RESULTS OF RESEARCH WORK ON FLEXIBLE GEAR DRIVES I.

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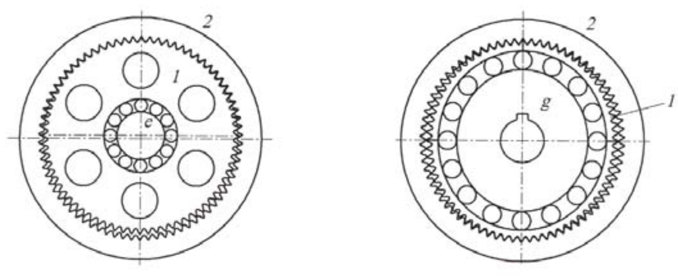
Abstract. *The team-mates of the Department of Machine Elements, University of Miskolc have been working on epicyclic gear drives for decades therefore one of the variants of the epicyclic gear drive got into the group of analysed and tested gear drives. The important parts of the research work are the following: determination of geometric data of the parts of the drive, revealing of phenomenon disturbing the proper operation, kinematic analyses, survey of the influence of load, production of test drive, laboratory tests and development of drives for industrial production. This paper summarises the achievements.*
Key words: *flexible gear drive, kinematic analyses, influence of load, laboratory test*

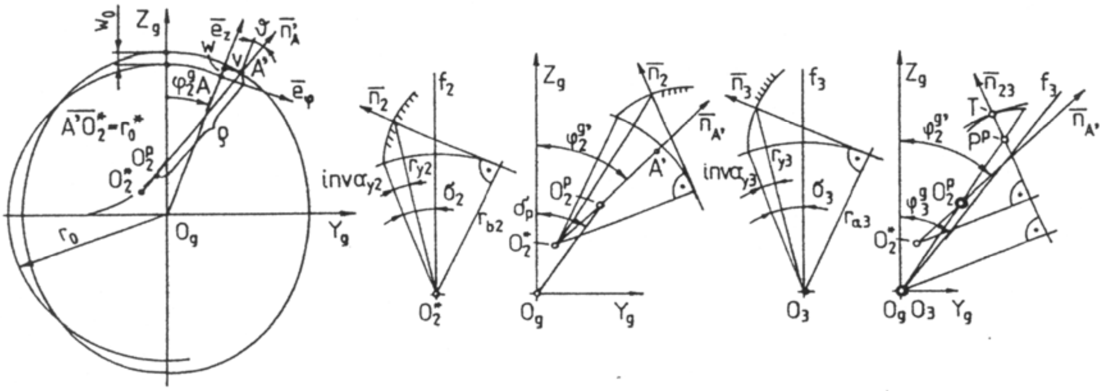
1. INTRODUCTION

The team-mates of the Department of Machine Element, University of Miskolc have been working on epicyclic gears since the foundation of the department. This is why one of the variants of epicyclic drives – the flexible gear drive got into the drives analysed.



a) *b)*

Fig. 1. *Variants of epicyclic gear drives. a) The gears are considered as rigid elements. b) Flexible gear drive, one of the gears is flexible*



a) b) c) d) e)

Fig. 2*. The flexible and rigid pair of gears in meshing. a) Displacement of a point located to the neutral layer of the flexible gear, and the relations of curvatures. b) The rigid tooth of the flexible gear. c) The rigid tooth of the flexible gear fixed to its deflected neutral layer. d) The tooth of the annular gear. e) The pair of teeth in meshing*

There are more papers and two scientific theses [1, 5] and a set of flexible gear drive developed for industrial production, as the outcome of this research work.

2.THE PARTS OF THE WORK

2.1. Recognizing the possibilities are inherent in the flexible gear drive

Recognizing the possibilities are inherent in the flexible gear drive, place of the flexible gear drive among the gear drives having high kinematic ratio, features of the flexible gear drives, field of application of the flexible gear drive; - these studies belonged to the first steps. During that time we tried to excite the inquiry of the potential consumers.

The flexible gear drive is visible at Fig. 1. b) is the variant of a simple epicyclic gear drive shown by Fig. 1. a).

2.2. Analyses of the geometry and the kinematics

During the work we were concerned with both the flexible gear drive and the flexible ring type gear coupling. In the analysis the flexible gear was substituted by a model, similar to an endless chain having links and joints. The teeth were corresponded to the rigid links and the spaces to the flexible joints. The existing problem is the meshing of a flexible external gear and a rigid internal gear. The model converts the real problem to the meshing of an annular gear and a spur gear having an offset of its axis, simplifying it. The geometrical data and the number of pairs of teeth in meshing simultaneously are determined, the type of meshing, the internal, external and addendum interference disturbing the operation were analysed with the assistance of the model.

The type of meshing of the pair of teeth is edge or profile meshing. In the analysed case the edge of the top land meshed the flank of the tooth of the annular gear. The actual kinematic ratio of the meshing pair of teeth fluctuates around the nominal kinematic ratio. Similarly to the traditional gear drives there are only one or two pairs of teeth in meshing simultaneously in an unloaded flexible gear drive at the peak of the wave, obtained from the calculations.

2.3 Influence of the external load

In an unloaded drive, before and behind the meshing of the elements with one or two pairs of teeth at the peak of the wave, there are a relatively wide range of arcs where the backlash is only some thousandth or hundredth of millimetres. Applying the external load the clearances among the wave generator, the flexible gear and annular gear are re-arranged and the elements of the transmission are elastically deformed. Through these deformations there will be further pairs of teeth coming into meshing. Increasing the load of the drive the belt of meshing becomes wider.

In the calculations the system of loads acting to the flexible gear is transformed to a distributed load, using Fourier series, that is equivalent to the original system of loads. The radial displacement of the neutral layer of the hollow cylinder that substitute the flexible gear, is available from the solution of an fifth order scarce linear inhomogeneous differential equation. After knowing the radial displacement we can determine the tangential displacement, the distortion of the cross-sections, the force acting from the wave generator to the highly flexible gear and the force between the teeth. The calculation is initiated without external load, slipping the wave generator into the flexible gear.

2.3. Production of experimental flexible gear drive

The effort of an engineer concerned with classical gear drives can be valuable without the production of any test pieces. His results are not utiliezed directly. The research worker who deals with flexible gear drive that is known only in a close group, had to devote an intense survey to the fabrication of test drives to prove the pertinence of his conceptions, and to gain the sympathy and support of the possible users.

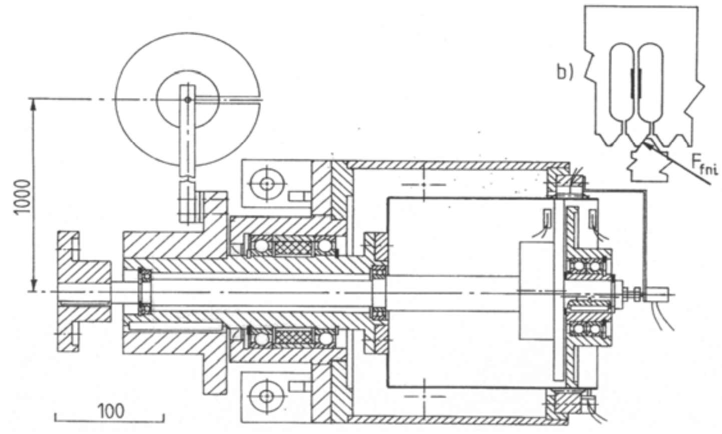
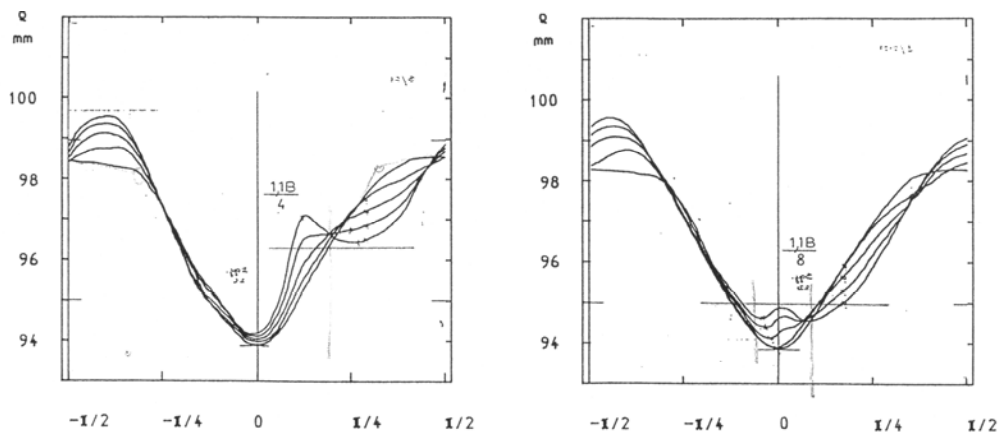
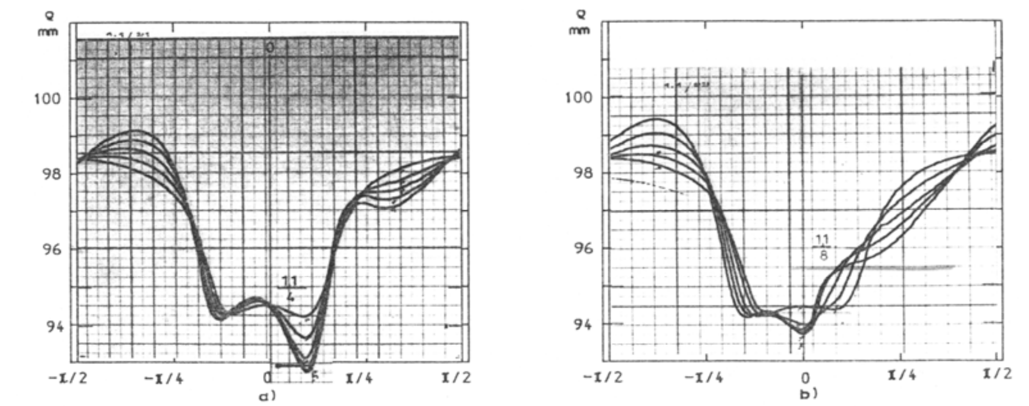


Fig. 3*. Drive prepared for laboratory tests. Measuring the radial deflection of the flexible gear, the radius of curvature and the force acting to the tooth of the flexible gear while the wave generator is revolved slowly.*



b) *c)*



d) *e)*

Fig. 4*. The Fig. b) - c) show the relation between the radius of curvature and the load of the drive. Generator: Fig. b) and c) cam type generator, Fig d) and e) disc type generator. Fig b) and d) flexible ring type gear clutch, c) and e) flexible gear drive*

At the Department of Machine Elements there were manufactured flexible gears of tube type having nominal diameter of 120 mm, cup type with diameter of 190 mm, tube and ring type with diameter of 160 mm, and the necessary internal gears, cam and disk type of wave generators to assemble the flexible gear drives and the flexible ring type gear coupling.

2.4 Laboratory tests

We have controlled the accuracy of the model and the results of calculations by the drives assembled from the elements. The drive prepared for the tests is shown in Fig. 3. The drive shown by the figure is capable for measuring the radial deflection, w along the face of the flexible gear, the radius of curvature, ρ at the plane parallel to the wave generator, and the force acting to the tooth of the highly flexible gear. The type of services like reducer or multiplier also can be studied, as the function of the load acting to the drive and the sense of revolution of the wave generator.

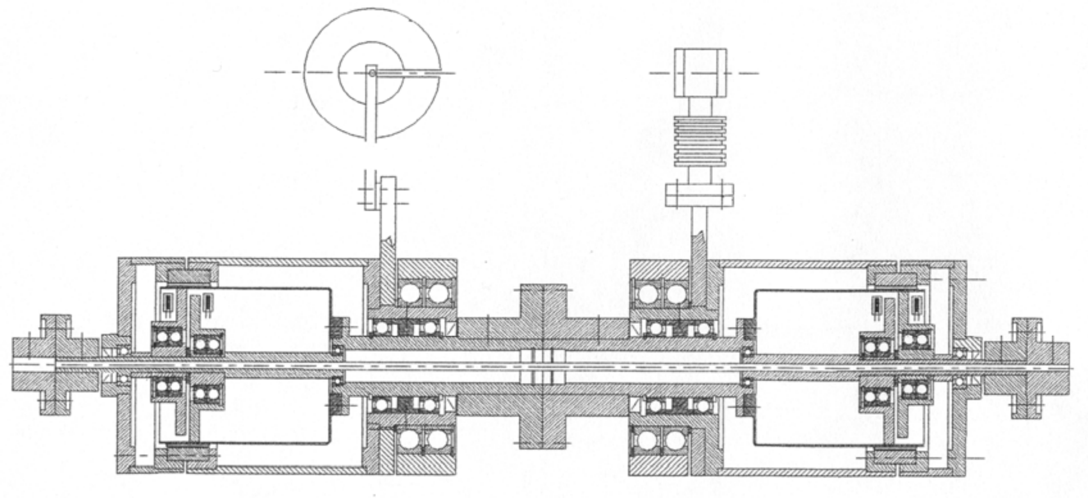


Fig. 5*. Laboratory test of the HNA-16 type drive on a closed energy loop test bench. University of Miskolc, Department of Machine Elements*

2.5 Flexible gear drive series

From the experimental drive there was a flexible gear drive series developed for the RECARD company. The nominal diameters available in the flexible gear drive series are 80, 120, 160, 200, 250, and 300 mm, the nominal kinematic ratios are 80, 100, 125, 160, 200, 250 and 320.

Due to the needs, we have tested the flexible gear drives having 80 mm and 160 mm nominal diameters. We have tested the efficiency of the drives at both reducer and multiplier service. The temperatures of the elements were also measured, and the wears of the elements were investigated. The test of the drive with 80 mm diameter was made on a test bench with open energy loop, and that of the drive with 160 mm diameter was made on a test bench with closed energy loop, shown in Fig. 5.

The slowly revolving shafts of the two drives are connected together by a coupling, the fast revolving shafts are connected by torsional shaft. One of the drive housing is fixed to the frame, the other can turn freely. The load was lead in trough an arm fixed to the housing of the freely turning drive.

3. SUMMARY

The intention of this paper is to survey and summarize the work carried out. The meaning of this goal is to carry on the research work.

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