

## A SOFTWARE SYSTEM FOR DETERMINING THE CUTTING EDGE PROFILE OF DISC CUTTER TEETH

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**Abstract:** The article describes the authors' developed algorithm for profiling the work part of the disc cutter for cutting gears with larger modules. A software system using the algorithm has been designed and the interface is given. The computing capabilities are used, applying the method of coating and its variant - a constructive coating method for determining the profile of cutting teeth - the angle of their slope from the perpendicular to the axis of the disc cutter. The software system allows profiling of involute gears with different number of teeth. The proposed software system is universal and therefore could be applicable from engineers in tool departments in different factories. The software system could be also used in training students in subjects, which study themes in profiling tools for cutting involute gears. In the paper is given a solution for application of the designed from authors software system, for profiling of prefabricated disk cutter for gear with the parameters, as follows: module  $m = 20$  mm; profile angle  $\alpha = 20^\circ$ ; number of teeth  $z_1 = 50$ ; coefficient of shifting the initial contour  $x_1 = 0$ .

**Key words:** disc cutter, profiling, cylindrical gear, software system, time for profiling.

### 1. INTRODUCTION

Disk module cutters are used for roughing and finishing in cutting of gears with large modules ( $m \geq 15$  mm), such as slow-speed gear transmissions, used for driving cylinders in cement, chemical, food processing, mining and other industries.

In processing gears, a lot of time is spared for cutting metal from the tooth gap. For instance, processing teeth of a gear, which has diameter 10 800 mm, module 42 mm and ratchet ring's width 350 mm, 2 350 kg metal are turned into chips [8]. Usually cutting is done applying some rough passages and one finished for final process.

For the circumstance of the big module, the cutters used for cutting such gears usually are made as prefabricated tools structures.

This leads to continuous growing competition through the companies in solving fundamental problems, connected with effective cutting of cylindrical gears.

The gear transmissions and gears requirements, associated with their quality work and reliability of the products in which they are included, are growing continuously.

The most promising and with rapidly, actual application proves the tendency – improvement of tools profiling using computers – development of specialized software systems, which allow receiving rational parameters of the tool's working part. Improving

profiling tools do not require large financial and material investments.

Investing in worm and disc cutters improvement, associated primarily with the profiling of their working part, leads to short time for realisation, low material and financial cost and. That is the shortest and economical way in growing their efficiency in cutting cylindrical gears. This is serious economic and industrial advantage of the companies, which design, use and manufactures worm and disk cutters.

If the computer aided design of tools is accompanied by introduction of new machines and equipment for cutting gears, it will effect in multiplying of affirmative results in growing quality and efficiency of the process, which is material to company productivity.

In the past century, priority in gears manufacture is given to the increase of its volume, as the quality remains in the background, but in XXI century, the priorities are exchanged. Main purpose is growing of the gears' quality, ensured in mass production, having at the same time increasing of the gears transmissions possibilities and reliability and minimization of the volume features. This basic problem could be solved using computer techniques, which give the possibility of finding solutions of all quality requirements.

Automated design of worm hob went through different periods of its development, related to the use of computers.

Initially systems for construction of worm cutters, which included full development of the constructional drawings and its graphical plotting were developed. Those systems have been developed in specialized institutes, especially for needs of large users of tooth processing machining tools (Fig. 1) [7].

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Later, it switched to a new phase – automated profiling only the work part of the instrument. The best decisions for each concrete case of cutting gear are looking for. Other cutter parameters have to be chosen from the possibilities of the gear-cutting machine and those of the manufacturer.

Using data from [5], only for the transition from “manual” to automated design, the costs for designing time decreases few times (Fig. 2). The costs for tool design are just about 5% of the whole costs [5]. At the same time, the influence of design on the quality of the gear is very high (almost 70%). This approves the advisability of costs for a CAD-system.

Our research [6] in this direction also gives us reasons that development of software system for design of complex-profiled tools is economical profitably task, its result could be used from small, medium and large factories.

## 2. NEEDFUL INFORMATION FOR PROCESSED GEAR

The gear information, which is necessary for development of a software system, is taken from the work drawing of the gear or is calculated according references data [1]. All information obtained in both ways is given in Table 1.

The input information for worpiece gear, which is needful for the profile determination of disk cutting teeth, is given in Table 1.

## 3. DETERMINATION OF THE NODES' PARAMETERS OF THE CUTTING WHEEL INVOLUTE PROFILE

Parameters of the nodes have to be determined in the following sequence:

- parameters, characterizing the main circle

$$d_{b1} = m \cdot z_1 \cdot \cos \alpha,$$

$$p_{b1} = \pi \cdot m \cdot \cos \alpha,$$

$$S_{b1} = W_1 - (z_{w1} - 1) \cdot p_{b1},$$

$$\theta_{b1} = \frac{p_{b1} - S_{b1}}{2r_{b1}}.$$

- parameters of the nodes (point N)

- Change of the radius and its value

$$\Delta r = \frac{r_A - r_L}{z_0 - 1};$$

$$r_N = r_A - \sum_{i=1}^{z_0-1} \Delta r,$$

- Profile angle

$$\alpha_N = \arccos\left(\frac{r_{b1}}{r_N}\right);$$

- Involute angle

$$\theta_N = \tan \alpha_N - \alpha_N;$$

- Angle of involute developing

$$v_N = \alpha_N + \theta_N;$$

- Profile angle of the cutting tooth

$$\psi_N = \alpha_N + \theta_N + \theta_{b1}.$$

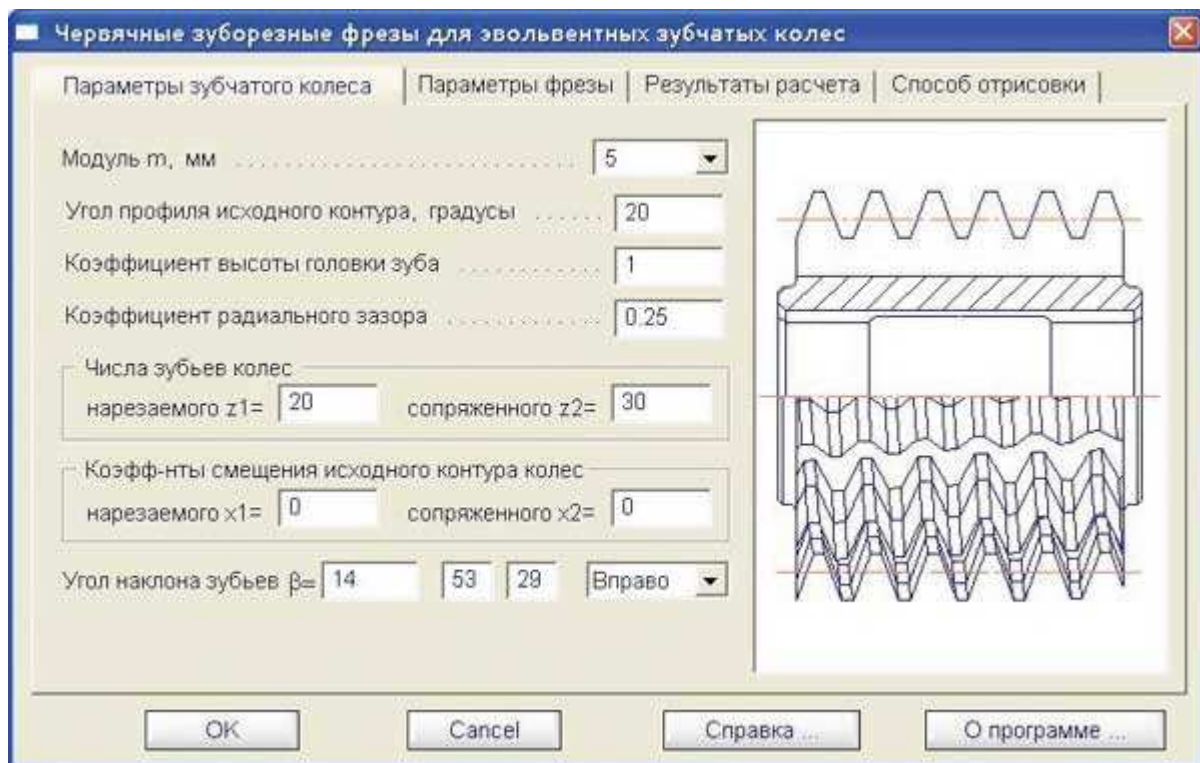


Fig. 1. Computer aided design of a worm cutter.

**4. DETERMINATION OF PROFILE DEVIATION OF THE WHEEL'S TEETH**

**4.1. Determination of the first point parameters – point A**

$$x_A = r_{a1} \cdot \sin \theta_A$$

$$y_A = r_{a1} \cdot \cos \theta_A$$

$$a_A = tg \left( \frac{\pi}{2} - v_A \right)$$

$$b_A = y_A - a_A \cdot x_A$$

$$\beta = \arctan \left( \frac{y_A - y_2}{x_A - x_2} \right)$$

$$v_m = \frac{\pi}{2} - \beta$$

$$x_m = r_m \cdot \sin \theta_m$$

$$y_m = r_m \cdot \cos \theta_m,$$

$$a_m = tg \beta$$

$$b_m = y_m - a_m \cdot x_m.$$

**4.2. Determination of the parameters of second (next) point**

$$x_2 = r_2 \cdot \sin \theta_2$$

$$y_2 = r_2 \cdot \cos \theta_2$$

$$a_2 = tg \left( \frac{\pi}{2} - v_2 \right)$$

$$b_2 = y_2 - a_2 \cdot x_2.$$

**4.5. Error determination**

$$R_z = \frac{y_n - a_m \cdot x_n - b_m}{\sqrt{a_m^2 + 1}}$$

**4.6. Parallel with the allowable error**

$$R_z \leq [R_z] = f_{fr}.$$

**4.3. Determination of the parameters of the crossing point - N**

$$x_n = \frac{b_A - b_2}{a_2 - a_A}$$

$$y_n = \frac{b_A \cdot a_2 - b_2 \cdot a_A}{a_2 - a_A}.$$

Calculation from point 2 to point 6 for determining the error of wheel tooth profile have to be repeated for each couple of two succeeding teeth of disk cutter.

**4.4. Determination of the parameters of the intermediate point - M**

The point M has variable values – the first one is for the first (top) cutting tooth, and the last one – for the last tooth, marked with  $z_0$ .

Using iterative way, the parameters of point M –  $r_m$ ,  $a_m$ ,  $\theta_m$ , are determined so that the condition to be observed [3]:

$$\left( \frac{\pi}{2} - \beta \right) - 0.0005 \leq v_m \leq \left( \frac{\pi}{2} - \beta \right) + 0.0005,$$

where

**5. APPLICATION**

**5.1. Theoretical results**

The theoretical development for profiling the cutting edges of disk cutter for cutting cylindrical gears with involute profile is formalized in such level [4], which is possible to use for designing a software system. The system could give as a final result, the necessary parameters for profiling of the tool's teeth.

The principle scheme of the algorithm, developed for designing the software system for determination of the profile teeth angle is given in Fig. 3.

The parameters of the gear, which has to be processed with the disc cutter, are given in Table 1.

An exemplary result from work of the software system is shown on Fig. 5.

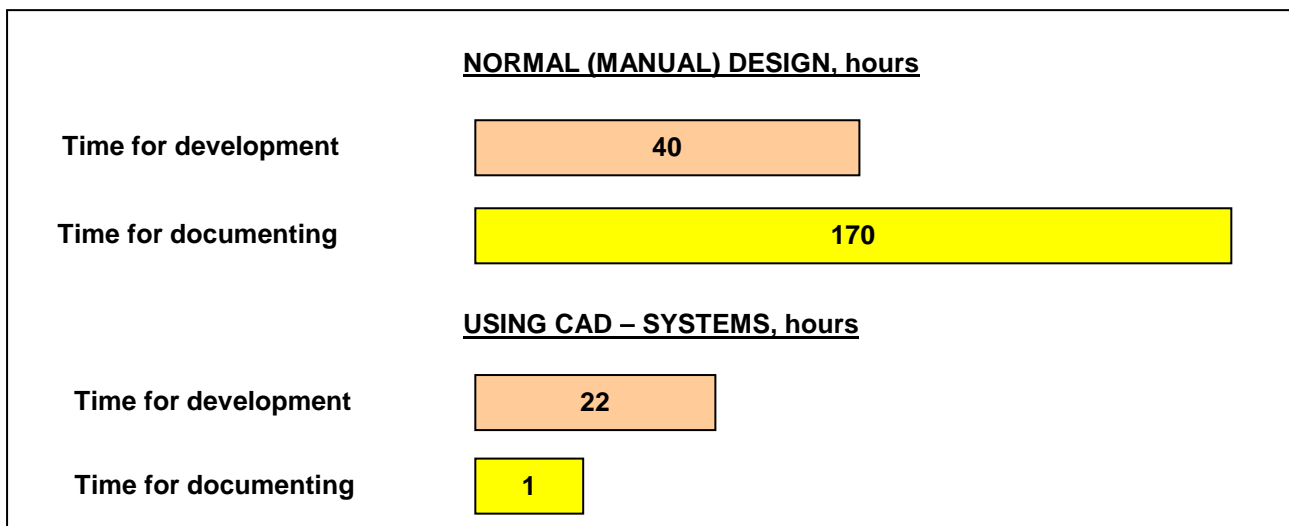


Fig. 2. Time for design and documentation.

Table 1  
Gear parameters, used in software system

$N\hat{o}$	Parameter	Symbol	Value
1	Gear module	$m$	20
2	Profile angle of the teeth	$\alpha^0$	20
3	Number of teeth	$z_1$	50
4	External circle diameter	$d_{a1}$	1040
5	Root circle diameter	$d_{f1}$	950
6	Diameter of the limit border involute point	$d_{L1}$	966,27
7	Length of the common normal	$W_1$	338,74
8	Number of the teeth included	$z_{w1}$	6
9	Error of the profile	$f_{f_r}$	0.095
10	Number of teeth of the gear	$z_0$	12

## 5.2. Practical results

Basic moment in designing of each precast reinforced concrete tool is connected with the question of adjunctive areas of precast teeth and the body of milling cutter, on which they have to be montaged.

Following requirements should be observed:

- 1) Usage of simple technological surfaces for machining the body of disc prefabricated cutter.
- 2) Technologically elementary adjunctive areas of the teeth.

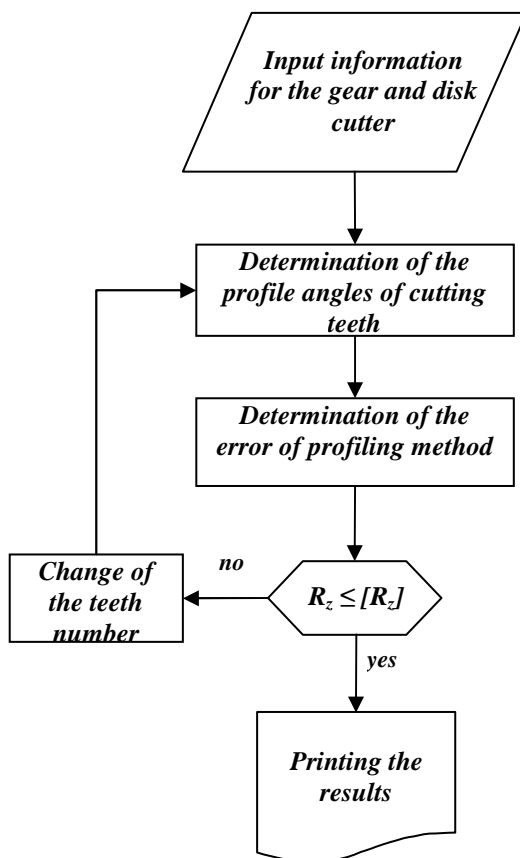


Fig.3. Flow chart of the algorithm for system action.

- 3) The devices for establishment of teeth for sharpening and subsequent re-sharpening have to be with

simple surfaces and to allow that all cutter teeth to be sharpen concurrent.

4) When machining the parts of precast cutter, use universal machine-tools, if it is possible.

5) Teeth profiling to be made on universal abrasive or grinder tools, using elementary application for their determination and profiling.

6) For technological support of precast disc cutters exploitation should not be demanded high constructive and technological skills of the worker.

Designed tooth, shown on Fig. 4, is one of the best variants, both in construction and technological approach, of joining two parts:

- front and back surfaces of the teeth are plane;
- supporting surfaces are plane;
- joining surfaces are plane;
- joining surfaces of the disc body, on which have to be specified teeth, are plane too.

These requirements on tooth give reasons for making the key elements of the disc cutter – body and teeth – will be used universal processes, realized on universal machine tools, if possible.


## 6. USAGE OF THE SOFTWARE SYSTEM

The software system is started from an executable file *Disccut.exe*. System requirements for it are very low – it is enough to have a PC with Windows XP, or later version. The system is easy for use and design especially for engineers or technologists in order to help in their work.

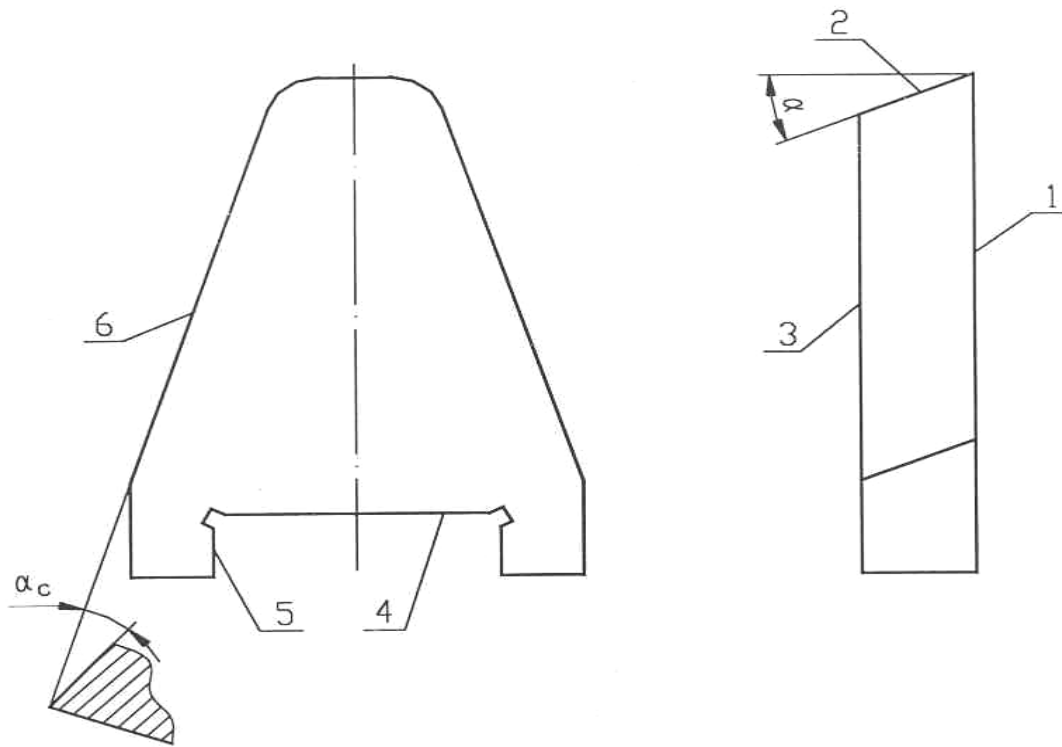
After starting the executable file, the starting window of the system is shown (Fig. 5). Working with the system could be separated in two parts. First the user has to prepare the values for the parameters needed. Then he has to fill the values for all ten parameters, as follows:

- Gear module;
- Profile angle of the teeth;
- Number of teeth;
- External circle diameter;
- Root circle diameter;
- Diameter of the limit border involute point;
- Length of the common normal;
- Number of the teeth included;
- Error of the profile;
- Number of teeth of the gear.

On the right of each name of parameter, there is an empty box, in which the user has to fill the values. There are two ways for shifting from each box to another. The user can point to each box with mouse pointer and then fill values using the keyboard. In the second way, he has the possibility to move from first box to next one only by pressing *Tab* key and filling the values.


After filling all the boxes with appropriate values, the system could be started by pressing  Calculate button (Fig. 4). The system calculates and shows the result of calculation, as it is shown on Fig. 4.

If some of the boxes do not have been filled with values, the system could not calculate accurately and that's why it shows a warning window with reminder which values have not been filled yet. The correct results could be achieved only if all the boxes are filled.



**Fig. 4** Tooth of prefabricated disc cutter: 1 – front surface;  
2 – back surface to the top of the tooth; 3 – support back surfaces;  
4 – support surface of the base;  
5 – side support surface; 6 – side cutting tooth.

After having the results, the system could be used again with other input data. It is enough to change one or more (even all) parameters and to press the button for calculation again.

Finishing work, the system should be closed, using the  button (Fig. 5).

The system has been developed especially for the Bulgarian market. But later we decided to change this feature. So, at the moment, it has three different interfaces – in Bulgarian, in English and in Russian. If there is an interest, the system could be translated in other languages, too.

As the system results has to be saved for later usage, there is an opportunity to save the results from systems work. When pressing the *Exit* button, the systems shows a message window, in which the user could choose to save the results or not.

If saving is chosen, results are saved in a text file in the working for the system directory. They contain not only the results received from the system work, but also all parameter values, which have been filled at the beginning. As further work, in the system will be added a special button, using which the results could be saved at each moment, not only when the system is closed.

It should be mentioned, that the profile angle is measured in degrees, and all parameters (except the number of teeth) are measured in mm and that is why there are no units of measurement written in the system.

In using the software system it is recommended to observe the requirement on module to be greater or equal to 15 mm ( $m \geq 15$  mm). The main reason for this requirement is that technological machines for producing worm hobs, which are much more efficient, usually are produced for cutting gears with modulus less than 14 mm. The machine tools for cutting cylindrical gears, as overall dimensions has smaller dimensions and their cost is economically profitably for usage in factories.

A module, which takes into account that the internal diameter of the wheel is greater than one of the main circle ( $d_{f1} \geq d_{b1}$ ), is built in the software program.

Having significantly fewer number of teeth, large transient curves are received, which are likely to cause the phenomenon of "interference", that being unacceptable for the joint operation of the gear.

In such circumstances, it is necessary that one of the disc cutter teeth to reduce the size of the transition curve. As a result it should create a positive rear corner of the tooth of disc cutter.

## 7. CONCLUSIONS

The system is designed in Delphi programming environment as an independent software system. It could be used for profiling disc cutters with sharp teeth.

The users of the software product should not need to be skilled in programming, so it could be used by every engineer or technologist. It is also very useful for teaching students in subjects connected to design and profiling disc cutters.

Input Parameters		Calculation results	
Gear module	20.00	$\Psi_1 = 28^\circ 7'$	
Profile angle of the teeth	20.00 °	$\Psi_2 = 27^\circ 9'$	
Number of teeth	50.00	$\Psi_3 = 26^\circ 9'$	
External circle diameter	1040.00	$\Psi_4 = 25^\circ 7'$	
Root circle diameter	950.00	$\Psi_5 = 24^\circ 3'$	
Diameter of the limit border involute point	966.27	$\Psi_6 = 22^\circ 58'$	
Length of the common normal	338.74	$\Psi = 21^\circ 45'$	
Number of teeth included	6.00	$\Psi_8 = 20^\circ 32'$	
Error of the profile	0.095	$\Psi_9 = 19^\circ 14'$	
Number of teeth of the gear	12.00	$\Psi_{10} = 17^\circ 50'$	
		$\Psi_{11} = 16^\circ 20'$	
		$\Psi_{12} = 14^\circ 40'$	

Fig. 5. Results of the software system work.

It should be used for profiling prefabricated disc cutters with large modules ( $m \geq 15$  mm). For those with smaller module the authors have developed another software system.

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