

A wide-angle photograph of a sunset over a mountain range. The sky is a gradient of orange and red, with a bright yellow sun partially obscured by the dark silhouette of the mountains in the foreground.

How to reduce vibration in metal cutting

Turning

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 toolholder 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 toolholder.

Silent Tools is a Trade Mark for a family of toolholders for turning, milling, boring and drilling with a damper inside to minimise the problems with vibration. You will find more information about these damped adapters 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.

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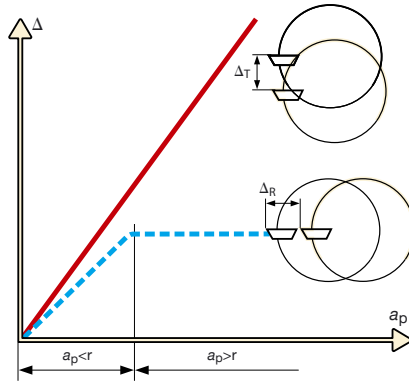
Turning

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Silent Tools

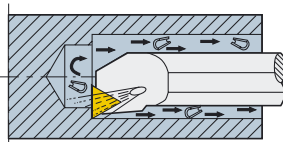
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Practical tips and hints on how to exclude vibration



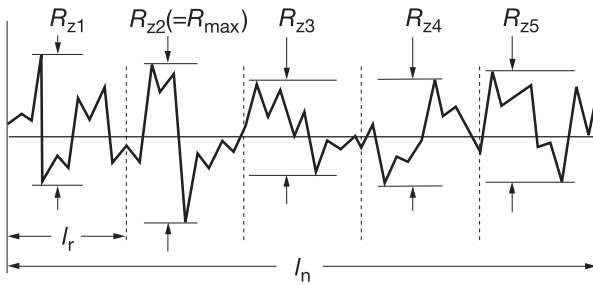
Dimension and tolerance problems:

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.



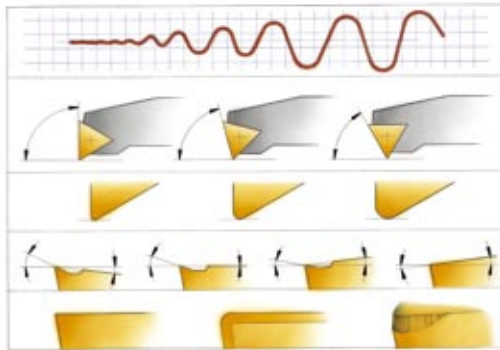
Chip jamming:

1. Increase the coolant flow.
2. Change the insert geometry.
3. Reduce the cutting speed.



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.



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.

Turning

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

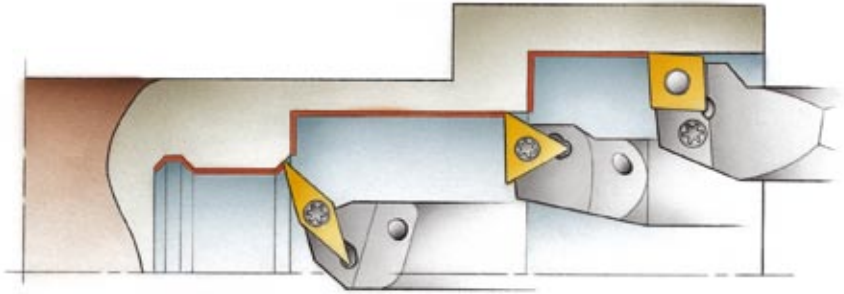
Depending on the application and the component it is important to choose the tool that can give the highest output and security.

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 including 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.

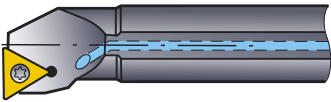
CoroTurn 111 is a system of inserts with eleven degree relief angle, designed for hole diameters from 6.5 mm - 32 mm where the overhang is generally longer and where there is a need for tools requiring lower cutting forces.



The boring bar families above include insert geometry's that are designed for specific applications, such as finish turning within steel materials, roughing of stainless steel machining etc. This is needed to become more productive at every application.

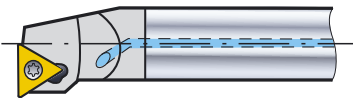
Solid steel bars

Recommended for overhangs up to 4 x bar diameter.



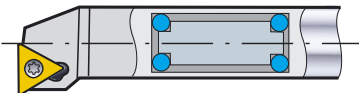
Carbide reinforced bars

Recommended for overhangs up to 6 x bar diameter.



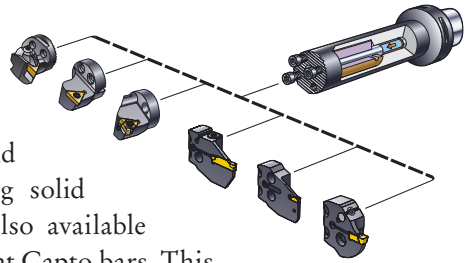
Carbide reinforced and damped bars

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 CoroTurn 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 holding system.



Turning

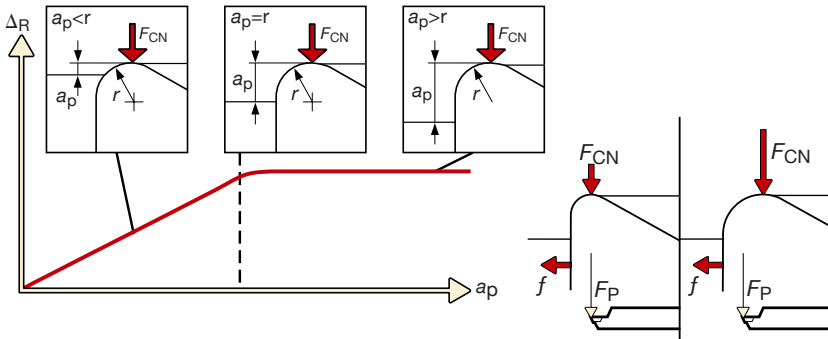
Choice of insert

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 it to internal turning. To decrease the radial cutting forces it is normally required 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 force 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.

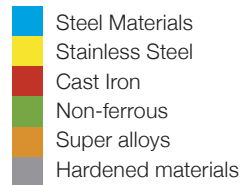
Carbide grade:

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 1025 and 4015, 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 around 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:

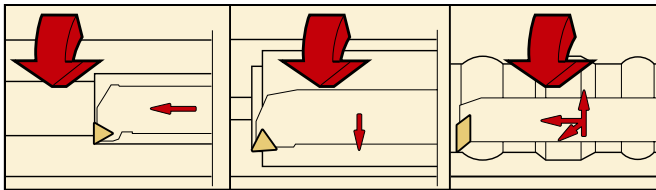
- PF: Finishing of steel materials
- PM: Medium machining of steel materials
- PR: Roughing of steel materials

Practical hints:

- Choose an open chip breaker, medium chip breaker (PM) instead of finishing geometry as the finishing geometry can break the chips too hard and lead to excessive cutting force 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 helps to reduce the force variation.

Tool overhangs:

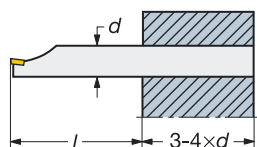
Depending on the depth of the hole that needs to be turned it is important to choose the correct type of tool holder and tool holder material.

Boring bar materials:

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

Steel boring bars:	Up to 4 x D	
Carbide boring bars:	Up to 6 x D	
Steel damped boring bars short design:	Up to 7 x D	Silent Tools
Steel damped boring bars long design:	Up to 10 x D	Silent Tools
Carbide reinforced damped boring bars:	Up to 14 x D	Silent Tools

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

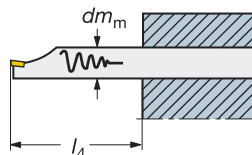


Solid bars

Smallest possible overhang.

Max recommended overhang for steel bars
 $4 \times D$ (l)

Max recommended overhang for Carbide bars
 $6 \times D$ (l)



Tuned damped bars

l_4 = damped part.

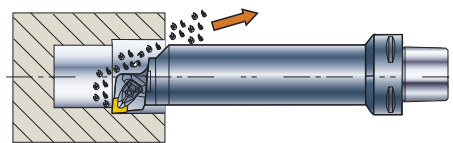
Do not clamp on this area. This is indicated on the boring bar.

Max recommended overhang for damped bars, short design $7 \times D$ and long design $10 \times D$.

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 presents 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, allows the chips to be blown through the spindle and collected in a container.



Chip evacuation is a critical factor for successful boring.

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.

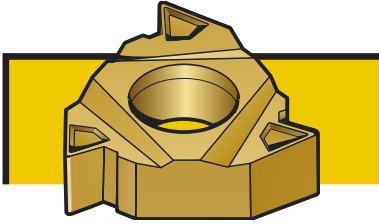
The infeed per pass should not be more than 0.2 mm and never less than 0.06 mm. Never run a final pass without infeed, and it is important to have a firm force on the bar to minimize vibrations.

Overhang:

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

2 - $2.5 \times D$ solid steel boring bars

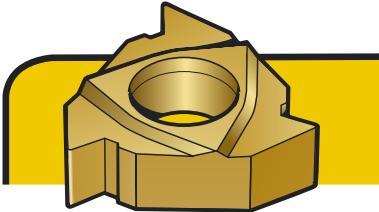
3 - $5 \times D$ Silent Tools boring bars



Rounded (ER treated) cutting edge

First choice in most operations and materials

Example: R166.0G-16MM01-150

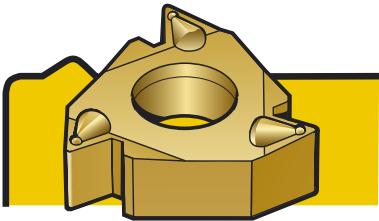


Geometry F

Sharp cutting edge

Reduced cutting forces and good surface finishes

Example: R166.0G-16MM01F150



Geometry C

Chip breaking geometry

For maximum chip control and minimum supervision

Example: R166.0G-16MM01C150

Inserts:

First choice is the all round geometry is 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 program 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. It is recommended, therefore, to choose Silent Tool holders or carbide reinforced so that the productivity can be increased.

2 - 2.5 x D solid steel boring bars

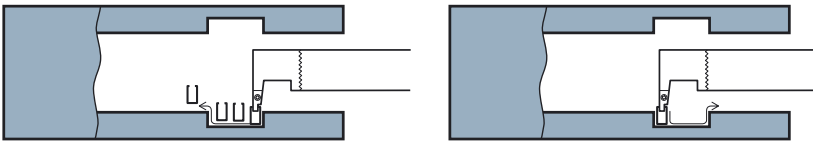
3 - 5 x D Silent Tool boring bars

Inserts:

It is recommended to 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 $5 \times D$.
- Choose sharp and positive insert geometry, CoroCut – CM or ground – GF as it enables a smooth cutting action and minimum deflection from the work piece.
- Make sure the tool is positioned at correct centre height. The deviation from the work piece should not be greater than ± 0.1 mm.
- Have the shortest possible overhang for the application to increase the stiffness of the bar. Max $2 \times D$ for steel bars and max $5 \times D$ for Silent tool bars. A rule of thumb is never to have a tool overhang larger than $8 \times l_a$ (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 it is required to select the most suitable clamping method for the machine in question.

Stability is the key word 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.

Clamping method	Stability
Cylindrical boring bars in split sleeve:	++
Boring bars with flats:	+
Coromant Capto boring bars:	++
Cylindrical boring bar with screw clamping:	--

(-- = 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.

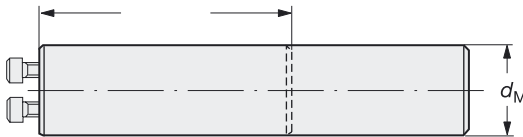
Sandvik Coromant also offers a full program of conventional tool holders.

Clamping with Easy Fix sleeves for cylindrical bars:

Easy Fix 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 Easy Fix 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.



Bar diameter	Design 570-3C	
dm_m	Short	Long
16	100	-
20	120	-
25	145	199
32	190	280
40	220	335
50	250	380
60	300	458

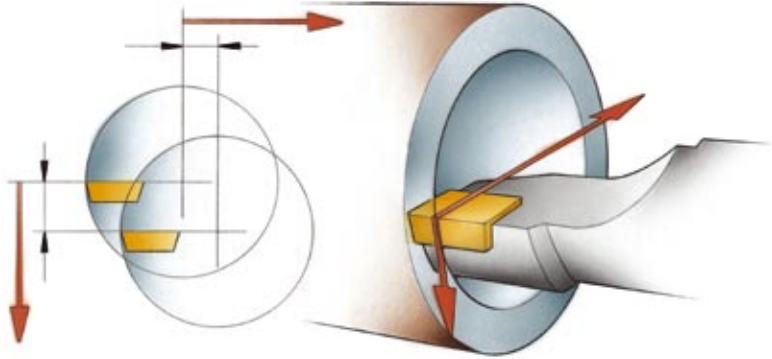
Internal machining theory

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.



Tool clamping at the front end and back end are important performance factors for machining with long boring bars.

When discussing tool overhangs of 10 times the diameter or more, tuned 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 a 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.



CoroTurn SL with radial adjustment.

The CoroTurn SL (570 coupling) provides the means for high stability, diameter reduction, quick change of cutting unit and radial adjustment of the cutting edge (f_1 dimension). Bar diameters of over 40 mm have adapters which reduces the coupling to accommodate the large 40 mm diameter range of cutting units.

Eliminating vibration with tuned 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 tuned boring bars, with damping elements integrated in the boring bars, improves the dynamic behaviour of the tools, making the process more stable.

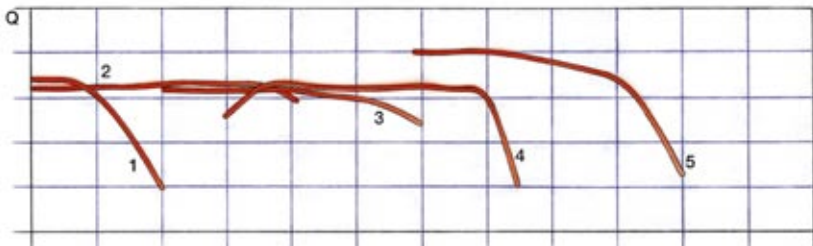
Generally, machining up to four times the diameter of boring bars does not cause any problems from the vibration point of view, provided that correct conditions apply as regards cutting data and inserts. With an overhang of more than 4 times the tool diameter, vibration tendencies can become more apparent and tuned 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 minimizing the vibration tendency.

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

The pre-tuning system of the tuned 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 tuned 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 performance 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 is a family of products for internal turning, milling, boring and drilling. These products are tuned 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

Pretuned 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 \varnothing 13 / \varnothing 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

Pretuned and easy to use Coromant Capto cylindrical boring bars. Coolant through the center 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

Pretuned and easy to use carbide reinforced cylindrical boring bars. Coolant through the center 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

Pretuned and easy to use cylindrical boring bars. Coolant through the center and SL quick change coupling in front. Optimum performance in a split sleeve holder. Designed for exchangeable SL quick change cutting heads or \varnothing 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 center and 580 coupling in front. Shank diameter \varnothing 80 - \varnothing 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 adapter in front makes it possible to use a wide range of cutting units.

580 Boring bars

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

Head office:

AB Sandvik Coromant
SE-811 81 Sandviken, Sweden
www.coromant.sandvik.com

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