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Simulation studies MES impact on terrain roughness friction in plastic deformation process steel

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ABSTRACT

Purpose: The article aims is discuss the impact the state of the 3D model geometry processes sliding friction FEM simulation.

Design/methodology/approach: Modeling and analysis of sliding friction tribological phenomena in the program Deform 3D.

Findings: The paper presents a comparison of the results of tests carried out in real and virtual. It describes the common features and differing accepted research methods.

Research limitations/implications: The research of sample upsetting in movement conditions enables to determinate the effectiveness of accepted research methods.

Practical implications: Finite element method can be used as an effective tool for the study of phenomena forming when considering different operating conditions of individual elements provided the appropriate tools for FEA.

Originality/value: The use of sliding friction apparatus and FEM for plastic deformation processes in research.

Keywords: FEM analysis; Tribological processes; Simulation for sliding friction; Plastic deformation modeling

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METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

The factor in the process of plastic deformation in the cold friction occurring during movement without lubricant it is called dry friction. It is described on the basis of many theories and hypotheses [1-3]. By Lawrowskiego friction is the result of the interaction of forces between molecular species, occurring on friction to surfaces. In theory the process Bowdena-Tabora friction is the result of formation and peeling micro welding, occurring in contact points micro inequalities. The total friction force is the sum of forces wherein the friction shear adhesion molecules ($F_ś$) connections and extrusion grooves in soft material (F_w).

The total friction force F_t is determined the following relationship (1):

$$F_t = F_ś + F_w \tag{1}$$

where: $F_ś$ - cutting force adhesion; F_w connections - the extraction pressure furrow in soft material. For metals with high hardness value furrow extrusion force is not negligible and the dependence (1) takes the form (2):

$$F_t = F_ś \tag{2}$$

Contact surface can be defined by formula (3):

$$s = \frac{F_N}{R_e} \tag{3}$$

where: FN - normal pressure, R_e - yield strength the soft material. Taking into account the relation (3) in the model (2) summary determines friction function (4):

$$F_t = N \cdot \frac{\tau_{pt}}{R_e} \tag{4}$$

where: s - surface contact real τ_{pt} - shear strength of soft.

The actual contact layer with the inequalities, distance between nodes and working such as corrugating parameter. Fractography of actual surface, in which there are a variety of inequalities are high value compared to the distance between the tips. Limit the value of this ratio is 1/40. Depending on the technological process surface is in the range of from 0.01 to 200 µm [4]. Such an approach to assessment of the status of the cooperation enables modeling using MES.

Inequalities friction faces are referred to as a set of cones cut height or depth parameter in relation to the neutral. The surface material, Fig. 1 is considered as a set of material contained between the outer surface and the surface, which is a contractual limit changes in the value of sub-surface areas caused as a result of external factors. For the actual impact of mating surface friction pairs are defined status of the following inequalities:

- S_n - nominal contact surface area defined as a collection of all possible contact surface.
- S_k - outline the surface contact area as a trace actual contact fields; the value depends on the shape, position, and working such as corrugating surface errors and to the load.
- S_r - the actual contact surface which is the sum of elementary contact surface; actual contact surface is in place at the apex physical contact inequalities.

For those states of relation exists:

$$S_n < S_k < S_r$$

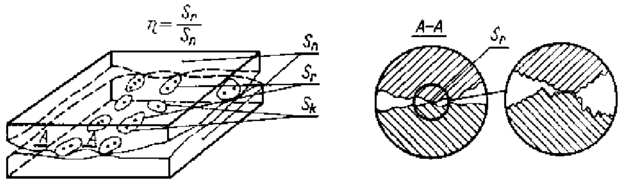

Fig. 1. The pin and slip mating surface friction slip [5]

In the process of sliding friction takes places in conditions of actual friction surface of the micro layers are coated with oxides metal, particles of the liquid or gaseous substances. In some cases, there is an adjacent arts path protects oxides friction surfaces before contact with metallic reducing adhesion and friction resistance. Hard and brittle oxide particles in certain conditions may perform the functions of an abrasive. When the node friction sliding friction for connections with metallic oxides of metals there are processes for creating and removing hydrogen peroxide micro layer resulting in bare surface is free of oxides. Crumbled oxides are involved in the sliding friction. The higher the value of the hardness is more fragile and less durable. It is easily damaged by the friction and, to a lesser extent prevents adhesion. Formation in the sliding friction micro layers of oxides in the surface layer due to oxidation diffusion is dependent on conditions of friction.

This type of phenomena cause the actual state of the contact surface is difficult to determine and mapping. Therefore, when computer modeling of contact phenomena most frequently chosen surface condition it is a state of nominal (S_n). The test is modeling phenomena occurring in the contact zone in the form of a simplified roughness take in their work Piotr Lacki [5]. It describes issues and the difficulty of mapping zones for numerical simulation and compares behavior of materials for the nominal and outline Fig. 2. In the process of deformation plastic pin may have a point, linear, or most prevalent-surface mount. The shape of surface contact and physical properties of materials friction influences the type and condition of stress in top layer as well as on the value of the force needed for the implementation of the process.

In literatures many papers describing the methods described geometrical profile of respondents surface. The work of Bowden and Tabor [1] suggests that the roughness affects the coefficient of friction for the respective materials. With the increase in roughness increases the friction coefficient. It is not known but the exact correlation between roughness, waviness and friction and is not included in the mathematical models of friction. Because of the simplification of the outline of the surface, geometric features and dimensions in the areas of micro and macroscopic surface obtained test results are generalized [6].

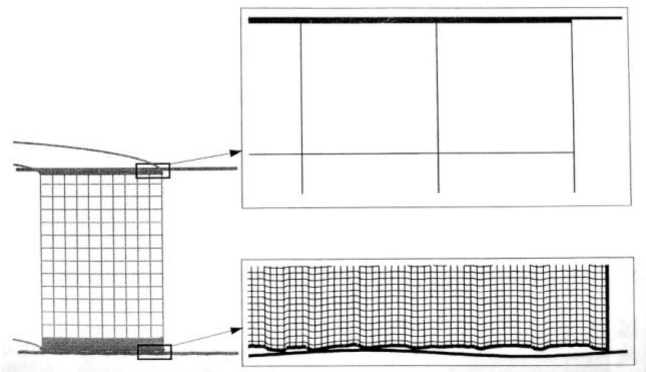

Fig. 2. The contact zone and the sliding surface of the model sample to friction sliding [5]

2. Results and discussing

The unit construction workers author of Fundamentals of Technology Faculty of the Lublin University of Technology where the sample deformation process was carried out cold in a static load forces and normal test also allows the frictional forces in the conditions of occurrence of plastic deformation in the tested material. The deformation is modeled composite sheet extrusion process. Tribotestera diagram shown in Fig. 3.

The device comprises two plates (1) and (2) to which are attached interchangeable plate (3) and (4) between which the test section of the channel section (5). is surrounded by a collar (6) in which the levels of the punch (7). Bracket is connected via a joint 8 to the replaceable monostrands 9. Screws 10 and 11 are hingedly connected to the pull rod 9 and the plates 1 and 2 form a gear knee.

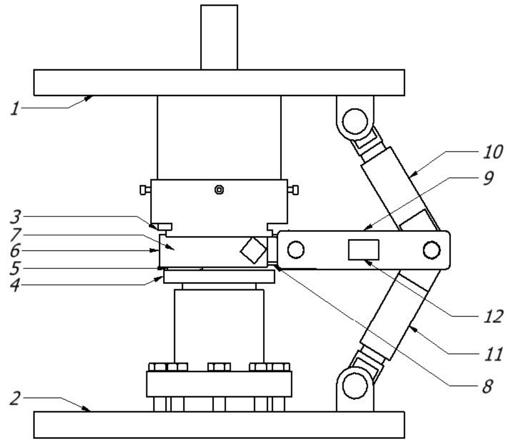

Fig. 3. Circuit apparatus for carrying out the process of sample deformation and sliding friction tests [Source: own]

On 9 tendon strain gauge mounted system (12) for registration of change of the force during the test pressing.

In the device during the test head plate (1) and lower (2) are compressed axially in the testing machine. At the same time an strain process is performed by moving the U-section disposed between the plates (6) and (7). Forces frictional resistance between the channel bar and the anvil of the machine match the forces acting on rods (9).

Changes in the frictional force during the operation specified on the machine by means of a strain gauge (12) and recorded using a measuring apparatus with high sensitivity. The rate of ejection of the sample (5) during compression was determined by means of two screw systems (10) and (11) and tie rods (9). The device is provided with a set of plates (3) and (4) mounted in the plates (1) and (2), to enable measurement of the forces of sliding friction. When the press force translational movement of the sample is forced by a system of legs and connectors attached to the lower and upper plates. At the tendon strain gauges are registered so that is the size of the force overcomes friction and forces the horizontal movement of the sample [7-9]. The results obtained were used to verify the numerical analysis of friction resistance in the conditions of deformation of the material.

Numerical analysis were four representative samples of digitized models of channel shapes with a thickness: 1.5 mm, 2 mm, 3 mm, 4 mm. The process of plastic deformation model systems shaped by numerical algorithm is dependent on the accepted boundary conditions. Each sample was determined initial conditions corresponding to conditions at the actual position. Adopted boundary conditions of altering the force of the top plate and the stamp and the coefficient of friction in a model system provided the opportunity to determine their correlation with the results obtained in the real experiment. Initial conditions were treated as variable factors experimental deliberately introduced into the calculation process. In this way, boundary conditions, took the form of variable controlled. Despite the presence of the planes of symmetry of the tribological model of the entire system has been tested in accordance with the instructions encountered in the literature [9-11].

When numerical analysis there is a relationship between the friction conditions and geometric conditions, kinematic and dynamic in the process. These conditions in the implementation of the simulation are referred to as simplified and representative of their selection process is based on the intuition and experience of the investigator [10].

In the implementation process of plastic deformation between materials and tools dominates the sliding friction, while the contact surfaces material tool surfaces are considered as nominal. Metallographic tests for samples channel shapes made of sheet steel S252. Sample results of structural steel after deformation in the sample drawing and compression samples having a thickness of 1.5 mm shown in Fig. 4 and 5.

During deformation of the friction at the contact area to inhibit the free flow of deformable metal, whereby the structure deformation of the sample areas were intentional beans having different degrees of deformation (Fig. 4 a,b,c). The subsurface areas sheet disclosed elongated ferrite grains and the baseband Fig. 5.

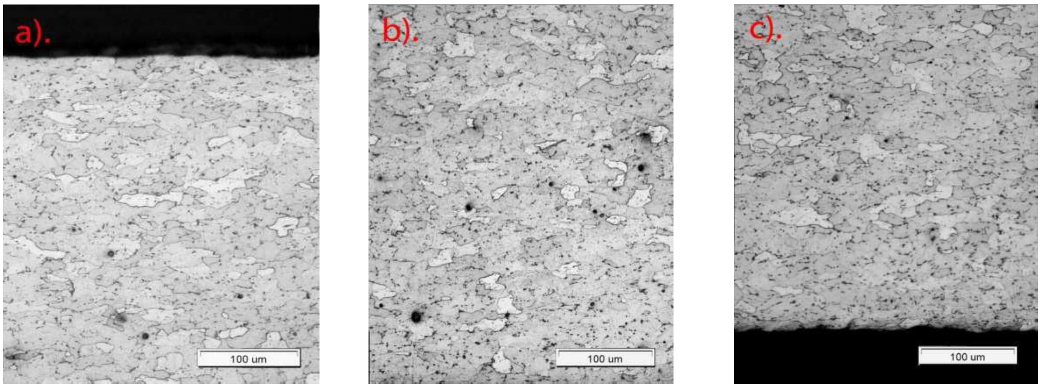

Fig. 4. Views of the structures of 1.5 mm sample with visible cementite precipitations after plastic strain process for cold work of approx. 13.3%; a) upper section of sample, b) middle section of sample, c) bottom section of sample. [Source: own]

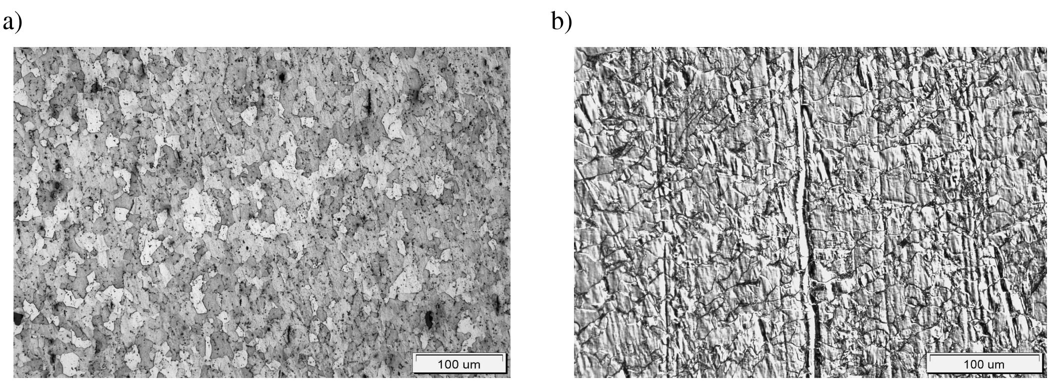

Fig. 5. View of the structure of surface layer of sample a) before strain-without ridging b) after strain-with ridging [Source: own]

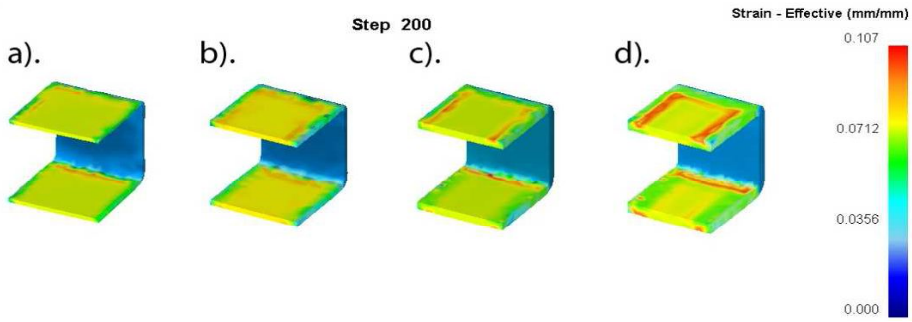

Fig. 6. Variable strain distribution for the material sampling step MES value 200 for the samples: a) 1.5 mm, b) 2 mm, c) 3 mm, d) 4 mm

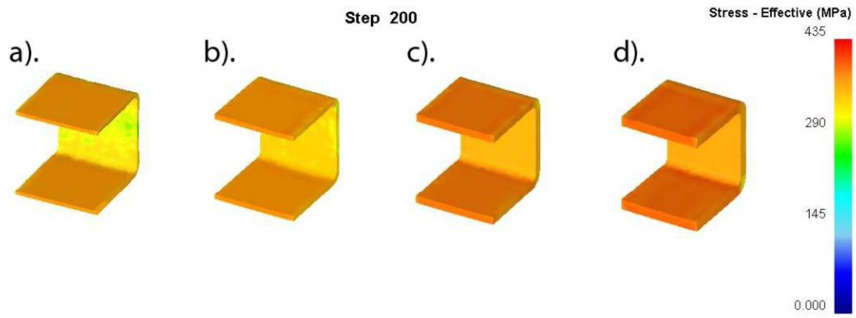

Fig. 7. Changes in the stress of the material for the sampling step MES value 200 for the samples: a) 1.5 mm, b) 2 mm, c) 3 mm, d) 4 mm.

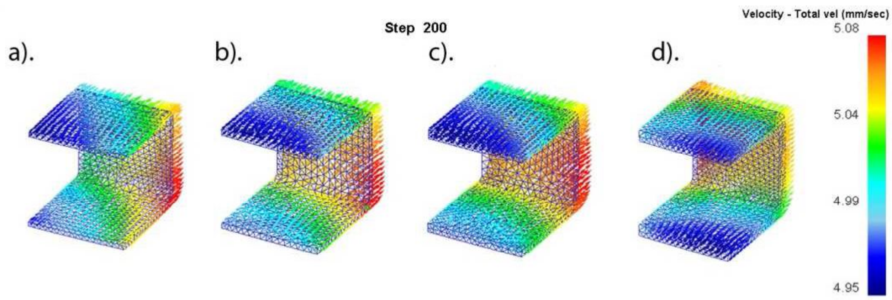

Fig. 8. Change the speed of movement of the material for sampling step MES equal to 200 samples a) 1.5 mm, b) 2 mm, c) 3 mm, d) 4 mm.

Due to the complex role of friction in the process of forming in the literature [12-14] may be cited technologies, in which the forces of friction is a beneficial and detrimental. This makes it possible to reduction the friction where it is undesirable and the use of the beneficial effects of friction in those areas of the material where it is desired. The quality of the results of simulation of tribological processes depends on the boundary conditions of the process, the geometry of the study area, his way of discretization, the number and shape of finite elements and physical properties of the object [1,15]. The simulation results obtained in the preprocessor module program Deform 3D enabled receive a range of information about the process. The simulation process allowed to obtain information that could not be obtained by the experimental [3,4,14].

Numerical analysis work tribo-tester allowed for the appointment of stress, strain, displacement speed of the material and the areas of the contact in the material. Exemplary distributions of changes in stress, strain and strain rate of the material shown in Fig. 6-8.

3. Conclusions

Despite the fact that in laboratory and FEM studies used the same research material that should be considered isotropic and material anisotropy in individual research techniques. The laboratory method used sample volume will vary with the MES analysis adopted the material is isotropic in nature, which in all directions exhibits the same physical properties. When the simulation process deformation of the sample is not taken into account the spatial distribution of the chemical elements of the test team. Based on the study of changes friction resistance, roughness plastically shaped samples and effects modeling this process by MES you can specify the following conclusions:

- Modeled processes plastic forming of materials they can be considered as tribological systems and undergoes computer simulation using MES
- Shaping processes the material may be considered as tribological systems in which material and tools are a pair smack in the system of normal and tangential stresses.
- The mapping error an area consisting of an inaccurate mapping of the area calculation, which does not correspond exactly to the actual area analyzed the tribological model.
- Tracking mapping error can be the result of not only the misentered of the geometry the input in the definition of the problem but also the cause may be inaccurate MES meshing. Too large size finite element causes the breakdown of the geometry of curved lines at broken. These types of models to simplify the mapping areas overlapping causes calculation errors resulting from multiple approximations processed value especially for iterative methods.
- The use of numerical algorithms allows to obtain research results in some approximation model. This is because as the level of idealization of objects at the stage of determining the boundary conditions differs slightly from laboratory conditions.
- The problem of modeling of tribological process is to obtain such approximations ambient conditions that are acceptable - What Were obtained in studies.

Additional information

Selected issues related to this paper are planned to be presented at the 22nd Winter International Scientific Conference on Achievements in Mechanical and Materials Engineering Winter-AMME'2015 in the framework of the Bidisciplinary Occasional Scientific Session BOSS'2015 celebrating the 10th anniversary of the foundation of the Association of Computational Materials Science and Surface Engineering and the World Academy of Materials and Manufacturing Engineering and of the foundation of the Worldwide Journal of Achievements in Materials and Manufacturing Engineering.

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