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ON SIMPLIFYING THE MACHINE TOOL FEED DRIVE FEM MODELS

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ABSTRACT
The paper presents research on modelling of HSM machine tool feed drive with use of Finite Element Method. The problems affecting generally considered machining accuracy were analysed, i.e. the problem of thermal displacements and the problem of displacements related to the feed drive stiffness. The research focused on possibility of simplifying (decreasing complexity) of the FEM models. Built, simplified models were compared to the base models in terms of accuracy of predicting temperature field and feed drive stiffness. Also, calculation time and size of hard disc files were considered.
Keywords: Finite Element Method, modelling, machine tool feed drive

1. INTRODUCTION
The Finite Element Method (FEM) is widely used for machinery modelling. In the Department of Machine Technology this method is used, among others, for modelling of heavy machine tools. Such a case can be considered as a specific one since it requires FEM in the process of design. This requirement is justified with lack of other possibilities to carefully study and verify the machine tool properties. In other words, heavy machine tools are produced in the single type of production. This means that no prototypes are available for designers to verify the design. Next, the revealed problems in the design can not be corrected in following machines produced, neither.
Another case example is related to High Speed Machining (HSM). Development of machine tools capable of performing HSM requires specific approaches to design, again. High cutting parameters can emphasize some undesirable phenomena, e.g. increased level of vibrations or thermal displacements. The design of HSM machine tools requires considering criteria, which could be partially disregarded while designing conventional machine tools. It concerns thermo-stability and stiffness, among others. In order to consider the above criteria, the FEM modelling seems to be very useful assuming that adequate models are developed.
The paper presents research on modelling of HSM machine tool feed drive with use of Finite Element Method. The both mentioned above problems affecting generally considered machining accuracy were analysed, i.e. the problem of temperature field and the problem of feed drive stiffness. In the first step of the research, the base FEM models were built [1]. The models were verified with the experimental data. Then, the research focused on possibility of simplifying (decreasing complexity) of the models [2]. The simplified models were finally compared to the base models in terms of accuracy of predicting temperature field and feed drive stiffness. Also, calculation time and size of hard disc files were considered. The model simplification is especially important while large objects or the objects with many details are to be modelled. In many cases, small elements, e.g. bearings, cause that the FEM models contains more that 500,000 nodes. Simulation of such models requires usually computers with high computation power and large memory capacity. Even though the high power computers are applied, the computation time can be still too long for practical engineering needs.

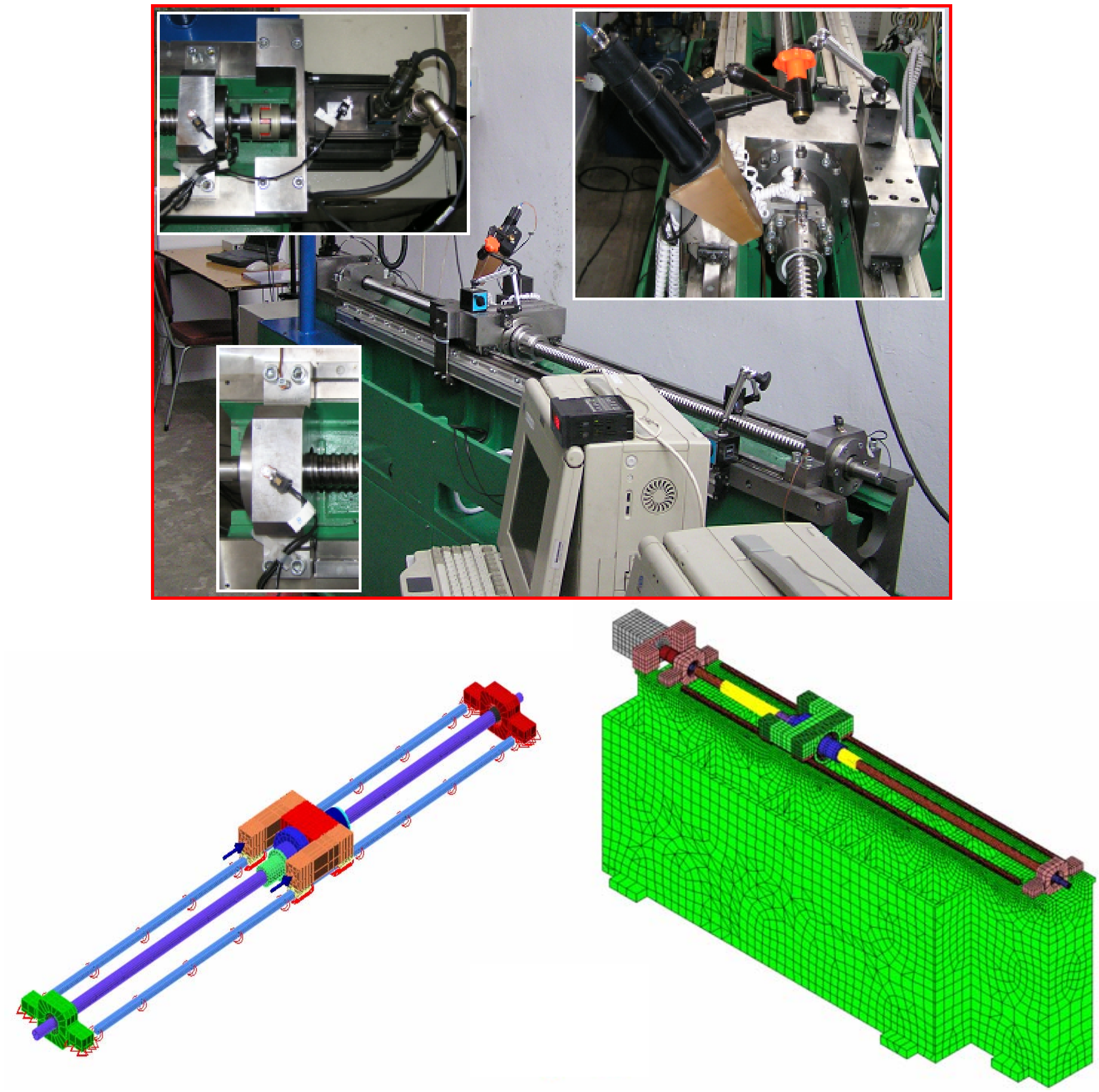


Figure 1. The modelled feed drive and base models of the drive

2. ANALYSED MODELS

As it was mentioned in the introduction, the presented research is related to modelling of HSM machine tool feed drive. In Figure 1, a photograph of the feed drive is shown together with, so-called, base models of the drive. Here, the base model stands for a model with high number of nodes, i.e. with high number of elements taken into consideration in their detailed form. After introducing some simplification we can talk about, so-called, simplified models.

The modelled feed drive consists of moving table, ball screw with ball nut and two supporting bearings. The drive can work in two ways. In the first case the servo-motor turns the ball screw. This is the configuration with fixed ball nut (ball screw driven). In the second case, the servo-motor is mounted on the moving table and it feeds the ball nut (the feed drive with fixed ball screw, ball nut driven). The both configurations were analysed in the research conducted.

In order to characterize the applied approach an example of bearing modelling can be presented. Modelling of such a machine element requires making a decision on the model complexity. In other words, one must decide if each rolling elements of the bearing and the inner and outer rings are to be explicitly modelled. The base model of ball nut bearing is presented in Figure 2. This model considers all detailed elements of the bearing. Thus, the inner and outer rings are considered together with the balls. These elements were connected using contact elements.

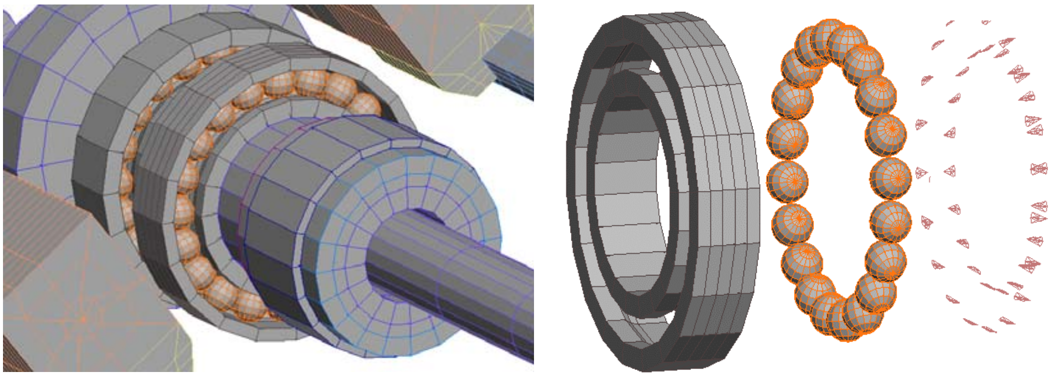


Figure 2. Base model of the ball nut bearing (the configuration with the fixed ball screw)

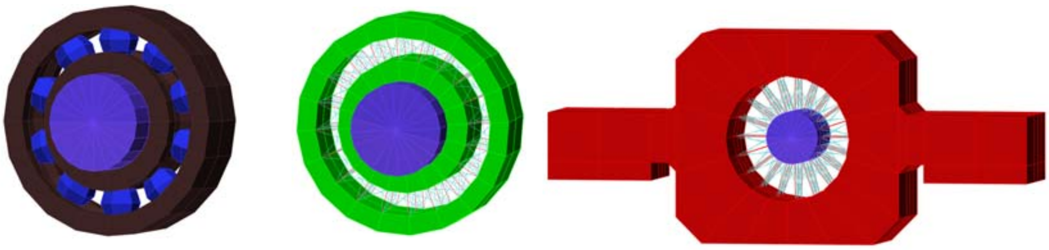


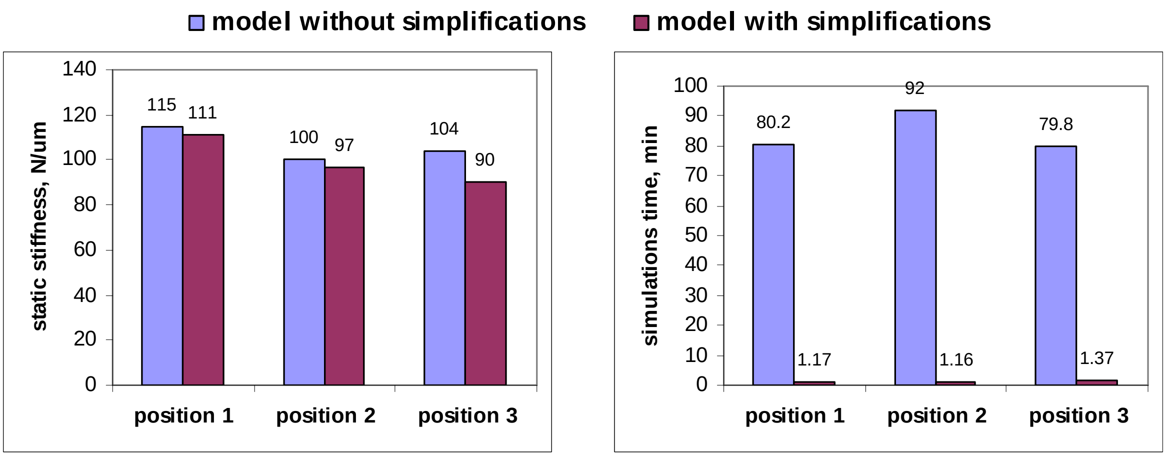
Figure 3. The steps of simplifying the ball screw bearing

The simplification procedure was done in steps (Figure 3). First, the rolling elements were replaced with rod-type elements. The number of these elements was equal to the number of balls in the bearing. Also, the shape of the rings was simplified. In this case the groove for the rolling elements was deleted. Finally, the bearing was completely removed from the model and represented with mentioned above rod-type elements. It should be added that in each step of model simplification, the overall stiffness of the bearing was checked and adjusted to the values provided by the bearing manufacturer.

In the described above way several parts / elements were simplified. The mentioned above ball screw bearings and ball nut bearings were simplified. Next, the ball screw geometrical shape was simplified by removing grooves of the helical line. In the analysed feed drive, the table is fixed to the body with rolling ways (ball slides). In the base model all rolling elements were considered while these elements were replaced with rod-type elements in the simplified model. In the case of thermal analysis of the feed drive model, the main changes were related to the body of the drive. It was assumed that the body temperature does not change substantially. This allowed to removed the body and assign the constant, ambient temperature to the areas where the other elements of the drive were joined to the body. Besides, smaller number of elements conducting the heat between ball nut and ball screw was assigned.

3. DISCUSSION OF THE SIMULATION RESULTS

As it was mentioned in the introduction, the research presented in the paper focuses on models allowing estimating the stiffness of the HSM feed drive and temperature field of such a drive. In order to estimate the stiffness, the axial force, i.e. force parallel to the ball screw axis, was applied to the table and the displacement of the table was measured in the same direction. The stiffness was expressed as a quotient of the above values. Also, the stiffness was estimated in the three positions of the table (left, centre and right position). As it can be noticed (Figure 4), the difference between models in terms of stiffness values are of few percents, only. This would suggest that before modelling a careful analysis of the modelled elements and parts should be conducted. Such an analysis can substantially reduce a generally considered size of models. This statement can be justified with the time and file size savings for model simulations, as shown in Figure 4. This is relatively important while practical implementation of FEM is considered. Especially much shorter time of simulations of the simplified model should be emphasised. Possibility of conducting many simulations can lead to an optimisation of the considered feed drive. Having several solutions, a designer can perform an analysis of the solutions in the light of different criteria and can choose one of them that fulfils his expectations. The similar conclusion can be expressed in relation to research on temperature field analysis (Figure 5), as well.



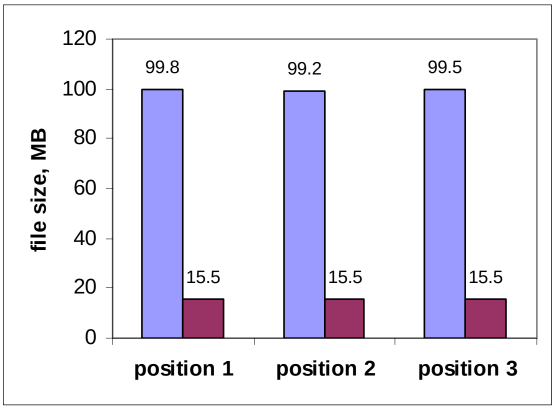


Figure 4. Selected results of simulations conducted for the configuration with fixed ball screw

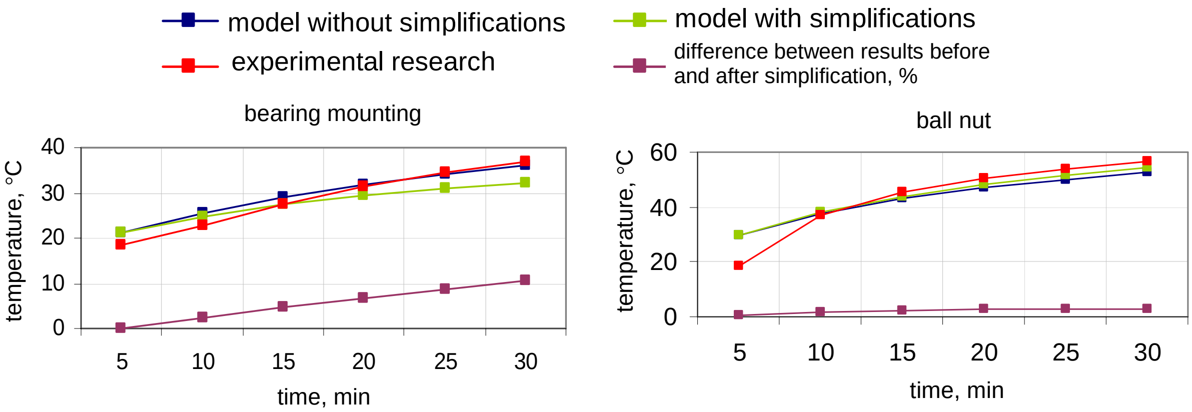


Figure 5. Temperature field analysis, selected results of simulations conducted for the configuration with fixed ball screw (position 2)

4. REFERENCES

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