





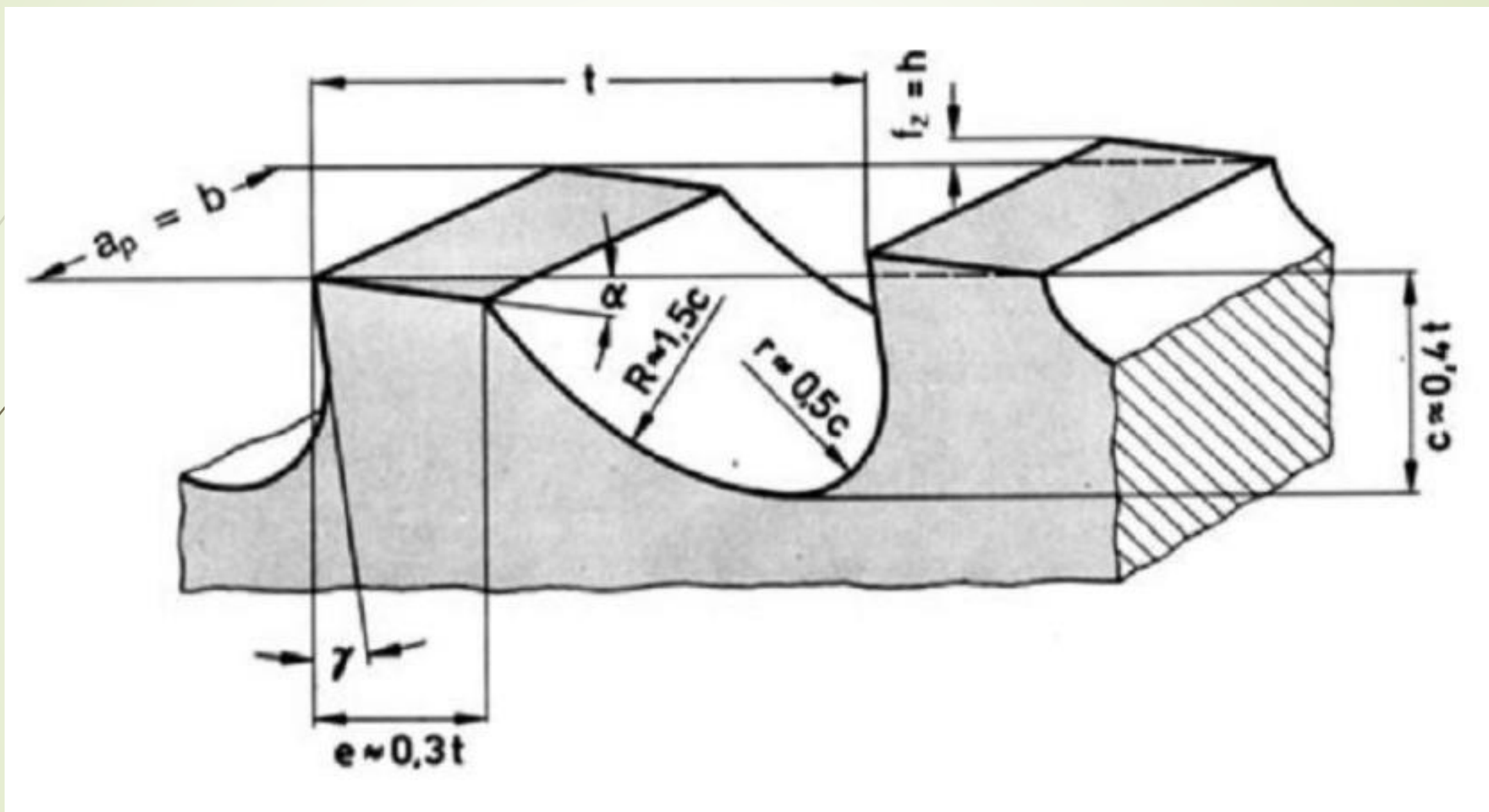
دانشگاه فنی حرفه ای

دانشکده فنی انقلاب اسلامی

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نام واحد درسی: ماشین ابزار تولیدی

# طراحی سوزن خانکشی



# پهنای برش

$$b = a_p$$

for internal broaching

$$b = \frac{a_p}{\cos \lambda}$$

for external broaching (see Figure 12.9)

$a_p$  in mm

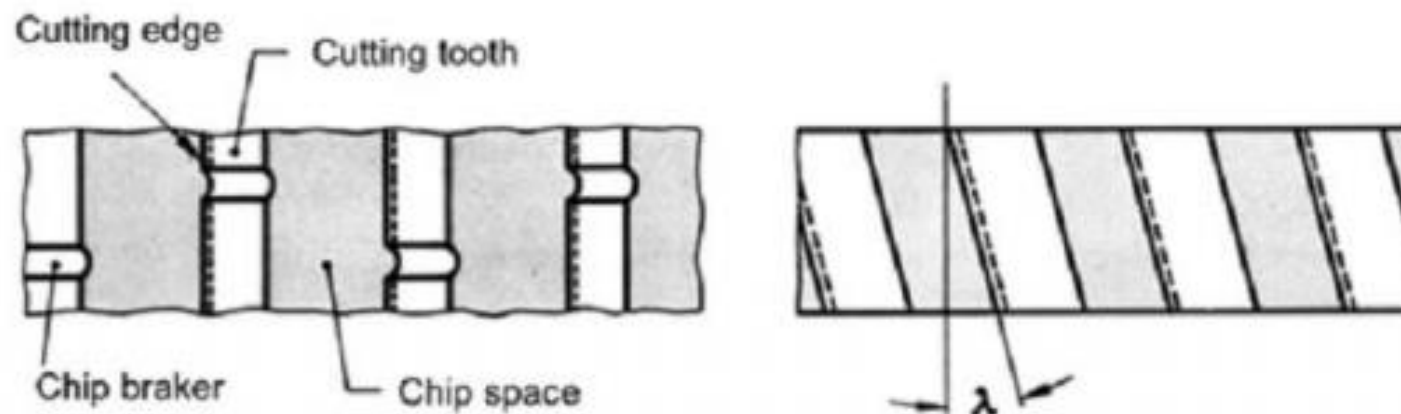
broach width

$b$  in mm

width of cut

$\lambda$  in °

tool cutting edge inclination (Figure 12.9)



## ضخامت برش

### Thickness of cut $h$

$$h = f_z$$

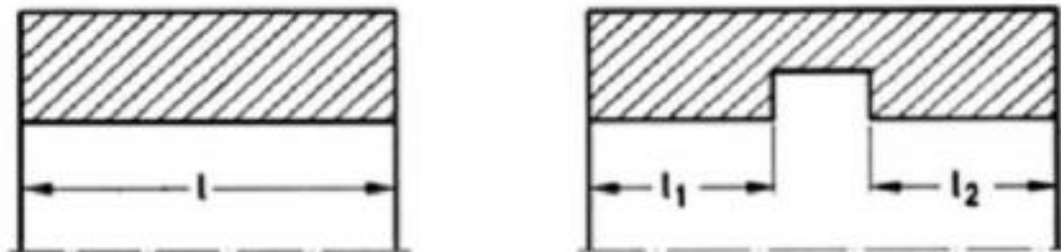
$h$  in mm thickness of cut  
 $f_z$  in mm feed per cutting edge

## تعداد دندانه درگیر

### Number of teeth in contact

$$z_E = \frac{l}{t}$$

$z_E$  number of teeth in contact  
 $l$  in mm broaching length in the workpiece (see Figure 212)  
 $t$  in mm toothing pitch



## حداقل اندازه گام

$$t_{\min} \approx 3 \cdot \sqrt{l \cdot f_z \cdot C}$$

$t_{\min}$  in mm

minimal permissible tooth pitch

$l$  in mm

broaching length in the workpiece

$C$

chip space number

**Table 12.1** Chip space number  $C$

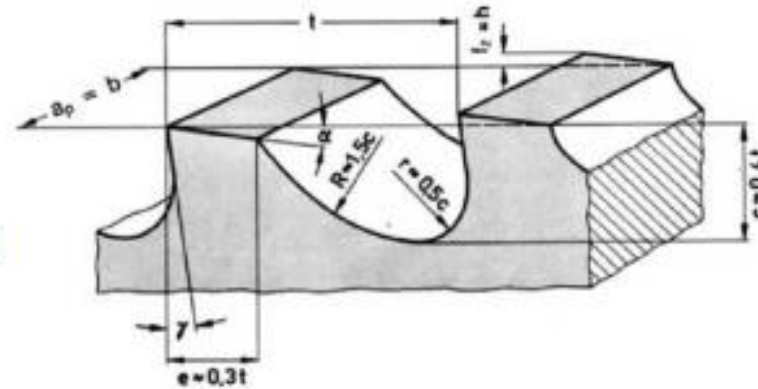
| Material           | Chip space number $C$ |       |                 |                |
|--------------------|-----------------------|-------|-----------------|----------------|
|                    | Internal broach       |       | External broach |                |
|                    | Flat                  | Round | with            |                |
|                    |                       |       | Offset in depth | Lateral offset |
| Steel              | 5–8                   | 8–16  | 4–10            | 1,8–6          |
| Cast steel         | 6                     | 12    | 7               | 4              |
| Grey cast iron     | 6                     | 12    | 7               | 4              |
| Non-ferrous metals | 3–7                   | 6–14  | 3–7             | 1–5            |

## عمق فضای دندانه

$$C \approx 0,35 \cdot t$$

$c$  in mm  
 $t$  in mm

tooth space depth  
 pitch



## ضخامت پشت دندانه

and rake face radius are to be selected in the ranges given below

$$e = 1,1 - 8 \text{ mm}$$

$$r = 0,8 - 5 \text{ mm}$$

Both values can be calculated in good approximation

$$\begin{array}{l} e \approx 0,3 \cdot t \\ r \approx 0,6 \cdot c \end{array}$$

## محاسبه زمان ماشینکاری

$$t_h = \frac{H}{v_c} + \frac{H}{v_r}$$

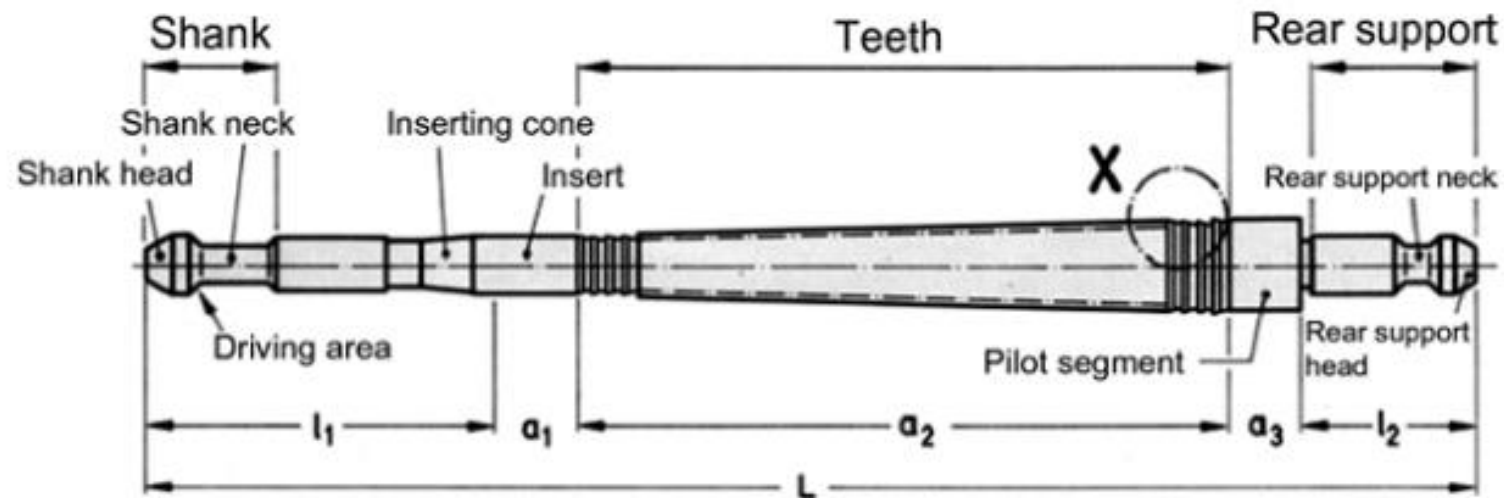
$$t_h = \frac{H(v_c + v_r)}{v_c \cdot v_r}$$

|       |          |                                                                |
|-------|----------|----------------------------------------------------------------|
| $t_h$ | in min   | machining time for one work cycle (cutting- and return stroke) |
| $H$   | in m     | required stroke                                                |
| $v_c$ | in m/min | cutting speed                                                  |
| $v_r$ | in m/min | return speed                                                   |

# سیکل کاری خانکشی داخلی

$$H = 1,2 \cdot l + a_2 + a_3 + l_2$$

|       |       |                                                                   |
|-------|-------|-------------------------------------------------------------------|
| $H$   | in mm | stroke during internal broaching                                  |
| $l$   | in mm | broaching length in the workpiece (see Figure 12.6, Chapter 12.5) |
| $a_2$ | in mm | length of the cutting portion                                     |
| $a_3$ | in mm | pilot length                                                      |
| $l_2$ | in mm | rear support length                                               |



**Figure 12.7**

Broach components

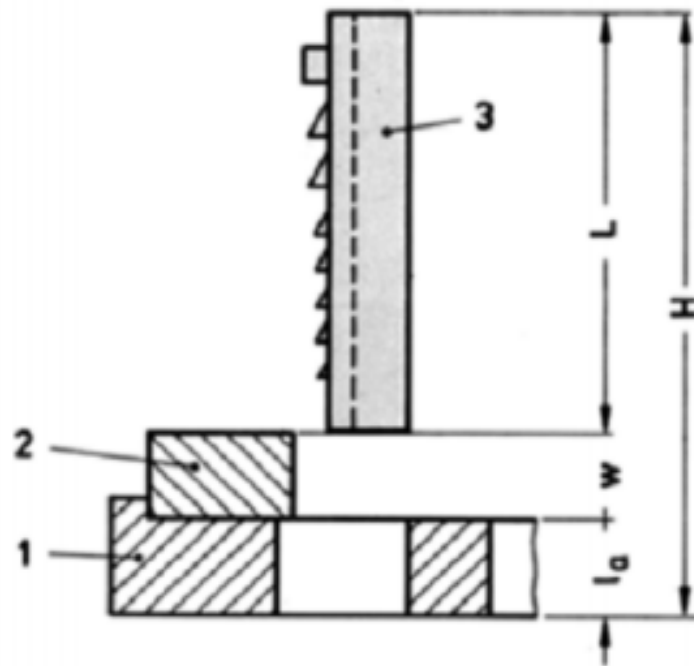
$l_1$  shank,  $a_1$  pilot,  $a_2$  cutting portion,  $a_3$  pilot,  $l_2$  rear support,  $L$  total length detail X

# سیکل کاری خانکشی خارجی

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$$H = 1,2 \cdot L + l_a + w$$

|       |       |                                  |
|-------|-------|----------------------------------|
| $H$   | in mm | stroke during external broaching |
| $L$   | in mm | tool length                      |
| $l_a$ | in mm | thickness of the closing plate   |
| $w$   | in mm | workpiece height                 |



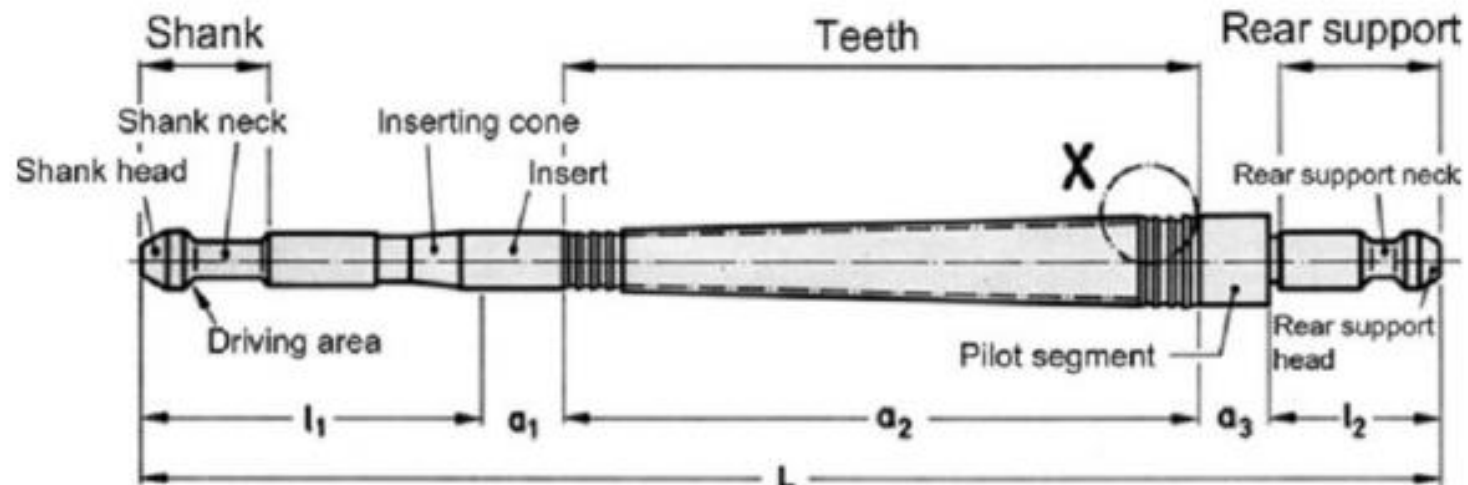
**Figure 12.8**

External broaching – working principle  
1 closing plate, 2 workpiece, 3 broaching tool

# طول بخش برشی سوزن خانکشی

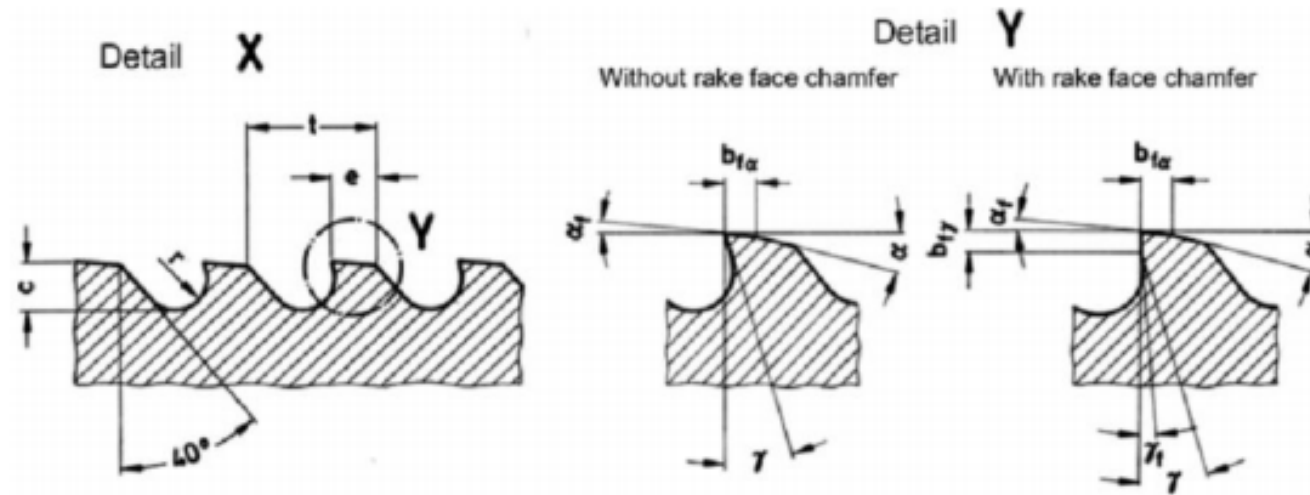
$$a_2 = t_1 \cdot z_1 + t_2 \cdot (z_2 + z_3)$$

|       |       |                                           |
|-------|-------|-------------------------------------------|
| $a_2$ | in mm | length of the cutting portion             |
| $t_1$ | in mm | pitch of the roughing teeth               |
| $t_2$ | in mm | pitch of finishing- and calibrating teeth |
| $z_1$ |       | number of roughing teeth                  |
| $z_2$ |       | number of finishing teeth                 |
| $z_3$ |       | number of calibrating teeth               |



# زاویه براده و آزاد لبه ها

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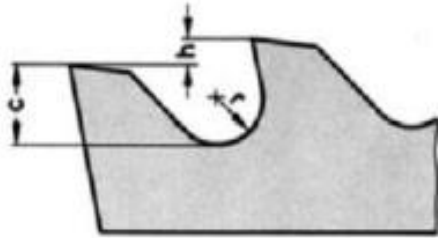


**Table 12.2** Rake angle and tool orthogonal clearance on broaches

| Material                                                           | $\alpha$ in ° | $\gamma$ in ° |
|--------------------------------------------------------------------|---------------|---------------|
| E 295–E 335<br>C 22–C 35                                           | 3             | 18–25         |
| E 360<br>C 60                                                      | 4             | 15–20         |
| Quenched and subsequently<br>tempered steel 1000 N/mm <sup>2</sup> | 4             | 12–18         |
| Tool steel                                                         | 4             | 12–18         |
| Grey cast iron                                                     | 3             | 8–15          |
| Al alloy.<br>9–13% Si                                              | 4             | 18–25         |
| Brass, bronze                                                      | 4             | 5–20          |

$$h = f_z$$

$f_z$  in mm    feed per cutting edge  
 $h$  in mm    thickness of cut



**Figure 12.11**  
Tooth offset

افزایش ارتفاع دندانه  
نسبت به دندانه قبلی

**Table 12.4** Depth- and lateral offsets during external broaching

| Material                                                            | Thickness of cut $h$ per tooth in mm |            |                |
|---------------------------------------------------------------------|--------------------------------------|------------|----------------|
|                                                                     | Offset in depth                      |            | Lateral offset |
|                                                                     | Roughing                             | Finishing  |                |
| S 275 JR–E 360<br>C 22–C 60                                         | 0,06–0,15                            | 0,01–0,025 | 0,08–0,25      |
| Quenched and tempered<br>steel 1000 N/mm <sup>2</sup> tool<br>steel | 0,04–0,10                            | 0,01–0,025 | 0,08–0,25      |
| Grey cast iron                                                      | 0,08–0,2                             | 0,02–0,04  | 0,29–0,6       |
| Al alloy<br>9–13% Si                                                | 0,1–0,2                              | 0,02       | not applied    |
| Brass, bronze                                                       | 0,1–0,3                              | 0,02       | not applied    |

## a) Total tooth number

$$z_w = \frac{h_{ges}}{f_z}$$

$z_w$  total tooth number of the broach  
 $h_{ges}$  in mm machining allowance (Figure 12.10)  
 $f_z$  in mm feed per cutting edge = thickness of cut  $h$

b) Tooth number  $z_2$  for finishing

For finishing, 5 teeth are used on average.

$$z_2 = 5 \text{ teeth}$$

$z_2$  number of teeth for finishing

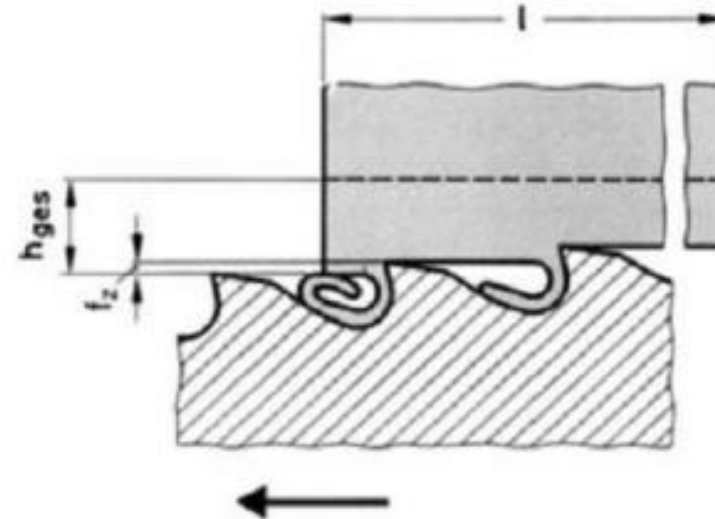
c) Number of teeth  $z_1$  for roughing

$$z_1 = \frac{h_{ges} - 5 \cdot f_{z2}}{f_{z1}}$$

$z_1$  tooth number for roughing  
 $h_{ges}$  in mm machining allowance  
 $f_{z1}$  in mm feed per cutting edge for roughing  
 $f_{z2}$  in mm feed per cutting edge for finishing

d) For calibration, one can also assume 5 teeth. However, since the calibration teeth only smooth instead of removing any allowance, this tooth number is not integrated into the calculation of  $z_1$ .

# تعداد لبه های برشی

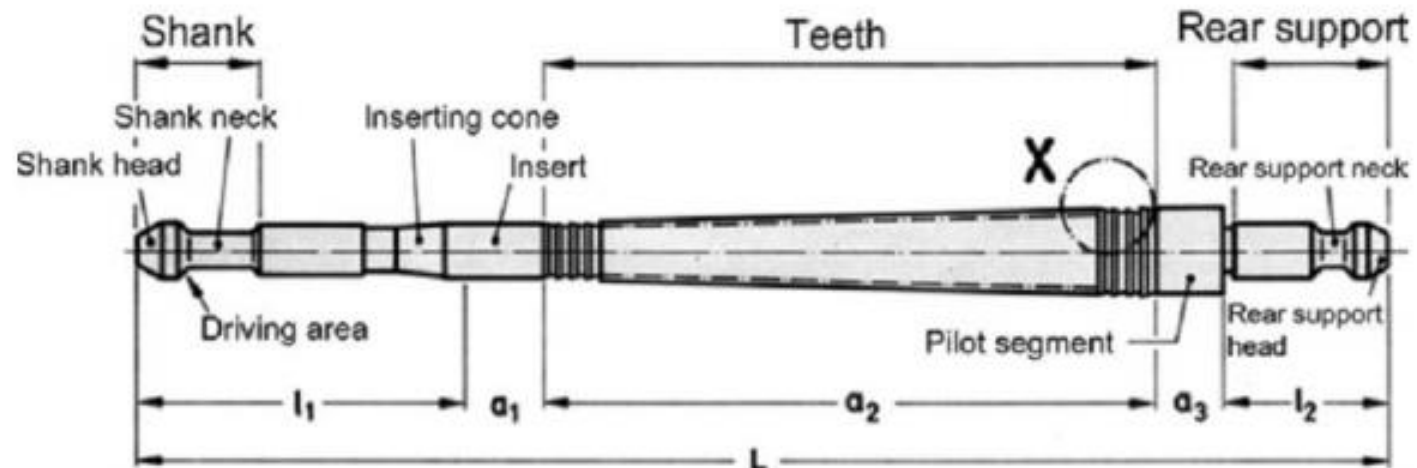


# طول کلی ابزار

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$$L = l_1 + a_1 + a_2 + a_3 + l_2$$

|       |       |                                     |
|-------|-------|-------------------------------------|
| $L$   | in mm | total length of the internal broach |
| $l_1$ | in mm | shank length                        |
| $a_1$ | in mm | pilot length                        |
| $a_2$ | in mm | length of the cutting portion       |
| $a_3$ | in mm | length of the rear pilot            |
| $l_2$ | in mm | length of the rear support          |



**Table 12.6** Length of round shanks  $l_1$  and rear supports  $l_2$  in mm as a function of the broach diameter  $d$  in mm (Figure 12.7)

| $d$ in mm | Shank length $l_2$ in mm | Rear support length $l_2$ in mm |
|-----------|--------------------------|---------------------------------|
| 20–25     | 180                      | 190                             |
| 28–40     | 200                      | 125                             |
| ⋮         | ⋮                        | ⋮                               |
| 100       | 360                      | 200                             |

# سرعت برشی و سرعت برگشت ماشین خانکشی

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**Table 12.8** Cutting speeds  $v$  in m/min for broaching [52]

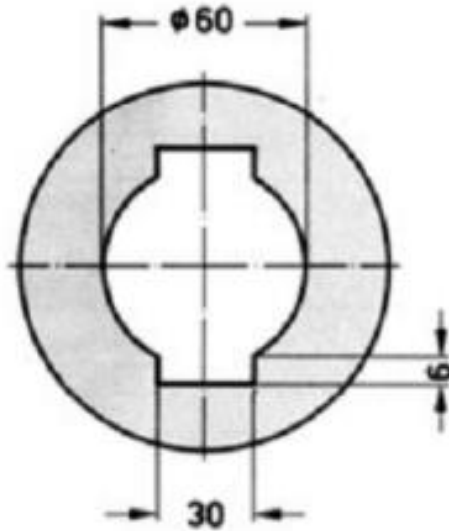
| Material                                    | Internal broaching | External broaching |
|---------------------------------------------|--------------------|--------------------|
| S 275 JR–E 335                              | 4–6                | 8–10               |
| E 360 and slightly alloyed steels           | 2–3                | 6–8                |
| Alloyed steels up to 1000 N/mm <sup>2</sup> | 1,5–2              | 4–6                |
| Cast steel                                  | 2–2,5              | 5–7                |
| Gray cast iron                              | 2–3                | 5–7                |
| Brass, bronze                               | 3–4                | 10–12              |
| Al alloys                                   | 4–6                | 12–15              |

**Table 12.9** Reverse speed  $v_r$  in m/min of the broaching machine

$$v_r = 12 - 30 \text{ m/min}$$

## مثال

The task is to simultaneously generate 2 opposite grooves in a pulley made of E 360, hub length 100 mm (see sketch). An internal broach is to be used.



**Figure 12.17**  
Pulley

Tooth pitch

Tooth number for roughing and finishing

Length of the cutting portion

Number of teeth being in contact

Machining time for one workpiece

### 1. Tooth pitch

Tooth pitch is calculated according to the required chip space.

$$t_{\min} = 3 \cdot \sqrt{l \cdot f_z \cdot C}$$

chip space number  $C$  selected from Table 12.1:  $C = 7$

$f_z = h$  is selected from offset table 77

$f_{z1} = h_1 = 0,1$  mm for roughing

$f_{z2} = h_2 = 0,02$  mm for finishing

Roughing:

$$t_{\min_1} = 3 \cdot \sqrt{100 \text{ mm} \cdot 0,1 \text{ mm} \cdot 7} = 25,09 \text{ mm} \rightarrow 25 \text{ mm selected}$$

Finishing:

$$t_{\min_2} = 3 \cdot \sqrt{100 \text{ mm} \cdot 0,02 \text{ mm} \cdot 7} = 11,22 \text{ mm} \rightarrow 11 \text{ mm selected}$$

# 1. Tooth pitch

Tooth pitch is calculated according to the required chip space.

$$t_{\min} = 3 \cdot \sqrt{l \cdot f_z \cdot C}$$

chip space number  $C$  selected from Table 12.1:  $C = 7$

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Roughing:

$$t_{\min_1} = 3 \cdot \sqrt{100 \text{ mm} \cdot 0,1 \text{ mm} \cdot 7} = 25,09 \text{ mm} \rightarrow 25 \text{ mm selected}$$

Finishing:

$$t_{\min_2} = 3 \cdot \sqrt{100 \text{ mm} \cdot 0,02 \text{ mm} \cdot 7} = 11,22 \text{ mm} \rightarrow 11 \text{ mm selected}$$

3. Length of the broach's cutting portion  $a_2$

$$a_2 = t_1 \cdot z_1 + t_2 \cdot (z_2 + z_3)$$

$$a_2 = 22 \text{ mm} \cdot 59 + 11 \text{ mm} \cdot (5 + 5) = 1408 \text{ mm}$$

4. Number of teeth in contact

$$z_E = \frac{l}{t} = \frac{100 \text{ mm}}{25 \text{ mm}} = 4 \text{ teeth}$$

8. Machining time

8.1. Working stroke for internal broaching

$$H = 1,2 \cdot l + a_2 + a_3 + l_2$$

$$l_2 = 125 \text{ mm from Table 12.6}$$

$$a_3 = 40 \text{ mm assumed}$$

$$a_2 = 1408 \text{ mm calculated under 3.}$$

$$l = 100 \text{ mm hub length given in this task}$$

$$H = 1,2 \cdot 100 \text{ mm} + 1408 \text{ mm} + 40 \text{ mm} + 125 \text{ mm} = 1693 \text{ mm}$$

## 8.2. Machining time

$$v_c = \frac{H(v_c + v_r)}{v_c \cdot v_r}$$

$v_c = 3 \text{ m/min}$  selected from Table 12.8

$v_r = 20 \text{ m/min}$  assumed (see Table 12.9)

$$t_h = \frac{1,693 \text{ m} \cdot (3 \text{ m/min} + 20 \text{ m/min})}{3 \text{ m/min} \cdot 20 \text{ m/min}} = 0,65$$

