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Optical Geometric Design of Small Modular Cylindrical Gears with Asymmetric Profile

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Abstract. **The article presents specific practical solutions for optimal geometric design of evolvental cylindrical gears with an asymmetric profile of cogs in the context of the basic principle of cog interlocking. In order to achieve unknown until now quality indicators, constructions with a minimum number of cogs and a maximum angle of interlocking are shown, which allow for the production of off-polar gears and significantly increase the gear ratio of the differential and planetary mechanisms. In the process of determining the geometrical parameters of the cogwheels of the gear, the "classical approach" is used by analogy with the parameters of the instrument, necessary for the production of the small-module cogwheels of the gear.**

Keywords: Asymmetrical profile of cogs, Geometric optimization, Border angles and number of cogs.

I. INTRODUCTION

In the classical theory of gear coupling, the parameters of the instrument, which is necessary for the production of the cogwheels of the gear, are accepted as the source parameters for the design. In order to perform geometric synthesis of a single evolvent cylindrical gear, four output parameters are required: Module size - m, Pressure angle - α, output contour (loop) displacement factor-x, number of teeth – z [11]. The four parameters determine the axiomatic design of gear mechanisms at known instrument parameters. Through the use of asymmetrical evolvent cylindrical gears the uncertainty deriving from the choice of independent parameters has been removed and "free geometric synthesis" can realized.

Based on the 20-years experience of the authors and over 60 publications on the problems of the asymmetrical profile, it has been found that a major problem in its use is the reversal of the direction of movement [1,2,3]. As a solution, the authors set out [4,5] a basic principle of interlocking, allowing the making of gears with an unachievable until now quality and strength indicators [12]. On the basis of the implications of this principle, three approaches have been developed for geometric synthesis and realization of unconditional areas of existence in the field of independent variables.

II. PRACTICAL IMPLEMENTATION AND OPTIMIZATION OF GEARS WITH ASYMMETRIC PROFILE

The free geometric synthesis of evolvent cylindrical gears [4,5] with an asymmetrical profile of the cogs, as defined by the authors, allows for various effects expressed in: increase the flow rate of hydraulic gear pumps; increasing the load capacity of ordinary and epicyclical gears; the production of self-locking gears when reversing the direction of movement.

A. Realization in hydraulic gear pumps

In the process of manufacture, a task has been set for designing a gear with a reduced number of cogs by the method of centroid wrapping with a non-standard instrument of comb type, while maintaining the overall dimensions. When the preset requirements for the gear can not be satisfied by the symmetrical cog profile with the displacement of the output contour, then it is possible to apply asymmetry of the profile and obtain a gear with different thanthe previously known qualitative indicators. A gear pump is realized, using this method, that increases its actual flow rate, at the expense of increasing the effective area of the pitch surface (bottom land). The main advantage of such gear is the possibility of reversing the direction of movement while maintaining the gear ratio, but with a significant change in quality performance [6].

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Fig. 1. Magnetization as a function of applied field.

A new hydraulic gear pump design was developed and experimentally tested and the following results were established by Protocol No 009/09.05.2002, on a stand of Kaproni AD — Kazanlak: The flow rate of pumps of type Х3П 00С 0,5Х047 — for the new design is higher by 20.2 to 23.3 %, compared to the flow rate of the existing pumps in production.

B. Increase the load-bearing capacity of cog interception in epicyclic cog mechanisms

In addition to the quality indicators of the interception, the asymmetrical cog profile can increase the load capacity of the gear with and without regard to reversing the direction of movement. This makes it possible to optimize gear mechanisms in terms of transmitted torque or locking stiffness, which are different when reversing the direction of movement.

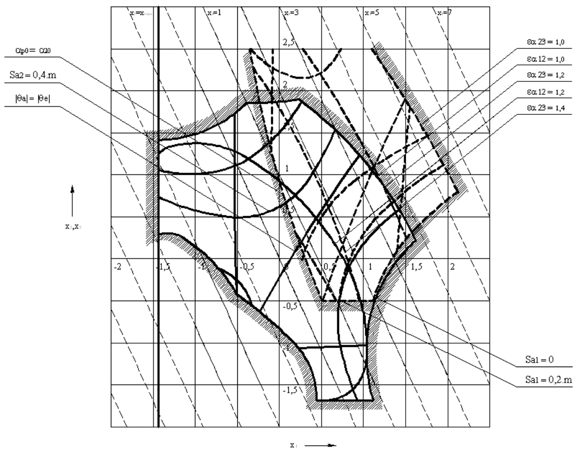

Fig. 2. Blocking contour of reverse differential 2K-H mechanism with asymmetric profile of teeth.

The use of the asymmetrical cog profile in differential and planetary mechanisms allows to increase their load capacity without changing their gear ratio [13]. In order to perform this optimization of the cog profile, blocking contours of 2K — H planetary mechanism have been developed, allowing the reconciliation of the areas of existence in the field of independent displacements of the instrument (Figure 2).

Figure 3 presents a spatial model of the differential gear, which served as the basis for the final - element analysis and a general view of the carving head "TARMATIC", production of "Balkan" JSC — Lovech [5].

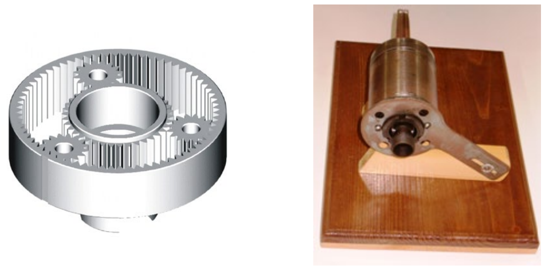

Fig. 3. Model and general view of carving head "Tarmatic".

Similarly, a planetary 2K-H gear with an asymmetrical profile was developed in an electro-mechanical screwdriver of Gabrovo PGI (Figure 4).

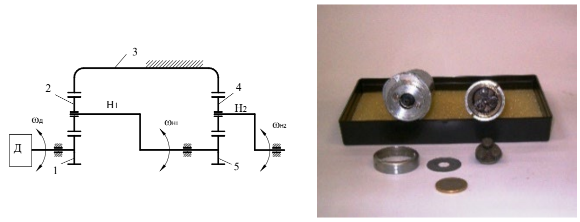

Fig. 4. Kinematic scheme and general view of electro-mechanical screwdriver of Gabrovo PGI.

In the two epicyclical mechanisms (Figure 4) with an asymmetrical profile of the cogs an effect was achieved of increasing the load capacity of the gear while preserving the number of cogs and the levels of freedom of the mechanism. Therefore, this effect should be used for mechanical devices that have a significantly higher load in one of the directions of their movement.

C. Realization of gears with a minimum number of teeth

Evolvent cylindrical gears with a minimum number of cogs allow the creation of special gears with reduced dimensions and maximum gear ratio.

In the context of the basic principle of cog interlocking in movement, an unconditional area of existence have been developed, and a gear layout for gear ratio u=1 and number of cogs $z_1=z_2=5$ (Figure 5) .

By using an asymmetric cog profile, it is possible to reduce the minimum number of cogs by 40 % from the minimal possible for a symmetrical profile with a standard contour $z_1=z_2=7$ to $z_1=z_2=5$ [7].

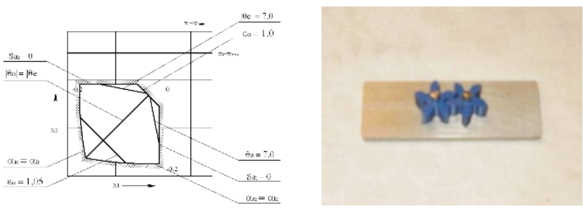

Fig. 5. Gear with asymmetric profile and minimum number of teeth.

Based on the depicted area (Figure 5), such a reverse gear with an asymmetrical profile of the cogs is realized, when the output contour is shifted $x_1 = x_2 = -0.15$, which has a frontal overlap coefficient of $\varepsilon_\alpha = 1.06$ and $\varepsilon^*_\alpha = 1.01$.

D. Realization of self-locking gears

The study of the unconditional areas of existence of an asymmetrical profile and external intersection has established the following general regularity: *as the value of one of the interlocking angles increases, the value of the other also increases, regardless of its initial value.* Therefore, the asymmetrical cog profile is characterized by: lower frontal overlap coefficients when one of the angles of intersection rises in value and higher when one of the angles of intersection is reduced (responsive to the output contour) compared to the output of symmetrical cog profile. This presupposes the existence of additional interlocking phenomena, that determines its specificity and practical limitlessness, such as the existence of a self-stop effect.

Such a gear with an asymmetrical profile was designed according to the classical approach, but due to the extreme angles of the comb-type instrument, a thread erosion method was used for the production of the wheels, with thread thickness of 0.2 mm, at Arsenal JSCo-Kazanlak [8].

In this gear with external interlock, a self-lock effect has been achieved at an angle of interlocking $\alpha^*_w = 48{,}23°$ (Figure 6), which cannot be achieved with a symmetrical profile. This restriction was first established by Prof. V. A. Gavrilenko, who recommended that the profile angles of the output symmetric contours to be determined by the unrestricted inequation $\alpha \leq 35°$.

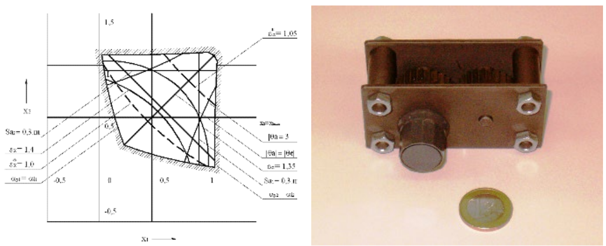

Fig. 6. Blocking contour of reverse differential 2K-H mechanism with asymmetric profile of teeth.

E. Realization of gears with internal interlocking and minimum number of cogs

With internal interlocking and minimal difference in the number of cogs of evolvental cylindrical gears with asymmetrical profile of the cogs, narrowing of the unconditional area of existence is observed, due to the presence of additional interference. A borderline case are the mechanisms with internal interlocking and equal number of cogs, in which there is a constant velocity of sliding at all points of the active line of interlocking for each of the profiles and different load capacity.

Figure 7 presents an evolvent cylindrical gear with asymmetrical profile, internal interlocking and equal number of cogs [9].

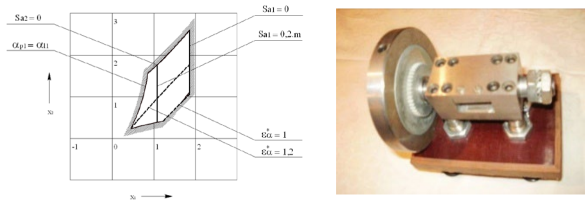

Fig. 7. Cog gear with asymmetrical profile and equal number of wheel cogs $z_2 = z_1 = 44$; profile angles of the instrument $\alpha = 20°$ and $\alpha^* = 30°$.

In the case of fixed gear axes, such a gear is used as a clutch, joining two parallel non-coaxial shafts. If the given gear is performed as a planetary mechanism, the satellite wheel moves translationally, the trajectory of each point being a circle with a diameter of $2.a_w$.

D. Cog gears with asymmetric profile and inclination of cogs

In order to obtain greater overlap coefficients, it is possible to realize gears with an asymmetrical profile and inclination of the cogs by using the theorem of reversing the direction of movement.

Figure 8 presents the unconditional area of existence of such gear and a layout of an evolvent cylindrical gear with an asymmetrical profile and inclination of the cogs.

Displacement factors $x_1 = x_2 = 0.5$ were selected from it, with wheel width b=5 mm achieving overlap coefficients $\varepsilon = 2{,}2$ (1,61); $\varepsilon^* = 2{,}0$ (1.46).

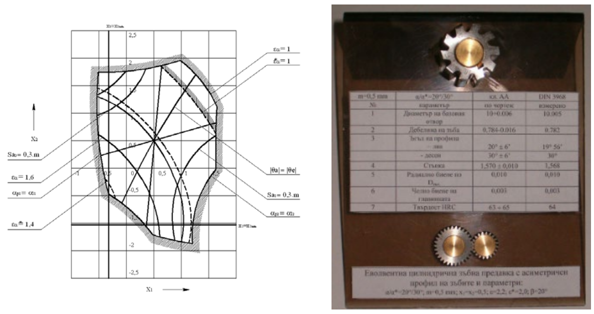

Fig. 8. Cog gear with asymmetric profile and inclination of cogs $\beta = 20°$.

E. Realization of gears with variable speeds and gear ratios

The eccentric gearbox creates at its output cyclically changing speeds and gear ratios. They are modified in a similar way to gears with elliptical cog wheels (Figure 9). The distance between the geometric centers, the angle of interlocking and the overlap coefficient are variables during the movement of the gears. At a specified output angle of interlocking, the maximum variation in the distance between geometric centers is expressed by the eccentricity of the gear, which is constant [10].

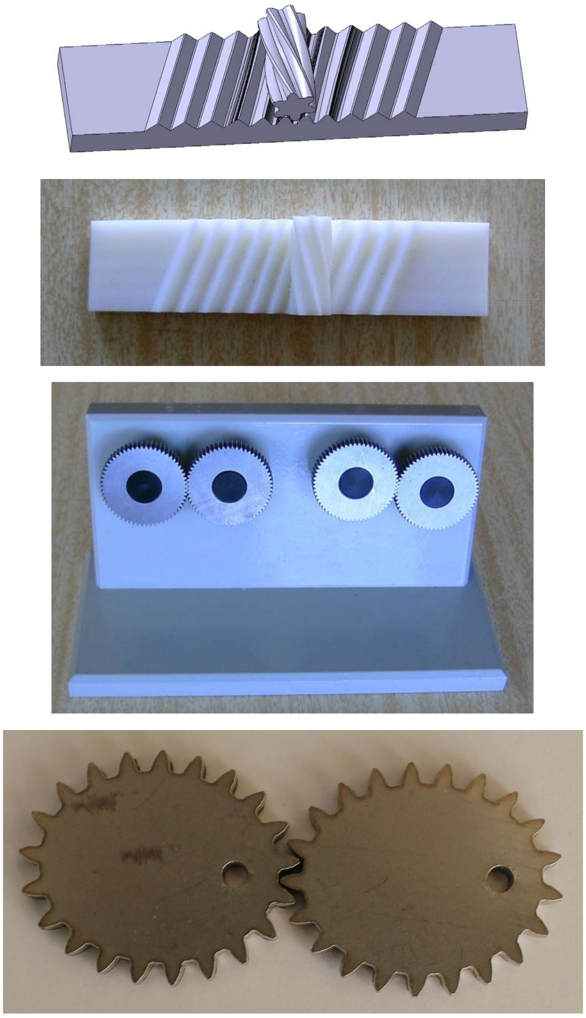

Fig. 9. Variable gears and asymmetric cog profile: model and prototype of comb gear with inclination of teeth, eccentric gear with round wheels and elliptical gears with asymmetric profile, made with laser cutting.

III. Conclusion

With the help of the basic law of interlocking of evolvent cylindrical gears with asymmetric profile, free geometric synthesis and conversion of the classical theory of gear interlocking by transforming the independent variable — the non-working angle of intersection into a dependent one was carried out, which achieved optimization of quality and strength performance, excluding the geometric parameters of the instrument required for the production of the wheels of the gear.

Summarized and shown is the 20 years of experience of the authors in the optimal geometric and strength synthesis, the practical implementation of evolvent cylindrical gears with asymmetric profile of the cogs, expressed in: reduction of the number of cogs on the interlocking with preservation of the quality and strength performance, thus reduction of the overall dimensions of the gear; optimization of epicyclic cog mechanisms; realization of gears with self-locking effect; design of gear couplings with compensation of shafts with axis inconsistency and obtaining mechanisms with variable gear ratio at a translation or rotation of the executive unit. A large part of the resulting gears with previously unknown quality and strength indicators are experimentally tested on test stands in production conditions and have been successfully implemented in practice.

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