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RESEARCH OF A COMBINED TOOL FOR EXPANDING AND SMOOTHING HOLES

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Abstract: The article shows the design of a combined tool for expanding and further smoothing of holes, using a new type of cutting-smoothing inserts. The goal is to achieve chip removal and subsequent smoothing without the need for using two separate tools. The article presents the results obtained in the study of the combined tool regarding the cutting forces of each cutting edge of the tool's cutting-smoothing elements and the results of simulation analysis carried out at simulating the actual operation of the tool.

Key words: combined tool, expanding holes, smoothing holes

1. INTRODUCTION

The manufacturing of important holes, to which there are high requirements related to the accuracy of shape and dimensions, as well as low roughness, is usually done through the following two types of sequential machining:

- Machining – by chip removing (drilling or boring of the hole) [19, 20];
- Surface treatment - mostly related to surface plastic deformation (SPD) [1, 2, 8, 9].

The final forming of the machined surface is done according to two principles:

- Sliding friction (burnishing), accomplished by one rectilinear movement [3, 6, 11, 13];
- Rolling friction - carried out in two movements-rotationally and rectilinear on the generatrix of the machined hole with tools built on rollers or balls [3, 6, 11, 13].

The execution of the listed operations is carried out by using of separate tools or by using of combined tools, which perform simultaneously chip removal and then smoothing by rollers (balls) mounted in a separator [4, 5, 7, 12, 21, 23-28].

A basic disadvantage of the listed combined constructions which work simultaneously (cutting and smoothing) is the difference in the dynamics of the two processes. This requires the mounting of several lines of supporting elements for both the cutting and the rolling part [10, 14- 17, 22]. In order to function as supports, in most cases there are six elements (evenly distributed on the treated diameter) in two lines, and it is necessary to have the option to adjust the diameter of the outside line of supporting elements.

2. CONSTRUCTION OF A COMBINED TOOL FOR EXPANDING HOLES

The combined tool for expanding holes works by removing thin metal layers and simultaneously smoothing by sliding friction [18]. The tool is designed for use in mechanical engineering and in particular in the production of parts with precision holes.

The general appearance of the combined tool respectively with cutting-smoothing guide inserts with 30° cutting edge inclination and 60° cutting edge inclination and is shown in Figure 1 and Figure 2.

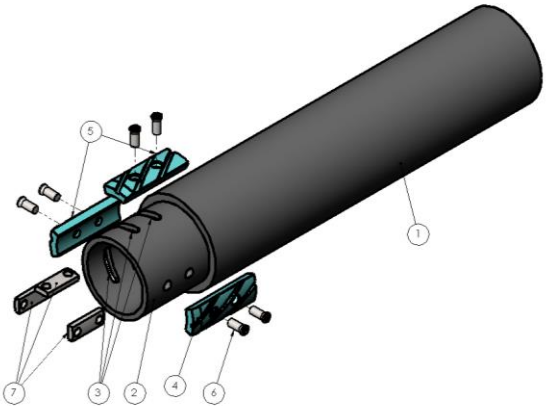


Fig. 1. General appearance of a combined tool for expanding holes with cutting-smoothing guiding inserts with 30° cutting edge inclination

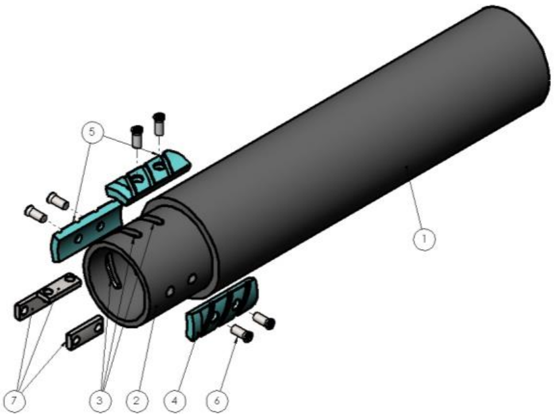


Fig. 2. General appearance of a combined tool for expanding holes with cutting-smoothing guiding inserts with 60° cutting edge inclination

The tool includes a cylindrical body 1 providing strength of the tool and ends with a conical or cylindrical tail (in the present case cylindrical). Body 1 is a thick-walled on which a surface 2 is machined for mounting cutting-smoothing guiding elements 4 and 5. The fixed element 4 is fastened by means of two screws 6 and a counter body 7 to a surface 2. The inner generatrix of element 4 is a part of a cylindrical surface with a diameter equal to that of surface 2.

The movable elements 5 have the same shape on the inner and outer surfaces by diameter. Their fixation is performed by counter bodies 7 and their rotation relative to the fixed element 4 is carried out on four sectoral channels 3.

The assembled view of the tool in the cutting part is shown on Figure 3 and Figure 4.

Fig. 3. Assembled view of a combined tool for expanding holes with inclination of the cutting edge 30°

Fig. 4. Assembled view of a combined tool for expanding holes with inclination of the cutting edge 60°

The fixed 4 and movable 5 cutting-smoothing guides are made with a steel base and a hard alloy working surface. Along the periphery are slit channels with an angle of 30° respectively (Figure 5) and an angle of 60° (Figure 6). These channels are in fact helical teeth with an angle of 2°. The inner generatrix has a radius R_2 equal to the radius of the outer circle of surface 2 and the outer radius R_1 is selected with a value corresponding to the requirements of the machined hole. In the front, the working elements 4 and 5 have a 5° conical section to assisting the incision of the tool.

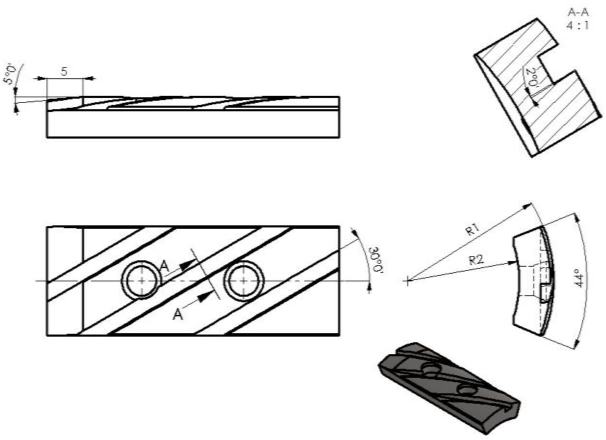


Fig. 5. Cutting-smoothing guiding insert with inclination of the cutting edge 30°

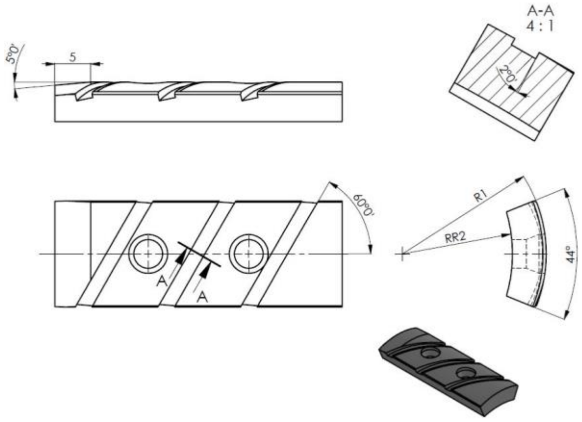


Fig. 6. Cutting-smoothing guiding insert with inclination of the cutting edge 60°

3. OPERATION OF THE COMBINED TOOL FOR EXPANDING HOLES

The purpose of the combined tool for the simultaneous expanding and smoothing of holes with three supports operating as cutting and smoothening elements is to remove the chip simultaneously and smooth the machined surface by sliding friction.

The forces of contact are changing by varying the angles of mutual disposition of the individual movable working elements.

Guiding cutting and smoothing elements are sectoral parts having three contact portions. The immovable element is attached to the body by two screws and a counter body. The other two movable elements are fastened in the same way. The working elements have an inner and outer cylindrical generatrix, the inner has the same diameter with the surface of attachment, and the outer has a diameter depending on the machined hole.

The rotating of the guides is carried out at the presence of four diametrically located channels.

Lubricant-coolant is fed into the clearance between the body and the machined hole.

The working elements are made of cermet, each of which can be made of different hard alloy, shape (outer radius) and dimensions according to the requirements for accuracy and roughness of the machined holes.

By replacing the cutting-smoothing and guiding modules with different radius R1 of the outer cylindrical generatrix (Figure 5 and Figure 6), holes with the same tool can be machined at difference between the smallest possible machined hole and the largest 6mm.

When using the tool, the machining elements contact the pre-treated hole by simultaneously removing chip, guiding the tool and smoothing the machined surface.

Smoothing is performed by sliding friction of the working surfaces located on the outer circle with a maximum diameter.

For changing the forces of impact of the working elements on the machined surface is used the change of the spatial system of forces arising at different angular position of the movable cutting-smoothing and guiding elements relative to the fixed one. By initial setting the angular position of the working elements, it is possible to set different in magnitude, but also approximately the same forces of impact, as well as different by value, but having a favorable effect on the quality of the machined holes. The changing of central angles of mutual positioning of the two movable working elements is accomplished by moving the two movable elements relative to the fixed one along two channels of the cylindrical surface. After positioning to the desired angles, the cutting-smoothing and guiding elements are fixed rigidly to the tool body by two screws and counter-body.

4. STUDY OF THE CONSTRUCTION OF A COMBINED TOOL FOR EXPANDING HOLES

In designing the tool shown in Figure 3 and Figure 4, the force load acting on the cutting-smoothing elements shown in Figure 5 and Figure 6 is essential. Arranged at different angles ω (30° and 60°) work areas form and component Fy (Figure 7).

Due to the gradual incision of the active cutting edges, a gradual change of the components Fx, Fy, Fz shown in the Table 1 and Table 2 is obtained.

There are two periods of operation of the tool:

- The first period encompasses the initial stage of cutting until complete penetration of the cutting-smoothing elements (Figure 5 and Figure 6);
- The second period represents the relative performance of the tool in stationary mode.

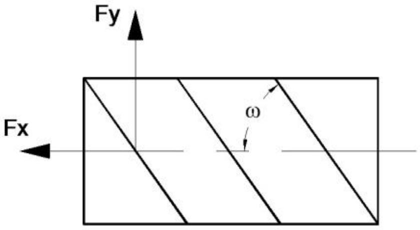


Fig.7. Components of cutting force in working position

Table 1. Change of cutting forces depending on the length of the machined hole (at incision) - for 30° cutting edge inclination

First cutting edge – 17mm							
Length of the cutting edge L, [mm]	2	5	7	10	13	15	17
Fx, [N]	107	268	374	536	695	802	910
Fy, [N]	61	151	211	302	393	453	514
Fz, [N]	126	315	440	630	818	944	1070
Second cutting edge – 17mm							
Length of the cutting edge L, [mm]	2	5	7	10	13	15	17
Fx, [N]	71	179	249	357	463	535	607
Fy, [N]	41	101	141	201	262	302	343
Fz, [N]	84	210	293	420	545	629	713
Third cutting edge – 17mm							
Length of the cutting edge L, [mm]	2	5	7	10	13	15	17
Fx, [N]	36	89	125	179	232	267	303
Fy, [N]	20	50	70	101	131	151	171
Fz, [N]	42	105	147	210	273	315	357

Table 2. Change of cutting forces depending on the length of the machined hole (at incision) - for 60° cutting edge inclination

First cutting edge – 14.5mm							
Length of the cutting edge L, [mm]	2	5	7	9	11	13	14,5
Fx, [N]	126	314	439	564	690	815	910
Fy, [N]	71	177	248	319	390	460	514
Fz, [N]	148	369	517	664	812	959	1070
Second cutting edge – 29mm							
Length of the cutting edge L, [mm]	2	7	10	15	20	25	29
Fx, [N]	42	146	209	314	418	523	607
Fy, [N]	24	83	118	177	236	295	343
Fz, [N]	49	172	246	369	422	615	713
Third cutting edge – 18mm							
Length of the cutting edge L, [mm]	2	5	7	10	13	15	18
Fx, [N]	34	84	118	168	219	253	303
Fy, [N]	19	48	67	95	124	143	171
Fz, [N]	40	99	139	198	258	298	357

When fully incision, the load is the maximum corresponding to L=17mm and L=14.5mm respectively for angle ω=30° and ω=60° respectively.

In Figure 8 and Figure 9 (a), (b), (c) are shown the changes of the components of the cutting forces in the whole process until a stationary mode.

The design of a tool shown in Figure 1 and Figure 2 requires the solving of two tasks:

- Determination of the load and deformations of the cutting-smoothing elements (Figure 5 and Figure 6);
- Determination of the fastening elements in the threaded joints, which fix working parts to the body 1 (Figure 1 and Figure 2).

To solve these tasks, a simulation analysis is carried out in which as the input data is used the load at fully incision of the tool, visible from the graphs (Figure 10 (a), (b), (c) and Figure 11(a), (b), (c).

The conditions under which it is conducted the simulation analysis is as follows:

-Tool body material: 41Cr4;

-Material of the insert: base base 41Cr4 and hard alloy coating

-Cutting forces: *at an angle of inclination of the cutting edge ω=30°*

-First cutting edge: Fx=910N; Fy=514N; Fz=1070N;

-Second cutting edge: Fx=607N; Fy=343N; Fz=713N;
-Third cutting edge: Fx=303N; Fy=171N; Fz=357N.
-Cutting forces: *at an angle of inclination of the cutting edge ω=60°*
-First cutting edge: Fx=910N; Fy=514N; Fz=1070N;
-Second cutting edge: Fx=607N; Fy=343N; Fz=713N;
-Third cutting edge: Fx=303N; Fy=171N; Fz=357N.

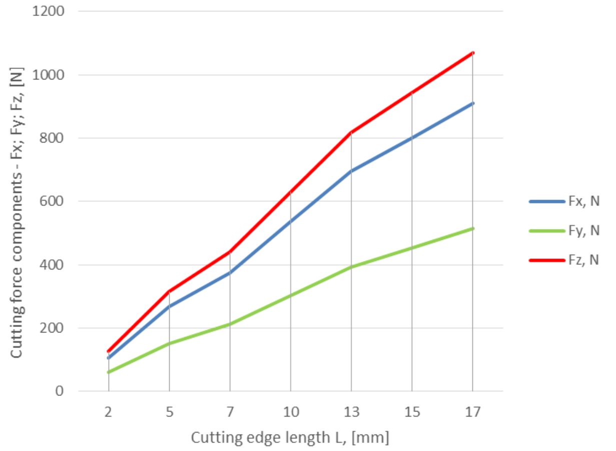
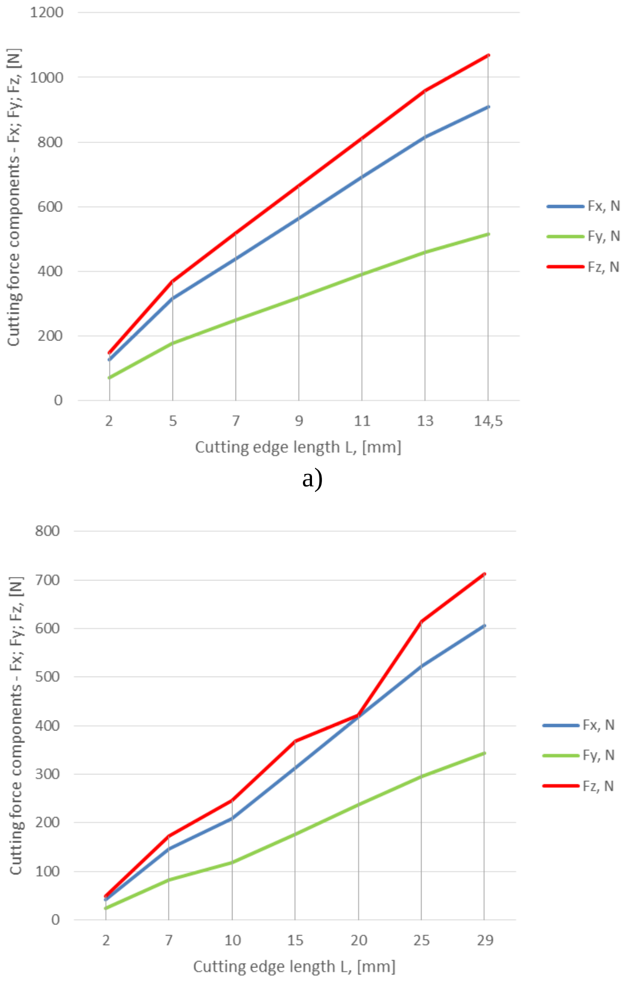
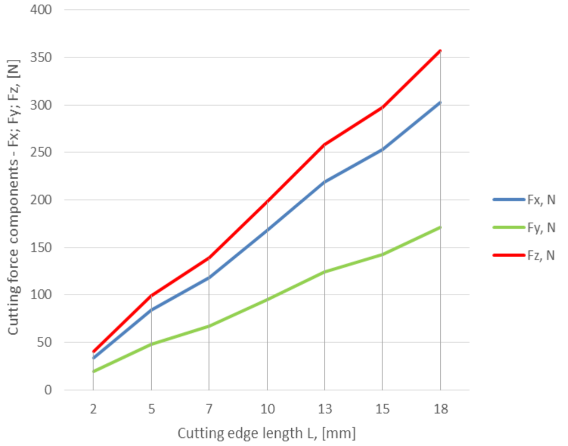


Fig. 8. Cutting force components at the three cutting edges of the cutting-smoothing guide insert - 17mm



a)

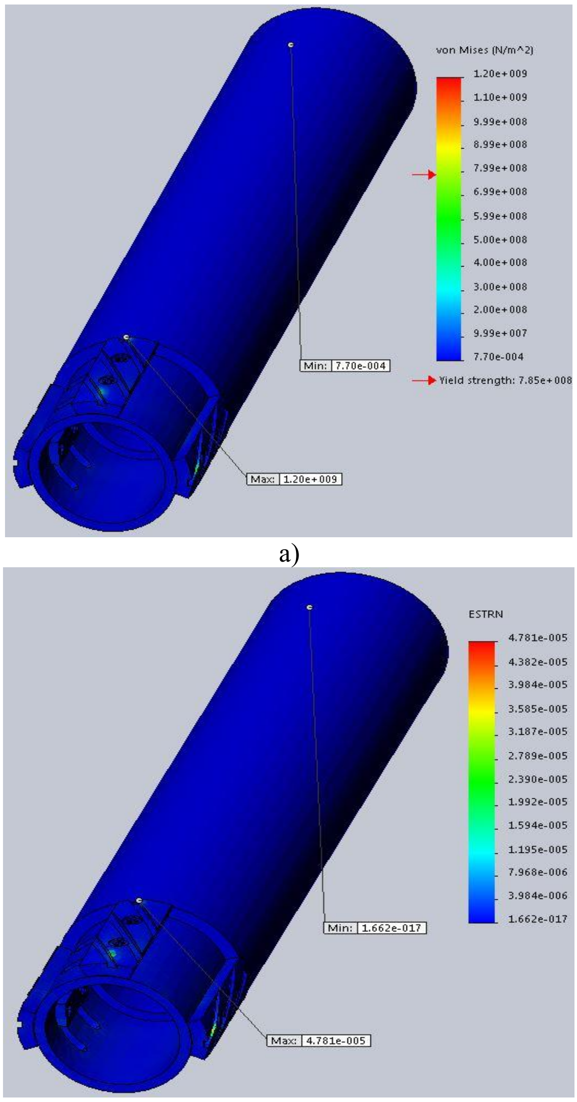
b)



c)

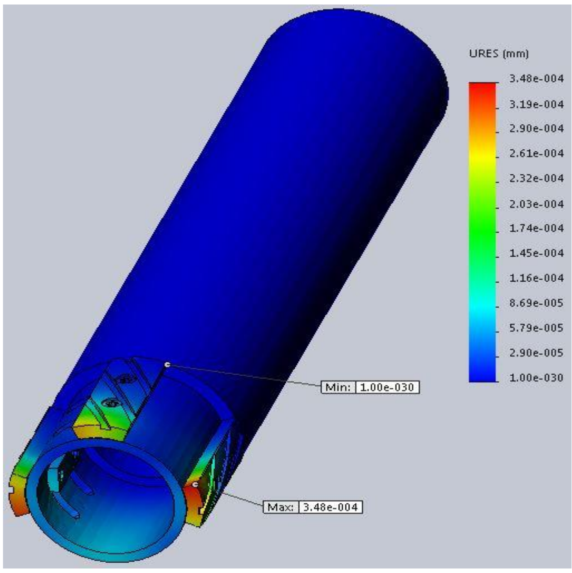
Fig. 9. Cutting force components at first cutting edge of the cutting-smoothing guide insert
a) 14.5mm; b) 29mm; c) 18mm

It should be noted that the total load includes the friction forces due to the smoothing of the machined surface. The analysis performed also allows determining the rational angle of inclination of the cutting sections of the working elements shown in Figures 5 and 6.



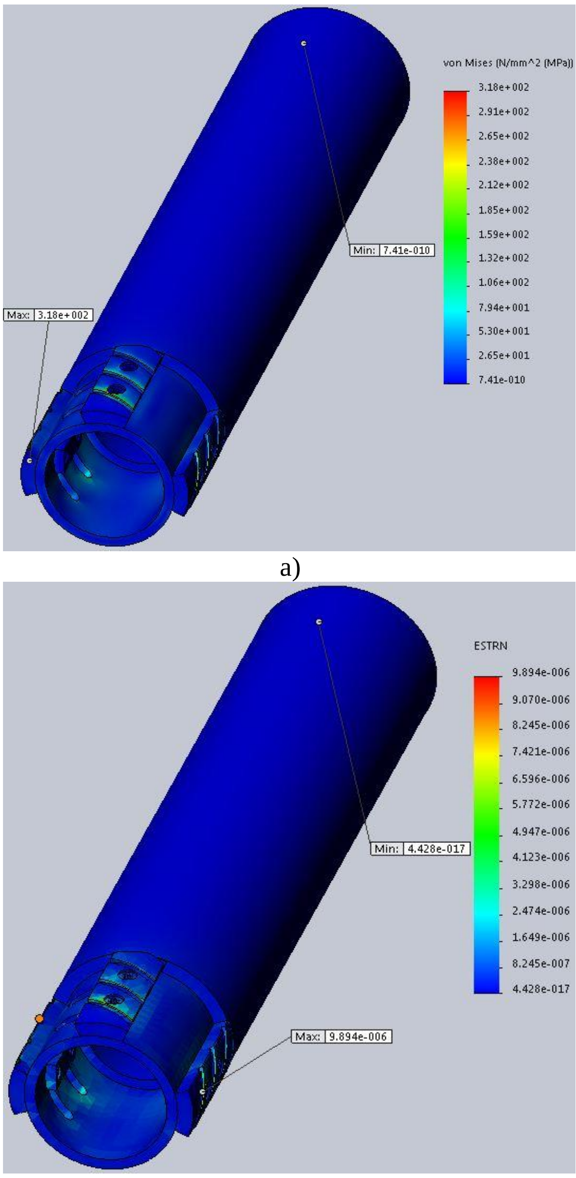
a)

b)



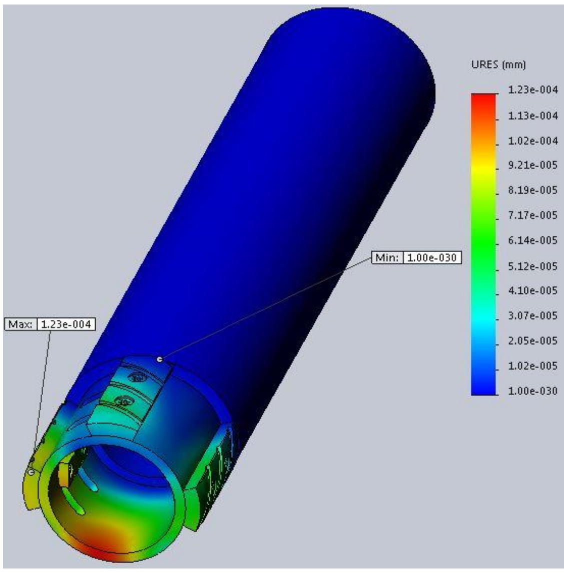
c)

Fig. 10. Results of force analysis at cutting edges inclination (ω=30°)
a) stress; b) deformations; c) displacement



a)

b)



c)

Fig. 11. Results of force analysis at cutting edges inclination (ω=60°)
a) stress; b) deformations; c) displacement

5. CONCLUSIONS

The following conclusions can be drawn from the conducted research:

- The gradual change in cutting forces in the incision process requires feeding the tool to achieve its full penetration into the machined hole (it is recommended to be used a technological device);
- The force load is fully acceptable, and the resulting stresses and deformations do not affect the tool from a strength point of view;
- The holes for fastening the working elements must necessarily be fixed between the cutting edges without affecting them. Otherwise, in those sections are obtained concentrators of stress, as well as receiving tracks on the machined surface;
- The most suitable angle of inclination of the cutting-smoothing teeth ω has a value of 30° as compared to the results of an angle of 60°, the values are considerably smaller (the same applies to the displacements of the cutting-smoothing elements (Figure 10 (c) and Figure 11 (c));
- The total force load at angle ω=60° is a consequence of the influence of the Fy component, which changes the overall load pattern.

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