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Modelling and simulation of the asymmetric rolling process – establishing the optimal technology parameters to asymmetric rolling

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Modelling and simulation of the asymmetric rolling process – establishing the optimal technology parameters to asymmetric rolling

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Abstract. Asymmetric rolling is a technique used to control both the texture and the grain refinement of metallic materials. The aim of asymmetric rolling is to apply a large shear strain uniformly through the thickness of the plate, by maintaining a high degree of friction between the sheet and the rolls. It can be used to improve the formability of material. One of the advantages of asymmetrical rolling is that the rolling force and torque can be decreased. An economic and technological reason, in particular the longitudinally asymmetric rolling is very important to determine the optimum process parameters. The paper presents a method of simulating the asymmetric rolling process. This simulation is carried out to establish the main parameters of rolling particular asymmetric regime. The main goal is to establish a link between the peripheral speed of rolls, pressure and contact length.

1. Introduction

Any well managed operation of rolling needs a precise determination of the force factors. It is a complicated problem, to solve it means knowing the basic rules of process of plastically deformation of metallic materials, generally, and also to know the physical and mechanical characteristics of the mentioned materials. One knows that the efforts applied to a metallic material during its plastic deformation are conditioned not only by its properties, but also by stress status applied to it. The metal material deformed between the rollers of rolling mill suffer high compression stress due to the action of the rollers, and it also bears tangential surface tensions because of the friction between the rollers and the metal material [1].

For the achievement of the rolling process parameters with an electronic calculation technique, their mathematical description has to be precisely formulated. This can be obtained by the elaboration of proper algorithms. Most of the times, the algorithm is written under a graphic form of a block–scheme, or under a textual form, in words. By textual expression of the algorithms is used the mathematical consecrated symbols and expressions that are attended by explanatory text. But, such writing is hard to understand and too complicated. Therefore, the algorithm's representation under a block–scheme form is usually used. The essence of the algorithm elaboration consists of choosing and establishing of such specific usage order of the mathematical expressions that would mandatory lead to the problem solution through any combinations of the initial data [2].

The methods for measuring the rolling forces are classified according to the type of equipment and the possibility to determine them for a particular type of rolling mill, as follows [3]:

- direct measurement of the forces occurring during the rolling process, using resistive transducers placed in the point in which these forces are acting:
- measurement of deformations or strains that develop in a certain part of the working stand, with subsequent recalculation of these deformations based on the values of the rolling forces.

In addition to the forces, the rolling moments represent one of the most important parameters, whose knowledge is necessary for the design and operation of the rolling lines. The electric motor torque, developed during the metal material deformation, determines the loading level of the machine, as well as the resistance of some parts and assemblies. The assessment of motor workload by taking into account the power consumption for deformation is not complete, because this parameter does not characterise the electrical and mechanical capacity of the equipment.

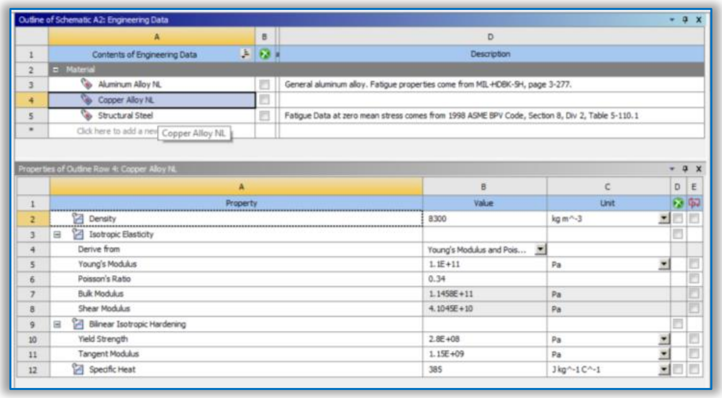
2. Methods and materials

The aim of asymmetric rolling is to apply a large shear strain uniformly through the thickness of the plate, by maintaining a high degree of friction between the sheet and the rolls. It can be used to improve the formability of material. One of the advantages of asymmetrical rolling is that the rolling force and torque can be decreased. An economic and technological reason, in particular the longitudinally asymmetric rolling is very important to determine the optimum process parameters.

The paper presents a method of simulating the asymmetric rolling process. This simulation is carried out to establish the main parameters of rolling particular asymmetric regime. The main goal is to establish a link between the peripheral speed of rolls, pressure and contact length. Since the intended purpose was to study the qualitative aspect of phenomena related to the asymmetric longitudinal rolling, for eliminating the inevitable influence of the iron oxides (scale) on the process, the tests were carried out on samples of aluminium and copper, with the following dimensions [4]:

$$h_0 = 12; 6; 2 \text{ and } 1\,\text{mm} \quad b_0 = 40\,\text{mm} \quad l_0 = 150\,\text{mm}$$

The mechanical properties of the material used (copper) to modelling and simulation are given in Figure 1.


Outline of Schematic A2: Engineering Data

	A	B	D
1	Contents of Engineering Data		Description
2	Material		
3	Aluminum Alloy NL		General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.
4	Copper Alloy NL		
5	Structural Steel		Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new		

Properties of Outline Row 4: Copper Alloy NL

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	8300	kg m^-3		
3	Isotropic Elasticity				
4	Derive from	Young's Modulus and Pois...			
5	Young's Modulus	1.1E+11	Pa		
6	Poisson's Ratio	0.34			
7	Bulk Modulus	1.1458E+11	Pa		
8	Shear Modulus	4.1045E+10	Pa		
9	Bilinear Isotropic Hardening				
10	Yield Strength	2.8E+08	Pa		
11	Tangent Modulus	1.15E+09	Pa		
12	Specific Heat	385	J kg^-1 C^-1		

Figure 1. The mechanical properties of the material used to modelling and simulation

Therefore, experimental research on pressure distribution is of particular importance for both the theory and the practice of lamination processes. They can serve directly for the experimental confirmation of the fairness of the theoretical conclusions regarding the general law of pressure distribution on the contact spring, as well as the influence of the main pressure factors on the pressure, such as: the external friction coefficient, the initial thickness of the metal material, the degree of reduction and temperature.

The symmetrical and asymmetric rolling process was obtained by equipping work cylinders with segments executed under different radius that allowed the following ratios to be obtained between the diameters of the upper D_s and lower D_i cylinders:

$$\frac{D_s}{D_i} = \frac{170}{170}; \frac{140}{200} [mm]$$

The cylinders are mounted in such a way that the measurement of the rolling pressure from each cylinder is made in the same plane (Figure 2).

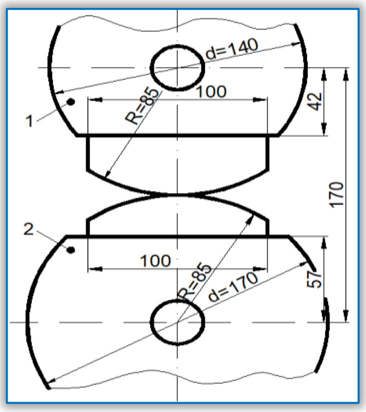


Figure 2. The cylinders work equipping with segments executed under different radius

The deformation of the metal by rolling is possible only in the presence of frictional forces on the contact surfaces of the cylinders. These forces exert influence on the entire volume of metallic material that deforms. As a result, any elementary particle of the respective material on the height and length of the deformation zone is found under volumetric tension conditions characterized by the differential equations of the plasticity theory.

3. Results and discussions

It is known that the efforts applied to a metallic material during its plastic deformation are conditioned not only by its properties but also by the state of tension it is subjected to. In the deformation of the metal material between the rolling mill cylinders it is subjected to high compressive stress due to the action of the cylinders and superficial tangential stresses due to the friction between the cylinders and the metal. Friction forces are also the cause of the reduction in metallic material between the cylinders.

Usually, the problems of the content of modern theory are given in a complicated mathematical form, which is sometimes difficult to understand, although their main ideas are quite simple [5], [6].

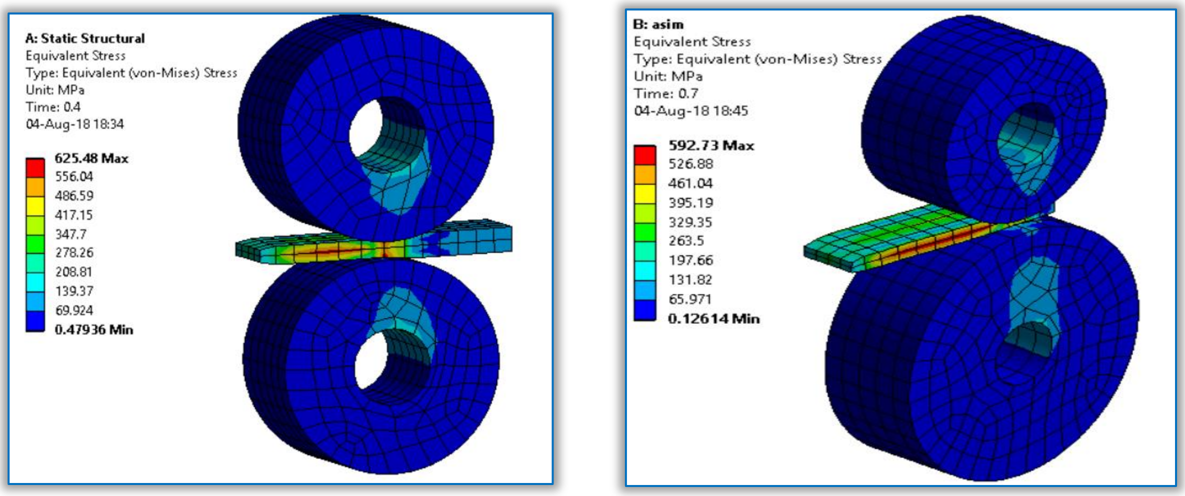


Figure 3. The Equivalent Stress (von–Mises)

For modelling and simulation we use ANSYS EXPLICIT DYNAMICS, it is a transient explicit Dynamics Workbench application that can perform a variety of engineering simulations, including the modelling of nonlinear dynamic behaviour of solids, fluids, gases and their interaction. A typical simulation consists of setting up the model, interactions and the applied loads, solving the model's nonlinear dynamic response over time for the loads and interactions, then examining the details of the response with a variety of available tools.

The relatively flat rolling of strips, in the general case, the geometric distortion is composed of two parts (Figure 4):

- the metal sliding portion on the cylinders, where the contact friction is subject to Coulomb's law; here are actually two portions, in the immediate vicinity of the geometric deformation zone, i.e., the inlet and outlet of the metallic material between the cylinders;
- the grip portion where the material slip on the surface of the cylinders is missing, i.e. the metal surface layer moves at a tangential velocity equal to the peripheral speed of the cylinders, or the particles of metallic material as if they stick to the surface of the cylinders.

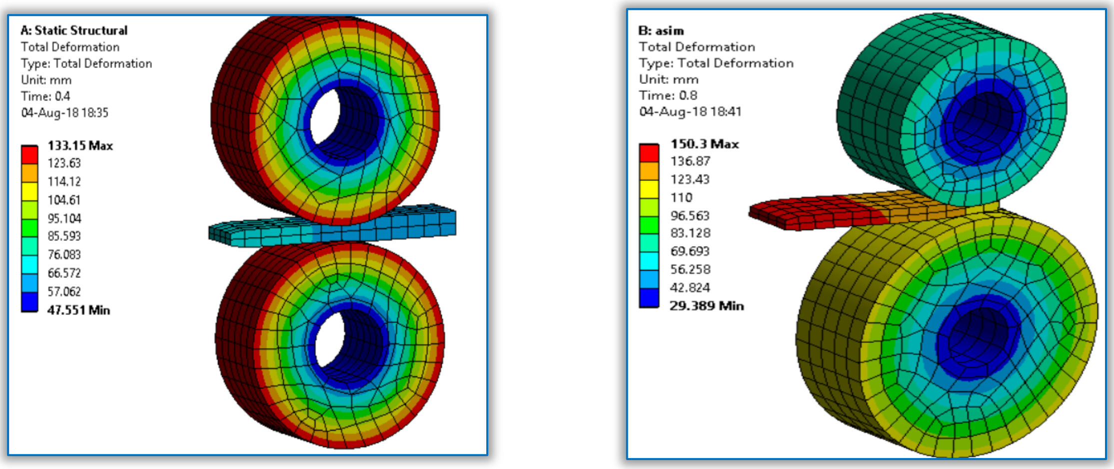


Figure 4. The total deformation

The typical diagram showing the unevenness of the deformation in the reduction of the outer and inner structures of the metallic material in the deformation area for the medium thickness laminates is given in Figure 5. As can be seen from the curve alloy shown in Figure 5, the metal layer on the roller contact surface (1–2) begins to thin, and the central layer (3) thickens until the geometric boundary of the plane of entry into the deformation zone.

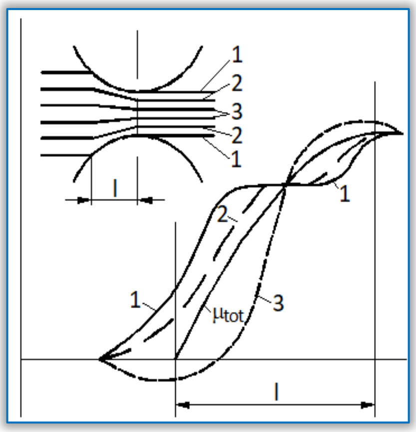


Figure 5. The graph of variation reductions elementary layers relative length of the deformation

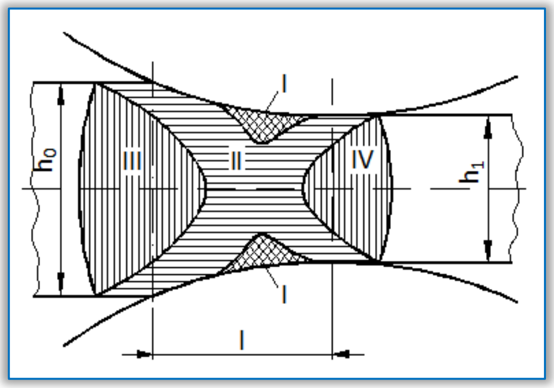


Figure 6. Diagram of distribution of plastic deformations in metallic material

The unevenness of the deformation as well as the length of the grip portion increases with the increase of the coefficient of friction and the thickness of the laminate (Figure 6):

- **I** – the area with difficult deformation;
- **II** – the range of plastic deformation by compression in height and stretching in the longitudinal direction;
- **III, IV** – the range of plastic deformation by longitudinal compression and height thickening.

Figures 7 and 8 show the elongation, respectively the width of the rolled strip according to the deformation direction:

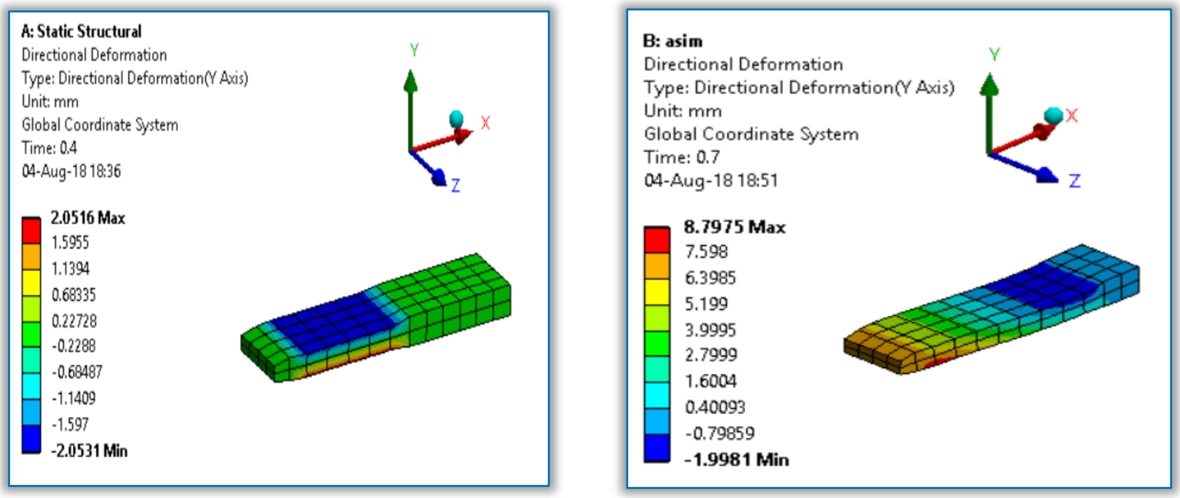


Figure 7. Directional deformation Y – axis

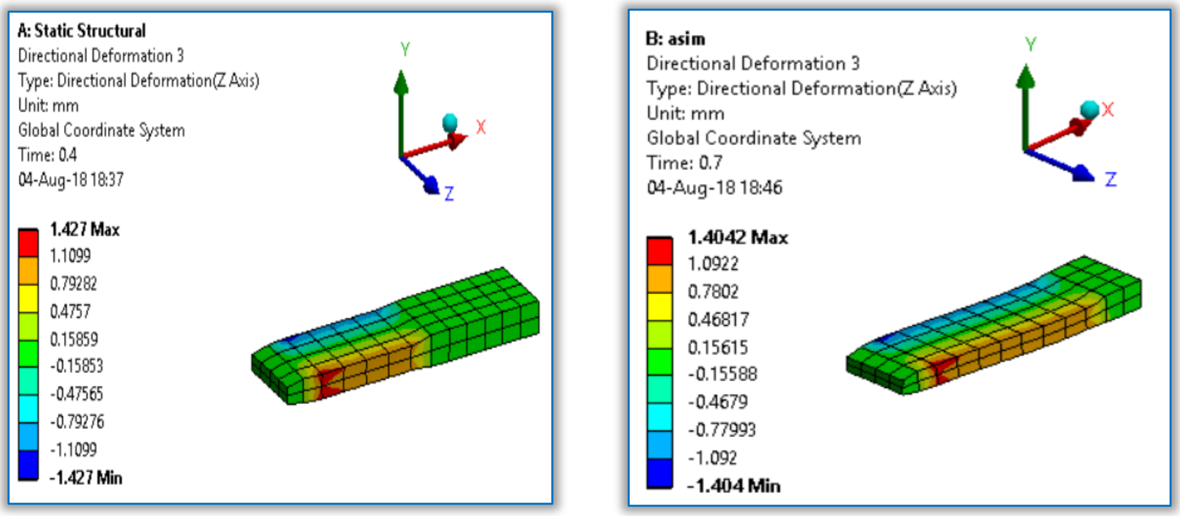


Figure 8. Directional deformation Z – axis

4. Conclusions

The stress state criteria depend only on the deformation method, the stress action character, and especially the friction conditions on the contact surfaces, i.e., for a given deformation method, dimensions and shapes of the deformation zone, stress state criteria do not depend on the fact that it deforms steel, copper or aluminium.

It should also be noted that some dependence of the stress state criteria on the nature of the material and its deformation conditions exists because the dependence of the external friction coefficient is known, depending on these factors, but this dependence is indirect and in the calculations thinks easy.

It has also been clarified by the present study the qualitative passage laws from the symmetrical to the asymmetric process, depending on the change in the lamination conditions, confirming the idea that the symmetric process is only a particular case of the asymmetric process that is widespread in the industry's rolling practice.

This interpretation of the functional dependence of the deformation resistance is based on the analysis of the physical content of the plasticity equation, allows for the division of the complicated dependence of the resistance to deformation towards the various factors in elementary parts, which considerably simplifies the study of the problem and allows for a more in– to obtain generalizations. In particular, it is possible to extend the results of research to any process to others, and vice versa, to generalize the data obtained by various methods of deformation.

As the linear deformation resistance and the stress state criteria influence the unitary pressure at the plastic deformation independently of each other, they can be studied separately. Therefore, the tendency to consider all the factors influencing both the state of tension of the respective material and its resistance to linear deformation (in particular, the extrusion in the rolling process) complicates without any justification the problem.

References

[1] Alexa V 2004 Analysis of the lateral efforts In asymmetrical longitudinal rolling, *Annals of the Faculty of Engineering–Hunedoara* **2** 45-50

[2] Alexa V, Ratiu S and Kiss I 2003 Calculation program for the determination of force parameters in rolling, *Annals of the Faculty of Engineering–Hunedoara* **3** 149-154

[3] Alexa V 2002 *Contributions to research asymmetric rolling process*, Politehnica University of Timișoara, Romania, Doctoral Thesis

[4] Alexa V, Ratiu S and Kiss I 2005 Theoretical and experimental analysis of the rolling strain in the deformation area, *Metalurgia International* **5** 20-28

[5] Kiefer T and Kugi A 2008 An Analytical Approach for Modelling Asymmetrical Hot Rolling of Heavy Plates, *Mathematical and Computer Modelling of Dynamical Systems* **14** 1-19

[6] Pesin A, Chukin M and Pustovoytov D 2015 Finite Element Analysis of Symmetric and Asymmetric Threeroll Rolling Process, *MATEX Web of Conference* **26** 03006