The study of the dynamic properties of some structural components of harmonic drive

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Abstract. The paper presents the geometric models of flexsplines and wave generators developed based on the actual construction and geometric dimensions of manufactured harmonic drives (type CSD, CSG, HFUS and HFUC). In order to enhance the data preparation process, the model geometry was recorded in a parametrical form. By altering the individual properties of the models, it is possible to automatically generate finite element grids for flexsplines and wave generators of various geometrical and structural properties. The calculations prepared for the sake of the study by application of the finite element method (FEM) were conducted using the Femap/NX Nastran software. A preliminary numerical modal analysis of the structural solutions for the harmonic driver flexsplines and wave generators assumed to be applied was conducted.

Keywords: harmonic drive, flexspline, wave generator, modal analysis.

1. Introduction

Recent technical developments have caused the emergence of new and improvement of old torque transformation methods. For large ratios, the classical multi gear transmissions are being replaced by planetary gears, and those by a more efficient harmonic drives [1-3]. Gear, which was first to use elastic deformation of the toothed ring gear in order to transform the torque, was patented in 1959 by W. Musser. Since then, especially during the last twenty years, various types of harmonic drive were developed and patented. Compared to classical toothed gears, harmonic drives have numerous advantages, but there are some disadvantages as well. Their main advantages include: high torque capacity, excellent positioning accuracy and repeatability, compact design, zero backlash, high single stage reduction ratios and high torsional stiffness. On the other hand, their drawbacks are: high elasticity and nonlinear stiffness and damping. The application of toothed harmonic drives in various fields of life is more and more wide. They are currently used by the automotive and space industry, in aviation, medicine, automatics and robotics, while most of them are two-wave harmonic drives with mechanical wave generators. When considering transmissions used in automatic control systems, issues connected with their high kinematic precision, smoothness of torque transmission and dynamic characteristics (stiffness, damping, moments of inertia and natural frequencies) gain utmost importance.

A harmonic drive (Fig. 1) consists of a toothed mechanism, which is composed of three main elements. The circular spline (mark 1 in Fig. 1) is a solid steel ring with internal teeth. The flexspline (mark 2 in Fig. 1) is a flexible steel cylinder with external teeth. The drive is executed by the wave generator (mark 3 in Fig. 1), a thin-race ball bearing that is fitted onto an elliptical plug. Generator produces the elastic deformation waves of the flexspline. Depending on the number of waves distortion we distinguish one-wave and two wave harmonic drives. The flexspline is the main component of a harmonic drive, which can generate a repeated vibration by the wave generator. From this reason, the flexspline should have flexibility and good vibration characteristics.

While choosing the flexspline material [3, 5-8], one must consider the deformations and stresses occurring in the flexspline operating in the driver, both unloaded and loaded by the torsional moment. The heat treatment method to be applied to a spline must be determined entailing the criterion of ensuring its elastic properties as well as the service life assumed.

Modal analysis is the study of the dynamic character of a system which is defined independently from the loads applied to the system and the response of the system [9-12].