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Issue of Rigidity of the Ball Screw Nut Exposed to Bending Stress during Bending Stress of the Ball Screw

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Abstract: Ball screws and nuts represent the inseparable part of machine-tool building. The thread lead accuracy ranges in hundredths of millimetres per 1 m. In addition to the undesirable phenomena caused by heat (dilatability) and, e. g., torsional and transverse oscillations, the bending stress of the ball screw is considerably undesirable too. This stress and at the same time behaviour are transferred to the bending stress of the ball screw nut. This has a very harmful influence on setting of the ball screws, when the machine tool is assembled. Using the analysis by means of the FEM method, the paper conducts a survey of deformation issue of the arrangement "machine – ball screw – ball screw nut" during the assembly stage as well as a survey of compensation possibilities and other technical measures determined to limit the undesirable deformations and stress of the ball screw originating already in the manufacturing stage of the machine tool.

Introduction

The ball screws and nuts are utilized at designing of machine tools [3] for transformation of the rotary motion to the translation motion. The machine tools represent precise manufacturing machineries which must comply with the dimensional and geometric requirements of the products and manufacturing technology.

According to the literature researches, the current knowledge level about internal kinematics and dynamics of the ball screws is not too large. It is limited predominantly on the description of the ball behaviour in the carrying part of the nut thread under the ideal geometric and loading conditions. At the current time the engineering designers and research workers dealing with the ball screws are interested in the contact tasks in the carrying part and their influence on the mechanism rigidity. For example, these issues have not been elaborated yet – the dynamic behaviour of the balls in the stage of their entering the thread and leaving the carrying part as well as the kinematic and dynamic behaviour of the balls in the transducer. Moreover, the coherence is not known with the processes taking place inside the nut and their external manifestations. The main aim of this analysis is to find the influence of the screw position towards the nut at the assembly of this design group. When the assembly is performed, the ball screw nut is bending-stressed, which is undesirable, and it is not known whether and how this stress is transferred and reflected in the assembled machine tool. The description and analysis of the issue contained in the text are the application issues which all manufacturers of machine tools are confronted with. Nevertheless, the authors do not know whether the issue has been already explored in the similar way.

Fig. 1 shows the design type execution of the drive for the linear motion axis [1]. The ball screw does not move and the nut is driven by the servomotor. The internal force effects – the force interaction among the screw, the nut and the balls can be expressed as the functional dependence. The contact relations and also the forces (force F_k) in the ball screw thread can be examined analytically or by means of the numerical methods (Fig. 2) [1]. Fig. 3 shows the dependence of the contact force (F_k) on the ball size (D_w) and the prestressing intensity (δ, i. e. at deformation loading) [1].

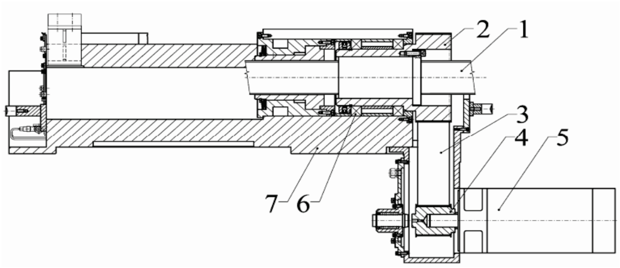

Fig. 1: Schema of the drive for the linear motion.

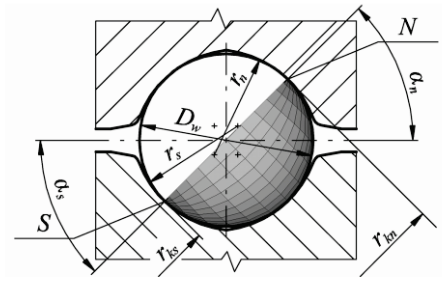

Fig. 2: Contact relations in the ball screw.

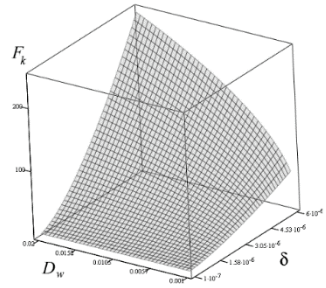

Fig. 3: Dependence of the contact force on the ball size and prestressing intensity.

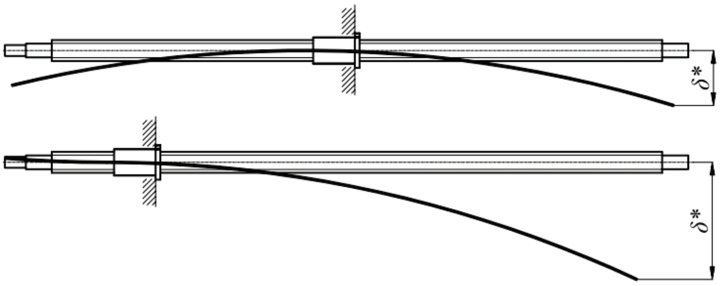

Fig. 4: Dependence of the screw deformations on the position of the nut.

Fig. 4 shows the situation which happens commonly at the machine-tool assembly. The ball screw nut is fixed with the frame through the flange. The ball screw (nut, this depends on the fact whether the screw or the nut can be rotated at the assembly) gets towards the screw from the middle position when the deformation (δ^*) is the smallest (Fig. 4). If the nut is at the ball screw end, it is obvious that the screw deformations (δ^*) are considerably bigger. When the assembly is performed incorrectly, these deformations are brought into the machine geometric inaccuracy and the brought bending stress of the ball screw nut reduces its service life. The nut service life can be calculated analytically [2]. However, as it is shown and the long-term observance of this issue, the theoretical values are not in accordance with the practical ones. The paper shows how the nut pliability can influence the paradoxical service life increase of the design group "ball screw and nut".

Summary

The paper shows that the way of calculation and external manifestations of the ball screw properties used in the text can be applied to the mechanism development as well as to the check of its operational condition at the machinery where it is used, i. e. at the machine tool. The numerical calculations show the behaviour of this motion mechanism (e. g. the nut pliability) which the analytical calculations are not able to catch (they are not able to work with it).

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