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Form error calculation during polygonal sharpening of polyhedrons with even number of sides

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Abstract
Questions concerning formation of many-sided outer surfaces by means of polygonal sharpening are considered in this article. It is drawn out that while polyhedron processing with even number of sides there exists a working error. On the base of fulfilled researches mathematical dependence for determination of form error during polygonal sharpening of polyhedrons with even number of sides is suggested.
Key words: METAL-CUTTING TOOL, POLYGONAL SHARPENING, WORKING ERROR

In mechanisms of various machines there find application the parts, which have wide variety of profiles. The parts, which have n-hedral surfaces, are used the most often [1].

Traditionally for formation of n-hedral surface there used milling machines with universal dividing head. But such method is unefficient [2]. The other variant of processing of out-of-round surfaces is the application of NC machines.

In result of experiment fulfilled by D.L. Bekasov and V.N. Voronov, it was proved that productivity of sharpening of out-of-round surfaces (according to basic time) corresponds to the productivity of circular shafts sharpening, which is notably higher, than while forming of polyhedrons with the help of dividing devices [3].

Polygonal sharpening principle lies in that the rotation is given to the section and tool, the axes of which are parallel to each other, and the tool is represented as cutter block with several cutting edges. In such a way movement pattern of cutting edge of a tool relatively coordinate system of the section will circumscribe it by trochoidal curve in the shape of ellipses.

As the trochoidal curve is not a linear function, the processable side plane is not a flat surface, so the obtained cross profile is of the polypolygon form with convex sides. Maximum value of variation in plane let us denote as piece form error Δ, i.e. shaping error, which will depend on processing options [4].

Calculation of form geometric error, i.e. form deviation of the obtained profile from the desired equilateral polygonis of great interest.

Let us consider analytic model (fig.1), parametric equation of hypotrochoid *γ*:

$$x(t) = A\cdot\cos(t) + (A-r)\cos\left(\left(\frac{\omega_2-\omega_1}{\omega_1}\right)\cdot t\right);$$

$$y(t) = A\cdot\sin(t) - (A-r)\cdot\sin\left(\left(\frac{\omega_1-\omega_2}{\omega}\right)\cdot t\right),$$

(1)

where ω_1 – angular velocity of cutter block; ω_2 – workpiece angular velocity; A – the distance between rotation axis of cutter block and workpiece rotation axis; r – radius of an inscribed circle into the obtained polypolygon; t – parameter changing from *0* to *2*.

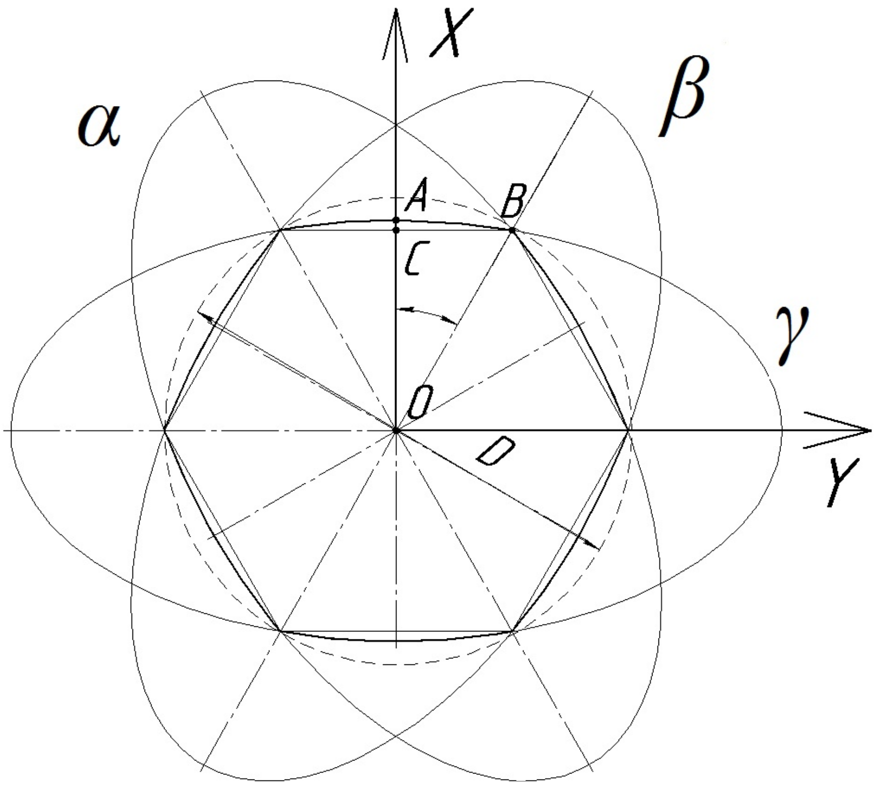

Figure 1. Computational scheme

Parametric equations of hypotrochoids α and β may be obtained by figure turn γ at the corner $\frac{\pi}{3}$ and $\frac{2\pi}{3}$ respectively.

For our case correlation $\frac{\omega_2}{\omega_1} = 2$ is not constant, system of equations (1) will convert into:

$$x(t) = A \cdot \cos(t) + (A - r)\cos(t) = (2A - r) \cdot \cos(t); \quad (2)$$
$$y(t) = A \cdot \sin(t) - (A - r) \cdot \sin(\cdot t) = r \cdot \sin(t),$$

To estimate accuracy of the form Δ (AC) of obtained polypolygon, it is necessary to find coordinates of hypotrochoid traverse points. The point B of hypotrochoid γ with coordinates $x(t_0)$, $y(t_0)$ corresponds to them, where the value of parameter t_0 may be determined in such a manner.
First of all let us calculate the angle between half-lines OA and OB (fig. 1).

$$\varphi_0 = \frac{\pi}{2} \div N ,$$

where N - number of cutters (for hexagonal section $N = 3$);
let us write the equation of tangent of angle φ_0

$$tg\varphi_0 = \frac{BC}{OC} = \frac{x(t_0)}{y(t_0)} = \frac{2 \cdot A + r}{r} \cdot ctg(t_0) = \frac{2 \cdot A + r}{r} \cdot \frac{1}{tg(t_0)}$$
(3)

From the equation 3 we will find the value t_0

$$t_0 = arctg\left(\frac{2 \cdot A + r}{r} \cdot \frac{1}{tg(\varphi_0)}\right) = arctg\left(\frac{2 \cdot A + r}{r} ctg(\varphi_0)\right)$$
(4)

Further we will find the distance from the center of hypotrochoid to its upper point

$$OA = y\left(\frac{\pi}{2}\right) = r \quad (5)$$

Desired absolute accuracy of the form is determined under the formula:

$$\Delta = AC = \left|OA - y(t_0)\right| \quad (6)$$

Inserting the expression (4) into the second expression of the system (2), we will find:

$$y(\varphi_0) = r \cdot \sin\left(arctg\left(\frac{2 \cdot A + r}{r} \cdot ctg(\varphi_0)\right)\right) \quad (7)$$

Inserting the equations (4) and (7) into (6), we will obtain:

$$\Delta = \left| r - r \cdot \sin\left(arctg\left(\frac{2 \cdot A + r}{r} \cdot ctg(\varphi_0) \right) \right) \right| =$$

$$= \left| r \cdot \left(1 - \sin\left(arctg\left(\frac{2 \cdot A + r}{r} \cdot ctg(\varphi_0) \right) \right) \right) \right|$$

In such a way there obtained a mathematical model for determination of default level of workpiece form. The dependency diagrams of the value of error on the size of processed polyhedron and size of cutter block were built on the base of this mathematical model.

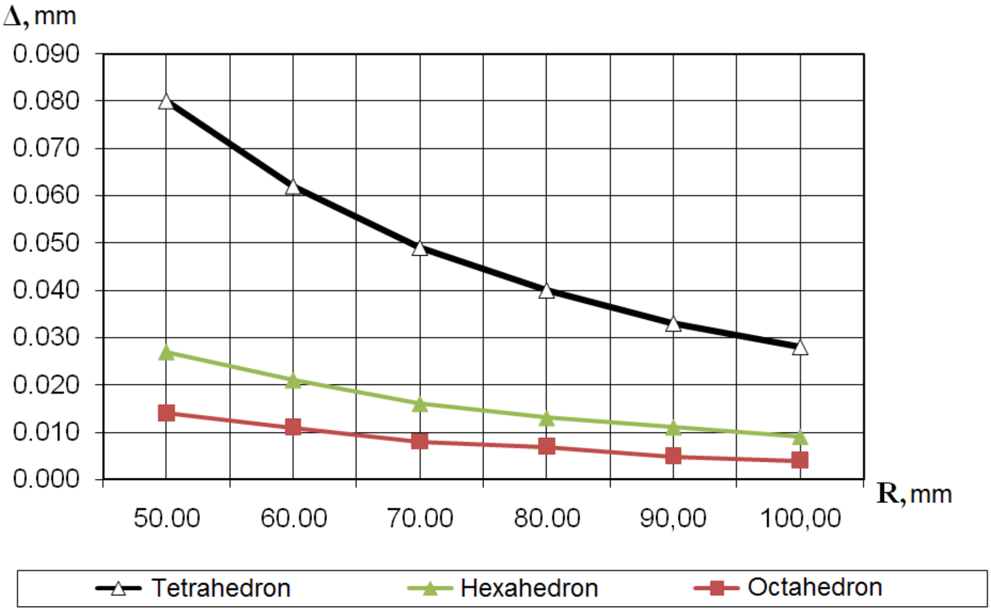

Figure 2. Dependency diagrams of form error of obtained workpiece on the radius of cutter block

On the diagrams of the figure 2 there built dependencies of form error of the obtained workpiece on the radius of cutter block under the condition that the radius of inscribed circle into the obtained polypolygon of cross section of produced workpiece is constant and equal to 15 mm. From the diagram it follows that while increasing the edges of obtained workpieces and radius of cutter block, the error reduces.

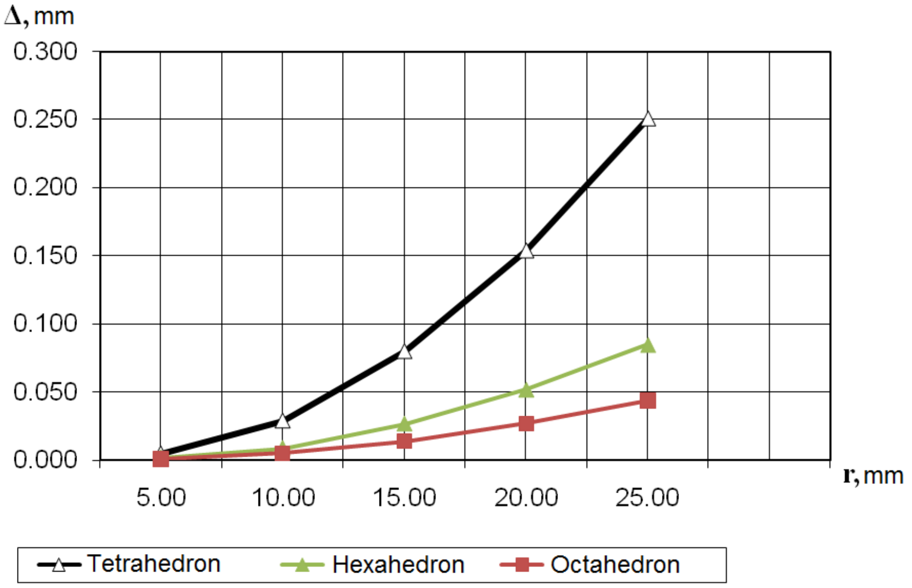

Figure 3. Dependency diagrams of form error of obtained piece on the radius of inscribed circle into the polypolygon with cross section of produced workpiece

On the diagrams of the figure 3, there built dependencies of form error of the obtained piece on the radius of incircle into obtained polypolygon with cross section of produced work piece under the condition that the radius of cutter block is constant and equal to 50 mm. From the diagram it follows that while increase of radius of incircle into obtained polypolygon with cross section of produced work piece, the error increases.

In such a way, there obtained mathematical model for determination of value of workpiece form error, which allows the technologist on the stage of development of production process to decide upon the effectiveness of application of polygonal sharpening. Technological parameters influencing the form error during polygonal sharpening, the change of which will allow to reduce this error are revealed.

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