ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XIII, NR. 1, 2006, ISSN 1453 - 7397

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Double Harmonic Transmission (D.H.T.)

The paper presents the construction and functioning of a new type of harmonic drive named double harmonic transmission (D.H.T.). In the second part of this paper is presented the dynamic analysis of the double harmonic transmission, which is based on the results of the experimental researches on the D.H.T. This study of the stress status and the forces distribution is necessary for to determine the durability on the portant elements of the D.H.T.

1. Introduction

In the last 3-4 decades, researchers payed more attention to mechanical transmissions through engaging due to multiple advantages that this type of drive has looking to improve them as much as possible but not sufficient enough.

The main trend during the present stage of development and modernization of technical industry is constituted by the automation of production processes and their integration within systems controlled and co-ordinate by computers. In this respect it becomes necessary to improve and create new mechanic transmissions able to perform precise motions and to transmit big loads.

This new category includes also the toothed harmonic transmission, mainly used in the design and manufacturing of drives for industrial robots [1],[2],[4].

The toothed harmonic transmission is essentially different from the classic mechanic transmissions as it transmits and transforms kinematics and dynamic parameters of the rotation motion through elastic deformation propagated according to a harmonic law of one of its elements named flexible toothed wheel.

Through constructive and functional diversification's of toothed harmonic transmissions one has created a new variant of the double harmonic transmission.

This transmission presents a series of advantages such as: great precision of positioning and repeatability, great transmission ratio (i = 40…150), reduced dead course, extremely small loose motions, small weight and size, small inertia moments, coaxial and modular construction, offering them a larger and larger range of applicability in the machine-building field.

The present paper presents the construction, functioning and some dynamic aspect of the double harmonic transmission.

2. Construction and functioning of a Double Harmonic Transmission

It is based on the same working principle as the simple harmonic transmission, but one must correlate the number of teeth of toothed wheels from the mounting condition [2], [3], [4]:

$$z_3 = z_2 + 2; \;\; z_2' = z_4 + 2 \qquad (1)$$

Figure 1 presents the structural scheme of a double harmonic transmission with short flexible wheel under the form of a circular tube with thin wall, open at both ends and having at each end a toothed crown (exterior z_2 and interior z'_2).

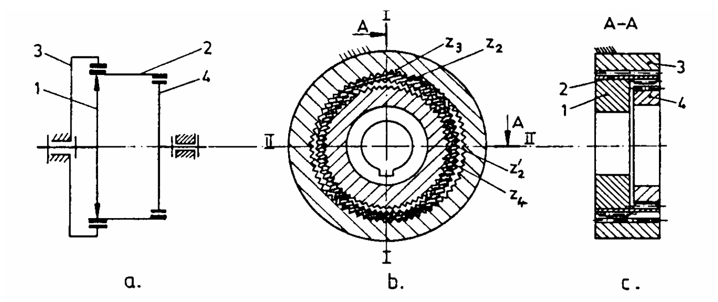

Figure 1. The structural scheme of a D.H.T.

A double harmonic transmission (Figure 2) is made of: a waves generator (1) flexible toothed wheel (2) with the respective exterior and interior toothed crowns, the fixed rigid wheel (3) and the mobile rigid wheel (4) as led element.

The waves generator being in sliding contact along the entire periphery of the flexible wheel, it deforms this toothed wheel so that it will have four equidistant driving zones: two with the fixed rigid gear having interior tooting and two with the mobile rigid gear having exterior teeth.

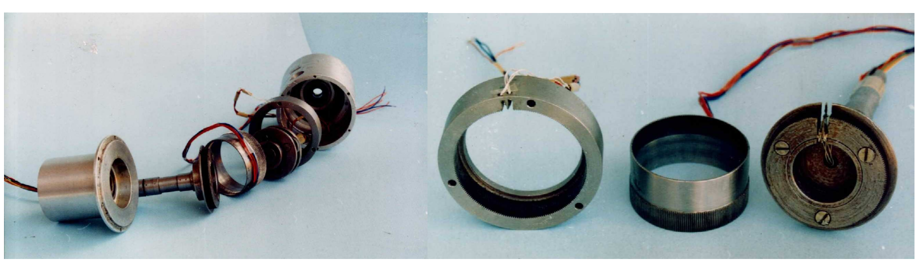

Figure 2. The double harmonic transmission

Between the two pairs of opposed zone of driving (I-I and II-II respectively) there is a 90^o angle. As these zones are at a 90^o angle from each other the transmission of loads is done through bending and torsion stresses.

At the beginning of functioning one finds in contact on the opposed vertical positions (I-I) the exterior teeth (z_2) of the flexible wheel whit the interior teeth (z_3) of the fixed rigid wheel, and in theposition disposed at 90^o angle to the vertical axis (II-II) one can find in contact the interior teeth (z'_2) of the flexible wheel whit the exterior teeth (z_4) of the led rigid wheel. Thus at a full 360^o rotation of the waves generator of the double harmonic transmission the led rigid wheel will rotate in the opposite sense with four teeth compared to fixed one.

The transmission ratio a double harmonic transmission is determined with Willis's relation, [2]:

Error! Objects cannot be created from editing field codes. (2)

where: ω_1 – the angular speed of the waves generator; ω_4 – the angular speed of the led rigid wheel; z – number of teeth of the transmission wheels; i_{34}^{1} - the transmission ratio.

2. Researches and experimental results

As in the case of long flexible toothed wheels, the wall of the short wheels situated at bottom of teeth is the most stressed and experiments have proved that the first fissures appear in this area which in the end leads to breaks that put the short flexible wheel out of use.

The experimental researches have been done on the double harmonic transmission with the following functional parameters (Figure 2): the transmission ratio (i = 48,2), the wave generator with eccentric disk, the maximum radial deformation (w_0 = 0,3mm), the number of teeth of the rigid wheels (z_3 = 202 teeth, z_4 =188 teeth), the number of the flexible short wheels teeth (z_2 = 200 teeth, z_2' = 188 teeth), the teeth modulus (m = 0,3mm).

For an experimental determination of the tangential forces which actuate against the flexible wheel's teeth, which are in process of gearing with the rigid wheel's ones (the two of double harmonic drive), the elastic deformation of the control teeth on the rigid wheels were measured.

Figure 2 presents the control teeth of the two rigid wheels and the possibility of soldering the two tensiometric detecting element on each control tooth, which were examined by experimental test.

For the experimental determination of the tangential forces (F_t) and of the stress status (σ_φ, σ_x, $\tau_{x\varphi}$) from the two zones of "harmonic" driving of the D.H.T. has been used the known method [2], [4], based on the resistive electrical tensiometry. From the analysis of the experimentally determined graphics we can notice the following:

- the distribution curve of the tangential force from the teeth situated in the "harmonic" driving (for section I-I) is analogical with the one from the simple harmonic transmission [2], [4];
- the zone of "harmonic" driving II-II (φ_{II}), at M_t = 50 Nm , is diverted with $\cong$ 90^0 towards the driving zone I-I (φ_I) and overtakes as extent with $\cong 25^\circ$;
- in the section I-I the shape of peripherical tension curve (1- σ_φ) is close to the one known from the simple harmonic transmission, and in section II-II the peripherical tension curve (2- σ_φ) has more peaks, but the ultimate tensions

don't overtake the maximum values of the peripherical tensions from the section I-I;

- the variation character of the tangential tensions ($\tau_{x\varphi}$) and its extents, in both sections, are aproximately identical.

4. Conclusions

In the thesis was presented a dynamic analyses of double harmonic transmission based on thin wall shells theory and on rotating character of distributed forces that actuate on flexible toothed wheel.

An important contribution in solving this problem have papers [2],[4], which permitted the identification on the distors forces from the waves generator with disk and came upon the flexible toothed wheel as well as the forces from the harmonic engagement.

From the analysis of the experimentally obtained results and of the one obtained theoretically, [2], we can affirm that on a great amount they confirm, the deviations being in the tolerable limits (under 5% at the tangential forces and under 8% at tensionsFrom the study of dynamic analysis it has been determined that the peripherical tension (σ_{φ}) in section I-I has a greater value and it has a determinant influence on the stability of the short flexible toothed wheel.

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