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Force Analysis of a Double Gear Harmonic Drive

The paper presents an original method for determining by experimental means the tangential forces distribution in the gearing's zones from the portant elements of the double gear harmonic drive, as well the scheme of the used testing stand. Taking into consideration the results of the theoretical and experimental tests it may be asserted that they concord almost entirely, the deviation being under 6%.

Keywords: *double gear harmonic drive, tangential force, experimental analysis, testing stand.*

1. Introduction

The continuous modernization and improvement of the actuator systems has lead to the implementation on a wide scale of more performing mechanical transmissions, able to assure high kinematic precision of positioning and repeatability, at a smaller gauge and mass

The category of these transmissions also includes the double gear harmonic drive, which imposed in the last period, by diversified applications in all of the top technological domains based on its high performance, which exceeds the one of the classic gears [1, 2, 3, 7, 8, 9]. The growing interest in double gear harmonic drive has justified the necessity of researching the dynamic behavior of these modern transmissions.

In order to determine by experimental means the tangential forces in the gearing's zones of double gear harmonic drive, there can be applied various methods and techniques of investigations. Choosing the optimal experimental method implies the necessity of the researcher to know main advantages and disadvantages of them.

Experimentally, taking into account the complex researches of double gear harmonic drive, a reduction gear was projected and then materialized, having the following constructive and functional characteristics [5, 6]: transmission ratio, i = 48; waves generator with cam; inner diameter of the flexible gear, d_{fg} = 58 mm;

module, m = 0,3 mm; maximum radial deformation, w = 0,3 mm and the number of teeth: z_{fgI} = 200 teeth; z_{frg} = 202 teeth; z_{fgII} = 190 teeth; z_{mrg} = 188 teeth.

The structure of the double gear harmonic drive (Figure 1) composes of: a waves generator as input element, a short flexible gear (under the form of a circular tube with thin wall, open at both ends and having at each end an external and internal toothed crown).

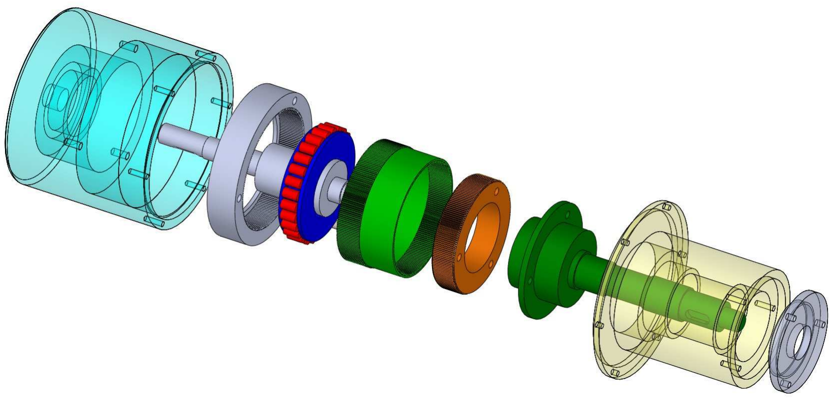

Figure 1. The structure of a double gear harmonic drive.

The wave generator being in sliding contact along the entire periphery of the flexible gear, it deforms this gear so that it will have four equidistant driving zones: two with the fixed rigid gear having internal teeth (first step, I-I) and two with the mobile rigid gear having external teeth (second step, II-II). Between the two pairs of opposing driving zones (I-I and II-II respectively) there is a 90^o angle.

The chosen constructive solution allows: to be carried out static or dynamic experiments, a quick assembling/disassembling, the existence of various possibilities of changing the main components, moreover taking over the signals from the measure transducer which investigates the short flexible gear and the control teeth of the rigid gears.

2. Test stand for the experimental determination of the forces

For an experimental determination of the tangential forces from the conjugate teeth, in the two harmonious gearing zones, it was used the well known method [4] based on the electrical resisting tensiometry.

The establishment of the character of the distribution's rule of the tangential forces between teeth (for I-I and II-II steps) is implemented through the tensiometric detecting element type EA-06-125BT-120 (Micro-Measurements Division, USA), stuck on the control teeth of the rigid gear, fixed or mobile, protected against humidity by rubberized putty type AK 22 Hottinger.

Figure 2 presents the control teeth of the two rigid gears and the soldering position of the two tensiometric detecting element on each control tooth, which were examined by experimental tests, as well as the picture of gears.

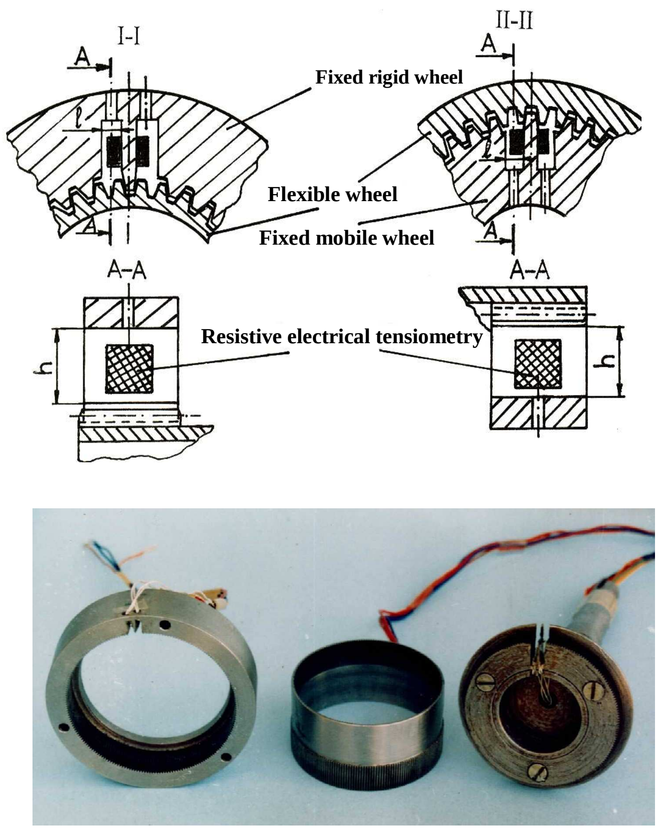

Figure 2. The control teeth of the two rigid gears

Figure 3 presents the block scheme of the stand and the equipments used for the experimental determination of the tangential forces from the harmonious gearing, in the two steps, which includes: ME- electric engine with the possibility of rotation's regulation; TC - belt drive; TI - inductive translator of impuls (type IWB 202-RFT), which shows a complete rotations of the wave generator; TADD – double gear harmonic drive liable to tests; SAD – acquisition of data system; PC - electrical computer; FM - mechanical brake and CE – elastic coupling.

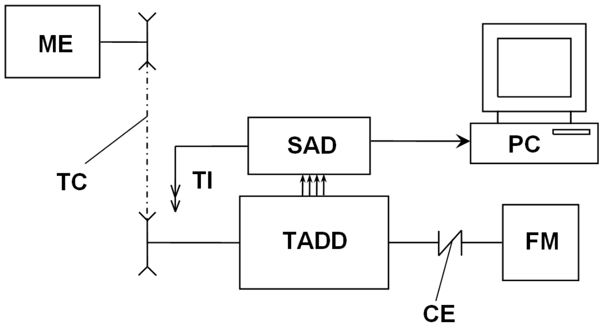

Figure 3. The block scheme of the test stand.

This assembly was chosen due to its constructive simplicity, to its high precision obtained as a result of the utilised equipment in the acquisition, recording and processing of the measured magnitudes.

3. Research and experimental results

For an experimental determination of the tangential forces which actuate against the flexible gear's teeth, which are in process of gearing with the rigid gear's teeth (în the two steps of drive), there was measured the elastic deformation of the control teeth on the two rigid gears.

Figure 4 presents the distribution's rule of the tangential forces on the short flexible gear's teeth in two steps: curve 1 – experimental, curve 2 – theoretical, obtained as a result of processing the oscilogram, recorded on the PC through the data acquisition system, for the cases: M_t = 50 Nm respectively 100 Nm and n = 50 rpm.

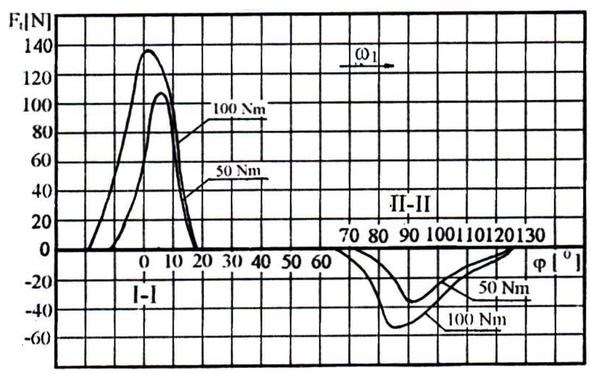

Figure 4. The distribution's rule of the tangent forces

4. Conclusion

From the analysis of the experimentally determined graphics, we can conclude the following:

- distribution curve's character of the force on the gearing teeth (for I-I zone of the double gear harmonic drive) is the same as the one of the simple gear harmonic drive [1, 2, 7];
- the harmonious gearing zone (φ_{II}), for zone II-II and M_t = 50 Nm, is deviated with ≈ 90° given the gearing zone I-I (φ_I) and it exceedes it as size (≈ 40);
- the differences between the diagrams of the force on the teeth from the gearing I-I and II-II, is explained as follows: in step I-I, the change of the shape of the short flexible gear is limited from two sides (the fix rigid gear and the wave generator) while in the step II-II section it is limited only by the mobile rigid gear; and there's a great possibility of changing the shape of the flexible gear for the increasing of the loading charge ($M_t > 50$ Nm);
- there are confirmed the theoretical results from regarding the character of the distribution's rule of the force situated on the teeth in the process of gearing (for the 2 gearing's steps) and the maximum value of the tangential experimental determined force deviates with 6% given the theoretical determined one.

From the analysis of the experimentally obtained results [2] and of the one obtained theoretically [1,7] we can affirm that on a great amount they confirm, the deviations being in the tolerable limits.

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