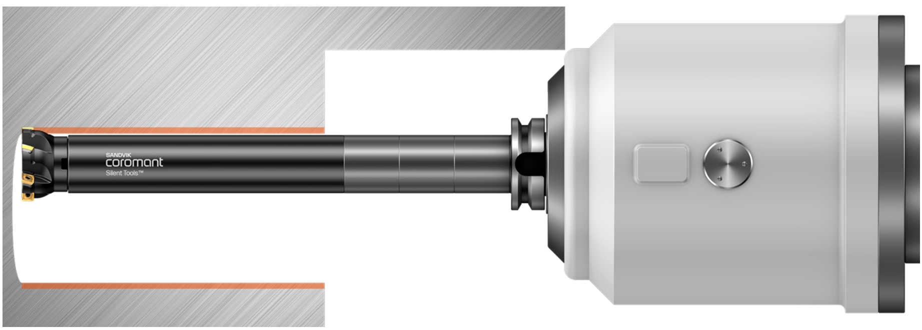
5 Engineered solutions

When you are not able to build the required assembly according to recommendations with standard Silent Tools® adaptors, you may request a special tool quotation (RFQ).

To ensure that the designers get the best possible basis for your rotating adaptors and tools or turning tools and their damper designs, the following information is required:

- Workpiece material
- Intended type of operation(s)
- Pre-machined feature dimensions, condition, and workpiece access for tool assembly
- Machine tool maker, model
- Tool clamping design, tool clamping length and turret or spindle interface
- Feature dimensions and surface requirements after machining
- Proposed turning cutting head, milling cutter or boring head, cartridges and inserts
- Possible proposed spindle adaptive item (between Silent Tools™ adaptor and spindle interface)





Additional information in request:
— Supply a component drawing/model to get the most optimized tool with lowest cost and highest performance
— Indicate on component drawings which surfaces to be machined
— Include the diameter and length of these surfaces

General rules for optimization of a Silent Tool® solution:
— Minimize the weight in front
— Maximize the diameter at the machine side
— Minimize the overhang
— Secure the best possible machine/clamping stability
— Secure the best possible workpiece stability

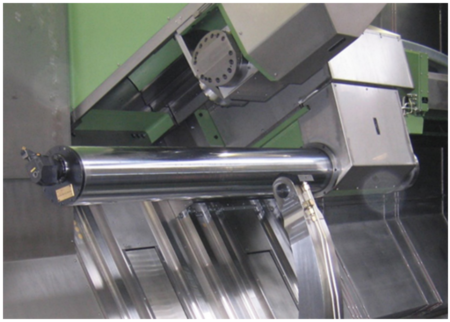
We will define and optimize your engineered Silent Tool™ according to your input and general specifications.

Special solutions for multi-task machine tools

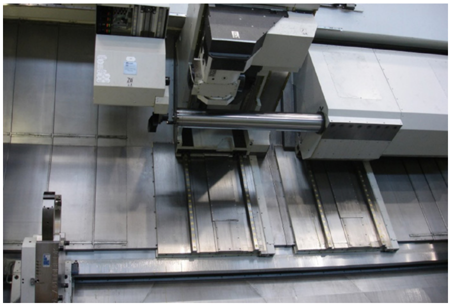
As multi-task machines are equipped with all the necessary tooling to perform complete machining in one set-up, they have to store both short and long tool holders in the tool magazine, plus all the cutting units needed for performing the complete operations. A range of long boring bars, with manual or automatic front-clamp systems, is available for the most common machines supplied. Examples are shown on the two following pages.

Mazak:
— Bar diameter: 100 or 120 mm (3.94 or 4.72 inch)
— Design ready with Coromant Capto® C6, C8 or special short BBT50 ATC front coupling
— Automatic tool change (ATC) activated by a mechanical spring

WFL:
— Bar diameter 100 up to 300 mm (3.92 or 11.81 inch)
— Design ready with Coromant Capto® C8 or HSK100
— Coolant ≤ UHPC 350 bar (5076 psi)
— Automatic tool change (ATC) activated by hydraulic oil

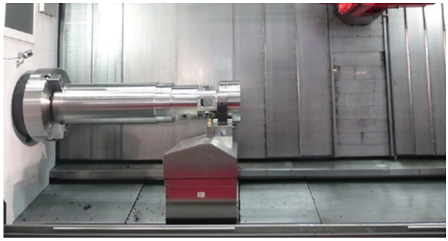


Niels Simmons:
— Bar diameter 100 up to 300 mm (3.92 or 11.81 inch)
— Design ready with Coromant Capto® C8 or HSK100
— Coolant ≤ UHPC 350 bar (5076 psi)
— Automatic tool change (ATC) activated by hydraulic oil

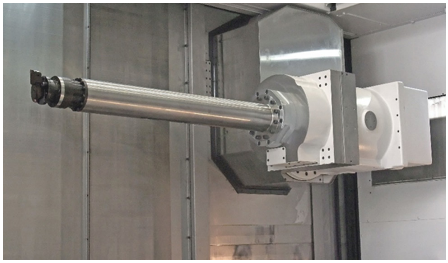


Weingartner:
— Bar diameter 100 up to 250 mm (3.92 or 9.84 inch)
— Design ready with Coromant Capto® C8 or HSK100
— Coolant ≤ UHPC 350 bar (5076 psi)
— Automatic tool change (ATC) activated by hydraulic oil

DMG Mori:
- Bar diameter 120 mm (4.72 inch)
- Design ready with Coromant Capto® C8
- Automatic tool change (ATC) activated by gas spring

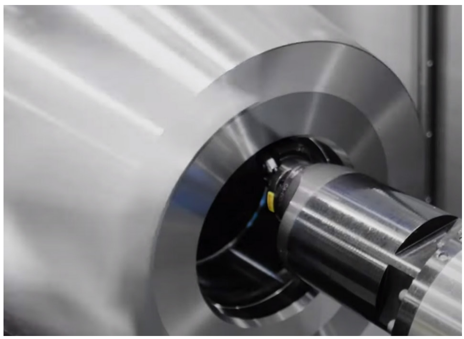


Okuma:
- Bar diameter 120 mm (4.72 inch)
- Design ready with Coromant Capto® C8
- Coolant ≤ UHPC 350 bar (5076 psi)
- Automatic tool change (ATC) activated by hydraulic oil



DN Solutions:
Coromant Capto® C4
- Bar diameter 100 mm (3.94 inch)
- Rigid clamping in cylindrical split holder
- Coromant Capto® C4 automatic tool change (ATC)
- Dedicated C4 tool magazine in the machine

Coromant Capto® C4 with ATC in the front
- Bar body diameter 100 mm (3.94 mm)
- The most precise and rigid coupling available
- Flexible and modular



6 Formulas and definitions

ISO 13399 is an international standard that strives to simplify the exchange of data for cutting tools.

There is a standardized way of describing product data regarding cutting tools. When all tools in the industry share the same parameters and definitions, communicating tool information becomes very straightforward.

What does this mean to you?
It means that your systems can talk to ours, as they all speak the same language. Download product data from our website and use it directly in your CAD/CAM software to assemble tools that you use in production. No need to look for information in catalogues and interpret data from one system to another. Imagine how much time this will save you!

Cutting tool parameters
sandvik.coromant.com/cutting-tool-parameters

Formulas and definitions for turning (metric)

Cutting speed, m/min

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

Spindle speed, rpm

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

Machining time, min

$$T_c = \frac{l_m}{f_n \times n}$$

Metal removal rate, cm^3/min

$$Q = v_c \times a_p \times f_n$$

Specific cutting forces

$$k_c = k_{c1} \times \left(\frac{1}{h_m}\right)^{m_c} \times \left(1 - \frac{\gamma 0}{100}\right)$$

Average chip thickness

$$h_m = f_n \times \sin \text{KAPR}$$

Net power, kW

$$P_c = \frac{v_c \times a_p \times f_n \times k_c}{60 \times 10^3}$$

Symbol	Designation/ definition	Unit
D_m	Machined diameter	mm
f_n	Feed per revolution	mm/r
a_p	Cutting depth	mm
v_c	Cutting speed	m/min
n	Spindle speed	rpm
P_c	Net power	kW
Q	Metal removal rate	cm^3/min
h_m	Average chip thickness	mm
h_{ex}	Maximum chip thickness	mm
T_c	Period of engagement	min
l_m	Machined length	mm
k_c	Specific cutting force	N/mm^2
KAPR	Entering angle	degree
$\gamma 0$	Effective rake angle	degree

Formulas and definitions for turning (inch)

Cutting speed, ft/min

$$v_c = \frac{\pi \times D_m \times n}{12}$$

Spindle speed, rpm

$$n = \frac{v_c \times 12}{\pi \times D_m}$$

Machining time, min

$$T_c = \frac{l_m}{f_n \times n}$$

Metal removal rate, in³/min

$$Q = v_c \times a_p \times f_n \times 12$$

Specific cutting forces

$$k_c = k_{c1} \times \left(\frac{0.0394}{h_m}\right)^{m_c} \times \left(1 - \frac{\gamma 0}{100}\right)$$

Average chip thickness

$$h_m = f_n \times \sin (90\ PSIR)$$

Net power, HP

$$P_c = \frac{v_c \times a_p \times f_n \times k_c}{33 \times 10^3}$$

Symbol	Designation/ definition	Unit
D_m	Machined diameter	inch
f_n	Feed per revolution	in/r
a_p	Cutting depth	inch
v_c	Cutting speed	ft/min
n	Spindle speed	rpm
P_c	Net power	HP
Q	Metal removal rate	in³/min
h_m	Average chip thickness	inch
h_{ex}	Maximum chip thickness	inch
T_c	Period of engagement	min
l_m	Machined length	inch
k_c	Specific cutting force	lbs/in²
PSIR	Lead angle	degree
$\gamma 0$	Effective rake angle	degree

Formulas and definitions for milling (metric)

Table feed, mm/min

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

Cutting speed, m/min

$$v_c = \frac{\pi \times D_{cap} \times n}{1000}$$

Spindle speed, r/min

$$n = \frac{v_c \times 1000}{\pi \times D_{cap}}$$

Feed per tooth, mm

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

Feed per revolution, mm/rev

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

Metal removal rate, cm3/min

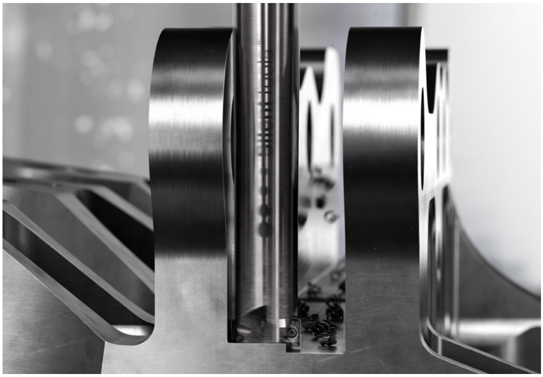
$$Q = \frac{a_p \times a_e \times v_f}{1000}$$

Net power, kW

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

Torque, Nm

$$M_c = \frac{P_c \times 30 \times 10^3}{\pi \times n}$$



Symbol	Designation/ definition	Unit
a_e	Working engagement	mm
a_p	Cutting depth	mm
D_{cap}	Cutting diameter at cutting depth a_p	mm
DC	Cutter diameter	mm
f_z	Feed per tooth	mm
f_n	Feed per revolution	mm/r
n	Spindle speed	rpm
v_c	Cutting speed	m/min
v_f	Table feed	mm/min
z_c	Number of effective teeth	pcs
h_{ex}	Maximum chip thickness	mm
h_m	Average chip thickness	mm
k_c	Specific cutting force	N/mm^2
P_c	Net power	kW
M_c	Torque	Nm
Q	Metal removal rate	cm^3/min
KAPR	Entering angle	degree

Formulas and definitions for milling (inch)

Table feed, inch/min

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

Cutting speed, ft/min

$$v_c = \frac{\pi \times D_{cap} \times n}{12}$$

Spindle speed, rpm

$$n = \frac{v_c \times 12}{\pi \times D_{cap}}$$

Feed per tooth, inch

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

Feed per revolution, in/rev

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

Metal removal rate, in³/min

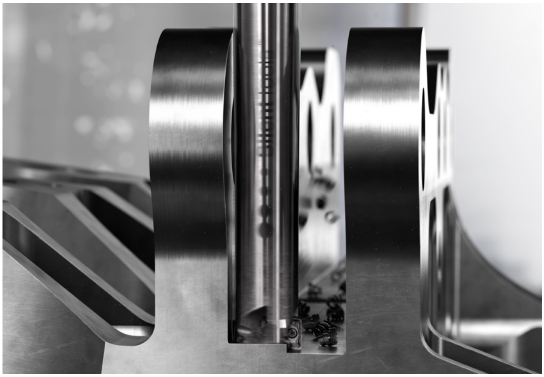
$$Q = a_p \times a_e \times v_f$$

Net power, HP

$$P_c = \frac{a_e \times a_p \times v_f \times k_c}{396 \times 10^3}$$

Torque, lbf ft

$$M_c = \frac{P_c \times 16501}{\pi \times n}$$



Symbol	Designation/ definition	Unit
a_e	Working engagement	inch
a_p	Cutting depth	inch
D_{cap}	Cutting diameter at cutting depth a_p	inch
DC	Cutter diameter	inch
f_z	Feed per tooth	inch
f_n	Feed per revolution	inch
n	Spindle speed	rpm
v_c	Cutting speed	ft/min
v_f	Table feed	in/min
z_c	Number of effective teeth	pcs
h_{ex}	Maximum chip thickness	inch
h_m	Average chip thickness	inch
k_c	Specific cutting force	lbs/in^2
P_c	Net power	HP
M_c	Torque	lbf ft
Q	Metal removal rate	in^3/min
PSIR	Lead angle	degree

Formulas and definitions for boring (metric)

Penetration rate, mm/min

$$v_f = f_n \times n$$

Cutting speed, m/min

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

Spindle speed, rpm

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

Feed per revolution, mm/r

$$f_n = z_c \times f_z$$

Metal removal rate, cm3/min

$$Q = \frac{v_c \times DC \times f_n}{4}$$

Net power, kW

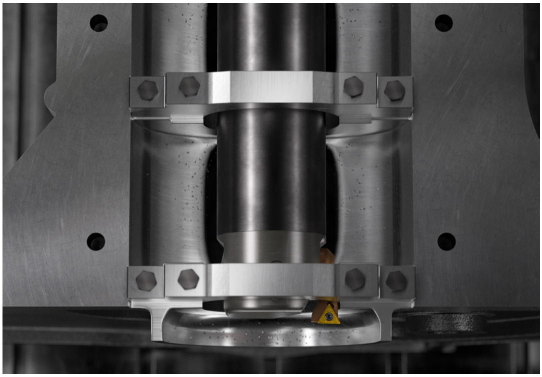
$$P_c = \frac{v_c \times a_p \times f_n \times k_c}{60 \times 10^3}\left(1 - \frac{a_p}{DC}\right)$$

Torque, Nm

$$M_c = \frac{P_c \times 30 \times 10^3}{\pi \times n}$$

Feed force, N

$$F_f \approx 0.5 \times k_c \times a_p \times f_n \times \sin KAPR$$



Symbol	Designation/ definition	Unit
DC	Drill diameter	mm
f_n	Feed per revolution	mm/r
n	Spindle speed	rpm
v_c	Cutting speed	m/min
v_f	Table speed	mm/min
F_f	Feed force	N
k_c	Specific cutting force	N/mm^2
M_c	Torque	Nm
P_c	Net power	kW
Q	Metal removal rate	cm^3/min
KAPR	Entering angle	degree
z_c	Number of effective teeth (z_c = 1 for step boring)	pcs

Formulas and definitions for boring (inch)

Penetration rate, in/min

$$v_f = f_n \times n$$

Cutting speed, ft/min

$$v_c = \frac{\pi \times DC \times n}{12}$$

Spindle speed, r/min

$$n = \frac{v_c \times 12}{\pi \times DC}$$

Feed per revolution, in/r

$$f_n = z_c \times f_z$$

Metal removal rate, in³/min

$$Q = v_c \times DC \times f_n \times 3$$

Net power, HP

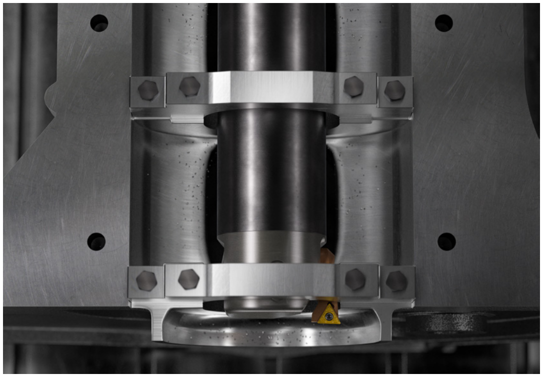
$$P_c = \frac{v_c \times a_p \times f_n \times k_c}{132 \times 10^3} \left(1 - \frac{a_p}{DC}\right)$$

Torque, lbf ft

$$M_c = \frac{P_c \times 16501}{\pi \times n}$$

Feed force, N

$$F_f \approx 0.5 \times k_c \times a_p \times f_n \times \sin KAPR$$



Symbol	Designation/ definition	Unit
DC	Drill diameter	inch
f_n	Feed per revolution	in/r
n	Spindle speed	rpm
v_c	Cutting speed	ft/min
v_f	Table speed	in/min
F_f	Feed force	N
k_c	Specific cutting force	lbs/in²
M_c	Torque	lbf ft
P_c	Net power	HP
Q	Metal removal rate	in³/min
PSIR	Lead angle	degree
z_c	Number of effective teeth (z_c = 1 for step boring)	pcs

Notes

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English
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Learn more
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