

Think **productivity**, Think **HSS**

BROACHING

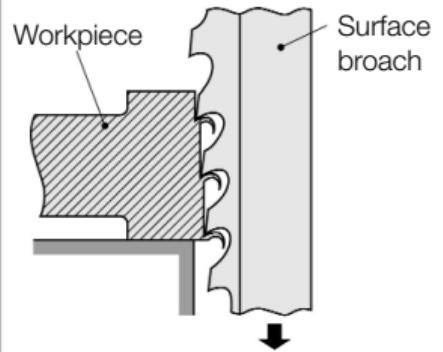
SUMMARY

BROACHING TOOLS

- 2** The basics of broaching
- 3** Benefits of broaching
- 4** Zoom on a broach
- 5** Which HSS for maximum efficiency?
- 6** Coatings for the best performance
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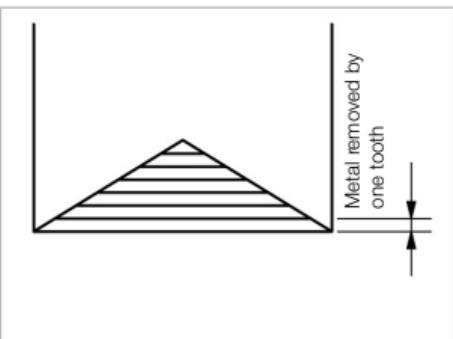
BROACHING PROCESS

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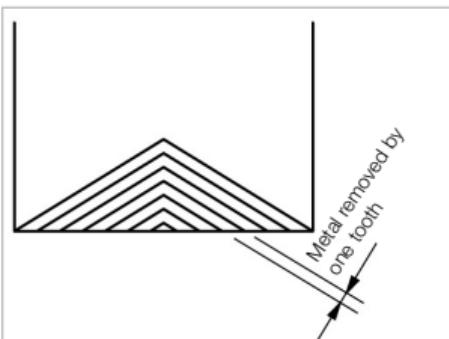


Surface broaching process

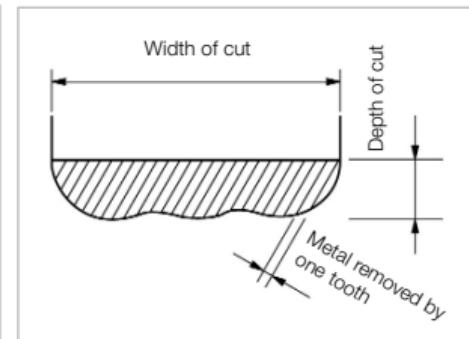
- Broaching is a machining operation in which the tool has a linear displacement.
- The tool shape is the same as the part shape and is well suited to producing complex cross sections.
- In broaching, each tooth progressively removes some material, to produce the final shape.
- All operations (roughing, semi-finishing, finishing) are achieved in a single pass.
- Specially recommended for large series, broaching is an alternative technology to milling, boring, turning, grinding and EDM.
- Prerequisite: the surface to broach must be parallel to the direction of tooth travel.



Conventional cut (OD or Height)



Form cut



Generating cut

The broaching process is extremely accurate. The efficiency demonstrated in heavy production is unmatched by any other process. Broaching is especially suitable for automotive factories where high efficiency and a high level of accuracy is required.

- **Reduced cycle time**

Parts are produced in a single pass (usually requiring less than a minute). With other machining processes, multiple operations are required to produce complex and/or irregular shapes.

- **Excellent process accuracy and repeatability**

Linear displacement means a reduced number of process variables.

- **Superior finish surfaces**

Fine quality is achieved in just one pass. The last teeth of a broach burnish or hone the pieces.

- **Long tool life**

Each tooth of the broach contacts the work surface only once per cycle. Therefore a broach can produce a very large number of parts before it needs resharpening.

- **Simplified training and maintenance**

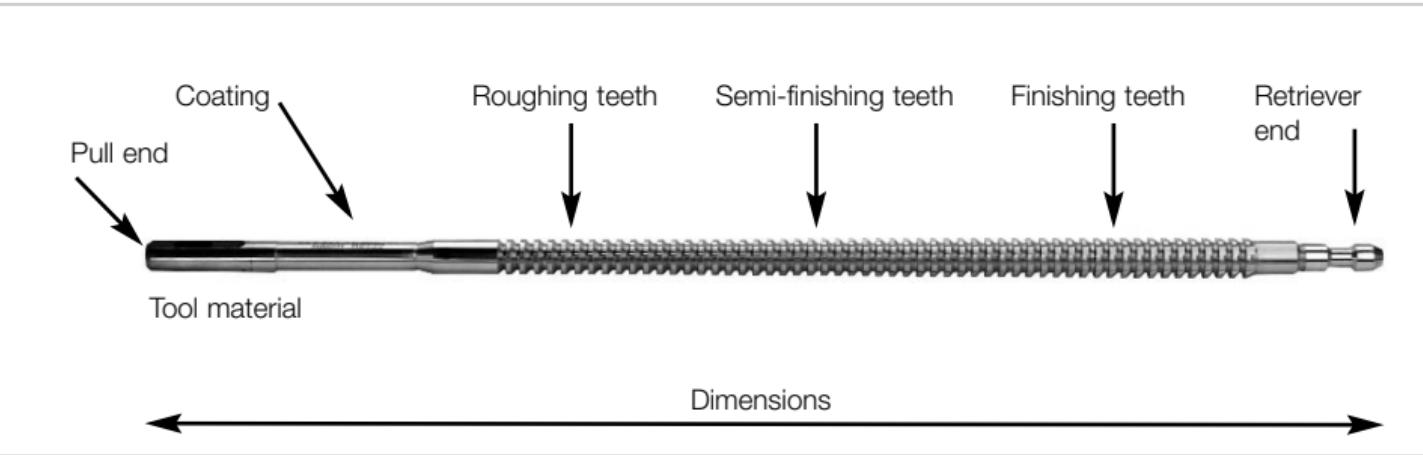
A broach machine is not complex. In addition, the loading and unloading of parts is easy to automatize.

- **Extremely cost competitive process**

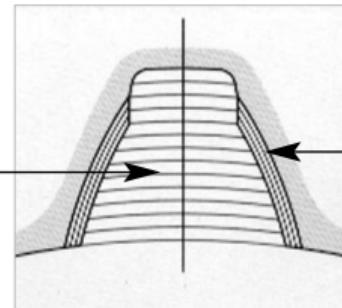
For high productivity, large batches of pieces can be broached in one pass.

TOOL MAKER'S TIP

Remember that
on a broach,
the finishing section
is larger than the
roughing section.



Metal removed
by roughing teeth



Metal removed
by finishing teeth

TOOL MAKER'S TIP

For large series,
boost your
productivity with
HSS-PM broaches

HSS

- For easy-to-machine materials such as aluminium, magnesium, free-machining steels ($R_m < 800$ Mpa)
- Decreasingly used

HSS-E

- Basic choice
- For materials such as steels, stainless steels, cast iron ($R_m < 1000$ Mpa)

HSS-PM (powder metallurgy)

- For higher productivity and longer tool life
- For nickel and titanium alloys
- Suitable for dry machining

TOOL MAKER'S TIP

For even better performance, combine a coating with a HSS-PM substrate.

TiN Gold

- Basic choice
- Improved abrasion resistance
- For longer tool life

TiAlN or TiAlCN Black-violet

- For high speed and high productivity, especially in steels
- Also suitable for microlubrication or dry machining

Steel C45

SUCCESS STORY

Operation

- High speed internal broaching with a TiAlN coated HSS-PM broach and microlubrication

Cutting length

- 30 mm

Benefits compared with machining with a HSS Co broach and oil

- **Cutting speed x10** (v_c 50 m/min vs. 5 m/min)
- **25% longer tool life**
- Better surface roughness
- 15% lower cost per part and lower energy consumption

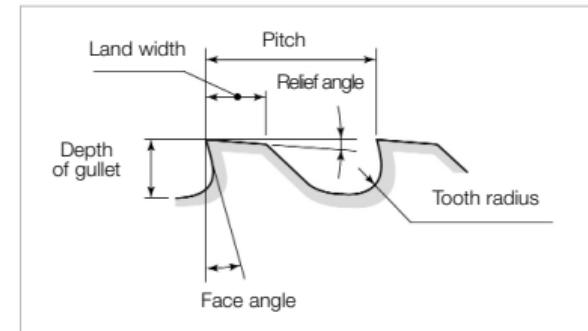
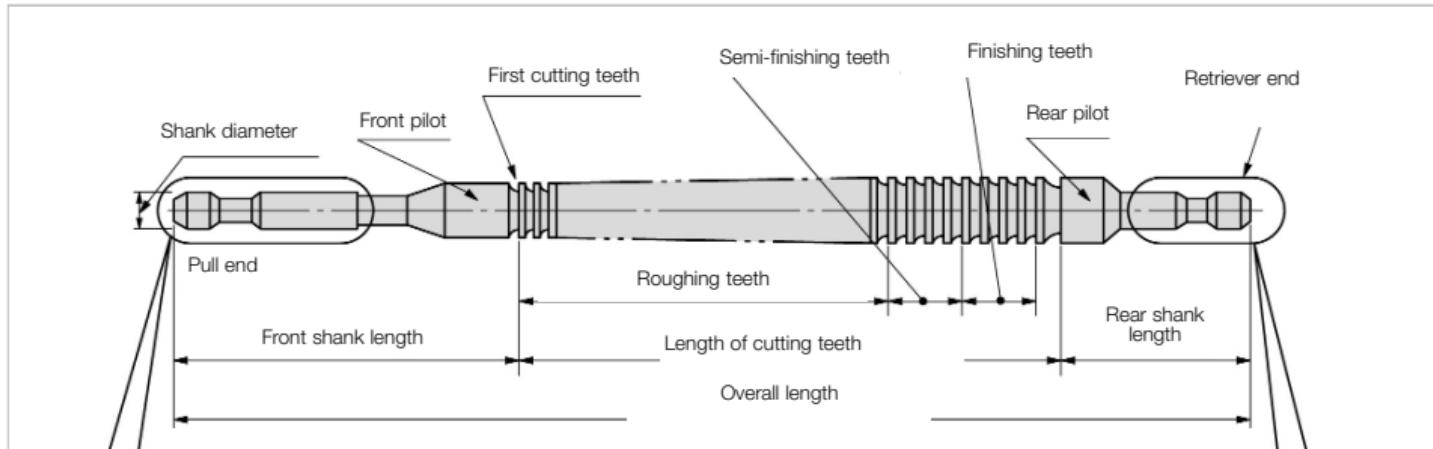
A BROACH AROUND THE WORLD

French:
une broche

German:
ein
Raumwerkzeug

Italian:
una broccia

Spanish:
una brocha



Tooth Form



Solid broach

The basic choice



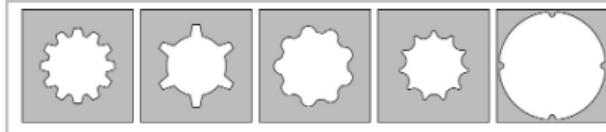
Assembly broach

Assembly broaches are composed of several broach segments.

- + Improved accuracy of workpiece
- + Longer tool length compared with solid broaches
- + Complex broach shapes which are not possible with solid broaches

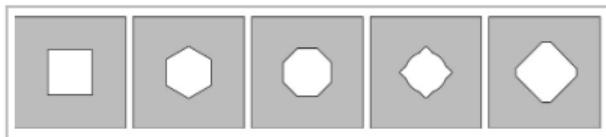
TOOL MAKER'S TIP

Broaching is the only solution for producing square holes with sharp angles.



Round broaching

Round broaches are used for high precision holes. There are several types of round broaches: rotary cut broaches used to cut castings without premachining, double cut broaches and burnishing broaches to improve surface finish.



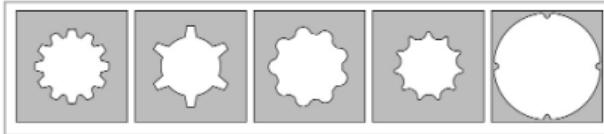
Square broaching

Flat and square broaches are used for producing flat and square holes



Keyway broaching

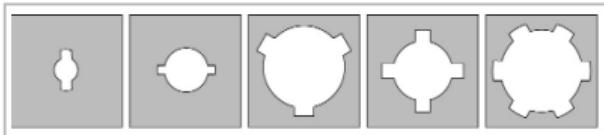
Keyway broaches, are widely used, often with a guide bushing that steadies the broach through the process. When the broach is not long enough to cut a high keyway workpiece in one pass, a liner is placed between the broach and the guide. This allows the broach to be pulled two or three times.



Broaching of splines

A spline broach is used to finish cut an involute spline or a straight sided spline.

Involute spline broaches are used in automotive production. They are available with round teeth at the front, or round teeth at the end or, to decrease the eccentricity on the minor and the major diameter of a spline, with alternating spline and round teeth.



Broaching of parallel side splines

Parallel side spline broaches are usually used in track parts or machine part production.



Broaching of serration

A combination broach, with both spline and round teeth, can decrease the eccentricity on the minor and major diameter of a spline.



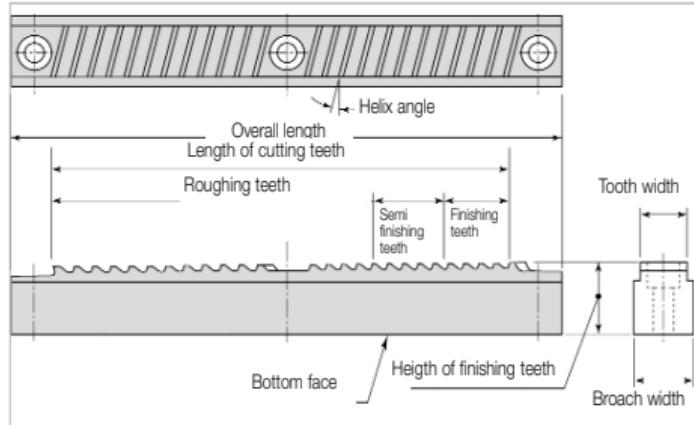
Broaching of special shapes

Helical splines can also be broached with spiral tooth broaches. The teeth are ground in a helical path around the tool axis. The helix angle corresponds to that required in the work.

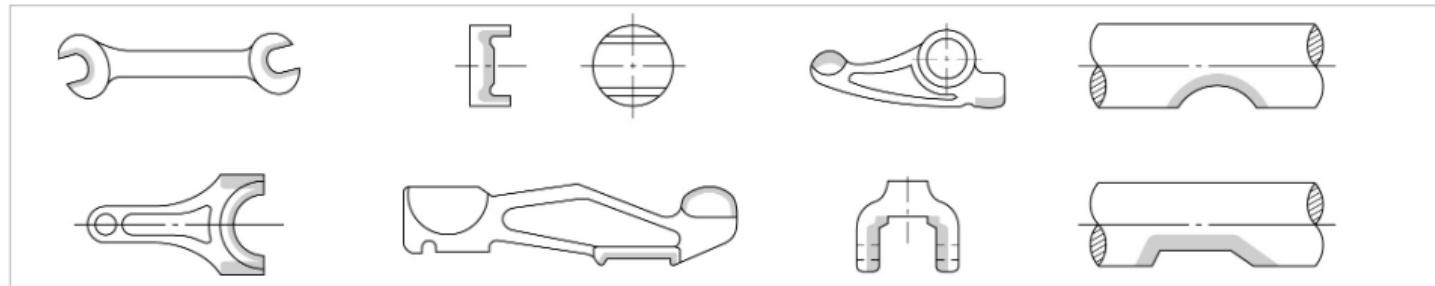
TOOL MAKER'S TIP

For mass-production,
broaching is a good
alternative to milling.

Accuracy
improves too!



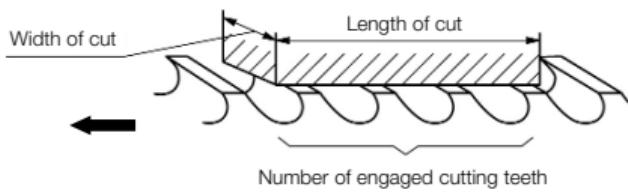
Surface broach



Example of broached parts

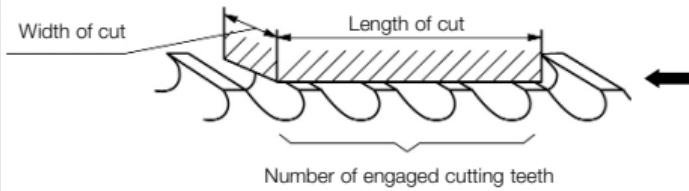
Surface broach

- A surface broach is used to remove material from an external surface.
- Surface broaching is usually carried out on a vertical machine with a broach which is either pushed or pulled down.
- The entire length of the broach is usually fixed to the machine.



Pull broaching

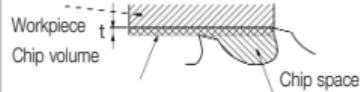
- Broaching is generally done by pulling.



Push broaching

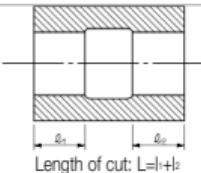
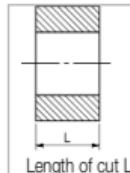
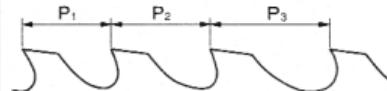
- When the cutting stock is relatively small, a push broach will be used.
- A pushed broach has a short life span due to rubbing that occurs on the return.
- Push broaching can also be done on a machining center or on a lathe.

Chip space \geq Chip volume X 6



Pitch and chip space

- Pitch is determined as a function of the amount of metal removed by one tooth (t = chip thickness). To prevent chips from jamming, the chip space must be 6 times larger than chip volume (Length of cut x chip thickness).



Pitch and length of cut

- Pitch $P = 1.2 \text{ to } 2.0 \sqrt{L}$.

Width of cut

Length of cut

Number of engaged cutting teeth

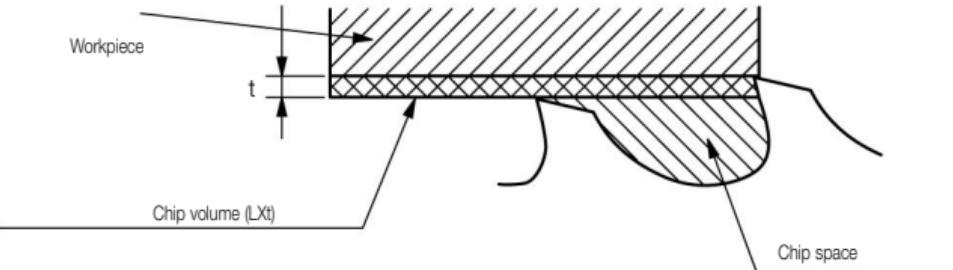
Number of engaged teeth

- Normally, several teeth cut simultaneously.
Number of engaged cutting teeth = Length of cut/Pitch (should not be a whole number).

TOOL MAKER'S TIP

*The chip space
must be six times
larger than
the chip volume.*

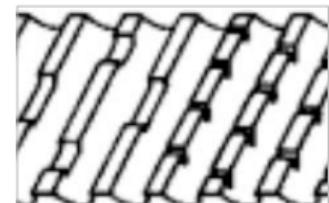
$$\text{Chip space} \geq \text{Chip volume} \times 6$$



Chipbreakers

Chipbreakers are used on broaches to prevent chip packing and to facilitate chip removal. Without chipbreakers, the broach would produce ring-shaped chips that would wedge in the tooth gullet and eventually cause the tool to break.

Chipbreakers are ground parallel to the tool axis. Chipbreakers on alternate teeth are staggered so that each set of chipbreakers is followed by a cutting edge.



Chipbreakers on
a flat broach

TOOL MAKER'S TIP

Broaches are usually very long tools, from 5xD up to 100xD or more.

To avoid any damage during storage, broaches should be hung vertically.



Small broaches

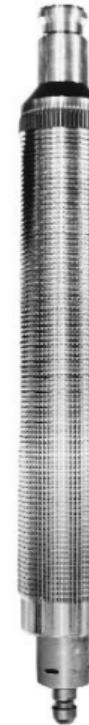
Examples:

Round keyway broach

- Width: 0.4181 mm
- Diameter: 3.175 mm
- Length: 332 mm

Square broach

- Square width: 2.3 mm
- Length: 220 mm



Large broaches

Example:

Internal gear broach

- Diameter: 290 mm
- Length: 2150 mm

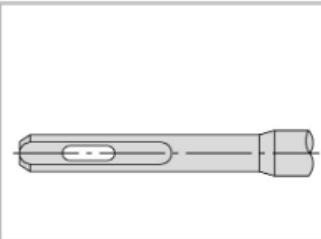
Broaches are usually very long tools, from 5xD up to 100xD or more

TOOL MAKER'S TIP

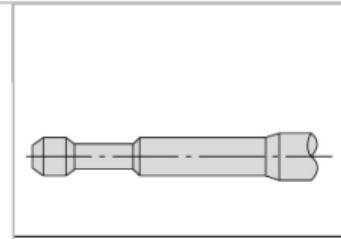
The choice of pull and retriever ends depends on the type of broaching machine used.

Do not forget that the diameters of both ends must be smaller than the pre-broached hole.

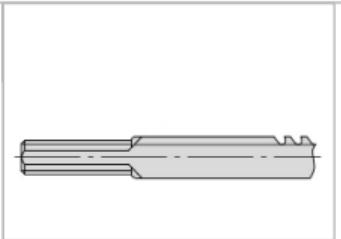
PULL ENDS



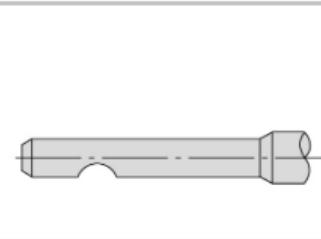
Cotter



Jaw/claw

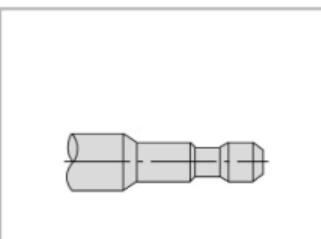


Threaded

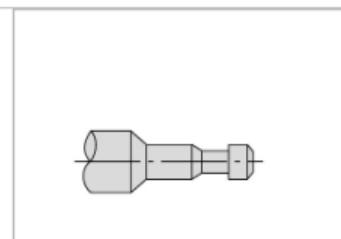


Pin

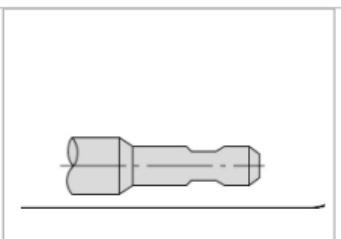
RETRIEVER ENDS



Jaw/claw



Round neck



Trapezoid

TOOL MAKER'S TIP

Higher speeds
can be achieved
thanks to new
HSS-PM materials
with new coatings

- Cutting speed influences broaching accuracy, the surface of the finished workpiece, and tool life.

Workpiece material	HSS broach	HSS Co broach	Coated HSS-PM broach
Steel	3-8	3-10	3-60*
Stainless steel - tough	2-5	2.5-4	2.5-5
Stainless steel free machining	4-6	4-8	4-10
Cast iron	8-10	8-12	8-60*
Brass	8-10	8-12	8-60*
Bronze	8-10	8-12	8-60*
Aluminium	8-10	8-12	8-80*
Magnesium	8-10	8-12	8-80*

* A special broaching machine is required

Cutting fluids in broaching

- Cooling is essential in broaching. Reducing heat by 50°C can increase tool life by 50%. Poor lubrication can even stop the broaching operation.
- The type of coolant used for broaching will have a large effect on the number of parts broached, accuracy, and efficiency.
- Coolant with low lubrication or low durability will cause cutting teeth to wear faster and, in turn, result in an inferior surface on the finished profile. If the viscosity is too high, chips will get stuck in the broach, lowering efficiency. In general, a higher viscosity is recommended for horizontal machines than for vertical machines.
- Oil is recommended for broaching with low friction additives. Coolant choice also depends on the type of broaching machine.
- Advanced water-based fluids are also increasingly used to improve cooling at high speed or for cutting heat resistant materials. The use of soluble oils is recommended to avoid having to clean parts and to reduce fire hazard.

Minimum Quantity Lubrication

- Microlubrication is also developing.
- Microlubrication makes part cleaning unnecessary and is an environmental-friendly technology.
- Spectacular results can be achieved with TiAlN coatings and HSS-PM steels (see case story on page 6).

Problem	Solutions
Dimensional accuracy (oversized, undersized)	Regrind earlier. Improve coolant flow. Check that there are no burrs on the teeth. Check the dimensional accuracy of the broach. Check workpiece.
Shape accuracy and position (roundness, run-out)	Check pull end. Check the face angle. Check workpiece clamping and alignment, especially if thin walls. Check the length of cut.
Rough surface finish	Regrind earlier. Improve coolant flow. Increase speed. Check that there are no burrs on the teeth. Check if vibrations occur.
Short tool life	Regrind earlier. Improve coolant flow. Use a HSS-PM broach and coatings. Check if vibrations occur. Increase the length of guide.

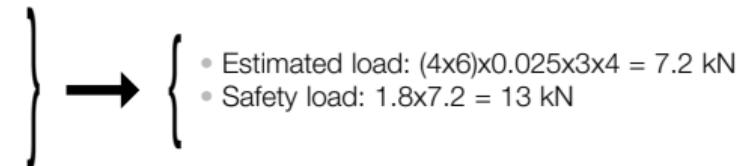
Flank wear	Crater wear	Deformation
<ul style="list-style-type: none">• Normal wear pattern• Decrease the cutting speed (v_c)• Use a HSS-PM broach with a coating• Increase coolant flow	<ul style="list-style-type: none">• To be limited• Decrease the cutting speed (v_c)• Use a coated broach to stop chemical wear• Check coolant flow	<ul style="list-style-type: none">• To be avoided• Decrease the cutting speed (v_c)• Increase coolant flow• Use a coated broach

- Estimated load (kN) = width of cut (mm)
x cutting depth/tooth (mm)
x number of engaged cutting teeth
x specific cutting resistance (kN/mm^2)
- Safety load (kN) = $1.8 \times \text{estimated load}$

Work material	Cutting depth/tooth (mm)			Specific cutting resistance (N/mm^2)
	Round broach	Spline broach	Surface broach	
Carbon steels	0.010-0.020	0.025-0.030	0.030-0.070	3000 - 4000
Alloy steels	0.010-0.020	0.025-0.030	0.030-0.070	3000
Cast iron	0.025-0.040	0.025-0.040	0.050-0.075	2000
Malleable cast iron	0.025-0.035	0.025-0.035	0.050-0.075	1300-3000
Stainless steels	0.020-0.030	0.020-0.030	0.030-0.060	4000
Non-ferrous alloys	0.035-0.050	0.030-0.040	0.060-0.100	1000-2000

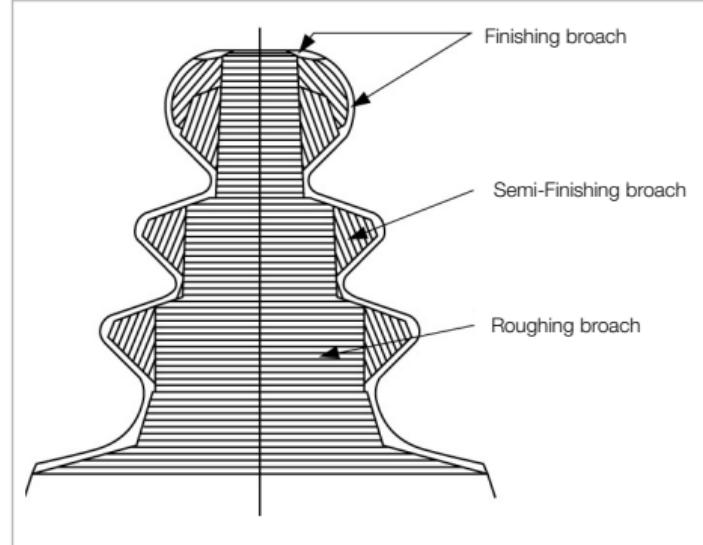
Example of calculation

Broaching of a parallel side spline $20 \times 16 \times 4 \times 6\text{SP}$ in alloy steels,

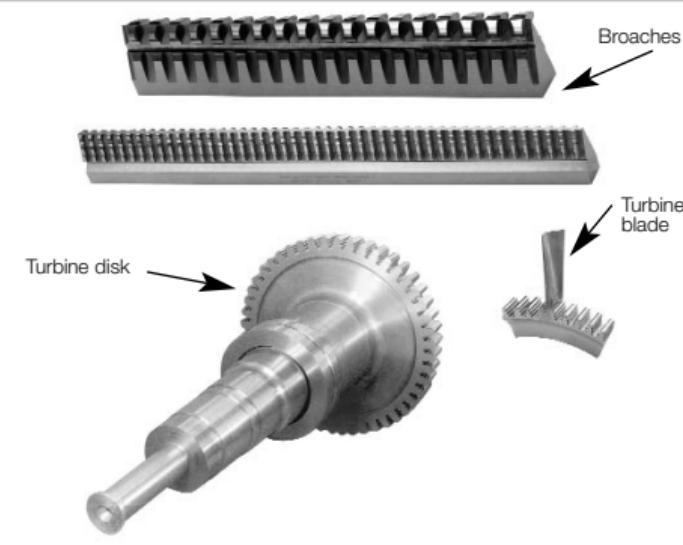
- Length of cut = 25 mm
 - Pitch: $1.5 \times \sqrt{25} = 7.5 \text{ mm}$
 - Number of engaged teeth: $25/7.5 = 3.4 \rightarrow 4$
 - Cutting depth/tooth: 0.025 mm
 - Cutting resistance: 3 kN/mm^2
- 
- Estimated load: $(4 \times 6) \times 0.025 \times 3 \times 4 = 7.2 \text{ kN}$
 - Safety load: $1.8 \times 7.2 = 13 \text{ kN}$

TOOL MAKER'S TIP

Christmas tree broaches are used to produce the grooves of turbine disks for the aeronautic industry or for the power industry.

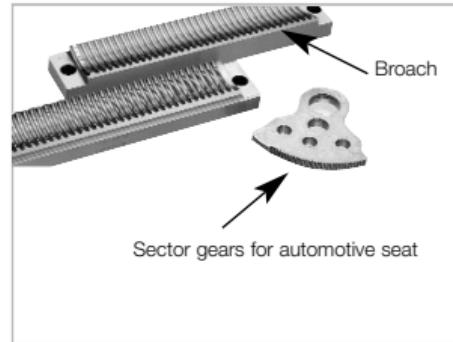


Christmas tree broach profile

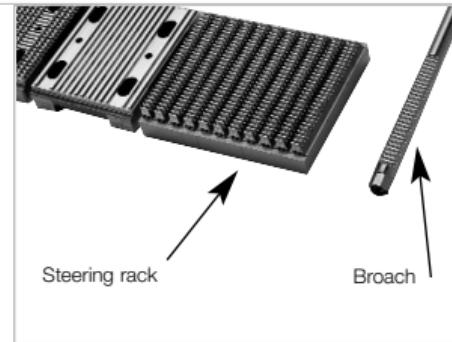


TOOL MAKER'S TIP

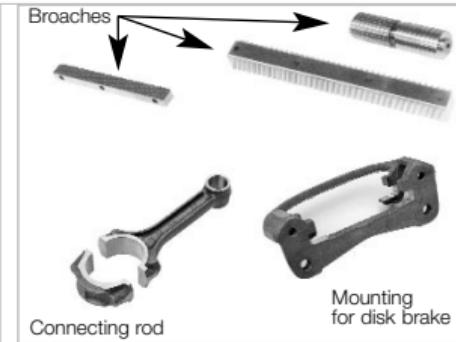
Broaches are very cost effective for mass-production of automotive components.



Broaching of sector gears



Broaching of steering racks



Broaching of connecting rods and disk brakes



Broaching of key holes