How to reduce vibration in metal cutting
Turning - Rotating

Introduction

Vibration in metal cutting is familiar to every machine tool operator. This phenomena is recognised in operations such as internal turning, threading, grooving, milling, boring and drilling, to which there are several reasons why this problem occurs. Some are related to the machine tool itself, to the clamping of the tool, the length and diameter of the tool holder and the cutting data to be used. More of this will be discussed later.

There will be several different actions to consider when solving this problem. Reducing the process parameters is one such consideration, however, this could have a negative effect on productivity. Our focus, therefore, will be easy hands on recommendations for productive solutions and easy to use products. This strategy will be emphasized throughout this guide which will also contain useful information relating to the tool holder e.g. clamping methods, extensions and the types of inserts that can be used.

Stretching beyond the normal limit of 4 x the L/D (Length by Diameter) ratio is possible when using a Silent Tools tool holder.

Silent Tools is a Trade Mark for a family of tool holders for turning, milling, boring and drilling with a damper inside to minimise the problems with vibration. You will find more information about these damped adaptors in a separate chapter. Products with a similar function can be referred to as tuned, damped or anti-vibration tools.

The aim, with this application on hand, is for you to have easy access to information giving you productive solutions for eliminating vibrations in your metal cutting process.

For further information and assistance, please contact your local Sandvik Coromant representative.
Sandvik Coromant – How to reduce vibration in metal cutting
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Turning

Practical tips and hints on how to reduce vibrations

Dimension and tolerance problems:
1. Choose a smaller nose radius.
2. Choose a more wear resistant grade.
3. If there is between 4 x D to 6 x D overhang choose a carbide bar.
4. If there is over 6 x D overhang, choose a Silent Tool.

Chip jamming:
1. Increase the coolant flow.
2. Change the insert geometry.
3. Reduce the cutting speed.
Vibration:
1. Choose a smaller nose radius than the depth of cut.
2. Choose a positive insert with open chip breaker.
3. Increase the feed.
4. If there is between 4 x D to 6 x D overhang, choose a carbide bar.
5. If there is over 6 x D overhang, choose a Silent Tool.

Bad surface finish:
1. Increase the coolant flow.
2. Choose an insert with a sharp cutting edge.
3. Check that all chips have been evacuated.
4. Choose a smaller nose radius than the depth of cut.
5. If there is between 4 x D to 6 x D overhang, choose a carbide bar.
6. If there is over 6 x D overhang, choose a Silent Tool.
Select your tool system

One application within metal cutting that is very sensitive to vibration is internal turning. The different tools for the applications have various parameters that can be adjusted to suit the machine, the component and the material.

In this chapter we will talk about the choice of tooling, various applications, how to minimise the risk of vibration and how to improve productivity.

**Choosing the correct tool for the application**
Depending on the application and the component, it is important to choose the tool that can give the highest output and security.

Depending on the component diameter there are three Sandvik Coromant systems available to you.

**CoroTurn RC** with double-sided negative inserts for applications with hole diameters from 20 mm. This system enables applications from finishing to roughing using modern grades and Wiper inserts for increased productivity.

**CoroTurn 107** single-sided inserts with seven degree relief angle are designed for turning applications with hole diameters from 8 mm and applications where copying is the main focus.

**CoroTurn 111** is a system of inserts with eleven degree relief angle, designed for hole diameters from 6.5 mm - 32 mm where the overhang is generally longer and where there is a need for tools requiring lower cutting forces.
The boring bar families above include insert geometries that are designed for specific applications, such as finish turning of steel materials, roughing in stainless steel machining etc. This is needed to become more productive at every application.

**Solid steel bars**
Recommended for overhangs up to 4 x bar diameter.

**Carbide reinforced bars**
Recommended for overhangs up to 6 x bar diameter.

**Carbide reinforced and damped bars**
Recommended for overhangs up to 10 x bar diameter.
**CoroTurn SL (type 570)**
Modular system for various operations – turning, grooving and threading and holders, including solid steel and Silent Tool holders. Also available are cylindrical bars and Coromant Capto bars. This Coro-Turn SL system of boring bars ranges from 16 mm to 100 mm diameter, and all having the benefit of a quick change system.

**CoroTurn, CoroCut and U-lock solid bars**
Boring bar programme including Coromant Capto steel bars and cylindrical bars with both steel and carbide bar material. Turning operations possible.

**CoroCut MB**
Boring bar programme includes steel and carbide bars focusing on grooving operations but also turning and threading operations are possible. Min hole diameter starts at 10 mm.

**CoroTurn XS**
For internal machining of small bores starting with minimum hole diameter 1 mm. CoroTurn XS enables turning, grooving and threading operations all with one holing system.
**Choice of insert**
Choosing the right insert can be enough to eliminate vibration and also improve your manufacturing productivity.

**Nose radius:**
It is important to choose a nose radius that is smaller than the cutting depth as this has the same effect as choosing the correct entering angle. If the nose radius is too large it will push the tool in the radial direction and affect the dimensions of the component.

Wiper inserts act as a large nose radius and will generally need a bit more care when applying to internal turning. To decrease the radial cutting forces it is a normal requirement to increase the feed.

**Practical hints:**
Always choose a smaller nose radius than the cutting depth.
**Insert size:**
It is important to choose an insert strong enough to withstand the cutting forces but at the same time it must suit the component and its application. Too large a cutting depth will lead to excessive cutting forces and too small cutting depth will lead to increased friction between the insert and component causing component dimension problems.

Cutting force is extremely important when using long overhangs.

**Practical hints:**
- Do not exceed 2/3 of the cutting edge length when turning as this will result in too high cutting forces on the cutting edge.

**Carbide grade:**
Generally when turning small holes with small boring bars it is beneficial to use sharp inserts as this helps to cut the metal more smoothly.

Sharp inserts need suitable grades, and grades such as the GC1025 and GC4015, have relatively thin coatings that will enhance the cutting action.

Choose a grade according to Sandvik Coromant’s CoroKey matrix.

- **Steel grades:**
  - 4000 series and
  - 5000 series (Cermet inserts)
- **Stainless grades:**
  - 2000 series
- **Cast iron grades:**
  - 3000 series
- **All round grades:**
  - 1000 series

**Geometries:**
Sandvik Coromant geometries are designed and dedicated for each application area and component materials. Choose your geometry with the application in mind, finishing-roughing, to give the best possible chip breaking together with good machining results.
Examples of geometry:
- PF: Finishing of steel materials
- PM: Medium machining of steel materials
- PR: Roughing of steel materials

**Practical hints:**
- Choose an open chip breaker, medium chip breaker (PM), instead of a finishing geometry as the finishing geometry can break the chips too hard and lead to excessive cutting forces resulting in bad surface finish.

**Insert style:**
Depending on the operation – longitudinal turning or copying – the choice of insert style affects the result of the machining process.

**Practical hints:**
- T-style inserts are first choice for internal longitudinal turning as this style of insert uses an entering angle at 91 degrees. This helps to direct the cutting forces correctly.

- D and V-style inserts both have good copying possibilities and small insert point angles, which help to reduce the force variation.
Tool overhangs:
Depending on the depth of the hole that needs to be turned, it is important to choose the correct type of tool holder and tool holder material.

Boring bar materials:
As seen on the diagram the following boring bar materials can be selected to suit the length to diameter ratio overhangs.

<table>
<thead>
<tr>
<th>Material</th>
<th>Max Recommended Overhang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel boring bars</td>
<td>Up to 4 x D</td>
</tr>
<tr>
<td>Carbide boring bars</td>
<td>Up to 6 x D</td>
</tr>
<tr>
<td>Steel damped boring bars short design</td>
<td>Up to 7 x D</td>
</tr>
<tr>
<td></td>
<td>Silent Tools</td>
</tr>
<tr>
<td>Steel damped boring bars long design</td>
<td>Up to 10 x D</td>
</tr>
<tr>
<td></td>
<td>Silent Tools</td>
</tr>
<tr>
<td>Carbide reinforced damped boring bars</td>
<td>Up to 14 x D</td>
</tr>
<tr>
<td></td>
<td>Silent Tools</td>
</tr>
</tbody>
</table>

All damped boring bars are called Silent Tools and consist of different variations of tools, the most common being CoroTurn SL (570) system.

Solid bars
Smallest possible overhang.
Max recommended overhang for steel bars 4 x D (l)
Max recommended overhang for Carbide bars 6 x D (l)

Tuned damped bars
l_4 = damped part.
Do not clamp on this area. This is indicated on the boring bar.
Max recommended overhang for damped bars, short design 7 x D and long design 10 x D.
Chip evacuation:
Chip evacuation during boring is critical to performance and the security of the operation. Relatively short, spiral-shaped chips should be aimed for with internal turning. These are easy to evacuate and do not place such large stresses on the cutting edge when chipbreaking occurs. Hard breaking of the chips, when very short chips are obtained, uses more power and increases vibration. On the other hand, long chips make chip evacuation more difficult and present a risk of swarf-clogging. It is necessary, therefore, to choose an insert geometry which, together with the chosen machining parameters, fulfil the requirements for good chip control.

When internal turning is undertaken, the chip flow can be critical – particularly when deep holes are being machined. The centrifugal force presses the chips outwards which means, with internal turning, that the chips remain in the workpiece. The remaining chips can be pressed into the machined surface or get jammed and damage the tool. It is recommended, therefore, that internal turning tools should have internal coolant supply. The chips will then be flushed out of the hole effectively. Compressed air can be used instead of cutting fluid and by way of through holes, allow the chips to be blown through the spindle and collected in a container.
Threading

Choosing the correct tool for the application

Choice of tooling family:

**T-MAX U-Lock** for threading hole diameters from 12 mm

**CoroCut MB** for threading hole diameters from 10 mm

**CoroCut XS** for threading hole diameters from 4 mm

**Chip evacuation:**
Chip evacuation is also very important when internal threading, particularly the feed direction which should be from inside out giving better chip control. This, combined with a modified flank infeed, will produce spiral chips which are then led out towards the mouth of the hole. Overhang, blind holes and material type are also of great importance when internal threading and should be given due consideration.

The infeed per pass should not be more than 0.2 mm and never less than 0.06 mm. Never run a final pass without infeed, and it is important to have a firm force on the bar to minimize vibrations.

**Overhang:**
Compared with turning, threading is limited to a certain overhang due to the increased side (radial) forces. For overhangs beyond 2.5 x D it is recommended to use Silent Tools holders or carbide reinforced shanks to minimize vibration and thus increase productivity.

2 - 2.5 x D solid steel boring bars
3 - 5 x D Silent Tools boring bars
Inserts:
First choice is the all round geometry the GC 1020 for the ISO P, M and K areas. F geometry with its sharp cutting edge is suitable for more tricky materials and C geometry for reliable chip breakage.

Threading applications:
When threading it is possible to change the programme in order to minimize the risk of vibration. By modifying the flank infeed, the axial cutting forces will increase, which will also reduce any vibration.
Grooving

Choosing the correct tool for the application

Choice of tooling family:

**CoroCut** for grooving hole diameter from 25 mm

**T-MAX Q-Cut** for grooving hole diameter from 20 mm

**CoroCut MB** for grooving hole diameter from 10 mm

**CoroTurn XS** for grooving hole diameter from 4.2 mm

Chip evacuation:
To avoid chip jamming within grooving operations it is important to direct the coolant into the groove and evacuate the chips. Chips in the groove can cause insert breakage, bad surface finish or difficulties in keeping tolerances. For this to be effective it is recommended to choose toolholders or cutting heads with integrated coolant.

It is also possible to change the programming of the machine with micro stops so that chip breaking can be achieved and the evacuation of chips is made possible.

Overhang:
Compared with turning, grooving is limited to a certain overhang due to the increased side (radial) forces. We recommend, therefore, you choose Silent Tool holders or carbide reinforced so that the productivity can be increased.

2 - 2.5 x D solid steel boring bars
3 - 5 x D Silent Tool boring bars
**Inserts:**
We recommend you use sharp, light cutting inserts with a positive chip breaker such as the CoroCut – CM or GF geometry or the T-Max Q-Cut 5F or 4G geometry. Also it is beneficial to use thin coated inserts which will enable a smooth cutting action and produce a minimal radial force.

**Grooving applications:**
When grooving it is possible to change the application to minimise the risk of vibration by selecting a smaller insert width and making several cuts instead of one. The operation can then be finished with a side turning motion, see fig.

In order to avoid vibrations when machining large, wide grooves, make several inputs with a narrower insert, (fig A), or groove with a narrow insert and longitudinal turning (fig B).
Problem solving

Chip jamming:
- Use the largest possible amount of coolant as this will help to evacuate the chips from the groove.
- Choose a different geometry to reduce the risk of chip jamming.

Dimension problems (tolerances):
- Choose a Silent tool holder which will reduce the vibration – max overhang is 5 x D.
- Choose sharp and positive insert geometry, CoroCut – CM or ground – GF as it enables a smooth cutting action and minimum deflection from the workpiece.
- Make sure the tool is positioned at correct centre height. The deviation from the workpiece should not be greater than +/- 0.1 mm.
- Have the shortest possible overhang for the application to increase the stiffness of the bar. Max 2 x D for steel bars and max 5 x D for Silent tool bars. A rule of thumb is never to have a tool overhang larger than 8 x \( l_a \) (insert width).
- Choose the largest possible boring bar diameter, to increase stability.

Vibrations (bad surface finish):
- Adjust the cutting speed (\( v_c \)) as the frequency of vibration can change and the vibration eventually can disappear.
- Increase the feed slightly as this can reduce the friction created when grooving and reduce the cutting action. However, this can increase the deflection (the radial force).
- Choose a thinner insert width and make several cuts, especially for the finishing cut.
- Check the clamping of the boring bar.
Holding the bar

After choosing the boring bar material select the most suitable clamping method for the machine in question.

   Stability is the keyword to turn bores to the appropriate criteria such as dimension tolerances and surface finish.

   It is essential, for retaining satisfactory results, to clamp the cylindrical boring bar in a split sleeve, as this will have maximum contact area. With EasyFix sleeves the best possible clamping is achieved together with exact centre height positioning.

   Achieving correct centre height is one of the most important factors towards gaining maximum benefit from the tool system used, as the centre height affects the rake angle and cutting force on the tool.

   Using screws directly in contact with the cylindrical boring bar will not give satisfactory results and maximum performance of the boring bar will not be achieved.

<table>
<thead>
<tr>
<th>Clamping method</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylindrical boring bars in split sleeve:</td>
<td>++</td>
</tr>
<tr>
<td>Boring bars with flats:</td>
<td>+</td>
</tr>
<tr>
<td>Coromant Capto boring bars:</td>
<td>++</td>
</tr>
<tr>
<td>Cylindrical boring bar with screw clamping:</td>
<td>--</td>
</tr>
</tbody>
</table>

(-- = not recommended + = adequate, ++ = very good)

**Practical tips:**

- Use Coromant Capto for its efficient function, good stability and also for the benefits of a quick change system.
- If you are using a cylindrical boring bar, always use split sleeves such as EasyFix giving an exact centre height.

On Silent Tool boring bars it is important not to clamp on the dampening part of the bar. For measurement information see the main turning catalogue and dimension \( l_4 \).

Good clamping of boring bars is a very important factor in all turning
operations in order to achieve the best results. It is particularly important when working with overhangs stretching beyond 4 times the L/D ratio.

Sandvik Coromant also offers a full programme of conventional tool holders.

**Clamping with EasyFix sleeves for cylindrical bars:**
EasyFix gives a fast and simple way to achieve correct indexing of centre height when mounting cylindrical bars into the machine, due to its spring loaded plunger design. Three EasyFix sleeves are available for clamping small 5-25 mm boring bars.

**CoroTurn SL Boring Bars:**
All boring bars have through-tool coolant supply via slots, on bars having diameters of 16 to 25 mm and through holes on the 32 to 60 mm range.

**Cut off length**
If shortening the bar, the minimum overall length from the serration after shortening, is given in the table below. This length includes a four times the diameter clamping length.

<table>
<thead>
<tr>
<th>Bar diameter</th>
<th>Design 570-3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_m$</td>
<td>Short</td>
</tr>
<tr>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>125</td>
</tr>
<tr>
<td>25</td>
<td>155</td>
</tr>
<tr>
<td>32</td>
<td>190</td>
</tr>
<tr>
<td>40</td>
<td>240</td>
</tr>
<tr>
<td>50</td>
<td>305</td>
</tr>
<tr>
<td>60</td>
<td>380</td>
</tr>
</tbody>
</table>
Internal machining theory

**Internal turning**
Many external turning operations are also found in boring, as performed with stationary turning tools, (as opposed to boring operations with rotating tools, such as in machining centres). With external turning, the tool overhang is not affected by the length of the workpiece and the size of the tool holder can be chosen so that it withstands the forces and stresses which arise during the operation. With boring - internal turning - the choice of tool is very much restricted by the component’s hole diameter and length as the depth of the hole determines the overhang.

A general rule, which applies to all machining, is to always minimize tool overhang and to select the largest possible tool size in order to obtain the best possible stability and thereby accuracy. Stability is increased when a larger boring bar diameter is used, but possibilities are often limited, since the space allowed by the diameter of the hole in the component must be taken into consideration for swarf evacuation and any radial movement.

The limitations with regard to stability in boring mean that some extra care must be taken with production planning and preparation. Selecting the right boring bar for the operation, applying it correctly and clamping it properly has considerable effect on keeping tool deflection and vibration to a minimum, and consequently the quality of the hole being machined.
Cutting forces in boring operations:
When the tool is in cut, the tangential and radial cutting forces will endeavour to deflect the tool away from the workpiece.

The tangential force will try to force the tool downwards and away from the centre line, and in doing so will also reduce the tool clearance angle. When boring small diameter holes, it is particularly important that the clearance angle of the insert is sufficient in order to avoid contact between tool and wall of hole.
Boring very deep holes

The internal machining of large diameter holes, deep holes and a combination of both usually needs tool solutions where stability during machining is maximized through combinations of tool solutions. In addition to basic points such as maximum bar diameter; sufficient chip evacuation; positive insert geometry; 90 degree entering angle; correct insert shape; small nose radius and sharp cutting edge; special tool features may need to be considered to provide the boring bar with every weapon there is against vibration tendencies, especially when tolerances are close and surface finish is an issue.

Stability starts at the back end, where the boring bar is clamped in the machine. Coromant Capto or complete encasement of the bar in a sleeve should always be the case.
When discussing tool overhangs of 10 times the diameter or more, damped boring bars and carbide re-inforcement should be considered or a combination of both. The cutting unit coupling is a critical link and needs to be beyond any risk of instability. The front end should also be characterized by low weight. This means that if there is scope for diameter reduction of the cutting unit or the last part of the bar, this is worth considering. It is the back end and the main part of the boring bar that should be as large as the operation permits – even tapered bars are suitable for some applications.

The CoroTurn SL (570 coupling) provides the means for high stability, diameter reduction, quick change of the cutting unit and radial adjustment of the cutting edge (f₁ dimension). Bar diameters of over 40 mm have adaptors which reduce the coupling to accommodate the large 40 mm diameter range of cutting units.
Eliminating vibration with damped boring bars

The usual cause of vibrations during machining is the dynamic interaction between the cutting process and the machine tool structure. The source is the variation of cutting force generated between the tool and workpiece. This force strains the structure elastically and can cause a deflection of the tool and workpiece, which alters the tool-work engagement. A disturbance in the cutting process, such as a hard spot in the work material, causes a typical deflection which then alters the cutting force. This may then cause the initial vibration to be self-sustaining and to build up with the machine oscillating in one of its natural modes of vibration. A long boring bar overhang can be a weak link in the set-up involving machine tool, tool, workpiece and the source of vibration.

In order to achieve sufficient process stability, the metal removal rate is often reduced or the cutting tool changed. But as productivity is normally a priority in manufacturing, this is the wrong route to go. Instead the means of eliminating vibrations and being able to machine at higher rates should be examined. The use of damped boring bars, with damping elements integrated in the boring bars, improves the dynamic behaviour of the tools, making the process more stable.

Generally, machining up to four times the diameter of boring bars does not cause any problems from the vibration point of view, provided that correct conditions apply as regards cutting data and inserts. With an overhang of more than 4 times the tool diameter, vibration tendencies can become more apparent and damped bars come into the picture as the solution. With a pre-tuned boring bar, machining of holes with a depth of up to 14 times the diameter of the bar can be performed with good results.

An increased length from 4 to 10 times the bar diameter will give a 16 times larger deflection for a bar being subjected to the same cutting force. A further extension from 10 to 12 times the bar diameter, gives another 70 % increase in deflection from the same cutting force. Holding the bar length constant while changing the bar diameter from 25 to 32 mm, reduces deflection by 62% for equal cutting forces. Reduced weight of cutting units
or the diameter at the front end of the bar will contribute towards mini-
mizing the vibration tendency.

Damped boring bars – Silent Tools - include tools that are pre-tuned to
the correct frequency in relation to the tool length. This basically means
setting up the damped boring bar and the machine to be set up the same as
a conventional, solid boring bar.

The pre-tuning system of the damped bar consists mainly of a
heavy tuning body (A) with a certain inertia mass, suspended
in two rubber bushes (B), one at each end of the tuning
body. The tuning body is surrounded by a special
oily liquid (C). If vibration tendencies should
arise during the machining process
using a damped bar, the dampening
system will immediately come into
force, and the movement-energy of
the bar will be absorbed into the
tuning system. As a result, vibration is minimized and machining per-
formance maintained or improved.

Q. Metal removal rate (cm³/min)
1. Solid steel bar
2. Carbide alloy bar
3. Short, damped bar
4. Long, damped bar
5. Extra long, damped bar
Silent Tools
Productivity with slender tools

When machining deep cavities or with long overhangs you can be faced with vibration problems. One way to overcome this is to reduce the depth of cut, the speed or the feed.

Losing productivity in favour of keeping the process running is not beneficial.

Productivity is the number one important issue in being competitive. The use of a Silent Tool when going deeper into a bore, will retain, or in many cases improve your productivity. You can keep your depth of cut, the same feed and speed and have a high quality surface finish, closer tolerances and improved tool life even when working with boring bars with overhangs from 7 up to 14 times the bar diameter.

Silent Tools are a family of products for internal turning, milling, boring and drilling. These products are damped to work on overhangs beyond the limitation of solid steel and solid carbide shanks. They are easy to operate and are very flexible due to the wide variety of back-end and front-end couplings.
Which products have Silent Tools

Bar dia. 10 - 12 mm
**CoroTurn 107 and CoroTurn 111 Boring bars**
Pre-tuned and easy to use cylindrical boring bars with carbide shaft. Optimum performance in a split sleeve holder. Do not use screws directly onto the bar. Shank diameter 10/12 mm and min. hole Ø 13 / Ø 16 mm. Recommended tool overhang from 6-10 x bar diameter. Integrated tip-seat pocket designed for T or D style inserts.

Bar dia. 16 - 60 mm
**CoroTurn SL Coromant Capto Boring bars & cylindrical boring bars**
Pre-tuned and easy to use Coromant Capto cylindrical boring bars. Coolant through the centre and 570 coupling in front. Coromant Capto C3-C8 back end coupling. Designed for exchangeable (570) cutting heads. Recommended tool overhang from 4-10 x bar diameter.

**CoroTurn SL Carbide Reinforced Boring bars**
Pre-tuned and easy to use carbide reinforced cylindrical boring bars. Coolant through the centre and 570 coupling in front. Carbide reinforced for increased static stiffness. Optimum performance in a split sleeve holder. Do not use screws directly onto the bar. Designed for exchangeable (570) cutting heads. Recommended tool overhang from 10-14 x bar diameter.

Bar dia. 80-100 mm
**CoroTurn SL quick change Boring bars**
Pre-tuned and easy to use cylindrical boring bars. Coolant through the centre and SL quick change coupling in front. Optimum performance in a split sleeve holder. Designed for exchangeable SL quick change cutting heads or Ø 40 mm 570 cutting heads. Recommended tool overhang from 0-10 x bar diameter.
**Bar dia. 80-300 mm**

**580 Carbide Reinforced Boring bars**
Tunable carbide reinforced cylindrical boring bars. Coolant through the centre and 580 coupling in front. Shank diameter Ø 80 - Ø 300 mm. Carbide reinforced for increased static stiffness. Do not use screws directly onto the bar. Recommended tool overhang from 10-14 x bar diameter. Designed for flat bed machines. Special tools available for slant bed machines. Reduction adaptor in front makes it possible to use a wide range of cutting units.

**580 Boring bars**
Tunable cylindrical boring bars. Coolant through the centre and 580 coupling in front. Shank diameter Ø 80 - Ø 300 mm. Recommended tool overhang from 5-10 x bar diameter. Designed for flat bed machines. Special tools available for slant bed machines. Reduction adaptor in front makes it possible to use a wide range of cutting units.
Milling

Practical tips and hints on how to reduce vibrations

Adaptor Type and Size
1. Choose the shortest possible adaptor. Every millimetre is important.
2. Choose the largest possible diameter/size of the adaptor
3. For small milling cutters use if possible a tapered adaptor.
4. If possible use Coromant Capto instead of a weaker coupling type.
5. For shank couplings and short overhang use a high clamping force adaptor, e.g CoroGrip.
6. For shank couplings and a bit longer overhang it can sometimes be beneficial to use power chucks/collet chucks.
7. For longer overhang (>5xD) use a damped adaptor, a Silent Tool.

Milling Cutter Body
1. Choose the smallest or lightest cutter body possible.
2. Try to balance the radial and axial cutting forces by using a smaller entering angle. E.g 45 or 10 degree. Or maybe a round insert cutter.
3. Choose a milling cutter with a coarse tooth pitch and a positive design.
4. Choose differential pitch.
5. Choose a milling cutter with internal coolant holes for proper supply.
Positioning, radial and axial depth of cut
1. Choose a milling cutter with correct ratio between the milling cutter diameter and the width of the workpiece.
2. The width of cut should be approximately 75% of the milling cutter diameter.
3. Positioning the milling cutter off-centre in relation to the workpiece surface.
4. Reduce the radial and axial depth of cut.

Insert
1. Choose a light cutting geometry (L-geometry) with a sharp cutting edge.
2. If possible choose a grade with thin coating and a sharp cutting edge.
3. Try to reduce cutting forces by using small corner radii and small parallel flats.
4. Adding more damping into a system by using more negative or tough (or even a slightly worn) inserts/cutting edges can in some applications improve the performance.
**Down Milling / Up Milling**
Generally Down Milling is recommended in almost every milling operation wherever the machine, fixturing and workpiece allows it. But in some cases it can be favourable to use Up Milling to reduce vibration tendencies. Especially when fixturing and/or workpiece is weak in a specific direction.

**Cutting Data**
1. If possible try to decrease (or in some cases increase) the cutting speed to move away from the vibration frequency range.
2. Normally increase the feed/tooth. In some cases with unstable conditions it can be better to decrease the feed/tooth.
Workpiece
1. Affix the workpiece in the most favourable way to support the cutting forces which arise during the machining process.
2. Use milling concepts with design and entering angle which generate cutting forces in the most stable direction of the workpiece.
3. Optimize the machining strategy and direction to obtain the most stable cutting conditions as possible.

Machine
1. Choose machining strategy and cutting force directions to take full advantage of the machine stability.
2. Machine condition can have a large influence on the vibration tendencies. Excessive wear of the spindle bearing or feed mechanism will result in poor machining properties.
Select your tool system

In some specific milling operations vibration tendencies will more or less always occur. Sandvik Coromant offers a lot of different milling concepts for a number of different applications. Each concept has its own specific properties and advantages considering machines, fixturing, components, materials, etc.

Below you will find a short description of each milling concept and a guide to what tool to choose for highest productivity and output.

Main applications and Milling concepts

Shoulder Milling

**CoroMill 390** - A positive and versatile cutter concept with a very large assortment for all applications from roughing to finishing. It generates a good 90-degree shoulder and is ideal for ramping and helical interpolation. It’s also suitable for face milling. Insert grades and geometries for all types of workpiece materials.
**CoroMill 290** - A good 90-degree shoulder milling concept with four cutting edges per insert for best economy. It’s the first choice for a square shoulder facemill in short chipping materials (ISO-K) and hardened steel (ISO-H).

**CoroMill 790** - A highly productive 90-degree shoulder milling cutter for a number of different operations from roughing to finishing. The first choice for ISO-N materials. Very good performance in helical interpolations and boring.

**Face Milling**

![CoroMill 245](image)

**CoroMill 245** - The first choice for face milling in most materials, from roughing to finishing. It combines high metal removal rate with very good surface finish. The 45-degree entering angle results in favourable axial cutting forces which minimize the vibration tendencies.
**CoroMill Century** - A lightweight milling cutter concept for face and shoulder milling in ISO-N, ISO-H and ISO-K materials. It is perfect for high speed machining in non-ferrous materials. Balanced cutter body and axial adjustability of the insert contributes to a smooth, stable and vibration-free cutting action.

**CoroMill 300** - A versatile and light cutting round insert concept for face milling, profiling, ramping and helical interpolation. High and vibration-free metal removal with both short and long tools. Insert grades and geometries for all types of workpiece materials.


**CoroMill 210** - A very productive cutter concept, with four cutting edges per insert, for primarily roughing operations in most materials. Suited for a number of different operations where high metal removal rate is a priority. The first choice in rough machining involving high feed face milling, helical interpolation and plunge milling, with or without long tool overhang.

**T-Max 45** - A heavy duty face milling concept for high metal removal in powerful milling machines or machining centres. The 45-degree entering angle and the strong insert allows the cutter to be used under tough and demanding conditions, including long overhangs.
Profile Milling


**CoroMill 216F** - A ball nose concept for high speed finishing to super finishing of profiles. Possible to achieve a workpiece surface finish equal to what’s possible with a solid carbide tool. Insert grades and geometries for all types of materials.

**CoroMill Plura** – A very versatile assortment of solid carbide endmills. Suitable for all type of operations, e.g profiling, shoulder milling, face milling, plunge milling and thread milling. Provides high productivity in all workpiece materials.
Slot Milling

CoroMill 331

**CoroMill 331** - A multi-purpose side and face milling cutter concept with high precision capability for numerous operations. A large standard programme and Tailor Made range make it possible to select and optimize for highest precision or productivity. The design makes the setting easy. Insert grades and geometries for all workpiece materials.

Operations – tool recommendations - some examples and alternative applications

General Shoulder and Face Milling

- Slot Milling - CoroMill 331
- Face Milling - CoroMill 200
- Face Milling - CoroMill 245
- Profile Milling - CoroMill 390
- Shoulder Milling (long edge) - CoroMill 390
- Shoulder Milling - CoroMill 390
- High feed Face Milling - CoroMill 210
- Face Milling - CoroMill 300
- Shoulder Milling, full slot - CoroMill Plura
General Profile Milling

- High feed Face Milling
  - CoroMill 210

- Profile Milling, finishing
  - CoroMill 216F

- Profile Milling, helical interpolation
  - CoroMill 216

- Profile Milling, ramping
  - CoroMill 390

- Plunge Milling
  - CoroMill 210

- Face Milling
  - CoroMill 200

- Profile Milling
  - CoroMill 300

- Profile Milling, helical interpolation
  - CoroMill 300

- Shoulder Milling, slot
  - CoroMill Plura
Aluminium machining, different operations

Profile Milling, pocketing
- CoroMill 790

Face Milling
- CoroMill Century

Slot Milling
- CoroMill 331

Profile Milling, pocketing
- CoroMill 390

Shoulder Milling, slot
- CoroMill Plura
Clamping

One application within metal cutting that is very sensitive to vibration problems is milling with long overhang. The different tools for the application have various parameters that can be adjusted to suit the machine, the component and the material. In this chapter we will show some comparison between different holding systems.

Holding tools for rotating
Coupling comparison

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<th>Bending stiffness</th>
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<th>Positioning and repeatability</th>
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Choice of holding tools
• Use stiff modular tools with good run-out accuracy
• Modular tools increase the flexibility and the possible number of combinations – use largest possible diameter on holding tools (extensions, adaptors) relative to cutter diameter
• For spindle speeds over 20,000 rpm use balanced cutting and holding tools

Long overhangs
The Coromant Capto® modular holding tool system allows combinations of long or short basic holders, extensions and reductions to an assembly of required length, with high stability and smallest run-out.

- maintain max productivity by choosing a series of extension modules for the roughing cutter set-up
- change extensions at pre-determined positions
- adapt cutting data for each tool length
- use damped, tapered bars for overhangs >4 - 5xD
CoroMill® cutters and holding tools with threaded coupling

Silent Tools™

Coromant Capto®  ISO/MAS  HSK

Basic holders

Intermediate adaptors

Solid carbide extension

Coromant Capto®  HSK

CoroMill cutters

210  390  300  216
Hands on information

**Insert grade:**
Choose a small edge rounding (ER).
Go from a thick coating to a thin one, if necessary use uncoated inserts.

**Insert geometry:**
Use sharp and positive inserts with a chip forming capacity.

**Entering angle:**
The smaller the entering angle, the thinner the chip will be and the further it will spread along the cutting edge.
This will allow a higher feed per tooth. Also a smaller entering angle will direct more of the cutting force in axial direction and reduce the risk of vibration.
Tooth pitch:
When machining with long tool overhangs or unstable conditions, it will have a positive effect using a coarse pitch (L) cutter.
Sometimes it can be a good idea to remove some of the inserts (e.g. remove two inserts from a four inserts cutter).

Milling direction:
Down milling is the first choice for most machining operations. In some cases, when the machine has insufficient power, the workpiece is very pliable, there is play in the table feed or vibrations arise during machining, up milling is the best choice. When up milling, remember that the cutting force tends to lift the workpiece up from the work table. This must be counteracted when clamping the workpiece.

Position/diameter:
In general, when face milling, the cutter diameter should be 20-50% larger than the cutting width. The cutter should be positioned slightly off centre. Do not position the cutter dead centre.
When the cutter diameter is smaller than the workpiece, it is recommended that maximum width of cut is 60-70% of the cutter diameter.
In full slot milling, it is very important to reduce the number of inserts to avoid vibrations.
**Entry/exit:**
Avoid a situation where the centre-line or the cutter is in line with the work-piece edge. In this situation the insert is leaving cut when the chip thickness is at its maximum, with very high shock-loads at entry and exit.

**Chip evacuation:**
Use compressed air to prevent recutting of the chips.
   In deep cavity milling, this is especially important.
   Notice that a coarse pitch (L) cutter will have more space to evacuate the chips.
Milling strategy for opening a cavity
There are several ways to open a cavity. Three common methods can be the following:

**Two axis ramping:**
One of the best methods to reach a full axial depth of cut is linear ramping in the X/Y and the Z axis.
If the correct starting point is chosen, there is no need for milling away stock from the ramping section.
Use compressed air to get the chips out of the cavity.

**Three axis ramping:**
Feeding the tool in a helical shaped path in the axial direction. It is recommended that the diameter of the hole is twice the diameter of the cutter.
Remember to check the maximum ramping angle for the cutter. Use compressed air to get the chips out of the cavity.
**Drilling/plunging:**
Pre-drilling followed by a plunge milling operation is a third option to open a cavity. This option requires an extra tool, more time for positioning and an extra position in the tool magazine. The positive advantage is that it is possible to machine with high axial feed.

Use compressed air to get the chips out of the cavity.

**Milling in corners:**
Ensure that all programmed radii are 15% larger than the cutter diameter. Keep the same feed and speed in the corners.
Boring

Practical tips and hints on how to reduce vibrations

Adaptor Type and Size
1. Choose the shortest possible adaptor. Every millimetre is important.
2. Choose the largest possible diameter/size of the adaptor.
3. For long overhang (>4xD) use damped adaptors, Silent Tools.
4. If possible, use a tapered adaptor to increase the static stiffness and to reduce the deflection.
5. For long overhang, make sure to have a rigid clamping with flange contact in the spindle.
Insert
1. Choose a light cutting insert with a positive cutting geometry. Knife-edge inserts are first choice.
2. Choose a small nose radius. For finish boring recommended nose radius is 0.2 mm. Do not use larger nose radius than 0.4 mm. Try to choose a nose radius which is smaller than the depth of cut.
3. Use sharp inserts with relatively thin coatings. Try an uncoated insert. They will have a sharper cutting edge.
4. T-style inserts are first choice for boring operations.

Entering angle
1. The entering angle should be close to 90 deg. This will give more axial cutting forces and less radial/tangential forces.
**Depth of cut**

1. Do not exceed half the cutting edge length when rough boring as this will result in too high cutting forces on the cutting edge. When finish boring the maximum cutting depth is small. Typically less than 0.5 mm.

**Tolerance of hole diameter**

1. For finishing with one insert, a tolerance of IT7 can be achieved under good conditions.
2. Tolerances will be influenced by the clamping of the tool holder, the fixture of the component, wear of the inserts etc.
3. It is recommended that a measuring cut is made to see what adjustment is needed to compensate for tool deflection.
4. To achieve a good surface finish and close tolerances it is important to use cutting fluid. Cutting fluid will prevent recutting of chips and prevent heat expansion of the tool and workpiece.
Select your tool system

For roughing and finishing in boring operations there are several options.

**Boring tools for roughing:**
For roughing operations use Duobore with two inserts or **CoroBore 820** with three inserts. For long overhang, beyond 4 x bar diameter, a damped Duobore adaptor is recommended.

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**Productive boring with three inserts**

**Duobore for general boring**

**Damped for deeper holes**

**Single edge boring with one insert**

**Twin edge boring with two inserts**

**Silent Tools**

**Heavy duty roughing with cartridges and adjustable extension slides**

**Step boring**
Boring tools for finishing:
For finishing operations use a single edge fine boring tool or **CoroBore 825** with one insert.
Hands on information

**Nose radius:**
Use a small nose radius, 0.2 mm is recommended for finishing. A bigger nose radius will give larger radial forces.

**Insert size:**
Do not use a bigger insert size than necessary.

**Geometry:**
Use a sharp and positive geometry. A knife edge insert is a good alternative.

**Insert style:**
Use a T-style insert and a 90 deg. entering angle.

**Tool overhang:**
Always use as short as possible overhang. Machining with tool overhang (from insert tip to gauge line) more than 4 x the shank diameter, use a damped tool, Silent Tools.

**Chip evacuation:**
Use cutting fluid to evacuate and to prevent recutting of the chips. Chips in the form of commas or determined spirals are the ideal.
**Off centre boring**

In some spindles it is possible to do off centre boring. It is important to remember that the centripetal force will increase and that too high spindle speed may give unstable conditions. Machining at long overhangs with damped tools the damping system can be taken out of function due to too high centripetal force. At Teeness.com it is possible to calculate the maximum spindle speed at a certain eccentric radius.

**Step boring**

In rough boring operations with two or more inserts, step boring is an effective way to increase the depth of cut without vibrations. The idea of step boring is to have the inserts set to different radial and axial distance. To achieve different axial distance, shims have to be used.
**Silent Tools**

Silent tools within milling

**Coromant Capto:**
- Shank with metric and inch pilot
- Shank with threaded coupling

**HSK:**
- Shank with metric and inch pilot
- Shank with threaded coupling

- For rough and fine boring operations beyond 4 x dia. tool overhang, it will be a big advantage to use Silent Tools.
- In milling applications, it is more difficult to give an exact overhang ratio when to change from solid tools to Silent Tools. For example will a 390 milling cutter (90 deg. entering angle) have more radial cutting forces than a 210 milling cutter (10 deg. entering angle), and the risk for vibrations to arise is higher. A damped tool might be necessary to maintain good productivity.