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STUDY OF STRESS-STRAIN STATE BILLETS WHEN ROLLING IN A CONTINUOUS MILL OF HOT-ROLLED THIN STRIPES USING MSC SUPER FORGE

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The article proposes a new design of a continuous mill. To study the stress-strain state during rolling of thin slabs on the proposed mill, a three-dimensional geometric and simulation model of the rolling process was developed using MSC SUPER FORGE. Based on the obtained results of numerical modeling, the distributions of equivalent strains in a thin slab when rolling in 1 mill stand, the distribution of equivalent stresses in a thin slab when rolling in 1 mill stand, the distribution of the temperature field in a thin slab when rolling in 1 mill stand.

Key words: rolling, thin stripe, stress-strain state, structure, temperature

INTRODUCTION

An important factor determining the quality of thin-sheet products is the stress-strain state of the metal during rolling [1]. Due to the complexity of its description the corresponding calculation is usually not considered when designing rolling technology on thin-sheet mills. Therefore, the tasks related to improving the production technology of sheet steel in order to improve product quality and reduce production costs are relevant. They can be solved by developing and practical development of new mills and technological methods for rolling sheet metal, evaluating the shape change and stress in the deformation zone, etc. we have proposed a continuous mill for rolling hot-rolled thin strips of steel and alloys [2]. This continuous mill for rolling strips of steel and alloys contains working stands, universal spindles, electric motor, gear stands, gearbox with conical gears, motor coupling, main couplings, spring balancing devices of spindles; support non-drive rolls, working drive rolls, bed, support plate, anchor bolts.

At the same time, the stands that are powered by a single AC motor contain working and support rolls of constant diameter [3]. It should be noted that in consecutive stands, the diameter of the working rolls decreases during rolling, and the diameter of the support rolls increases. In this case, the diameters of the working and support rolls are determined by the formula, respectively:

$$D_i = \frac{\pi \cdot h_i \cdot n}{60}, D_j = \frac{\pi \cdot h_i \cdot n}{60},$$

$$(i=1, 2, \ldots, N-1, N \text{ by } j=N, N-1,\ldots 2, 1), \quad (1)$$

where h_i – thickness of the rolled strip; n – the number of revolutions of the rolls for passage of the rolling; N – the serial number of the stand, and the distance between the working rolls from one stand to another against the rolling directions increases by $kh_ê$, $h_ê$ – final thickness of the rolled strip; k – serial number of the stand in the reverse direction of rolling.

Rolling strips of steel and alloys on a continuous mill is carried out as follows. Thin slabs are fed to the furnace for heating and transferred to the first crate of the proposed mill by a roller roller [4]. When moving a thin slab through a series of stands located in the direction of rolling, in which the distance between the working rolls from one stand to another against the rolling directions increases by an amount $kh_ê$, the height is reduced and the required strip thickness is reached.

Making the working roll diameters smaller and the support rolls larger in the rolling direction allows you to significantly reduce the metal pressure on the rolls in the stands located at the end of the rolling mill and increase the rigidity of this mill. Reducing the forces acting on the rolls, as well as increasing the rigidity of the mill, reduces the size of the stands and drive power on the one hand and increases the accuracy of the rolled strip on the other hand. The use of working D_i and reference D_j rolls, the diameters of which are determined by the formula (1), allows you to reduce the inter-cage tension to zero, due to strictly maintaining the constancy of the second volumes when rolling in different stands. Reducing the inter-cell tension to zero allows you to avoid tearing the strips dur-

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ing rolling. Increasing the distance between the working rolls, from one stand to another against the rolling directions by an amount of kh_e, also reduces the tension of the rolled stock. Thus, the use of the proposed continuous mill for rolling thin slabs can improve the quality of the resulting strips. To study the stress-strain state when rolling thin slabs on the proposed mill, a three-dimensional geometric and simulation model of the rolling process has been developed [5].

MATERIALS AND METHODS

The study of the stress-strain state (SSS) of a thin slab in the rolling process from the point of view of mathematical modeling is a complex process due to the very large number of determining parameters and the ambiguous nature of their influence. The correct formulation of the problem even for simple rolling cases leads to a system of integral-differential equations, which cannot be solved analytically [1]. However, at present, the finite element method implemented in software products of finite element analysis is widely used to solve such problems. One of the leaders in finite element analysis software products specialized for calculating metal processing processes is MSC Super Forge. The problem of studying the volume SSS of a thin slab during rolling is con-tact, elastic-plastic, nonlinear, taking into account the temperature regime of deformation, as well as large displacements and deformations. It is required to calculate SSS and temperature in a thin slab at one pass through the mill stands. A thin slab is a parallelepiped in size 5 × 20 × 50 mm (figure 1). Carbon steel St3 with a deformation temperature range of 1 100 – 1 250 ^{o}C was selected as the material of the billet. The Johnson-cook elastic-plastic model was chosen for modeling the plasticity of the billet material. In MSC Super Forge, tools are assumed to be absolutely rigid and provide only the properties of thermal conductivity and heat transfer, i.e. the specific thermal conductivity, specific heat capacity and density are taken into account, while the mechanical properties are ignored. The roll material is assigned by default to tool steel H13. Also, for this material, the density and thermal properties will be assigned by default. The interaction between the rigid roll and the deformable material of the workpiece is modeled using contact surfaces that describe the contact conditions between the roll surfaces and the slab surface [2]. During the simulation process, the contact conditions are constantly updated, reflecting the rotation of the rolls and the deformation of the material, which allows you to simulate sliding between the roll and the material of the processed workpiece. The contact between the roll and the thin slab is modeled by Coulomb friction, the coefficient of friction was assumed to be 0,3. The rolling temperature regime consists of the exchange of heat between the roll, the thin slab and the environment, as well as the thermal effect due to the deformation of the metal. Heat transfer is carried out during convective and radiant exchange with the environment and contact of the roll with a thin slab. The roll-

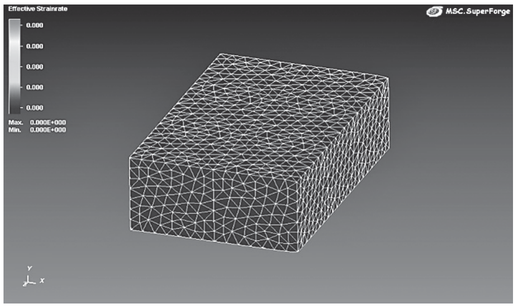


Figure 1 Finite element model

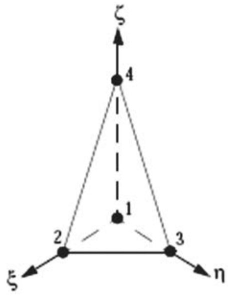


Figure 2 End element CTETRA

ing process takes place at room temperature, so the initial temperature of the roll is assumed to be equal to 20 °C.

A three-dimensional geometric model of a thin slab and roll was built in the Inventor CAD program, and imported into the CAE MSC Super Forge program. When creating a finite element model of a thin slab and roll presented in Figure 1, a three-dimensional volume element CTETRA (four-node tetrahedron) was used for modeling three-dimensional bodies (see Figure 2). The thin slab model required 2 518 elements and 3 180 nodes. The process calculation time was 24 minutes on a Pentium Duo computer with a clock speed of 3,4 GHz and 2 GB of RAM.

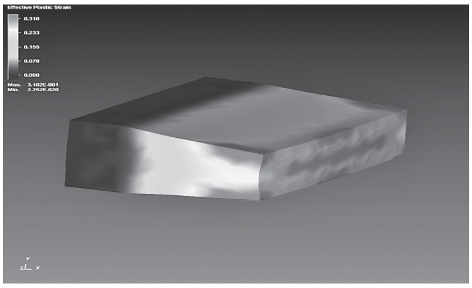
RESULTS AND DISCUSSION

The rolling process in the proposed mill can be conditionally divided into four stages. Therefore, for clarity of displaying the calculation results, data for four stages were taken as a percentage of the total deformation time, i.e. the following intervals were selected: first stage 40, and second stage 80 percent of the total deformation time [3]. Figures 3, 4, 5 show the distribution patterns of equivalent stresses and strains, the temperature field in a thin slab when rolling in the first stand (due to the large volume, equivalent stresses and strains, the temperature fields obtained when rolling in other stands are not presented).

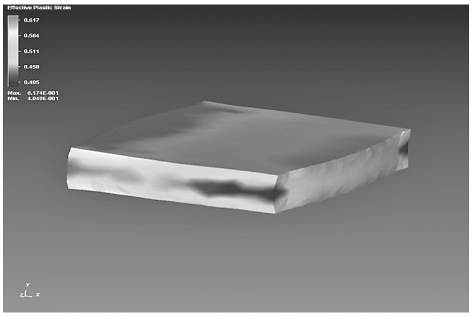
CONCLUSIONS

Based on the obtained results of numerical simulation, it was found that:

1 When rolling in the first stand, the equivalent deformations (G) and stresses (σ_i) at the initial moment of rolling, they are concentrated in the zones of metal capture by the rolls of the mill (see Figures 3 and 4). With an in-

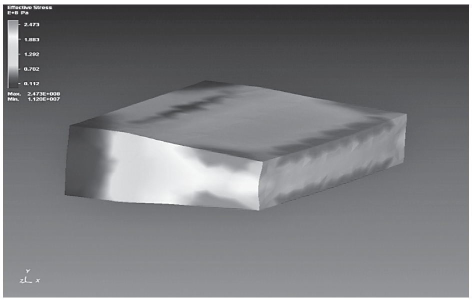


a) 40 %



b) 80 %

Figure 3 Pattern of the distribution of equivalent deformations in a thin slab during rolling in 1 mill stand



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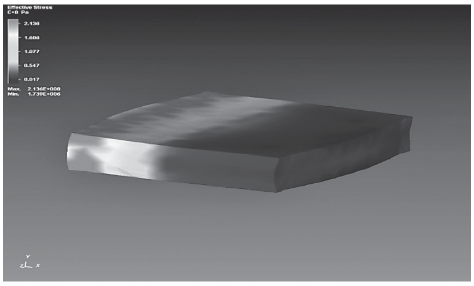
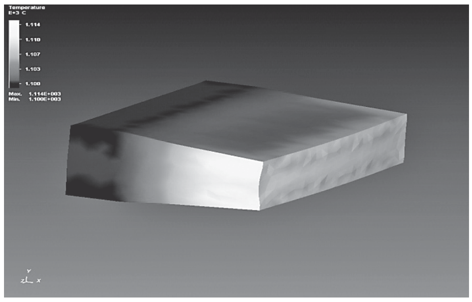


b) 80 %

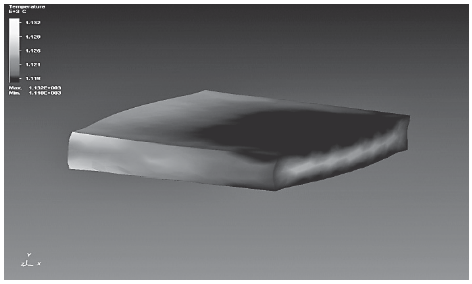
Figure 4 Pattern of the distribution of equivalent stresses in a thin slab when rolling in 1 mill stand

crease in compression, the accent G and σ_i transferred from the surface to the center and edges of the deformable workpiece. A further increase in the reduction leads to a more or less uniform distribution G and σ_i, and at the end of the pass, equivalent strains and stresses are concentrated in the entrance zone of the deformation zone;

2 During rolling in the first stand, the temperature in the contact zones “hot metal - rolls” decreases (see Figure 5). In the subsequent stages of rolling, due to the release of the heat of deformation and friction, the temperature in the deformation zone is leveled. However, at the end of the pass, sections of the workpiece located in the outlet of the deformation zone are strongly cooled;



a) 40 %



b) 80 %

Figure 5 The picture of the distribution of the temperature field in a thin slab when rolling in 1 mill stand

3 When rolling in the second, third, fourth and fifth stands of the zone of intense concentration of G and σ_i during rolling they are mixed gradually from the beginning to the end of the deformation zone;

4 The temperature field during rolling in the second stand is unevenly distributed. At the same time, the areas outside the zone of the deformation zone are intensively cooled and the metal of the workpiece located in the zone of deformation is heated.

5 When rolling in the third, fourth and fifth stands, the high-temperature zones move along with the deformation zone from the beginning to the end of the pass. At the same time, the contact zones of the deformed metal with the roll, as well as the zones outside the deformation zone, are cooled.

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Note: The responsible for England language is Aigerim Nauryzbayeva, Almaty, Kazakhstan