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THE MATERIAL-TECHNOLOGICAL MODELLING OF THE REAL DYNAMIC PROCESS

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Abstract: *Because of high costs and high level of usage of production equipment, it is not always possible to test or optimize new production techniques and material treatments directly in production conditions. One very effective way of developing and optimizing new techniques is material-technology modeling of the development of structures. This paper deals with the creation and testing of a model for wire mills, including controlled cooling. Modifying the deformation conditions in the model provided information about their influence on the development of structures and material properties. The model process was verified using two types of low-alloyed steel. The modeled rolling process was such that after optimization, deviations between the model and the real process were for most parameters under 10%.*

Key words: *material-technology modelling, thermo-mechanical simulator, optimizing rolling*

1. INTRODUCTION

Material-physical modelling is an intensively developing field of science which enables real processes to be modelled under laboratory conditions. Because of the small amount of test material required, low energy requirements and the use of a thermomechanical simulator this technology can be used to modify existing production processes without the need for investing large sums into testing on real production equipment.

For physical modelling it is essential to know the influences of individual parameters and according to their intensity select the parameters for the model. When suitable parameters are selected, strong agreement with real processes can be expected.

This paper introduces the wide range of possibilities offered by modern material-technology modelling using newly-developed, original equipment which can with very high accuracy simulate the conditions of real, complex technology chains.

2. EXPERIMENT

2.1 Selection of material

Creation of the material-technology model was tested on two steels, A and B. They are modern low-alloyed steels alloyed with only manganese and a small amount of boron.

The initial state of both modelled materials showed ferrite-pearlite structure with marked, characteristic for rolling, texture in longitudinal section.

Material	R_m [MPa]	A_{5mm} [%]	KCV [$J.cm^{-2}$]	HV10	Ferrite grain size [μm]
A	543	50	84	141	8.4 ± 5.8
B	524	49	81	143	8.8 ± 5.5

Tab. 1.Mechanical properties of material in initial state and ferrite grain size in longitudinal section

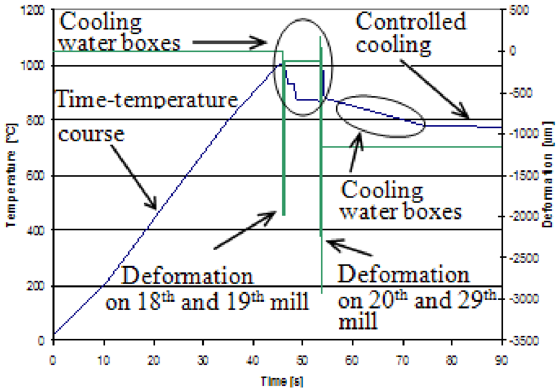

Fig. 1. Model of rolling mill, diagram of temperature course and deformation after transfer of data for simulator

Samples were taken directly from a real production process. They are a semi-product with diameter 23 mm with free cooling in air taken directly from the rolling mill.

The size of ferrite grains in both samples was between 8 and 9 μm. No significant deviation was seen in the proportion of ferrite between longitudinal and transverse sections. Ultimate strength of steel A in initial state was 543 MPa and for steel B it was 524 MPa (**Błąd! Nie można odnaleźć źródła odwołania.**).

After comparing with the modelled results, the properties of the real product were evaluated after complete treatment on the rolling mill. Ultimate strength for both steels was between 507 – 513 MPa, ductility A_{5mm} cca. 51% and average grain size for steel A was 6.5 μm and for steel B it was 6.2 μm.

2.2 Material-technology model of production process

Material-technology model of the real technological process was created from data transferred from the measurements obtained from the rolling mill and the remaining data by calculation (Fig. 1). Model treatment was carried out in a thermomechanical simulator. The regimes of heat and deformation were according to time dependency programmed from the instruction table. A test sample was resistance heated with direct flow of current in the body of the sample. Temperature was measured by thermocouples welded to the surface of the sample. Cooling was in air and water.

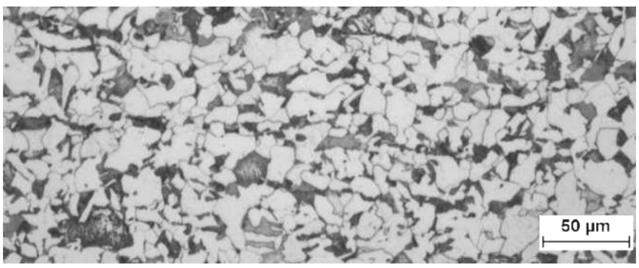

Fig. 2. Steel A, basic model treatment on simulator, Nital

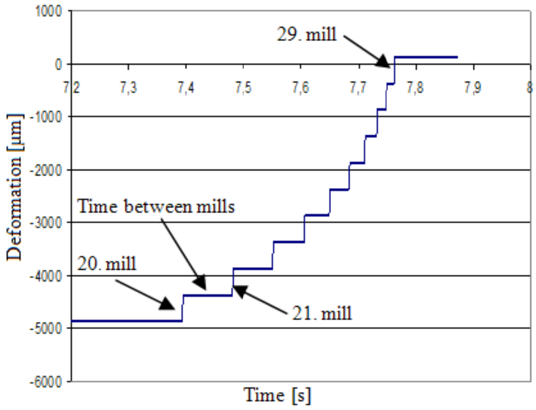

Fig. 3.Detail of deformation course in relation to time from the 20 to 29 mill in model of unidirectional 5 mm deformation

2.3 Results of material-technology modelling

The samples of both steels, after complete thermomechanical modelling, were first evaluated metallographically. The structure was formed of ferrite and pearlite (Fig. 2).

Ferrite grain size in steel A was 7.3±4.9 µm and for material B 7.1±4.8 µm. Hardness was found to be about 150 HV for both steels and ultimate strength was greater than 510 MPa (Tab. 3).

2.4 Model assisting creation of textures

In order to obtain a longitudinal texture similar to that found in wire from a real rolling mill, the deformation regime was further modified (Fig. 3). Two deformation regimes were designed which were introduced to the part of the model corresponding to the last rolling block with a unidirectional tension deformation of 5 mm and 10 mm respectively. So that this large unidirectional deformation could be performed without destroying the sample, a two step unidirectional compression deformation had to be carried out on the model of the penultimate block. This created a pre-tamped sample for the following intensive tension.

The 5 mm tension deformation gave rise in both cases to a lower intensity of deformation in comparison with the basic model and somewhat coarser ferrite-pearlite structure with ferrite grain size greater than 8 µm (Tab. 3). The 10 mm tension deformation gave rise to a ferrite-pearlite structure with significantly elongated structures (Fig. 4.). A higher degree of deformation created finer grains. The ferrite grain size for both materials was 7.2 µm (Tab. 4).

As far as mechanical properties are concerned, no fundamental differences were found between the variants. For the model with 5 mm tension deformation for material A was measured a strength of 504 MPa and ductility of A_{5mm} = 44 % (Tab. 3). Material B showed after the same treatment a strength 17 MPa higher and almost the same ductility (Tab. 3).

Fig. 4.Steel B, longitudinal section, model with unidirectional 10 mm tension deformation, Nital

Material	R_m [MPa]	A_{5mm} [%]	KCV [$J.cm^{-2}$]	HV10	Ferrite grain size [µm]
A	504	44	84	138	8.7 ± 5.8
B	521	46	82	146	8.2 ± 5.6

Tab. 3.Mechanical properties of materials after unidirectional 5 mm deformation

Material	R_m [MPa]	A_{5mm} [%]	KCV [$J.cm^{-2}$]	HV10	Ferrite grain size [µm]
A	508	45	86	143	7.2 ± 4.3
B	505	46	88	150	7.2 ± 4.6

Tab. 4.Mechanical properties of materials after unidirectional 10 mm deformation

3. CONCLUSION

The experiment was focused on verifying a complex material-technology model of a rolling mill and its similarity to the real process. The main attention was paid to the differing characteristics of the deformations used in the model. The modelled results from alternating tension-compression deformation and incremental unidirectional tension deformation were experimentally compared. By analysing the sample material and material taken from the real production process it was found that for most parameters of structural and material properties the model did not deviate more than 10% from the real process. Because of the significant difference in the character of the deformations, this method is not suitable for modelling textures, but only for structural components and mechanical, in particular, strength properties.

4. ACKNOWLEDGEMENTS

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