ANALYSIS OF NUTATION SPEED REDUCER USING ANSYS SOFTWARE PACKAGE

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The calculation of the stress-strain state (SSS) of engagement of gear teeth by analytical methods leads to large errors in the results, especially for bevel gears with circular teeth due to the complex geometry of the gearing. With the advent of numerical methods, solving this problem has become easier especially when applying the finite element method [1].

In this paper, we consider the development of a static finite element model for modeling the engagement between the teeth of a Nutation Speed Reducer.

Nutation speed reducer with face teeth is a totally innovative gear transmission developed in recent years [2], which bases its functioning on the mathematical concept of nutation motion, that is the main feature that characterizes nutation gear from conventional gear. It has unique features which include high reduction ratio in one stage, very high profile contact ratio and an overall higher power density transmission. In addition, the contact is theoretically pure rolling in the gear, the heat generated should be lower and the efficiency higher.

The Nutation Speed Reducer was proposed in [3]. The component names of the NSR illustrated in Figure 1 are (1) an input shaft; (2) the stator gear; (3) the nutator gear; (4) the rotor gear and (5) the output shaft.

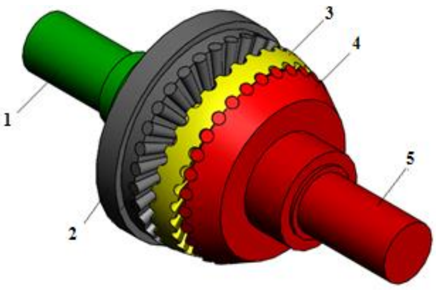

Figure 1 – The Nutation Speed Reducer

The nutator has gear faces on either side of the body that are in mesh with both the stator and the rotor gears. The motion and torque transfer from nutator to rotor gear and output shaft.

The numbers of teeth on the stator gear 2 and rotor gear 4 is Z1, Z4 respectively. The numbers of teeth on the nutator gear 3 meshing with stator gear is Z2. The numbers of teeth on the nutator gear 3 meshing with rotor gear is Z3. The gears of NSR simultaneously share the tooth loads with high contact ratios as a result of its unique assembly [4].

The ABCD tooth contour (Fig. 2) consists of a semicircle of radius r and two arcs of radius r *. The centers of the semicircle and arcs lie on the pitch circle of the gear. The EFGH line defines the base contour.

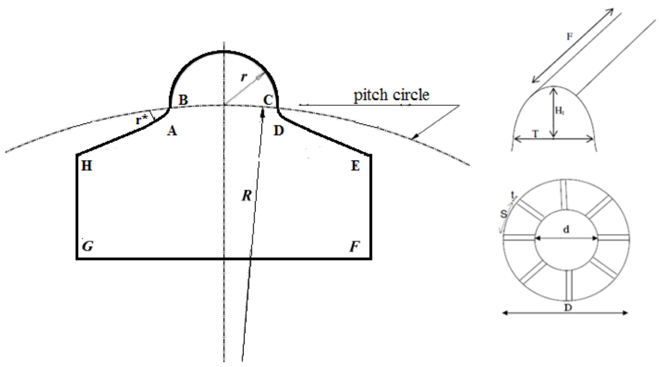

Figure 2 – Tooth contour in cross section

The following elements were used when building the structure of a finite element mesh: Solid 185 (volume elements) and Targe 170 (contact surface elements)

In order to provide a more accurate calculation of the stress-strain state (SSS), a grid was thickened in the area covering the contact spot. In fig. 3 shows the finite element model of the Nutation Speed Reducer.

Figure 3 – Finite element model of the Nutation Speed Reducer

The 3-D model elements type used were solid 92 and targe 170. The following assumptions were made:

Assumed Static Analysis: Modeled in a static (steady state) FE analysis;

- Model face spur gears as solid cylinders;
- Modeling teeth of both gears pairs as surface contact elements;
- The contact elements were created by GUI in ANSYS.

The bending stresses are calculated by the Maximum Principal Stress function, and the contact stresses - by the function of finding the equivalent stresses [Von Mises Stress] resulting from the combination of the main stresses in the x, y and z directions. This value can be compared with the yield strength of the material. The Von Mises Stress is determined by the ratio:

$$\sigma_{eq}^2 = \sigma_{XX}^2+\sigma_{YY}^2+\sigma_{ZZ}^2-\sigma_{XX}\sigma_{YY}-\sigma_{YY}\sigma_{ZZ}-\sigma_{ZZ}\sigma_{XX}+3\sigma_{XE}^2+3\sigma_{YZ}^2+3\sigma_{XZ}^2$$

The contact stresses were calculated by an analytical method based on the Hertz theory. And the calculation of the bending stresses are carried out with the following assumption: the entire load is replaced by the resultant force applied in the pole of the engagement and directed along the engagement line. The resultant force is transmitted by one pair of teeth [5].

The stress value obtained using three-dimensional analysis was an order of magnitude greater than the theoretical result. The reason for such a high estimate can be explained by the fact that the analysis was non-linear and due to the absence of teeth on the gear wheel, which would lead to a lower stress value, as shown in the theoretical equation. Finite-element analysis helped to determine whether the developed product meets its functional requirements.

References

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