



## How to cite this article:

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Title of article: „Modelowanie procesu kształtowania ślimaków przekładni spiroidalnej” (“Modeling the process of shaping worm gears of spiroid gear”)

*Mechanik*, Vol. 91, No. 1 (2018): pages 24–27

DOI: <https://doi.org/10.17814/mechanik.2018.1.3>

# Modeling the process of shaping worm gears of spiroid gear

## Modelowanie procesu kształtowania ślimaków przekładni spiroidalnej

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The article presents various methods of shaping cylindrical spiroid worm gear of asymmetrical outline using two tools. Cutting thread of worm gears is made on CNC lathes with blades in the form of universal inserts. Shows the geometric model and technological machining cylindrical worm gear spiroid on a CNC lathe. The correctness of the test results obtained in numerical developed program was tested through experimental studies of the process of cutting worm gears given parameters. Cutting process of worm gears was made on a lathe CTX210 using overlay ShopTurn in module for threading. The process uses a standard turning tool with interchangeable inserts and turning tools with a specially designed geometry. Studies performed on various cutting parameters and for a various materials of cutting inserts.

**KEYWORDS:** spiroid gear drive, cylindrical worm gears, turning

Development of numerically controlled machine tools and tool materials forces the research into new technologies. In the case of waste technologies, the tendency to reduce the costs of manufactured parts of machines and devices is directed to the use of mass-produced interchangeable blades of tools in the form of cemented carbide inserts. The selection of the geometry and material of the cutting blade depends on the material being processed and technological parameters of the cutting process.

Analyzing the method of forming cylindrical screws of spiroid gears, one should pay attention to the difference between them and snails used in worm gears. The Russian Standard GOTS 22850-77 on spiroidal transmissions contains, among others, description of a dozen or so types of such transmissions and technologies for making screws (conical and cylindrical). The feature that distinguishes the spiral worm snails from screw auger worms is the occurrence of asymmetric outlines of the screw's reel. In the worm gears, both angles of the spiral profile of the screw are usually  $20^\circ$  [20], while in spiroid gears they are always different, and their value is calculated for a given case of a structural solution [1–5,10,18, 20]. The sum of the angles of the spiral profile of the screw is usually taken as  $40^\circ$  for the solutions of the highest efficiency spiroid gears and approx.  $35^\circ$  for gears, from which greater kinematic accuracy is required, whereas efficiency is less important here (e.g. in rotary table applications) [6–8].

Different ways of shaping the snail worm gear have been described, among others in [12–14, 20], where the theoretical and technological foundations are discussed. Most often, however, forming machining of a screw roll takes place on a lathe, and finishing work – on a grinder, after a heat treatment. In worm gear applications in rotary tables, two-stroke screws are usually used, which allow adjustment of the tooth clearance. Japanese company Nikken performs sintered carbide snails [9], which ensures the highest screw life, although the cost of its production is very large compared to snails made of alloy steel.

In spiroid gears, auger rolls can be shaped using a milling head [3] or on lathes and finished with a special grinding method [16, 17]. The finishing of the screw roll (after heat treatment) is also performed on a lathe with a high cutting speed (the lathe must have an electro-spindle) and with the use of cermet blade [18].

### Shaping the spiral worm gear with the use of a rhomboid plate

Manufacturers' catalogs include sintered carbide inserts of various geometries and materials. A rhomboid plate with an apex angle of  $35^\circ$  was selected for the study of the spiral worm gear forming, which corresponds to the minimum value of the snail's spiral angle currently produced in spiroid gears for rotary tables [6–8,10,20].

In the case of using a worm on the market for a turning tool for diamond-shaped inserts, it should be screwed at the right angle in the lathe holder in order to ensure the correct positioning of the plate in relation to the shaft in which the screw roll will be cut. An example of how to fasten a turning tool in a turret lathe tool holder, whose angle setting was obtained by means of a protractor, is shown in fig. 4.

The choice of cutting strategy for spiral worm gear with the use of a diamond plate largely depends on the geometry of the insert (entering angle) and the angles of the asymmetrical spiral profile of the screw. These dependencies are described in the appropriate formulas [15].

In practice [20], it is only possible to cut a snail's coil with the tool movement in the direction of a larger inclination angle of the lateral surface of the screw turn (fig. 1).

The incision of a screw roll with an angle greater than the angle of the tip plate (turning tool) requires the use of two turning tools with set angles (fig. 2).

In order to properly execute the coils of the auger, the second tool should be appropriately oriented, which will shape the screw roll against the workpiece in the form of a shaft, and set the angle of the screw [11] accordingly.

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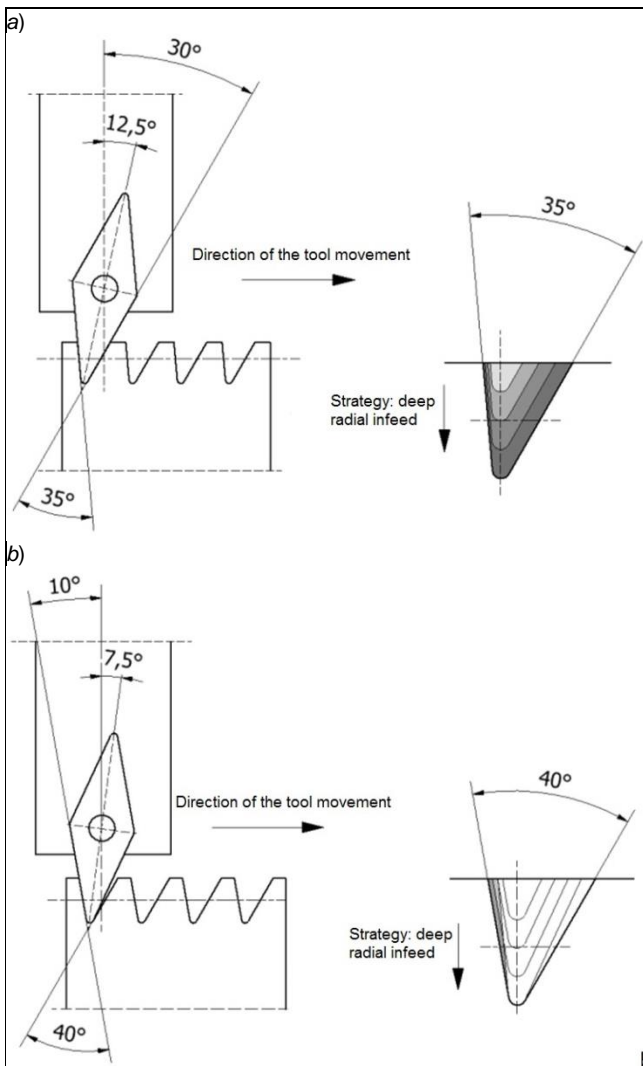


Fig. 1. Position of the first (a) and second (b) turning tools and the method of penetrating the blade into the material

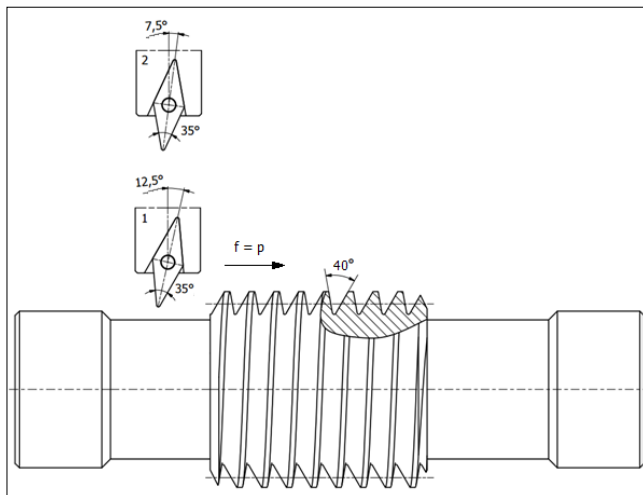


Fig. 2. The position of the tools for processing each of the side surfaces of the screw turn

Depending on the type of screw (cylindrical or conical), the tool moves parallel to the forming cylinder or cone. Roughing of the screw turns must be carried out in several passes of the tool, leaving the finishing allowance.

Ensuring the correct screw geometry requires machining of each of its side surfaces of coils separately. For this purpose, two turning knives with the appropriate geometry were used and a machining was carried out using the strategy of inserting the cutting blade into the material by means of radial infeed for both knives.

The study of the process of cutting a spiral of auger consisted in the use of a standard turning tool in the preliminary tests, placed at the right angle in the tool holder, while in the basic research, specially designed turning knives were used. During the research, the screw was machined to gears with ratios 1:60 and 1:90. The machining was carried out on a CTX210 lathe.

### Investigation of the process of cutting a spiral of a screw with the use of standard tools

Preliminary research, which was aimed at checking the correctness of the development of a computer program, was carried out using a standard turning tool. Fig. 3 shows the program window with dimensions of the slotted screw.

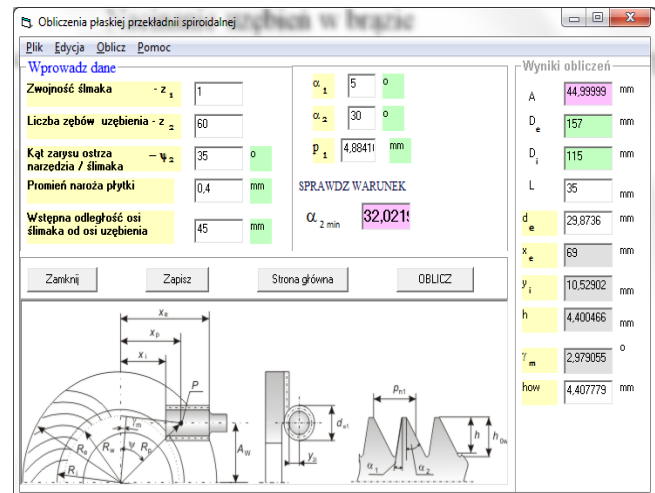


Fig. 3. View of the computer program window for determining geometrical dimensions of shaped screws for gear ratio 1:60. Inclination angles  $\alpha_1 = 5^\circ$ ,  $\alpha_2 = 30^\circ$

On the basis of calculations of the geometry of the spiroidal gear, in which the cylindrical worm cooperates with the front teeth, special constructions of tools for notching the screws were developed (asymmetrical contours). The developed construction prototypes of tools (turning knives) enable cutting unbalanced turns of the Archimedes screw. As part of the research work, these tools were tested on a CNC lathe.

A turning tool with interchangeable cutting inserts is used to cut the winding. The knife was placed in the holder, while in order to set the right angles of the blade's contour in the coordinate system of the lathe, a protractor was used (fig. 4).

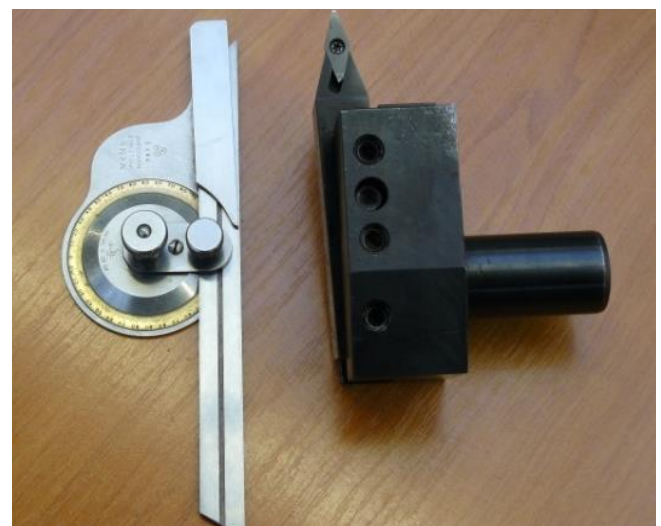


Fig. 4. Setting of the turning tool in the holder mounted in the lathe head

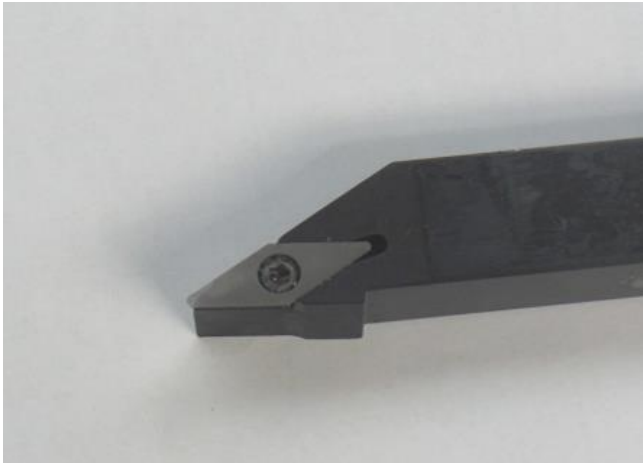


Fig. 5. View of a designed turning tool (together with a cutting insert) enabling the cutting of a screw roll with angles  $\alpha_1 = 5^\circ$ ,  $\alpha_2 = 30^\circ$

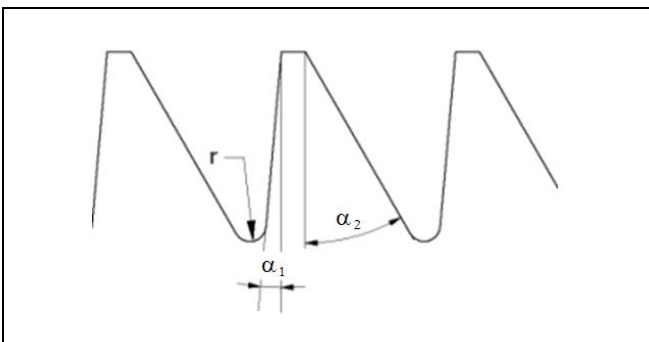


Fig. 6. Geometry of cut worm threads

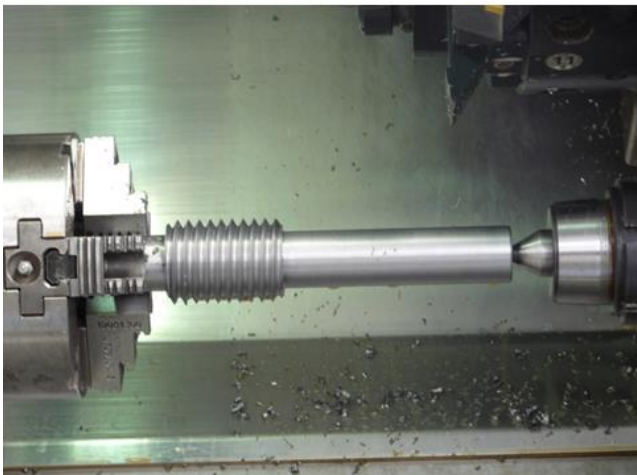


Fig. 7. View of the cut worm



Fig. 8. View of the cutting tools' blades after cutting the worm's coil

For further research, new turning knives with the construction shown in fig. 5 have been developed. The designed turning tool is equipped with a socket for rhomboid plates with an apex angle of  $35^\circ$ . The tests were carried out for cylindrical snails with the following geometries and profiles of coils:

- variant I –  $\alpha_1 = 3^\circ$ ,  $\alpha_2 = 33^\circ$ ,  $r = 0.2; 0.4; 0.8$  mm;
- variant II –  $\alpha_1 = 5^\circ$ ,  $\alpha_2 = 33^\circ$ ,  $r = 0.2; 0.4; 0.8$  mm;
- variant III –  $\alpha_1 = 7^\circ$ ,  $\alpha_2 = 33^\circ$ ,  $r = 0.2; 0.4; 0.8$  mm.

The process of cutting snail coils on rollers of different diameters and strokes as well as for different geometries (different modification values) was investigated. The tests were carried out with the use of turning tools with a blade in the form of a convertible diamond carbide insert. During the research, the following were changed:

- cutting data – cutting speed, number of passes, number of final finishing transitions, number of finishing passes after one work step (using the capabilities of a standard program for thread cutting in the ShopTurn system by Siemens, which is equipped with a lathe);
- type of cutting insert – with and without coating, for aluminum;
- corner radius of the tile – 0.2; 0.4 and 0.8 mm.

Fig. 7 shows the view of the cut worm of the auger (according to the data from fig. 3), and fig. 8 – the designed turning knives with the cutting inserts used during the tests.

## Conclusions

The tests have confirmed the possibility of cutting a screw roll with the use of two turning tools and a numerically controlled lathe. Investigating the processes of cutting the rolls of screws with the use of knives of various designs, various cutting inserts and various cutting parameters, allowed to draw the following conclusions:

- for cutting coils of the screw, plates with corner radii of not less than 0.4 mm should be used – recommended radius is 0.8 mm;
- at least three wiping passes must be made after each roughing pass;
- cutting data must be in accordance with the recommendations of the cutting insert manufacturer;
- use the machining of the auger of the screw with tangential insertion of the edge of the tool's edge, shaping the larger angle of the coil ( $\alpha_2$ ).

The use of the ShopTurn software greatly simplifies the preparation of the process of cutting the scrolls of the worm. The built-in overlay in the program allows to determine the initial position of the tool, which in turn allows to process the turns of the screw with several tools (roughing and finishing). In the case of heat treatment of the screw shaft, it is possible to finish the coils. The screw must always be set in the same angular position (ShopTurn program specifies the initial angular position of the screw), e.g. using special tooling.

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Translation of scientific articles, their computer composition and publishing them on the website [www.mechanik.media.pl](http://www.mechanik.media.pl) by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.



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