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ТОРАЙҒЫРОВ УНИВЕРСИТЕТА

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## **DESIGN OF SHAPED CUTTERS**

*The article proposes an algorithm for designing round shaped cutters by graphical and analytical methods. Depending on the shaped profile of the part, this algorithm systematizes the calculation and allows you to apply a unified approach and easily automate it.*

*The purpose of the design is the possibility of automating and reducing the calculation time of shaped cutters and is based on determining the radii of the nodal points of the shaped cutter through projections between the nodal points on the horizontal plane.*

*A feature of the proposed algorithm for calculating shaped cutters is the consistency and the possibility of automating calculations that are simple and visual.*

*Keywords: round shaped cutter, graphics, profiling, analytics, design, calculation algorithm.*

### **Introduction**

The existing methods of designing flat form tools [1–5] are not characterized by universality, and for each cutter profile there is needed a separate diagram of designing.

The purpose of developing a new method of design is the possibility to automate and to reduce the time of designing flat form tools with a baseline.

The tasks of the new method of design are: developing a methodology of graphical and analytical design of a flat form tool with a baseline, using it in practice and publishing articles for the methodology dissemination in the practice of tools manufacturing.

In spite of the wide introducing of CNC machine tools machining complicated part shapes, the practical use of form tools is widely spread, therefore the new method of analytical and graphical shaping of form tools with a baseline for more accurate parts machining is expedient and will be used in future.

### **Substantiation of the Study Line**

There is no graphical shaping of form tools with a baseline in the literature on cutting tools, namely, on form cutters [2, 4, 6]. In [5, 7] there is presented the design of a flat form tool based on determining the tool junction points radiuses through the projections between the junction points on a horizontal plane.

At this the design diagram is not unified but strictly individual for each part profile. This does not permit to build a unified design algorithm and to automate the design. There

has been developed a method of graphical and correction analytical design of form tools with a baseline. A characteristic feature of the suggested method is its system and possibility to automate designing. Graphical shaping is simple, visual and easy to understand [8–12].

### Methodological Approach

In the new method of graphical shaping there are considered three projections of a flat form tool in the working position and one view by the arrow  $K$ , directed at the angle  $\gamma$  (frontal angle) to the horizontal plane perpendicular to the workpiece axis, along the front surface (Figure 1).

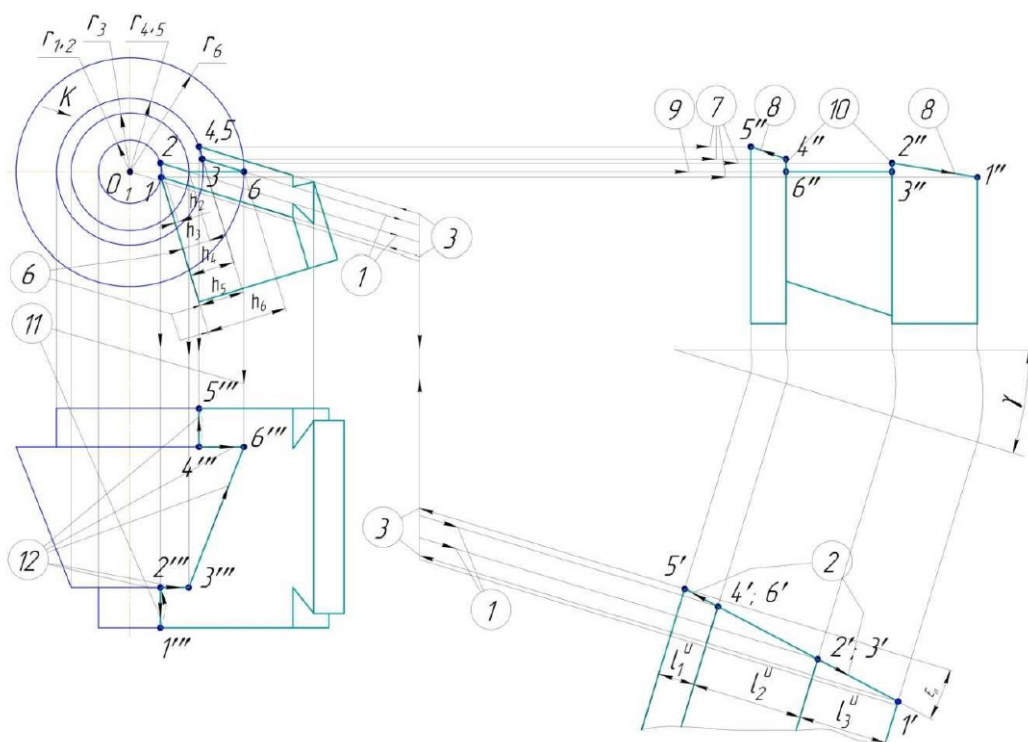


Figure 1 – Graphical shaping of flat form tool

### Results and Discussion

For graphical shaping it is necessary at the beginning to draw the baseline on the frontal projection of the shaping diagram (Figure 1, line 3–6 lying in the horizontal plane passing through the workpiece axis and coinciding with the generatrix of the workpiece cone). After this there is begun graphical shaping of a form tool.

First step. There are found points 3' and 6' limiting the baseline on the view  $K$ . To do this from points 3 and 6 on the frontal projection at the angle  $\gamma$  (by arrow  $K$ ) there are drawn lines with arrows marked by figures 1 in a circle for obtaining points 3' and 6' on the view  $K$  at the crossing of the lines with arrows 1 with the boundaries of the part stepping points.

Second step. Line space 3'-6' stretches to both sides (to the right and to the left on the view  $K$ ) for obtaining the extremities of the form tool blade 1' and 5'. The obtained line space 1'-5' (straight line) is a projection of the complicated blade of the form tool on

the view  $K$  coinciding with the trace of the tool frontal surface on the perpendicular to the plane frontal surface. Points  $1', 2', 3', 4', 5', 6'$  are the points obtained at the crossing of the frontal surface of the corresponding boundaries of the form tool shape stepping points. They are the junction points on the view  $K$ . The lines of the graphical shaping second step are marked by arrows with figures 2 in a circle on the view  $K$ . Points  $3'$  and  $6'$  position is defined by the angle  $\varepsilon_n$ , i.e. the angle of the frontal surface inclination along the form tool with a baseline axis. Angle  $\varepsilon = \varepsilon_n$  is determined graphically and is verified analytically in the correction design of the tool profile.

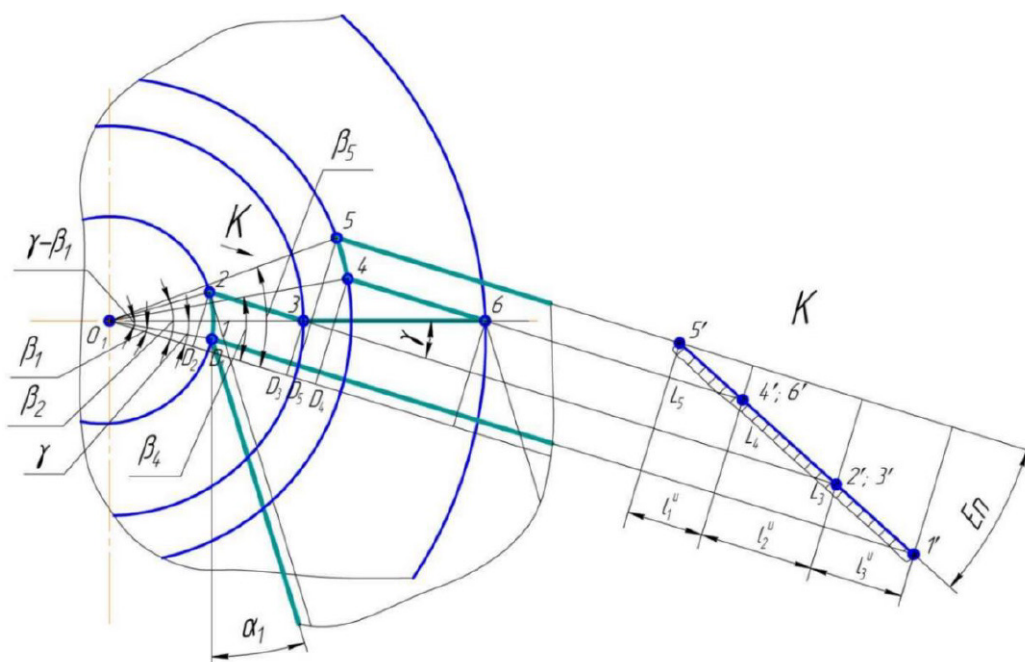


Figure 2 – Analytical shaping of flat form tool

Third step. From points  $1'$  and  $5'$  there are drawn the lines parallel to the lines with arrows 1, in the opposite direction, till crossing with the circles drawn through the corresponding junction points for obtaining points 1 and 5 on the frontal surface of the design diagram. The third step is marked by lines and arrows with number 3 in a circle.

Fourth step. Through points 3 and 6 on the frontal projection there are draw the lines parallel to the lines marked by numbers 1 and 3 (at the angle  $\gamma$ ) till crossing with circles of  $r_{1,2}$  and  $r_{4,5}$  radiuses for obtaining points 2 and 4. These two lines and arrows are marked by number 4 in a circle.

Fifth step. Points 1 and 2, 4 and 5 are connected by the segments of circles with radiuses  $r_{1,2}$  and  $r_{4,5}$  respectively. Radiuses  $r_{1,2}$  and  $r_{4,5}$  are projections of the cutting edges of a flat form tool inclined relative to the axis and generatrix due to the frontal surface grinding at the angle  $\varepsilon_n$ . To do this the back surfaces finishing when making a form tool, is to be performed using a grinding wheel-disc shaped by radiuses  $r_{1,2}$  and  $r_{4,5}$ . After the fifth step there is obtained a projection of the complicated cutting

edge 1-2-3-6-4-5 – of the form tool on the frontal plane. The fifth step is marked by number 5 in a circle.

Sixth step – defining the profile depth at various stepping points of the form tool. This step is marked by number 6 in a circle. The remaining steps have the purpose of building the other projections of the form tool cutting edges. The profile depth for each point is a distance from a point to the most extruding section of the back surface (at point 1) on the frontal plane. From each point there are drawn the lines parallel to the back surface at the angle  $\alpha_1$ , and between them there are measured distances  $h_1, h_2, h_3, h_4, h_5, h_6$  which are the result of graphical determining the profile dimensions of the form tool.

On format A4 the diagram in Figure 1 is small, therefore it is recommended to look at the diagram element (frontal projection, Figure 2) in Figures 2 and 3 where there are clearly seen all the relations between the diagram elements and the needed dimensions.

Seventh step. From points 1, 2, 4, 5 of the frontal projection (figure 1) there are drawn horizontal lines for determining points 1'', 2'', 4'', 5'' on the profile projection by means of crossing the lines with arrows 7 in a circle with the boundaries of corresponding stepping points of the form tool (see also figure 3 with the view K).

Eighth step. Point 1'' is connected with point 2'', point 4'' is connected with point 5'' – there are obtained blades 1''-2'' and 4''-5'' of the edge stepping points of the form tool on the profile projection. The eighth step is marked by arrows with number 8 in a circle.

Ninth step. From points 3 and 6 on the frontal projection there are drawn horizontal lines (they are combined in one line) for obtaining line space 3''-6'' (baseline projection on the profile plane). The line of the ninth step due to combining two lines is marked by a figure with two arrows and marked by number 9 in a circle.

Tenth step. There are connected points 4'' and 6'', 2'' and 3''. There is obtained a projection of the complicated cutting edge of the form tool on the profile projection: 1''-2''-3''-6''-4''-5''. The tenth step (drawing lines 4''-6'' and 2''-3'') is marked by number 10 in a circle.

Eleventh step. From points 1, 2, 3, 4, 5, 6 on the frontal projection there are drawn vertical lines marked by number 11 in a circle till crossing with the junction points of the tool projection on the horizontal plane, there are found points 1''', 2''', 3''', 4''', 5''', 6''' of the complicated cutting edge of the form tool on its horizontal projection.

Twelfth step. There are connected points 1''' and 2''', 2''' and 3''', 3''' and 6''', 4''' and 5''' by the lines with arrows marked by number 12 in a circle. There is obtained the projection of the cutting edge of the form tool on its horizontal projection: 1'''-2'''-3'''-6'''-4'''-5'''.

The form tool cutting edge in the plane of the frontal surface with inclination  $\varepsilon_n$  relative to the workpiece cylinder generatrix (horizontal plane) corresponds to the elliptical line (cylinder section by the inclined plane). The form tool cutting edge is to be elliptical, concave in this section. To ensure these conditions in the cutting zone and obtaining the preset cylinder on the workpiece, the form tool final shaping is to be performed by a finishing wheel-disc with the profile radius equal to the radius of the workpiece cylindrical segment, with placing the finishing disc axis relative to the form tool frontal surface at the angle  $\varepsilon_n$ , or by a wheel – disc specially charged, with another

diagram of shaping. In this case there is easily ensured theoretical of machining and there is not introduced any error.

This stage of the form tool designing can be performed, as a rule, only after graphical shaping and determining the form tool junction points position. Therefore an obligatory requirement is the form tool graphical shaping. Of course, a design diagram can be built, if there is enough experience, without graphical shaping but this is for trained specialists. For the design visualization and simplification of its automation it is divided into five steps (stages) – Figure 2 and 3.

First step. Determining the distances from the form tool profile junction points on the frontal surface to the workpiece axial plane parallel to the frontal surface, and projections of the distances between junction points on the plane parallel to the lateral sides of the form tool and perpendicular to the workpiece axis, parallel to the frontal surface (Figure 2).

$$\text{Projection } 1-2 = 1'-2' = 1'-3' = L_3 - 3' = \ell_3^u \operatorname{tg} \varepsilon_n;$$

$$\text{Projection } 2'-4' = 3'-4' = 2'-6' = 3'-6' = L_4 - 6' = \ell_2^u \operatorname{tg} \varepsilon_n;$$

$$\text{Projection } 4'-5' = 6'-5' = L_5 - 5' = \ell_1^u \operatorname{tg} \varepsilon_n;$$

$$\text{Distance } D_2 - 2 = r_2 \sin \beta_2;$$

$$\text{Distance } D_3 - 3 = D_2 - 2 = O_1' - 3' = O_1' - 2' = r_3 \sin \gamma;$$

$$\text{Distance } D_1 - 1 = O_1' - 1' = (O_1' - 2') - (1' - 2') = (O_1' - 3') - (1' - 3') = r_3 \sin \gamma - \ell_3^u \operatorname{tg} \varepsilon_n$$

$$\text{Distance } D_5 - 5 = O_1' - 5' = (1' - 5') + (O_1' - 1') = (L_3 - 3') + (L_4 - 4') + (L_5 - 5') + (r_3 \sin \gamma - \ell_3^u \operatorname{tg} \varepsilon_n) = (\ell_1^u + \ell_2^u + \ell_3^u) \operatorname{tg} \varepsilon_n + r_3 \sin \gamma - \ell_3^u \operatorname{tg} \varepsilon_n = (\ell_1^u + \ell_2^u) \operatorname{tg} \varepsilon_n + r_3 \sin \gamma;$$

$$\text{Distance } D_4 - 4 = D_6 - 6 = (O_1' - 1') + (1' - 4') = (O_1' - 1') + (1' - 6') = r_3 \sin \gamma - \ell_3^u \operatorname{tg} \varepsilon_n + (\ell_3^u + \ell_2^u) \operatorname{tg} \varepsilon_n = r_3 \sin \gamma + \ell_2^u \operatorname{tg} \varepsilon_n = r_4 \sin \beta_4 = r_6 \sin \gamma;$$

$\ell_1, \ell_2, \ell_3$  – are axial dimensions of the form tool profile; at the end stepping points there should be taken into account additional cutting edges.

Second step. Determining intermediate angular parameters  $\beta_i$  for designing auxiliary dimensions  $A_i$  (figure 2).

$$\sin \beta_1 = (D_1 - 1)/r_1 = (O_1' - 1')/r_1 = (r_3 \sin \gamma - \ell_3^u \operatorname{tg} \varepsilon_n)/r_1;$$

$$\sin \beta_2 = (D_2 - 2)/r_2 = (O_2' - 2')/r_2 = (r_3 \sin \gamma)/r_2;$$

$$\text{Angular parameters for the baseline points: } \beta_3 = \gamma, \beta_6 = \gamma;$$

$$\sin \beta_4 = [(D_4 - 4) = (D_6 - 6) = (O_1' - 4')]/r_4 = (r_3 \sin \gamma + \ell_2^u \operatorname{tg} \varepsilon_n)/r_4;$$

$$\sin \beta_5 = [(D_5 - 5) = (O_1' - 5')]/r_5 = (r_3 \sin \gamma + (\ell_1^u + \ell_2^u) \operatorname{tg} \varepsilon_n)/r_5;$$

Third step. Determining auxiliary linear parameters  $A_i$  (figure 3).

$$A_1 = r_1 \cos \beta_1; A_2 = r_2 \cos \beta_2; A_3 = r_3 \cos \gamma;$$

$$A_4 = r_4 \cos \beta_4; A_5 = r_5 \cos \beta_5; A_6 = r_6 \cos \gamma.$$

Fourth step. Determining auxiliary linear parameters  $C_i$

$$C_2 = A_2 - A_1 = r_2 \cos \beta_2 - r_1 \cos \beta_1 = r_{1,2} (\cos \beta_2 - \cos \beta_1);$$

$$C_3 = A_3 - A_1 = r_3 \cos (\beta_3 = \gamma) - r_1 \cos \beta_1;$$

$$C_4 = A_4 - A_1 = r_4 \cos \beta_4 - r_1 \cos \beta_1;$$



$$C_5 = A_5 - A_1 = r_5 \cos \beta_5 - r_1 \cos \beta_1;$$

$$C_6 = A_6 - A_1 = r_6 \cos(\beta_6 = \gamma) - r_1 \cos \beta_1.$$

Fifth step. Determining the tall dimensions of the flat form tool in the direction perpendicular to the back surface (Figure 3).

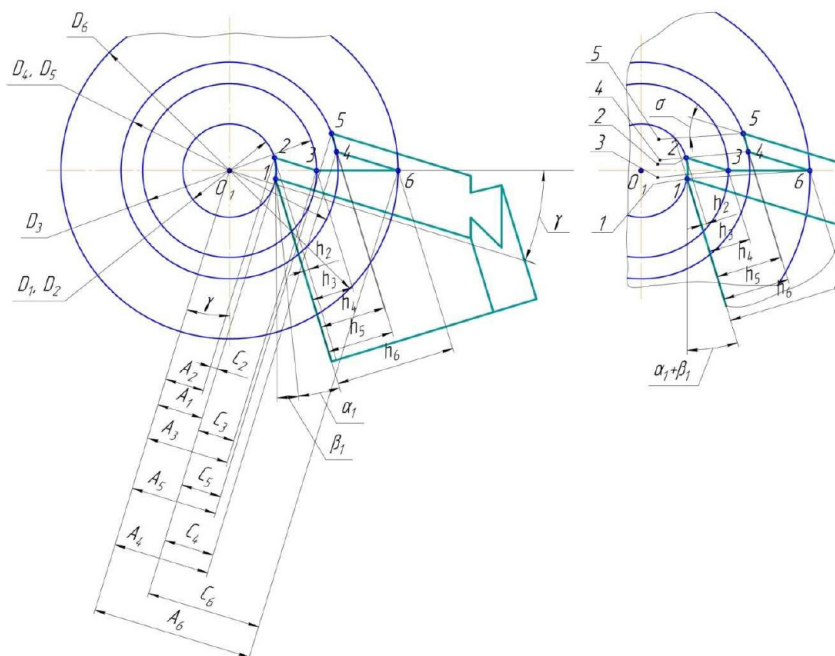


Figure 3 – Analytical shaping of flat form tool

Due to a large drop between points 1 and 2 in figure 2 and scale distortions that always have place with an abstract workpiece profile, dimension  $C_2$ , obtained in Figure 2, turned out to be on the left of point 1. With reducing line space 2–3 to the left there will be point 1, then the location of  $C_i$  and  $h_i$  will correspond to each other and  $C_i$  sign will be positive. However, with negative value of the calculated dimension  $C_i$ , the  $h_i$  dimension will be correct, as in the Figure it takes a corresponding position and there are actual ratios between  $h_i$  and  $C_i$ .

$$h_2 = C_2 \cos \sigma; h_3 = C_3 \cos \sigma; h_4 = C_4 \cos \sigma;$$

$$h_5 = C_5 \cos \sigma; h_6 = C_6 \cos \sigma; \sigma = \alpha_1 + \gamma_1.$$

All the tool parameters have been designed.

Thus, there has been obtained graphical shaping and calculated parameters – twelve steps; correction analytical shaping of a flat form tool – five steps.

## Conclusions

1 There is suggested a simple and visual method of graphical and correction analytical design of flat form tools with a baseline.

2 Graphical shaping of a flat form tool consists of twelve stages.

### 3 Correction analytical shaping of a flat form tool includes five steps.



4 The characteristic feature of the suggested method of designing circular form tool with a baseline consists in the system and unified approach.

5 The method permits to reduce labor intensity of designing flat form tools with a baseline.

6 The developed method of graphical and correction analytical design of flat form tools with a baseline permits to automate the design easily.

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### ПІШІНДІ КЕСКІШТЕРДІ ЖОБАЛАУ

*Мақалада графикалық және аналитикалық әдістермен дөңгелек пішінді кескіштерді жобалау алгоритмі ұсынылған. Бөлшектің пішінделген профиліне байланысты бұл алгоритм есептеуді жүйелейді және бірыңғай тәсілді қолдануға және оны оңай автоматтандыруға мүмкіндік береді.*

*Жобалау мақсаты – пішінді кескіштерді есептеу уақытын автоматтандыру және қысқарту мүмкіндігі және көлденең жазықтықтағы түйін нүктелері арасындағы проекциялар арқылы пішінді кескіштің түйіндік нүктелерінің радиустарын анықтауға негізделген.*

*Пішінді кескіштерді есептеудің ұсынылған алгоритмінің ерекшелігі – бұл жүйелілік пен қарапайым және түсінікті есептеулерді автоматтандыру мүмкіндігі.*

*Кілтті сөздер: дөңгелек пішінді кескіш, графика, профильдеу, аналитика, жобалау, есептеу алгоритмі.*

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### ПРОЕКТИРОВАНИЕ ФАСОННЫХ РЕЗЦОВ

*В статье предлагается алгоритм проектирования круглых фасонных резцов графическим и аналитическим способами. В зависимости от фасонного профиля детали, данный алгоритм, систематизирует расчёт, позволяет применить унифицированный подход и легко его автоматизировать.*

*Цель проектирования – это возможность автоматизации и сокращения времени расчёта фасонных резцов и основана на определении радиусов узловых точек фасонного резца через проекции между узловыми точками на горизонтальной плоскости.*

*Особенность предлагаемого алгоритма расчёта фасонных резцов – это системность и возможность автоматизации расчётов, которые являются простыми и наглядными.*

*Ключевые слова: круглый фасонный резец, графика, профилирование, аналитика, проектирование, алгоритм расчёта.*

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