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SPECIAL INTERNAL WORM GEAR PAIRS WITH HELLICAL WORM

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***Abstract**: The internal worm gear pairs are special ones, which are composed by a helical worm and an internal teeth worm wheel. In the case of internal worm gear pairs, when the internal teeth worm wheel are manufactured by a worm hob with same geometrical parameters like the helical worm the manufacturing not represent a difficult problem, especial in case if the axis of worm and worm wheel are non perpendicular. .The paper presents some aspects on construction models; on using special devices; the mathematical modeling in the case of non perpendicular axes and some aspects of manufacturing.*

***Key words:** internal worm gears, helical worm, special devices.*

1. INTRODUCTION

In 1972 at "Bucharest International Exhibition and Fair" the Japanese [11] have presented a machine-tool for manufacture internal teeth gears by generation. This incite the interest of the Romanian specialists in the field, we tried to identify the preoccupations in this field. We discovered preoccupations in Japan, Russia and Germany. From the obtained bibliography we observed, are exists some problems on the worm hobs manufactured precision.

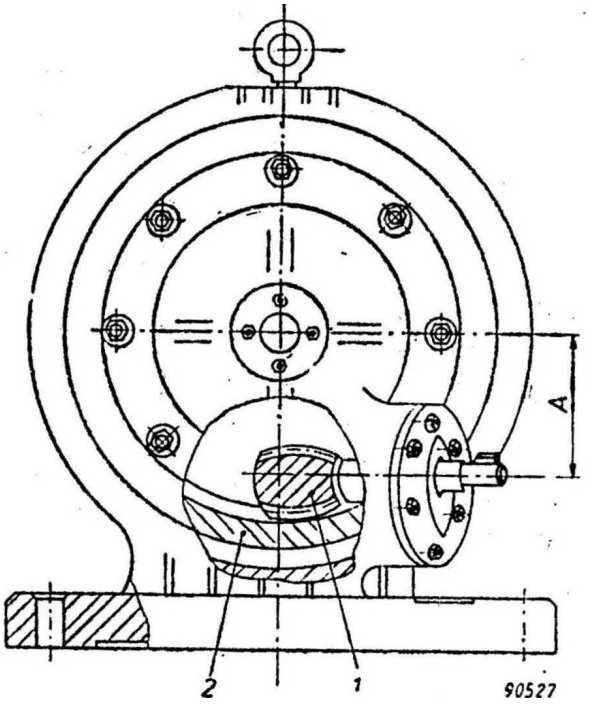

Fig. 1. Reducer with internal worm [3].

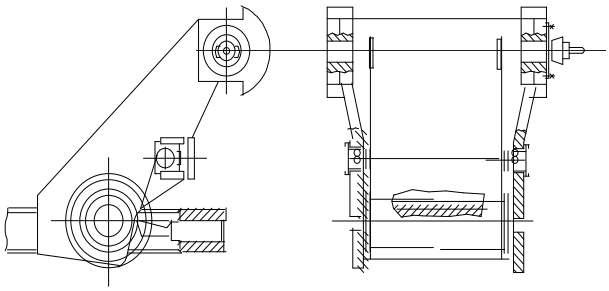

Fig. 2. Arm device for helical worm manufacturing.

Pay E. and Jankó B. [2] tried to determine the mathematical model of internal teeth cylindrical gears manufacturing with worm hob. Thus, in 1979 are presented for the first time in Romania theoretical aspects regarding the geometry of the worm hob for internal teeth manufacturing, which incite general interests. After these preoccupations, after the analysis of technological gear what exists at the execution of internal teeth with worm hob, have been appeared the idea of the internal worm gear pairs. It was patented under the name "Reducer with internal worm" (figure 1.) in 1986 [3]. After the publication of this patent appeared the necessity of the execution of helical worm, essential element of the worm gear pair. Thus in 1987 is patented the "Worm hob for the manufacturing the helical worm" [4]. Two years later, after solve of some technological problems at the I.M.M.U.M. enterprise, had been executed the first helical worm with the devices patented in 1987 (Figs. 2 and 3).

The results were promising. Thus, after the political transformations in 1989–1990, using performing computers and adequate software were approach aspects regarding the precision, the mating surfaces, and the gearing conditions of these worm gears.

Were published a lot of papers and were presented works in national and international Conferences, for examples [7, 8, 9, 10].

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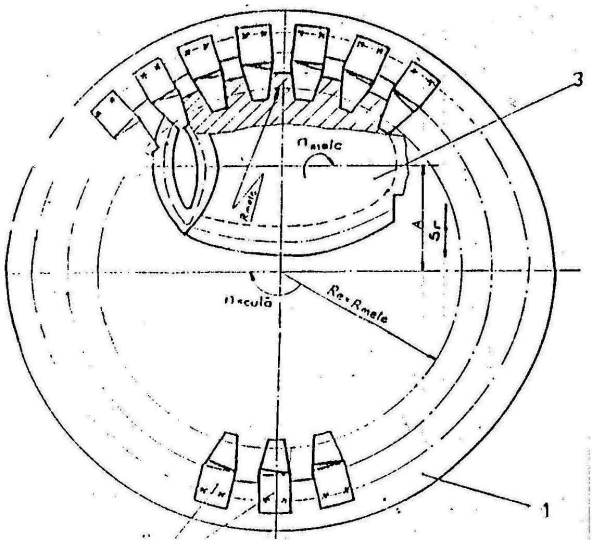

Fig. 3. Multi-cutter device [4].

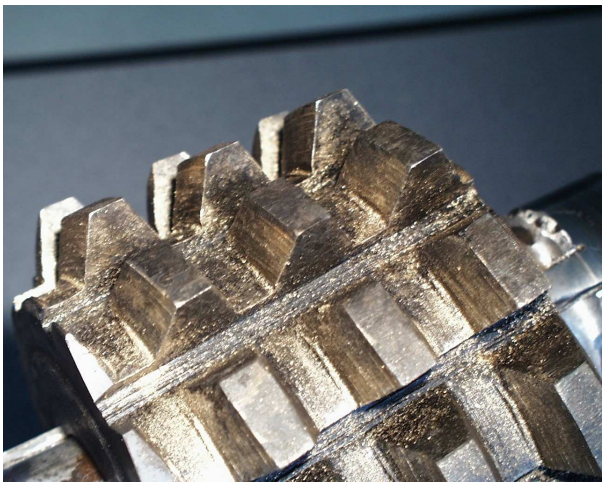

Fig. 4. Helical worm hob [1, 6].

The first recognition of the success was obtained after two Ph.D. theses on this field, one in Romania in 1999 [1] and one in Hungary in 2001 [6]. Also, was realized the first helical worm hob (Fig. 4) [1] and were established the gearing limits in the general case [6] when the angle from the worm's and worm wheel's axis is between 0 and 90 degree.

In the paper we will presents the constructive models, the mathematical model in the general case and the execution method of these special worm gear pairs.

2. CONSTRUCTIVE MODELS

A helical worm and an internal teeth worm wheel compose the internal worm gear pairs. At this gear pair the axis can have different positions: parallel, perpendicular or general (no perpendicular).

Further on several constructive model [1, 5, 6, 7, 8, 9, 10] are presented.

Figure 5 presents an internal worm gearing with parallel axes. For this case, mathematical modeling is relatively simple and its does not raise either technological or assembling problems regarding worm bearing. This type of gearing resembles the helical gearing, but as a worm gearing higher transmission ratios and a higher covering

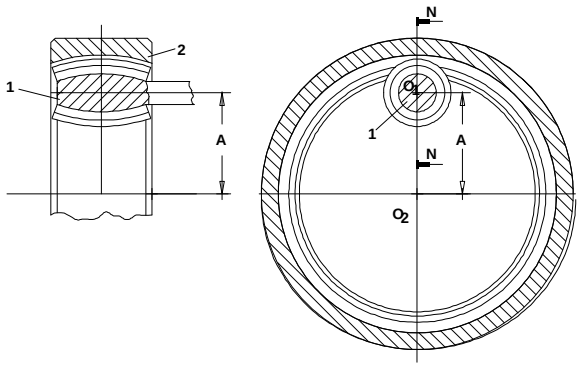

Fig. 5. Parallel –axes internal worm gearing.

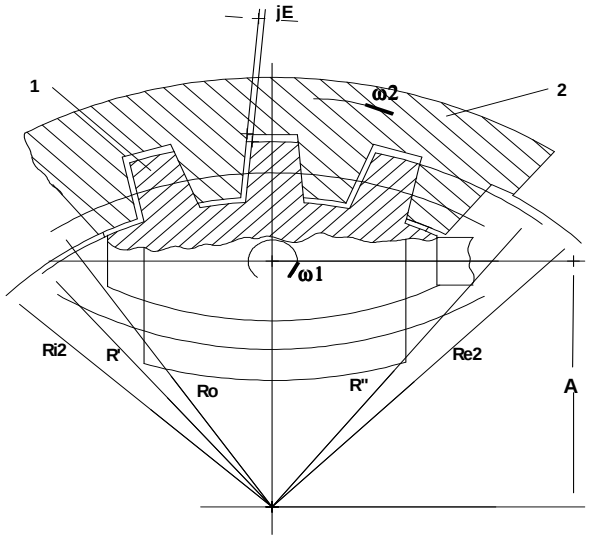

Fig. 6. Perpendicular-axes internal worm gearing.

degree can be obtained. At present, this type of gearing does not belong to the narrow frame of our research.

Figure 6 presents an internal worm gearing with perpendicular axes. This is actually the gearing that has triggered our research. After mathematical modeling, there followed its computer simulation [1, 6, 8, 10].

Mathematical modeling resembles that of the globoid worm gearing .At this type of gearing, assembling problems occur, as for worm bearing very large worm wheels are to be used.

Figure 7 represents the general case, which is the one when the angle between the worm's axes and that of the worm wheel encloses an angle between 0º and 90º.

Though mathematical modeling is more difficult, we can state that it is the most favorable case for an internal gearing, as worm bearing faces no problems and we can reach reasonable dimension, along with high efficiency.

At the same time, the driving elements can be fixed in the interior of the worm wheel so as to obtain a reduction of the necessary space also. The determining of the gearing field and the computer simulation of this type of gearing represent the research at present.

As we can observe from the facts above, at internal worm gearings it is not necessary for the angle between axes to be of 90º, even any angle between the axes being favorable, contrary to the cylindrical or globoid worm gearings, where the angle between the axes is of 90º.

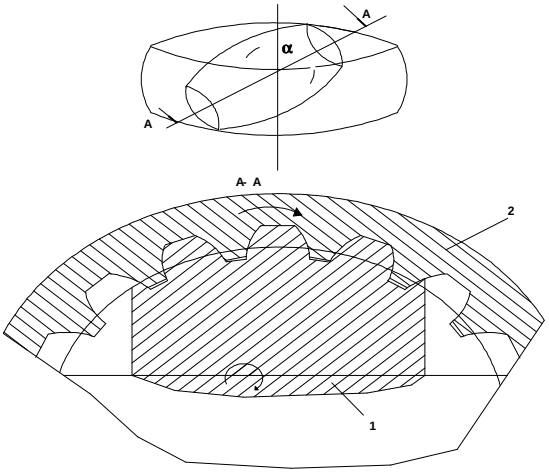

Fig. 7. Internal worm gearing with any axes.

3. THE MATHEMATICAL MODELLING OF INTERNAL WORM GEAR PAIRS

The model of the general case for these type of gears is presented in Fig. 8. In figure we used following coordinate systems:

- $O_1x_1y_1z_1$ – the worm related reference system; the worm rotation axis is the Y_1 axis; the relative position of the technological reference system is given by the φ_1 parameter - the worm rotation angle;
- $O_0x_0y_0z_0$ – the functional reference system; it is the reference system considers to be fixed;
- $O_1^*x_1^*y_1^*z_1^*$ – a fix system, which is rotate to $O_0x_0y_0z_0$ system with γ = constant angle, where γ = (0°, 90°);
- $O_2^*x_2^*y_2^*z_2^*$ – intermediary fix system which is translate to $O_0x_0y_0z_0$ system with the distance between the axis "a" on the direction of O_0z_0 ax;
- $O_2x_2y_2z_2$ – the wheel related reference system; the wheel rotation axis Z_2 is parallel to Z_1 and perpendicular on the paper plane; the relative position to the technological reference system is gave by the φ_2 parameter – the wheel rotation angle;

The worm's flank is generated by "*u*" straight line, which is in the paper plane, also the division diameter of the wheel. The generate line is always tangent to the profile circle with "*r*" radius (Fig. 9).

The coordinates of motion point from the worm after the transformed of generate line's coordinate from the worm wheels system into the worm system is the follow:

$$\begin{cases} x_1 = -\cos\varphi_1[a - r_0\sin(\varphi_2 - \alpha_{ax}) + u\cos(\varphi_2 - \alpha_{ax})] \\ y_1 = -\sin\gamma\sin\varphi_1[a - r_0\sin(\varphi_2 - \alpha_{ax}) + u\cos(\varphi_2 - \alpha_{ax})] + \\ \quad + \cos\gamma[r_0\cos(\varphi_2 - \alpha_{ax}) + u\sin(\varphi_2 - \alpha_{ax})] \\ z_1 = -\cos\gamma\sin\varphi_1[a - r_0\sin(\varphi_2 - \alpha_{ax}) + u\cos(\varphi_2 - \alpha_{ax})] - \\ \quad - \sin\gamma[r_0\cos(\varphi_2 - \alpha_{ax}) + u\sin(\varphi_2 - \alpha_{ax})] \end{cases} \quad (1)$$

Using this equation for each flank we obtain the simulated worm, which is presented in Fig. 10.

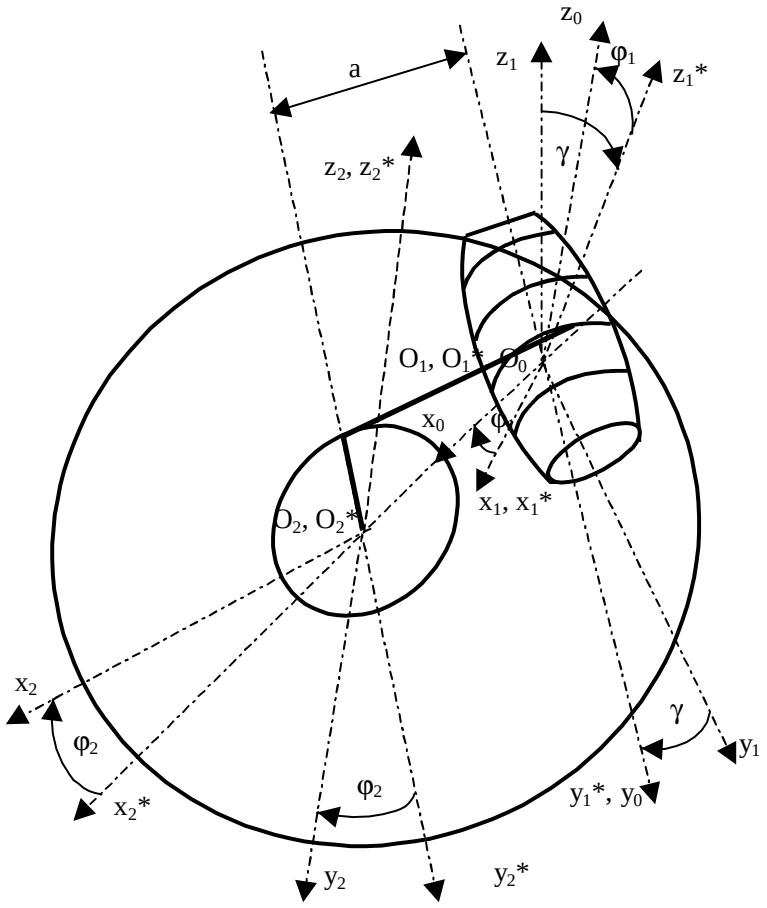

Fig. 8. The general model of internal worm gear pair.

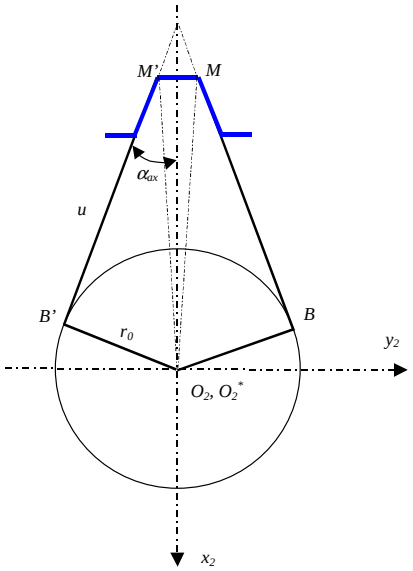

Fig. 9. The scheme used for generation.

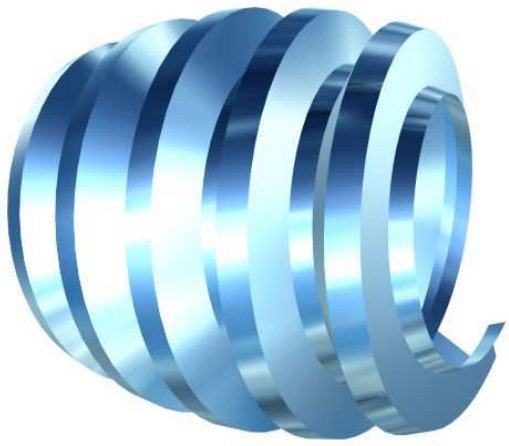

Fig. 10. The simulated worm [6].

4. THE MANUFACTURE OF THE INTERNAL WORM GEAR PAIR ELEMENTS. SPECIAL DEVICES. HELICAL WORM HOB

One of the most important achievements of the research group was the execution of the prototype of the internal worm gearing elements. It was achieved on a universal gear grinding machine of Donini type, which can cut teeth of to modules of m = 20 mm [1, 5, 6, 8].

Taking into account the advantages of the ruled profile generation, we considered both the helical worm and the helical worm hob with ruled profile. Figure 11 presents the technological scheme of manufacture the elements of this type of drive, and the special devices, which are necessary, and Fig. 12 presents the manufacturing method, which is appropriately to the manufacturing of globoid worms with the CONE method.

The helical worm precision is influenced by the fixing precision of the hob's teeth, by the precision of the tool's edges, by the precision of the devices used etc. Some of the errors can be avoided if the processing is divided into two operations: a roughing by the multi-knife device and a finish by a flying cutter.

Since now we can achieved only the worm wheel with attached teeth. The teeth were realized by casting, and were finishing with the helical worm hob (Fig. 13).

In Fig. 14 we present the helical worm – internal teeth worm wheel drive.

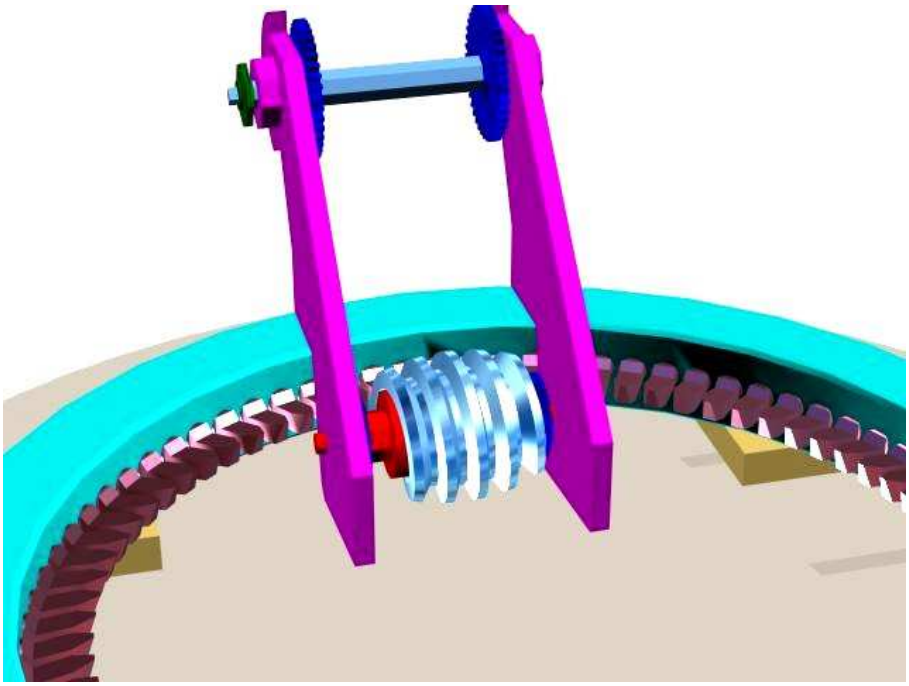

Fig. 11. The execution scheme of the drive:
a –arm device, *b* – tool arbor, *c* – the semi-manufactured worm, *d* – multi-cutter device.

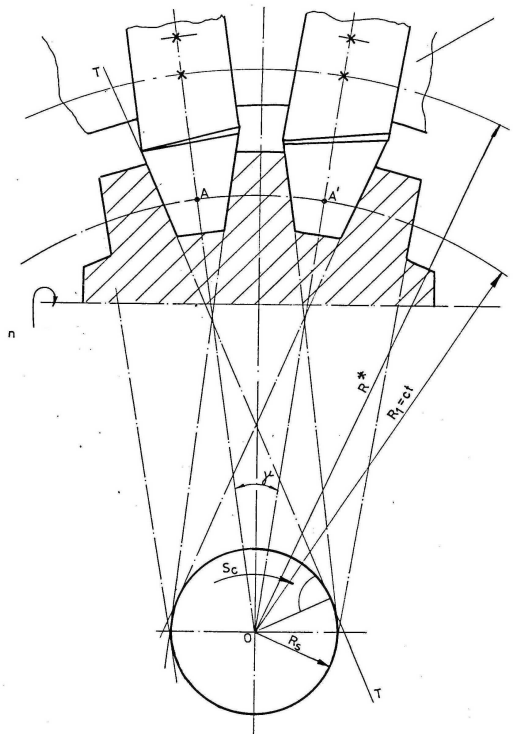

Fig. 12. The manufacturing method of the helical worm.

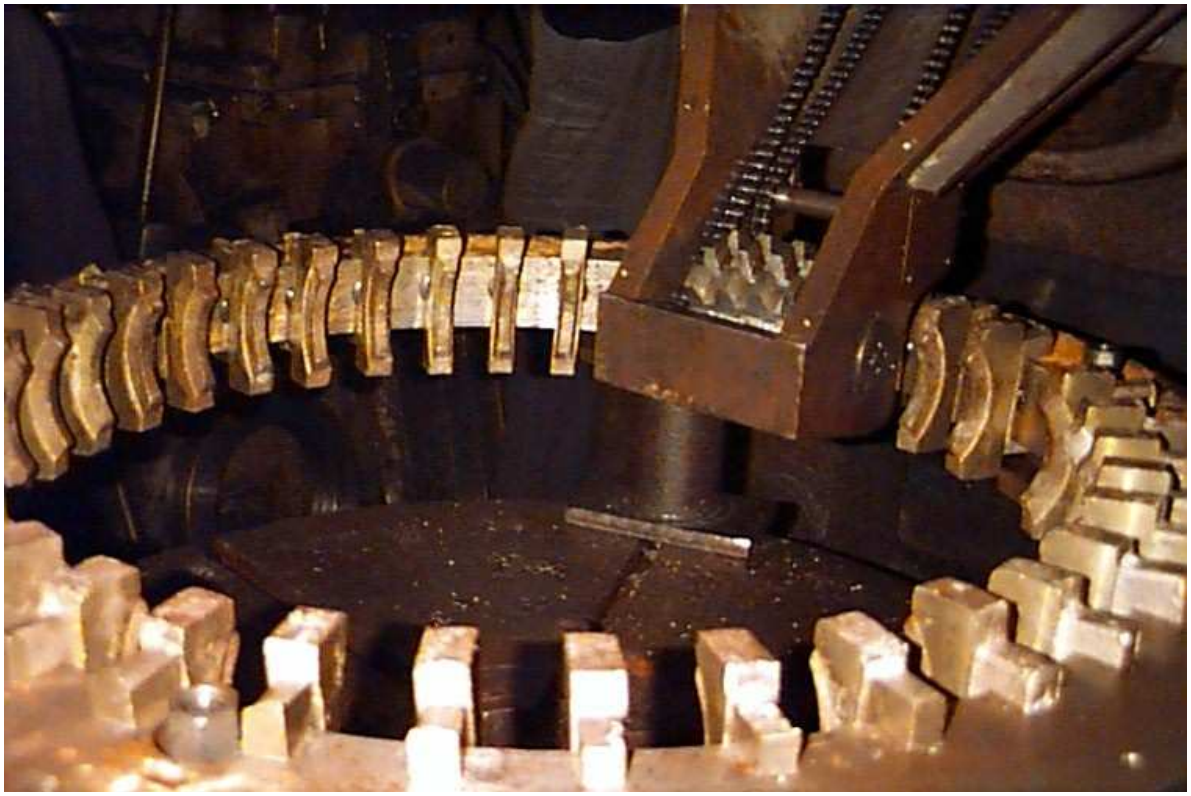

Fig. 13. The finish manufacturing of the internal teeth worm wheel.

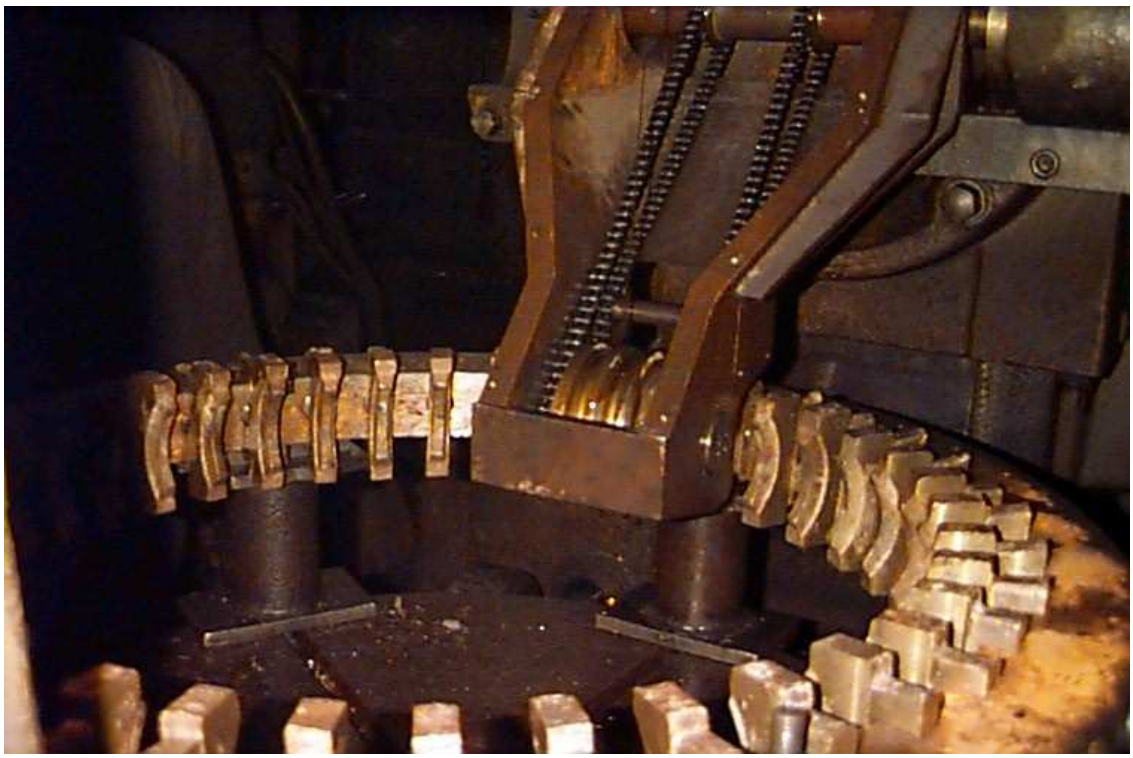

Fig. 14. The helical worm–internal teeth worm wheel drive.

5. CONCLUSIONS

- The internal worm gearings are made up of an ellipsoid worm and an internal teething worm wheel. These gearings, especially those with perpendicular axes, can be named reverse globoid worm gearings or antiglobоid, as they have similar characteristics.
- The angle between the worm axes and of the worm wheel can range between 0º and 90º. It is even advantageous for the angle to be other than 90º, thus not considering the problem of worm bearing.
- Are a lot of possibilities to use helical worm for different type of gear pairs.
- The mathematical modeling give the possibility to change the angle between the axis and analyze the mating surfaces.
- For the time being we consider both the worm and the helical worm hob with ruled profiles, but theoretically their profile can be generated by any curve. For processing, we used a universal teeth-grinding machine of Donini type, with two special devices respectively. By there aid a processing, which we could call of anti Cone type, occurred.
- The present research heads towards the determining of the gearing surfaces generally, towards the achievement of helical worm hob respectively.

REFERENCES

[1] H. Cioban, *Contribuţii la studierea angrenajului melc butoi – roată melcată cu dantură interioară şi a unor factori tribologici asupra comportării acestuia* .(Contributions on study of helical worm – internal teeth worm wheel and of some tribological parameters on its functioning) Ph.D. Thesys, Cluj – Napoca, 1999, Coordinator Prof. univ. dr. ing. Pay Eugen.

[2] E. Pay, B. Jankó, *Contribuţii privind stabilirea geometriei frezei melc pentru generarea danturii interioare* (Contributions for determination of worm hob's geometry for generation of internal teeth), Scientific Session "Construcţia, fabricarea si încercarea automobilelor" (Construction, fabrication and testing of cars), Piteşti, Vol. I., Part TCM, 1979, pp. 179–184.

[3] E. Pay, *Reductor melcat cu melc interior* (Reducer with internal worm), Romanian patent no. 90521, 1986, Buchatest, Romania.

[4] E. Pay, M. Vijdeliuc, V. Sziklai, *Freză pentru prelucrarea melcului butoi* (Worm hob for the manufacturing the helical worm), Romanian patent no. 103382, 1987, Bucharest, Romania.

[5] E. Pay, G. Páy, H. Cioban, *Study Regarding the Internal Worm Gearings and Their Simulation Using the CAD System,* Journal of Intelligent Mechatronics, Design and Production, vol. I., no. 4/1995, Ankara, Turkey, pp. 204–211.

[6] G. Páy, *Belső csigás hajtások* (Internal worm gears), Ph.D. Thesys, Scientific Coordinator Dr. Siposs István, University of Miskolc, Hungary, 18.06.2001.

[7] G. Páy, E. Pay, *Special worm gears with internal worm. Mathematical model and manufacturing technology*, CEEPUS Science Report, Poznan University of Technology, Poznan, 2006, pp. 199–210.

[8] G. Páy, E. Pay, *Special Internal Worm Gearings with Helical Worm*, 2nd International Conference on Technology Knowledge and Information'08, Ustí nad Labem, Czech Republik, 24.01.2008.

[9] G. Páy, E. Pay, *Kutatások a belsőcsigás hajtásokról* (Research regarding the internal worm gear pairs), Gép, LX évfolyam, 2009, pp 25–29.

[10] G. Páy, E. Pay, *Internal Worm Gearings, with Non Parallel Axis. Modelling and Manufacture***.** Scientific Bulletin, Serie C, Volume XXIII, Ostrava, Czech Republic, 2010, pp. 155–162.

[11] T. Ueno, K. Terashima, M. Sakamoto, (1972) *Study on Hobs for Cutting Internal Gears* . In: Publication ASME, New York.