Cutting with broach

You can find here some notices about broaching operation.

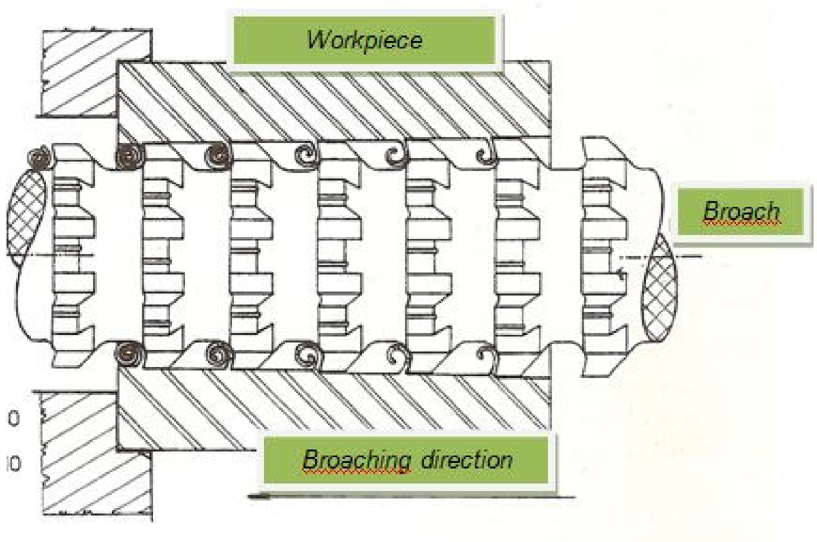

Fig.N°1

Amount of cut per tooth

This parameter depends on many characteristic of broaching operation like:

- *Material of the broach*
- *Material of workpiece (resistance and machinability)*
- *Diameter and length of workpiece*
- *Minimum section of the broach*
- *Power available on broaching machine*

The amount of cut per tooth (radial) is calculated by $i = \frac{K_d}{K_s}$

Where the values of K_s in function of the material of workpiece are shown in the table N°1.

Tab. N°1 . Specific cutting strength K_s in Kg/mm^2

Workpiece material	K_s	Workpiece material	K_s
Steel with R = 90 - 115 Kg/mm^2	500	Hard cast iron	160
Steel with R = 70 – 90 Kg/mm^2	400	Normal cast iron and hard bronze	125
Steel with R = 50 - 70 Kg/mm^2	315	Malleable cast iron and soft bronze	100
Steel with R = 50 Kg/mm^2	250	Brass	80
Soft steel	200	Aluminium alloy	63

The value of K_d in function of the type of broach and the workpiece material are shown in the following table N°2

Tab. N°2 . Specific load K_d in Kg per mm of length of cutting edge

Broach type	Workpiece material		
	Steel Hard cast iron	Soft cast iron Bronze and brass	Aluminium alloy
Round	12,5	10	8
Spline	16	12,5	10
Groove	20	16	12,5
Flat	25	20	16

At last the table N°3 shows the values of $i = \frac{K_d}{K_s}$ (radial)

*Tab. N°3. Maximum values of **i** (radial) in function of K_d e K_s (values in mm)*

K_s↓ K_d→	8	10	12,5	16	20	25
500	0,016	0,020	0,025	0,0315	0,040	0,050
400	0,020	0,025	0,0315	0,040	0,050	0,063
315	0,025	0,0315	0,040	0,050	0,063	0,080
250	0,0315	0,040	0,050	0,063	0,080	0,100
200	0,040	0,050	0,063	0,080	0,100	0,125
160	0,050	0,063	0,080	0,100	0,125	0,160
125	0,063	0,080	0,100	0,125	0,160	0,200
100	0,080	0,100	0,125	0,160	0,200	--
80	0,100	0,125	0,160	0,200	0,250	--
63	0,125	0,160	0,200	0,250	--	--

If the pre-broaching bore is very irregular, like shown in figure N°2, it's better to share the total amount of material to remove in 4 steps; for example:

- *Zone A : remove the material with a very high value of **i** (0,08 – 015 mm);*
- *Zone B : the value of **i** must be 1,5 – 2 times the normal value;*
- *Zone C : the value of **i** must be 1,2 – 1,5 times the normal value;*
- *Zone D : removing with the normal value of **i** .*

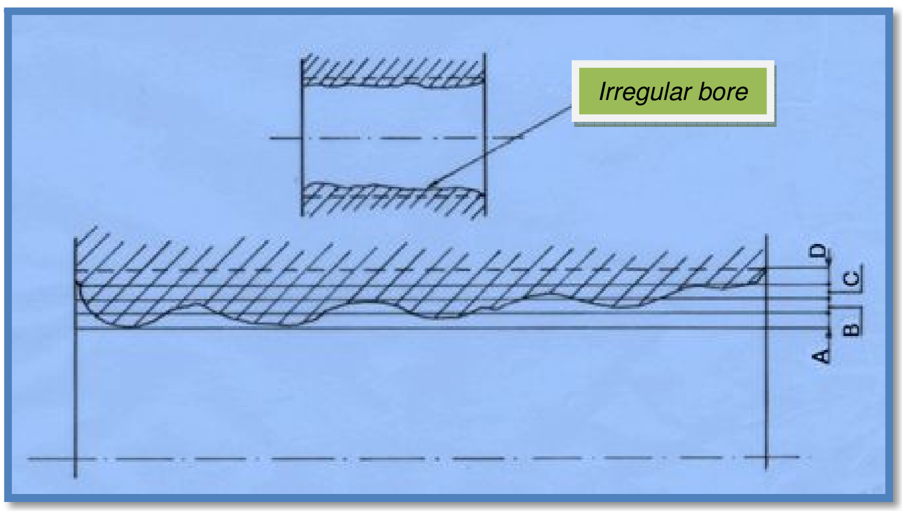

Fig. N°2

<u>Flat broaches</u>

Surface broaching also has commonality to internal broach.

Pitch and the amount of cut per tooth are decided in consideration of cutting length, broaching machine and accuracy required.

Strength seldom becomes a problem because surface broach is seldom controlled by size like internal broach is.

The broach which cut a wide plane should adopted helical teeth. Since helical tooth cuts continuously, a good finishing surface can be obtained.

Practically the helix angle is ever between 5° to 20°, because it is not good to have too much large helix angle, since it increases lateral pressure.

Helical tooth is not suitable for deep flute cutting because chip is pressed against one side of the flute and damages the finishing surface.

Cutting action

An operator can freely select depth of cut and feed rate, however, the amount of material removed by one cutting tooth of broach, equivalent for these is decided when designing.

All that an operator can change is cutting speed.

Chip in a normal cutting operation, like turning, hobbing or shaving, is removed as soon as it is generated, whereas in broaching, chip from all cutting length must be accommodated in the chip room.

Therefore, the size of chip room is an important point. When designing, a suitable chip room for cutting length is adopted.

Therefore, if material, which is longer than designated length on the drawing, is to be cut, chip gets stuck in the chip room. It may end up in remarkably bad finishing surface and causes cutting tooth chipping and breakage.

Length of chip that broach generates is always shorter than cutting length, and it's about 0,5 – 0,25 of cutting length.

Oppositely thickness of chip increases by 2 to 4 fold. Thickness of chip varies due to rake angle, material to be processed, cutting edge, cutting speed, and the cutting oil.

The figure N°3 shows the shape of normal chip generated by a well designed broach.

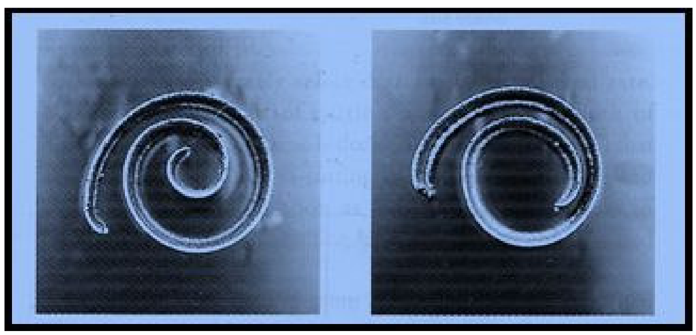

Fig. N°3

When cutting edge meshes with work material and start shearing, removed chip slips up along the tooth face, just like others cutting tools.

Then when cutting edge further progresses shorn chip will weld to front chip and will make a layer of parallelogram.

These chips overlap one after another and create a single bound chip.

Rake angle applied for a broach range from 5° to 25° depending on condition.

When chip is generated, an angle is formed with the direction of progress and the shearing surface where chip slips. This is called shear angle. This angle plays an important role in cutting resistance and cutting mechanism.

The smaller this angle is, the longer shearing surface becomes and the thicker chip becomes. Ultimately cutting resistance grows.

On the contrary, the larger shear angle is, the shorter shearing surface becomes and thinner the chip becomes, then cutting resistance decreases. See figure N°4.

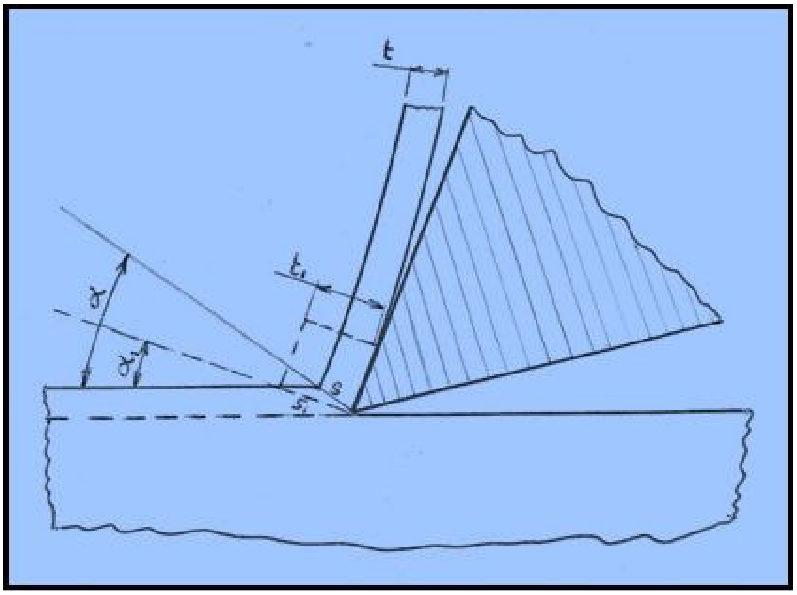

Fig.N°4

α = large shear angle *α_1 = small shear angle*
t = thin chip *t_1 = thick chip*
s = short shearing surface *s_1 = long shearing surface*

The best shape of chip is a swirl rolling well, and chips from material with toughness form chip shape.
Rolling chip varies according to hardness of work material, amount of cutting by one tooth, cutting length, chemicals elements etc.
Generally soft material creates larger rolling diameter than hard material. Since chip from fragile material like cast iron does nor curl and is not bulky, chip room with small capacity can handle it.
The figure N°5 shows chip freely curling, we can see that the diameter of chip is very large.

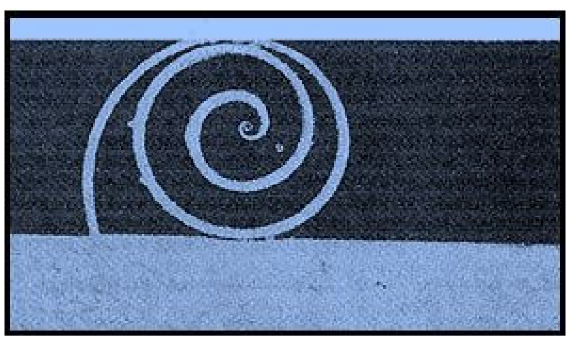

Fig. N°5

The figure N°6 shows chip in insufficient chip room, we can see that the chip are compressed, with a danger for the broach tooth.
The figure N°6a shows a normal chip in a well designed chip room and the figure N°6b shows a deformed chip due to irregularity of chip room generated by a bad resharpening operation.

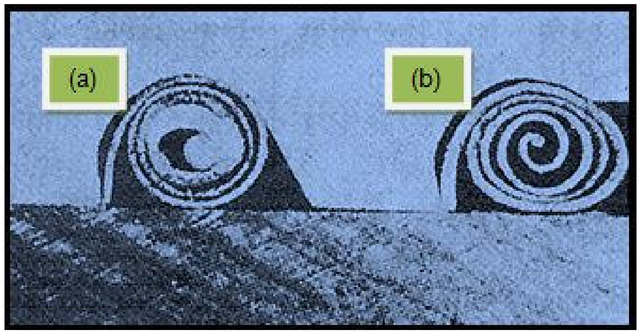

Fig. N°6

Wall thickness

In internal broaching operation, wall thickness of workpiece sometimes slightly influences the final accuracy of hole diameter and roundness.
While broaching work material expands due to back force, causing elastic and plastic deformation.
However, when broaching ends, it recovers to almost original by elastic recovery (spring back). When deformation is larger, some part may remain as plastic deformation.
The degree of this recovery greatly depends on wall thickness of the workpiece.
For example, even when same broach are used for processing, workpiece with a thinner wall will have a small hole diameter compared with a workpiece with a thicker wall.
In addition, when wall thickness of material changes along into the direction of circumference or cutting, it will obtain a hole with roundness error or with a different diameter in each section.

Cutting oil

The cutting oil greatly influences life of the broach. The following is its main purpose of use.

- *To improve finishing surface*
- *To improve size accuracy*
- *To control wear of cutting edge*
- *To remove chip and clean the working area*

Broaching is a low speed cutting, normally 2 – 8 m/min or in modern machine 15 – 40 m/mm or more, therefore rise of cutting temperature remain little, compared with other processing methods.
Cutting oil does not easily infiltrate blade tip in cutting processing because relief angle is reduced from the point of view of regrinding. It gets even more difficult for oil to come in as cutting progress. So that generation of chip, roughness of finishing surface and processing accuracy present a complex aspect.
To solve this various problem selecting the most appropriate cutting oil is an important point. It's important that the cutting oil have inside the EP additive (Extreme Pressure additive).
It should not forget that if cutting oil is mixed with water, lubricant and light oil, finishing surface may be extremely bad and abnormal wear may be caused.