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FEM applications to model friction processes in plastic strain conditions

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ABSTRACT

Purpose: The analysis of FEM applications to evaluate stress states in investigated tribologic processes of plastic working in a special tribological device designed for the purpose of this research.

Design/methodology/approach: The analysis and modeling of upsetting processes in movement conditions by means of FEM.

Findings: The paper presents the application of FEM and its methodology of computations for the established friction conditions in real conditions and in virtual conditions. The common properties and differing ones for both methods have been described.

Research limitations/implications: The research on the carried upsetting process in movement conditions makes possible to determine the effectiveness of applied methodology of investigation.

Practical implications: Finite Element Method can be successfully used as a tool to examine plastic strain phenomena at considerations of different working conditions of particular elements.

Originality/value: The use of a special instrument for friction tests and of FEM to evaluate friction processes in plastic strain conditions.

Keywords: Analysis and modelling; CAD/CAM; Process Systems Design; FEM analysis; Tribo-meter

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TECHNICAL PAPER

1. Introduction

One of the basic problems in different aspects of movement is the determination of frictional resistance occurring in the analyzed friction node. Plastic working processes are also included in such generation processes where tribological problems are considered. Then, the problems how to evaluate friction with the consideration of plastic strain emerge. In these cases, the rigid-plastic systems must be considered. The research on plastic strain by means of FEM (Finite Element Method) model analyses can be one direction for considerations. The application of this method enables the examination of processes in modeling conditions at ensured simultaneous control and verification with the results obtained from real condition experiments.

The purpose for this type of research is to determine the co-influence of friction conditions and plastic strain parameters on process progress in displacement conditions in a specially designed instrument for tribological tests. The research that has been carried out in real conditions and in FEM model conditions show the coincidence and the usefulness of both for this type of tribological process analyses. [1-15]

2. Results and discussion

The laboratory stand to test tribological processes designed and constructed in the Department of Fundamental Technology enables the research on frictional resistance in upsetting processes. Fig. 1 shows the construction of the stand. [6]

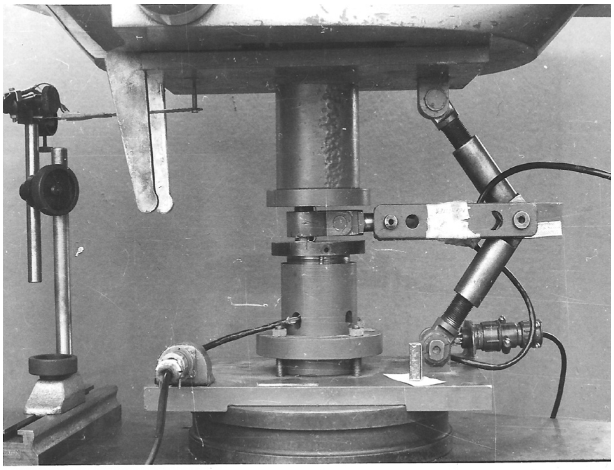

Fig. 1. Test stand image

The presented instrument can be used to examine frictional resistance, in particular, when one element of a frictional pair is submitted to plastic strain (rigid – plastic tribological system). This device makes possible to model frictional processes in conditions similar to the reality. It provides the possibility to carry out the research in conditions of a normal pressure and with the possibility to move material samples on the tool. It is also possible to test upsetting forces and tangent forces acting on the contact surface. The presented instrument enables also simultaneous measurements of pressure and displacements at action of normal force and tangent force. It takes into account velocity changes in horizontal material shift during modeled processes of plastic working. [5]

The construction of this tribological device is presented schematically in Fig. 2. The instrument consists of two plates: 1 and 2, to which another two exchangeable working plates: 6 and 7 are mounted. There is a tested material sample 3 installed between them and surrounded with a clamping ring 8 that is connected through an exchangeable pull rod 5 with two screws 4 connected through the articulation to the pull rod 5 and to the plates: 1 and 2. There are extensometers stuck to the plate 2. The side surface of the sample is tangent to the clamping ring fixture.

The operational principle is based on two plates: the upper one 1 and the bottom one 2 which are axially compressed in a hydraulic press or in a mechanical press. In the case of plastic strain modeling at the same time the material sample 3 is moved between the working plates 6 and 7. The measurements of the normal force and the tangent force are taken by means of the system of extensometers 9 and 10 and the relevant measuring equipment. The movement velocity of the sample 3 during compression is adjusted by means of two screws 4 and the pull rod 5. The device is equipped with the set of plates 6 and 7 mounted on the plates 1 and 2 which makes possible to take measurements of physically different materials and samples.

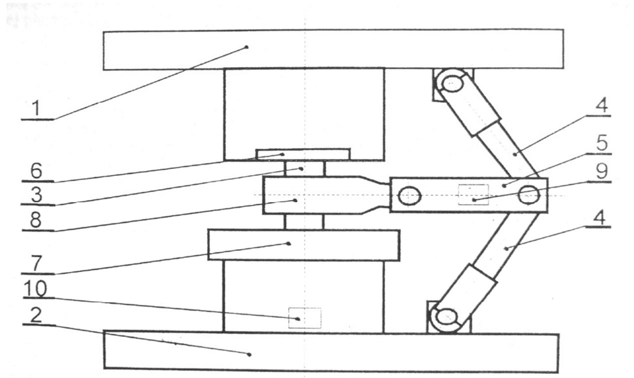

Fig. 2. Test stand construction

The feed of samples is driven by means of the system of pull rods and connections fixed to the bottom plate and to the upper one. There are extensometers on pull rods, thanks to which, the force, interacting with the friction force and driving the horizontal feed of the sample, is registered. The system of extensometers on the bottom plate enables the examination of different frictional conditions between the surfaces [5,6]

The research on the established system in the processes of displacements and strains enables their analysis. The important aspect of the modeled object applications is the possibility to use Finite Element Method. The numerical analysis provides individual consideration of investigated phenomena but at the same time requires some verification of boundary conditions [2,3,4].

The application of this method can be treated as the use for the examination of slide friction phenomena during plastic working. The advantage of this modeling is the possibility to perform numerous experiments at different process conditions. Despite the fact that the constructed model is simplified, the choice of computational parameters is connected to the creation of conditions which are very close to the experimental ones [8,9,11].

The analysis of the investigated phenomenon does not require to model the whole device together with its equipment. Fig. 3 shows the image of main working parts – item 6 and 7 from Fig. 2. It is a model of the testing instrument presented in Fig. 1. For better visualization, it is presented in the form of a cross section. The schematic images are presented in Figs. 3 to 7 in the same way.

The completion of the analyzed process depends on the necessity of detailed description of cooperation conditions with the modeled object. These conditions are determined as boundary condition parameters consisting of supports and loads of the machine model. They are created with some simplifying assumptions but this simplification should not significantly influence the correctness of results. The correctness of analysis procedure depends on correct assembling of particular working elements and on correct allocation of relevant bounds to these elements [1,7,12].

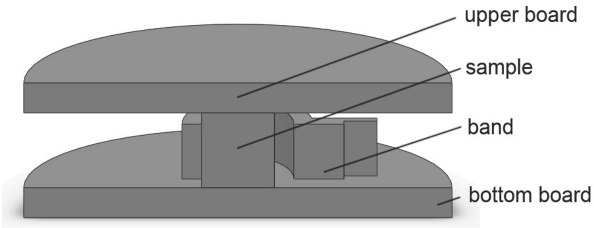

Fig. 3. The cross section image of the working part of the test stand

The modeling of cooperation among particular elements of tribological machine through the determination of relevant boundary conditions consists of several tasks.

The first is the determination of material parameters that have significant influence on the correctness of the results. That is why it is necessary to know material properties either for the analyzed samples or for the device elements. The values relevant to these properties have been derived from the software data basis. Tool steel NC9 has been allocated to the bottom plate, to the upper one and to the clamping ring, according to the reality of the process. The sample material has been determined as carbon steel 45.

The second stage of the formulation of boundary conditions is to reduce the relevant degree of freedom of models and to determine external loads. Thanks to this, the cooperation of model objects reflects the real work of device elements. The allocation of contact bounds between the forehead surface of samples and the upper plate and the bottom one enables the simulation of slide friction node [14,15].

The reduction of degree of freedom and the determination process of forces acting on device elements is presented in Fig. 4. This figure shows schematic continuous load on the whole upper surface and the bottom surface of both working plates by means of arrows on edges. Moreover, the force system has been allocated on the clamping ring that drives the feed of the tested sample.

The third stage of modeling is upsetting process in the conditions of horizontal shift of the sample and it concerns the discretization of the model. The network has been established as standard and its density as fine. [10,13] The computations delivered the series of data of stress pattern presented in Fig. 5.

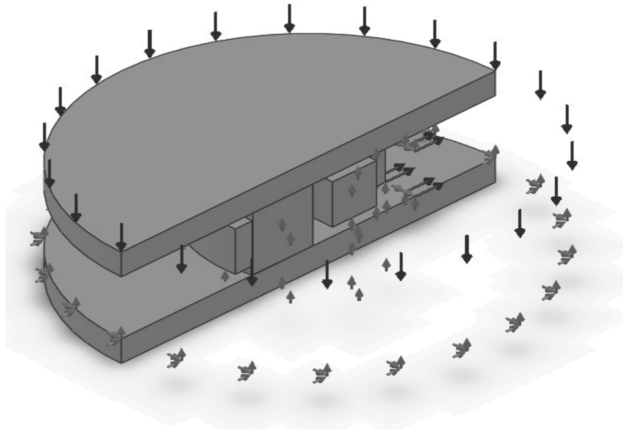

Fig. 4. The image of the cross section of elements together with the conditions of actions

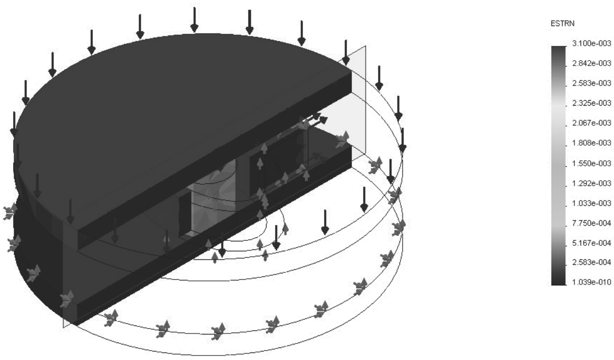

Fig. 5. The stress pattern in the analyzed tribological machine model

The models of working parts with strain states of samples are presented in Figs. 6 and 7.

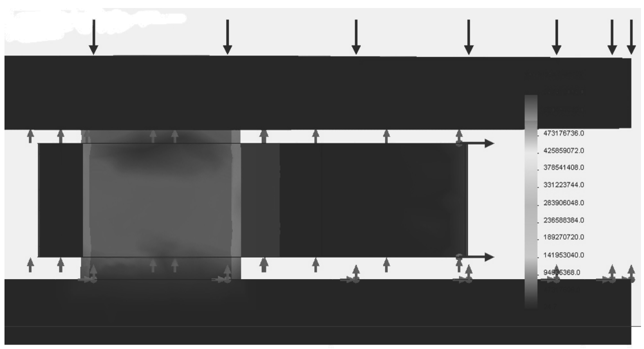

Fig. 6. The visualization of the device with a deformed sample – Variant 1

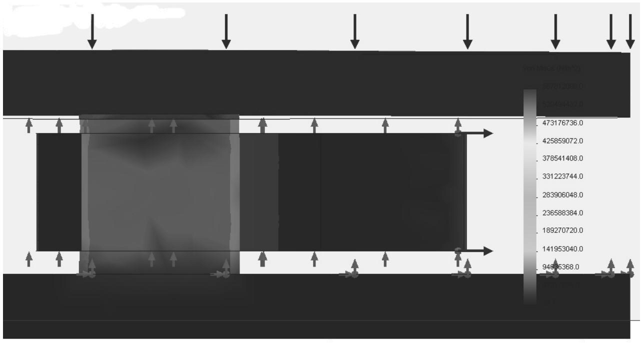

Fig. 7. The visualization of the device with a deformed sample – Variant 2

In the result of carried procedures the confirmation of coincidence between computational results and laboratory test results has been obtained. Table 1 presents the approximation of computational effects at applied working conditions.

Table 1.
The approximation of computational effects at applied working conditions

Sample parameters	Tests in real conditions	Results obtained from FEM application
Height before upsetting [mm]	30	30
Height after upsetting [mm], Variant 1	24	23
Height after upsetting [mm], Variant 2	24	24
Material	Carbon steel 45	

The research confirms preliminary the possibility of the application of described tests of plastic working to the evaluation of usefulness of eutectic coatings on frictional surfaces of tool materials.

3. Conclusions

The Finite Element Method can be successfully used for theoretical determination of expected strain in conditions of plastic working with the consideration of slide friction laws.

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