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SIMULATION OF THERMAL PROCESSES IN WINDED HOT-ROLLED STRIP COIL MADE OF LOW CARBON STEEL

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Відомо, що при гарячій прокатці, одним з основних параметрів, що впливають на властивості і геометрію штаби, є температурний режим прокатки. В роботі представлені результати дослідження розподілу температури по перерізу рулону гарячекатаної штаби, яка прокатана на безперервному стані гарячої прокатки. Виконано моделювання зміни температури в змотаному рулоні, відповідно до запропонованої математичної моделі. Для підтвердження точності та адекватності запропонованої математичної моделі, результати моделювання були зіставлені з даними, наявними в науковій літературі, та з результатами моделювання в пакеті програм для кінцевоелементного аналізу ANSYS Workbench Результати моделювання підтвердили точність запропонованої математичної моделі для розрахунку розподілу температури по перерізу рулону. Підтверджено можливість застосування запропонованої моделі для визначення розподілу температури по перерізу рулону, змотаного в "Coilbox", на безперервному стані гарячої прокатки.

Ключові слова: *прокатка, стан, штаба, рулон, МКЕ, температура.*

It is known that in hot rolling the temperature mode of rolling is one of the major parameters influencing the properties and geometry of the strip. Results of investigation of the temperature distribution through the section of the coil of strip rolled in continuous hot rolling mill are presented in the given article. Simulation of changing the temperature in the reeled coil had been carried out according to the proposed mathematical model. To confirm the precision and adequacy of proposed mathematical model, the results of simulation had been compared with data available in the scientific literature and with results of simulation in the package of programs for the finite-elements analysis ANSYS Workbench. Results of simulation confirmed the precision of the proposed mathematical model for calculating the temperature distribution through the section of coil. Possibility of using the proposed model for determination of the temperature distribution through the section of coil reeled in "Coilbox" in continuous hot rolling mill had been confirmed.

Key words: *rolling, mill, strip, coil, FEM, temperature.*

Introduction. Production of thin hot-rolled sheets takes a significant part in the global production of rolled products. At the present time, increasingly high requirements are imposed to the quality of rolled sheet products regarding both their geometric parameters and the level of their mechanical properties.

It is known that in hot rolling the temperature mode of rolling is one of the major parameters influencing the properties and geometry of the strip. A uniform temperature distribution throughout the length and width of the strip is one of the factors conditioning uniform and stable mechanical properties of finished rolled products.

Continuous wide-strip hot mills are the main plants for the production of hot-rolled steel stock. Therefore, the predictability of the temperature distribution throughout the strip length in the mill train is an urgent task.

Production of a thin hot-rolled sheet on a continuous wide-strip mill with a traditional configuration is accompanied with a number of problems associated with the loss of temperature of a feeding strip on the intermediate roller table between roughing and finishing trains. When rolling in the roughing train and transporting the feeding strip on the roller conveyer to the finishing train, there is an uneven distribution of temperature across the length of the feeding strip, i.e. the so-called "thermal wedge" occurs. The temperature difference between the front and rear ends of the feeding strip can reach 40° to 60°C, and higher [1].

Such differential can cause longitudinal gage interference and irregularity of the structure and mechanical properties across the length of the strip leaving the last finishing train.

One of the ways to reduce the value of the temperature drop across the length of the semi-finished rolled product for the finishing train is the application of the Intermediate Rewinder (IR) of “Coilbox" type (Fig. 1) [2]. This device is installed on an intermediate roller table in front of the finishing train. The semi-finished rolled product that comes out of the last stand of the roughing train is rolled in the IR so that the front, hotter end of the semi-finished rolled product is inside the rolled coil and the rear end, more cooled one, is on the surface. Then unrolling of the coil towards the finishing train begins. Thus the ends of the feeding strip change places which makes it possible to align the "temperature wedge".

In case of the "Coilbox" utilization, a change in the strip temperature is effected by the operation mode of the IR, thickness of the rolled feeding strip, steel grade of the rolled sheet, etc. Therefore, statistical models to determine the change in temperature of the metal during its rolling and unrolling in the "Coilbox" are created for each particular mill. Such models may be used only for the mill under which conditions they were obtained.

The aim of this paper is to determine analytically the change in the temperature of a rolled sheet rolled in the IR.

Fig. 1. "Coilbox" of the compact hot strip mill (Çolakoglu Metalurji AS, Turkey)

Material and Experimental Methods.

To solve this problem, a mathematical model presented in the paper [3] was used. This model is based on the solution of the differential heat transfer equation using the finite difference method.

To check the adequacy of the mathematical model, a comparative simulation with ANSYS Workbench software was carried out. This FEM software is often used to investigations of thermal processes [4, 5]. Conditions and input data for the simulation were taken from the paper [6] in which calculation of changes in the temperature of metal roiled in a coil was carried out. Heat distribution over the cross section of the rolled strip coil was seen as the heat transfer in the stout wall. Heat was transferred both to the external and the internal coil surfaces.

The initial temperature of the wall was assumed to be constant (650°C) over the entire thickness. The ambient temperature - 30°C. The cooling time - 10 hours. Results of FEM modelling are given in Fig. 2.

The thickness of the coil was assumed to be 0.20 m and 0.32 m. The thermal conductivity coefficient was taken based on the availability of scale on the surface of the feeding strip and gaps in the coil. The physical properties of the material (density, heat capacity, thermal conductivity) were taken as those of low-carbon steel at preset temperatures [6].

Results and discussion.

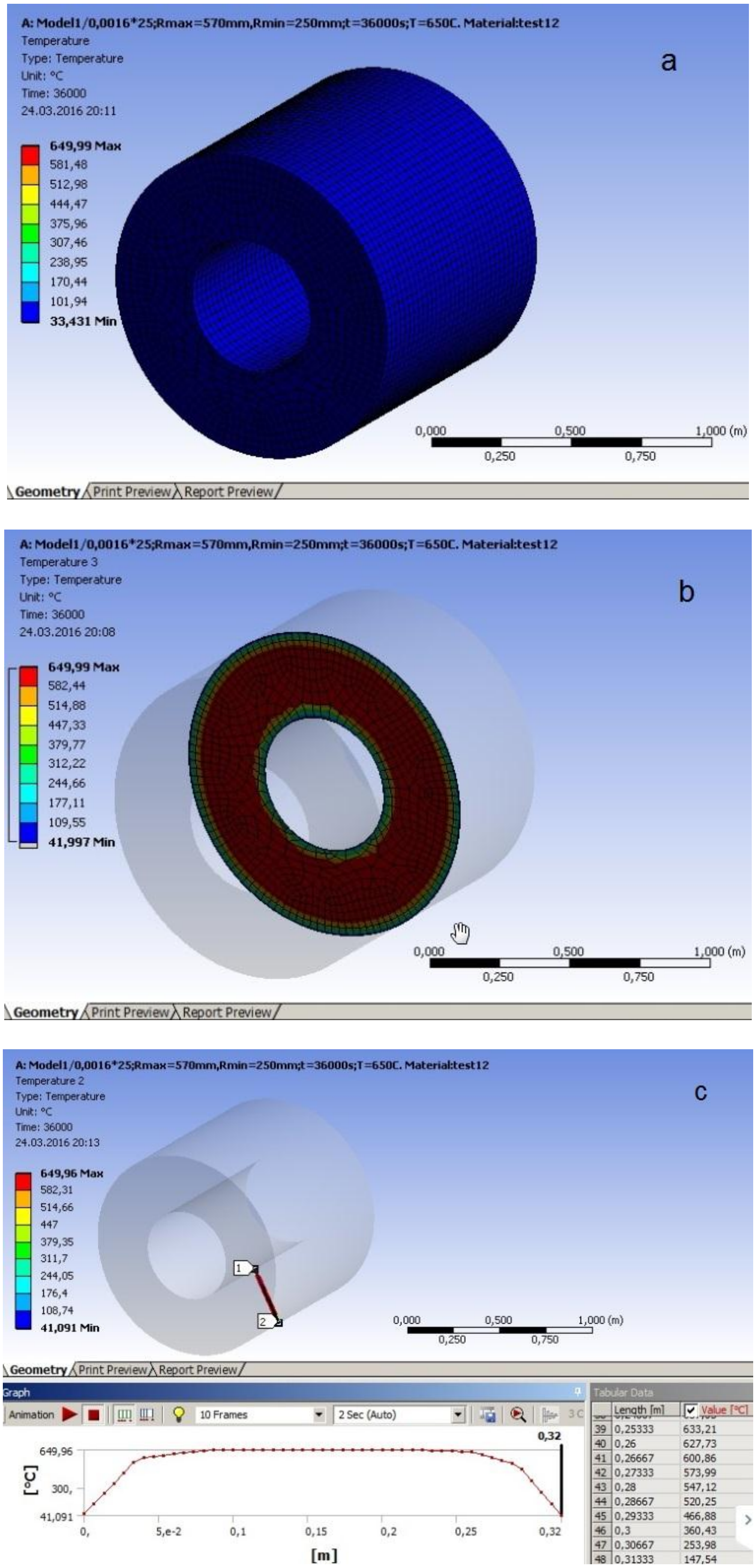
The results of simulation carried out using the proposed model [3], FEM model and the results of the paper [6] are shown in Fig. 3.

As it can be seen from the figure, curves 1, 2 and 3 qualitatively coincide. However, curves 1 and 2 are quite close and in some areas they practically coincide. This suggests that the results obtained using the proposed mathematical model correspond to the data obtained in FEM simulation using ANSYS Workbench software.

The curves practically coincide at the extreme points which characterize the surface temperature of the coil.

The discrepancy with the data given in the paper [6] can reach 40 to 50°C in the areas located on the outer and inner surface of the coil. This can be explained by the inability to observe the complete identity of the source data and boundary conditions. At the same time the qualitative picture of the temperature distribution over the cross section of the coil is the same.

Based on the obtained results we can conclude that the mathematical model proposed in the paper [3] makes it possible to determine a change in the temperature of metal in a rolled coil with sufficient accuracy and adequacy. The model can be used to calculate the temperature change of a feeding strip rolled in the "Coilbox".



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Temperature
Type: Temperature
Unit: °C
Time: 36000
24.03.2016 20:11

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Temperature 3
Type: Temperature
Unit: °C
Time: 36000
24.03.2016 20:08

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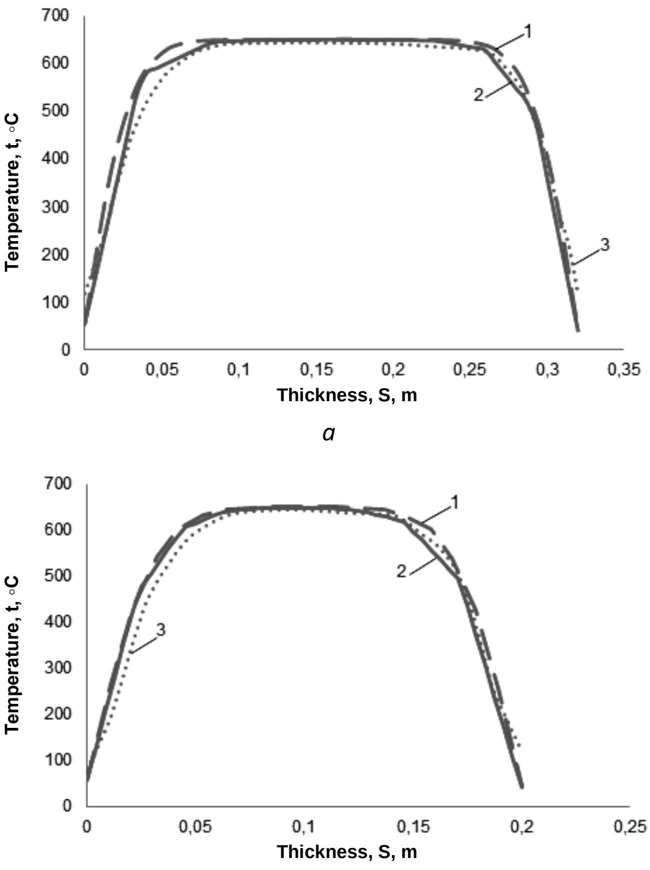
Temperature 2
Type: Temperature
Unit: °C
Time: 36000
24.03.2016 20:13

	Length [m]	☑ Value [°C]
39	0,25333	633,21
40	0,26	627,73
41	0,26667	600,86
42	0,27333	573,99
43	0,28	547,12
44	0,28667	520,25
45	0,29333	466,88
46	0,3	360,43
47	0,30667	253,98
48	0,31333	147,54

Fig. 2. The temperature distribution over the volume of the coil: a – the temperature distribution over the surface; b – cross-sectional temperature distribution; c – the temperature distribution over the coil's thickness



a

b

Fig. 3. Temperature distribution over the cross section of the rolled strip with the wall thickness: a – 0.32 m; b – 0.20 m; 1 – the obtained with proposed mathematical model data [3]; 2 – ANSYS Workbench model; 3 – data of the paper [6]

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CONCLUSIONS

A comparative study of changes in the temperature across the section of a hot-rolled strip coil using the developed mathematical model, FEM model and the data presented in the paper [5] has been carried out. The results of simulation of cooling of a coil of low carbon steel with a thickness of 0.20 m and 0.32 m for 10 hours show qualitatively similar results in all cases (Fig. 3). The closest quantitative equivalence of the results is observed in simulation in ANSYS Workbench software and using the proposed mathematical model.

This fact suggests the possibility of using the proposed mathematical model to calculate the temperature distribution in the coil rolled in the IR on a continuous wide-strip hot mill.

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