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INVESTIGATION OF A FLAT WHEEL HARMONIC DRIVE

Dr. István Házkötő, Associate Prof., BUTE, Institute of Machine Structures, H-1111. Budapest, Muegyetem rkp. 3. Tel: (1) 463 2528, email:hazkötö.istvan.@gszi.bme.hu

Robert Krisch, Ph.D. student ,BUTE, Institute of Machine Structures H-1111. Budapest, Muegyetem rkp. 3. Tel: (1) 463 1323, e-mail: krisch.robert.@gszi.bme.hu

ABSTRACT: *A flat-wheel harmonic drive has been constructed at the BUTE. The functions of the principal members of the drive are similar to the functions of a traditional harmonic drive, but the feature of the flexible and the solid wheels are diffrerent. The rotable wave generator deforms continuously different portions of an annular face gear on the flexible member into engagement with teeth on an annular face gear on the solid member. The number of teeth of the face gears are different. For the reason of examination of the drive a testing desk has been made, where the number of the connected teeth and the tangential component of the acting force on them in mesh could be indicated. The number of teeth in mesh depends on the momentof load, so investigations were launched at different levels of torques.*

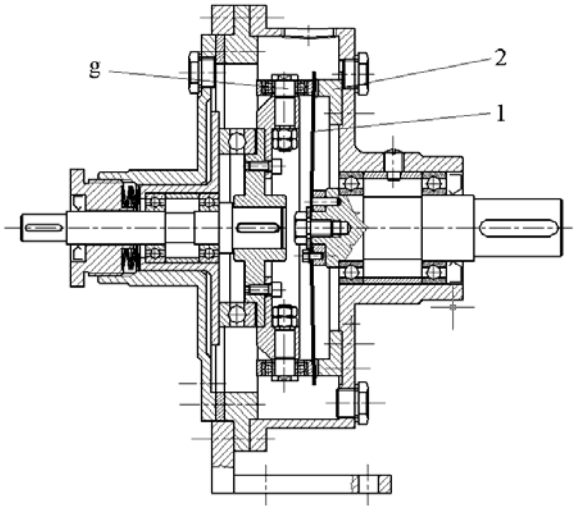
1. INTRODUCTION

Under the „Investigation of face-gear harmonic drives” project (sponsored by OTKA Project No. T032528)) at the Budapest University of Technology and Economics, Institute of Machine Structures a flat wheel harmonic drive was designed and tested. This article reports the investigations and the results of them.

2. DESCRIPTION OF THE FLAT WHEEL HARMONIC DRIVE

As for the function principle of the flat wheel harmonic drive (Fig.1), it is similar to the basic principle of the classical harmonic drives; it could be regarded as a special variety of them. The flexible and the solid gear of the drive are coaxial flat wheels. The rollers of the rotating wave generator (g) periodically and elastically deform axially the flexible gear (1), which teething comes into mesh with the toothing of the solid gear (2). Since the flexible and solid gears have a different number of teeth, there will be a relative rotational motion between the flexible and the solid gear. The gearing ratio of the investigated harmonic drive can be calculated as the following:

$$i_{12} = \frac{\omega_1}{\omega_2} = \frac{z_1}{z_1 - z_2} \tag{1}$$



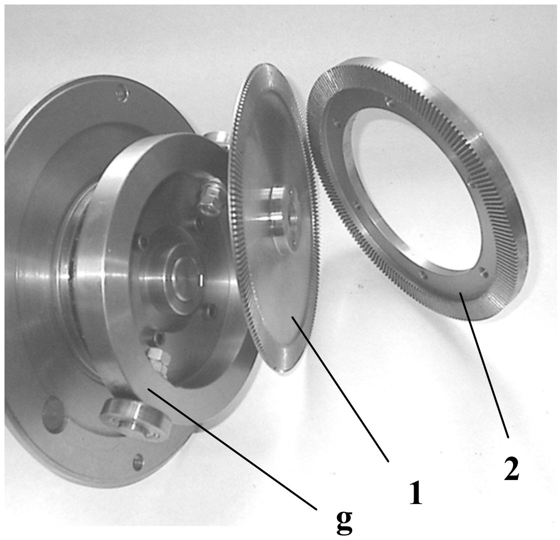


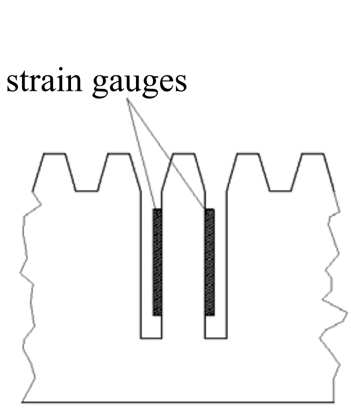
Fig.1 *The investigated harmonic drive (1 – flexible gear, 2 – solid gear, g – wave generator)*

The main sizes and toothing parameters of the flexible and solid gears of the investigated harmonic drive were determined according to non-fictional recommendations [1]: D = 180 mm – outer diameter, d = 45 mm – inner diameter, h = 1.5 mm – thickness of the flexible gear, w = 3,5 mm – maximal deflection of the flexible gear in axial direction. The number of teeth on the flexible gear: $z_1 = 180$, on the solid gear: $z_2 = 178$, module of toothing: m = 1 mm. Gearing ratio of the drive according to (1): i = 90.

3. METHOD OF INVESTIGATION, DESCRIPTION OF THE TEST BENCH

The purpose of the investigation of the flat wheel harmonic drive was to analyze the condition of the toothing connection between flexible and solid gears and to determine the number of teeth in mesh. It was supposed that increasing moment of load on the output shaft of the drive causes increasing number of teeth in mesh, so measures have been carried out in different load cases.

For the investigation one tooth of the teething on the solid gear had been modified to measure-tooth. That means booth tooth grooves beside it were milled deeper, so that strain gauges (Fig.2) could be sticked on both sides of the tooth. In case of the measure-tooth is in



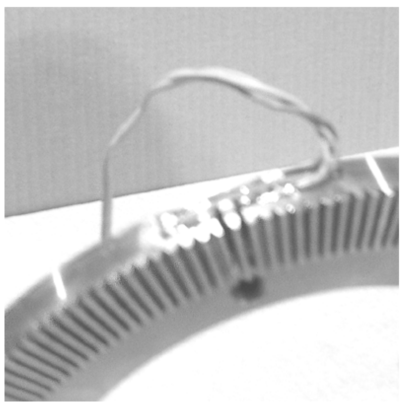


Fig.2 *The strain gauges on the measure-tooth*

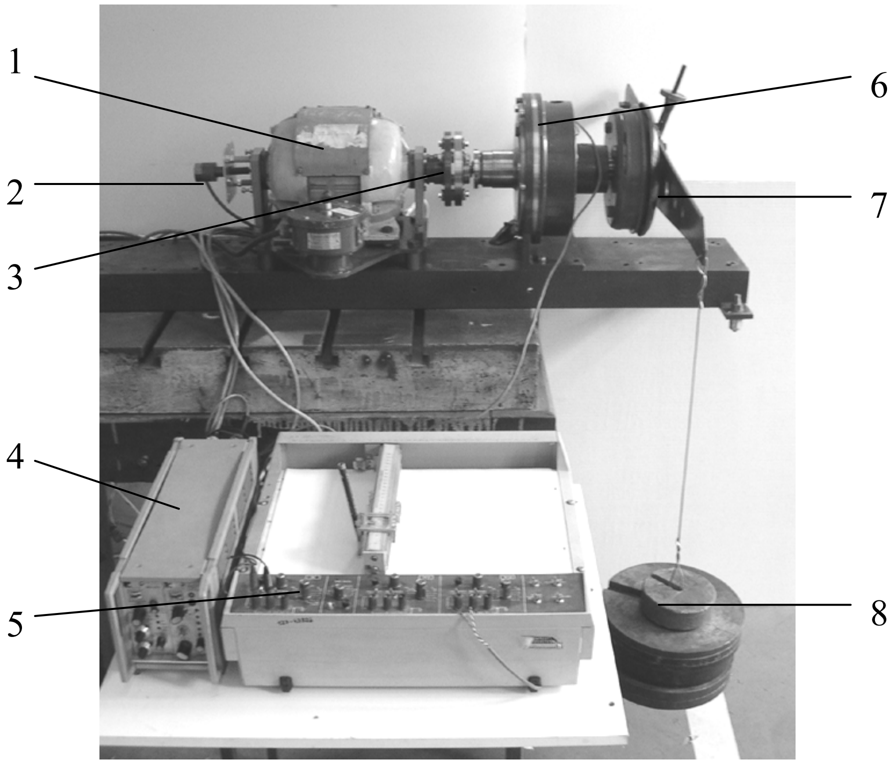


Fig.3 *The test bench*

mesh, the strain gauges could indicate the force effecting on it. By revolving the wave generator, the relative position of the measure-tooth from the centre of the deflected area could be changed. Indicating the force on the tooth versus angle of position of the wave generator the length of the connecting area and the number of teeth in mesh could be determined.
The test bench [2] can be seen in Fig.3, where the input shaft of the harmonic drive (6) is connected to the shaft of an electromotor (1) by a coupling (3). The electromotor need not have been used during this investigation, but the relative angle-displacement of the shaft of it (which is equal to the relative position of the wave generator) could be measured by an analog angle-meter (2). The signs of the angle-meter and the strain gauges were amplified by an amplifier apparatus (4); the results have been plotted by an X-Y recorder (5). An arm (7) was fixed onto the output shaft of the harmonic drive, loading (8) were hung on the end of it. By changing weight, different levels of moment of load could be obtained.

4. RESULTS OF INVESTIGATION

The number of teeth in mesh and distribution of forces acting on teeth have been determined by the measurements in case of different levels of loading moment. Scanned curves of a measurement series of the investigated experimental harmonic drive can be seen in Fig.4.

In case of no-load and low level of loading moment were only 1-2 teeth in mesh, but if the moment of load was increased, the number of teeth in mesh increased too. The number of teeth taking part in the load-transmission versus moment of load on the output shaft can be seen in Fig.5.

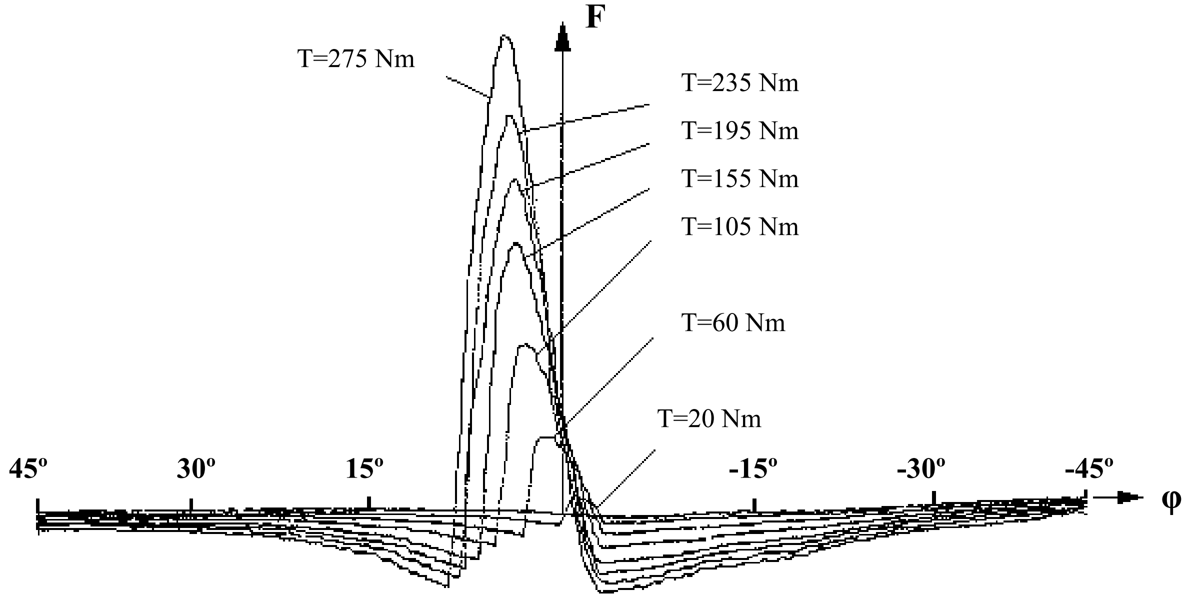


Fig.4 *Scanned curves of a measurement series plotted by X-Y recorder (F – force acting on the measure-tooth, φ – relative angle of position of the wave generator)*

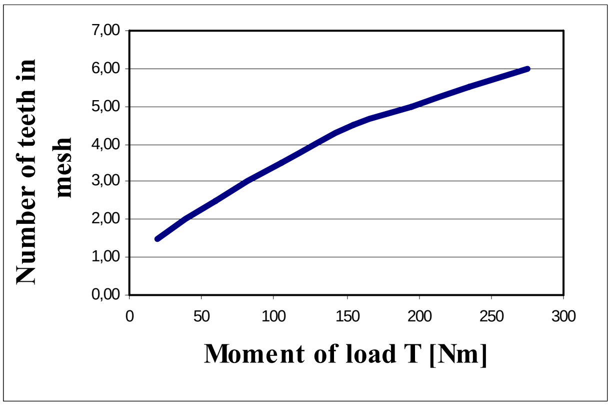


Fig.5 *The number of teeth taking part in the load-transmission versus moment of load*

5. CONCLUSIONS

The executed measurements on the flat-wheel harmonic drive were appropriate for analyzing the condition of toothing connection between flexible and solid gears. We experienced, that in case of higher levels of loading moment, there are more teeth in mesh, according to classical harmonic drives. It can be stated, that increasing moment of load on the output shaft of the drive causes increasing number of teeth in mesh. Seeing Fig.4 it can be set out, that in case of loading moment on the output shaft and an angle of the wave generator between approximately -50º < φ < 50º out of the load-transmission area the force acting on the teeth has a negative sign, which shall mean contact between the coasting sides of the teeth. It requires more investigations to check this fact.

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