THE NUMERICAL ANALYSIS OF THE EXTERNAL ROUND THREAD ROLLING

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The papers [1] describe modeling of the contact problem in the external thread rolling process. This paper shown an application of obtained model for the thread with round outline. The mathematical model of process, were presented. The variational and finite element method, were used. The algorithm of numerical analysis in ANSYS system, were elaborated. Numerical computions of displacements, strains and stresses have been conducted without the necessity to introduce boundary condition in the contact zone - a proper definition of the contact zone by single surface auto 2D. Exemplary results of numerical analysis for various condition of the process realization in the discretized model has been presented.

1 Introduction

The round threads with quick pitch make up the specific group. The screw joint folding from nut and screw is used mainly in the construction of communication tunnels and construction engineering to support ceilings and in earth works for the protection of excavations. The screw threads are used with an nominal diameter of $d = 31$ and $d = 38$ mm, the pitch of $P = 12.56$ and $P = 12.78$ mm respectively and typical lengths of $L = 6000$ mm. The basic problem to design the rolling process of the round thread on pipe is elaborate proper construction of the tool and select of the processing condition for provide technical requirements and property of surface layer of the screw, simultaneously increase the tool life and process productivity. Therefore, at the our faculty a scientific research is carry out of the round thread rolling method on pipe.

2 Mathematical Model

A mathematical model of the process is formulated in increments and contains the following: a material model, an equation of motion and deformation, with initial and boundary conditions.

2.1 Incremental model of yield stress and elastic/visco-plastic material

Yield stress $\Delta\sigma_y$ is the most important parameter characterizing the resistance of a visco-plastic deformation. The incremental model of the yield stress for a typical step time $t \to \tau = t + \Delta t$ was defined as:

$$\Delta\sigma_y = F_2(y)\Delta y + (\partial F_1[\bullet]/\partial\dot{\varepsilon}_{eq}^{(VP)})\Delta\dot{\varepsilon}_{eq}^{(VP)} + (\partial F_1[\bullet]/\partial\sigma_{st})F_3(\varepsilon_{eq}^{(VP)})\Delta\varepsilon_{eq}^{(VP)} \tag{1}$$

where $\Delta\varepsilon_{eq}^{(VP)}$, $\Delta\dot{\varepsilon}_{eq}^{(VP)}$are the incremental of effective visco-plastic strain and strain rate, $F_2(y)\Delta y$ is the component of change in the initial yield stress with a change of chemical composition, $(\partial F_1[\bullet]/\partial\sigma_{st})F_3(\varepsilon_{eq}^{(VP)})\Delta\varepsilon_{eq}^{(VP)}$ is the component of change in the temporary yield stress σ_y with change of the visco-plastic strain, $(\partial F_1[\bullet]/\partial\dot{\varepsilon}_{eq}^{(VP)})\Delta\dot{\varepsilon}_{eq}^{(VP)}$ is the component of change in the temporary yield stress with change of the visco-plastic strain rate, σ_{st} is the state stress depending on the accumulated effective visco-plastic strain and time.

A new model of mixed hardening for isotropic material which includes the combined effects of elasticity (a reversible domain) and visco-plasticity (a non reversible domain) (*E/VP*) is used. The model takes into account the history of the material.

The constitutive equation of increment components of a total strain tensor takes form:

$$\Delta\varepsilon_{ij} = [D_{ijkl}^{(E)}\Delta\sigma_{kl} - A\tilde{S}_{ij}^{*}]/(1 - \tilde{S}^{**}) \tag{2}$$

and of increment components of the total stress tensor:

$$\Delta\sigma_{ij} = C_{ijkl}^{(E)}\Delta\varepsilon_{kl} - \psi\tilde{S}_{ij}^{*}[\tilde{S}_{ij}C_{ijkl}^{(E)}\Delta\varepsilon_{kl} - A] \tag{3}$$

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where: $\tilde{S}^{**} = \tilde{S}^{*}_{ij} C^{E}_{ijkl} \tilde{S}_{kl}$ is a component of a stress tensor, $\tilde{S}^{*}_{ij} = \tilde{S}_{ij}/[\tilde{S}_{ij} C^{(E)}_{ijkl} \tilde{S}_{kl} + (2/3)\sigma^2_y(\tilde{C} + E_T)]$ is a component of a stress tensor, $A = (2/3)\sigma_y[(\partial\sigma_y/\partial\dot{\varepsilon}^{(VP)}_{eq})\Delta\dot{\varepsilon}^{(VP)}_{eq}]$ is a positive scalar variable, $\Delta\sigma_{ij}$ is the increment component of the second Piola-Kirchhoff stress tensor, $D^{(E)}_{ijkl}$ are the components of tensor $\mathbf{D}^{(E)} = [\mathbf{C}^{(E)}]^{-1}$ in time t, $\Delta\varepsilon_{ij}$ is the increment component of Green-Lagrange strain tensor, $C^{(E)}_{ijkl}$ are the components of elastic constitutive tensor $\mathbf{C}^{(E)}$.

2.2 Incremental model of motion, deformation and DEM solution

Using the conditions of stationary of functional $\Delta\mathbf{J}(\Delta\ddot{u}_i, \Delta\dot{u}_i, \Delta u_i) = \Delta\mathbf{J}(\cdot)$ where $\Delta\ddot{u}_i, \Delta\dot{u}_i, \Delta u_i$ are the *ith* increment components of the displacement, velocity and acceleration vectors, respectively and a finite element method, we can write an equation of motion and deformation, in the updated Lagrangian formulation, for typical step time $t \rightarrow t + \Delta t$, in the form:

$$[\mathbf{M}]\{\Delta\ddot{\mathbf{r}}\} + [\mathbf{C}_T]\{\Delta\dot{\mathbf{r}}\} + ([\mathbf{K}_T] + [\Delta\mathbf{K}_T])\{\Delta\mathbf{r}\} = \{\Delta\mathbf{R}\} + \{\Delta\mathbf{F}\} + \{\mathbf{R}\} + \{\mathbf{F}\}, \tag{4}$$

where: mass matrix $[\mathbf{M}]$, damping matrix $[\mathbf{C}_T]$, stiffness matrix $[\mathbf{K}_T]$, internal force vector $\{\mathbf{F}\}$ and external load vector $\mathbf{R}$ are known at time t. However, increment stiffness matrix $[\Delta\mathbf{K}_T]$, external incremental load vector $\{\Delta\mathbf{R}\}$, internal incremental forces vector $\{\Delta\mathbf{F}\}$, incremental vectors of displacement $\{\Delta\mathbf{r}\}$, velocity $\{\Delta\dot{\mathbf{r}}\}$ and acceleration $\{\Delta\ddot{\mathbf{r}}\}$ of finite element assembly at a typical step time are not known. In order to solve this problem we apply the integration methods - central difference method (DEM), which it is one of methods of direct integration the equation (4). Assuming that the step time t is very small, it is possible to execute a linearization of equation (4) (elimination of $[\Delta\mathbf{K}_T]$ and $\{\Delta\mathbf{F}\}$, and using the incremental decomposition, then using the central difference method (DEM), we obtain:

$$[\tilde{\mathbf{M}}]\{^{\tau}\mathbf{r}\} = \{^{t}\tilde{\mathbf{Q}_T}\} \tag{5}$$

where: $\{^{t}\tilde{\mathbf{Q}}_T\} = \{^{t}\mathbf{F}_T\} + \{^{t}\mathbf{Q}_T\} - [\mathbf{K}_T]\{^{t}r\} + ((2\{^{t}\mathbf{r}\} - \{^{t-\Delta t}\mathbf{r}\})/\Delta t^2)[\mathbf{M}] + \{^{t-\Delta t}\mathbf{r}\}/2\Delta t[\mathbf{C}_T]$, $[\tilde{\mathbf{M}}] = [\mathbf{M}]\Delta t^2 + 0.5[\mathbf{C}_T]\Delta t$.

3 Numerical analysis

The application developed with regard to the method of finite elements in ANSYS program provides a complex time analysis of physical phenomena during the rolling process. The main aim of the simulations were to define the influence of friction coefficient on the states of deformations (displacements and strains) in the surface layer of the object. The friction coefficient has high influence on value and distribution of strain. For $\mu = 0$ the maximum strain intensity $\varepsilon_i = 0.78$ is located on the bottom of the thread, close to the contact surface (MX1, Fig. 1). For $\mu < 0$ appear an adhesion zone of material in the bottom of the thread, which take characteristic shape of a wedge. In this zone the value of strain is very small. For $\mu = 0.2$ $\varepsilon_i = 0.1$ - (MN) and for $\mu = 0.39$ strains are closer to the contact surface and getting smaller to value $\varepsilon_i = 0.0016$ (elastic strains) (MN). However, the local maximum of strains (MX1, $\mu = 0.39$) more and more moving down from the contact surface. Then appear additional two local maximums of the strains. First one (MX2) is placed close to the contact zone of the side of the thread, where higher value of friction coefficient increase strains value from $\varepsilon_i = 0.4$ for $\mu = 0.2$ to value $\varepsilon_i = 0.54$ for $\mu = 0.39$. Next one local maximum (MX3) is located in depth of material on symmetry axis pass through top of the thread,where strains are getting smaller together with increasing of friction coefficient value.

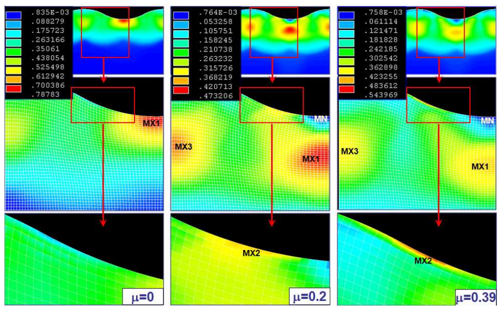

Fig. 1 The maps of strain intensity and deformation of the grid for various lubrications conditions

4 Conclusions

The mathematical models of the process, the algorithms for the solution of discrete equations of motion and the application in the ANSYS system developed in the present work could be used to improve the design process of the thread rolling. The obtained results of the computer simulation of the thread rolling process show that the friction coefficient influence on the states of displacements, and strains in the surface layer of the thread, also is one of the factors deciding about the technological and the exploitation quality. The best quality of the thread is received during the rolling process when $\mu = 0$.

References

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