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NUMERICAL MODELLING OF ASYMMETRIC DOUBLE-LAYER Al-Cu PLATE ROLLING PROCESS

ABSTRACT

An unfavourable phenomenon accompanying the process of rolling flat bimetal products is the curvature of the band on leaving the roll gap, resulting from the uneven deformation of the bimetal plate's layers. The introduction of asymmetrical velocity or roller diameters offers a possibility to quickly and easily overcome this effect.
This article presents computer research of the process of rolling double-layer Al-Cu plates. Computer simulations were performed in the commercial Forge 2D software.

INTRODUCTION

Modern rolling plastic working technologies should provide for the manufacture of high quality products at ever lower costs. Computer simulations of rolling mechanical working processes, undoubtedly, have a number of advantages. These include the relatively low costs of implementation, universality and the possibility of repeating calculations. Computer calculations can, furthermore, be used for examining parameters that are difficult, or even impossible to measure.

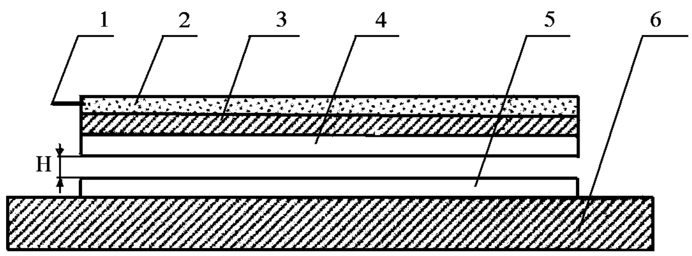
That is why this paper presents results of numerical research on the asymmetrical double-layer metal plate rolling process. The technology of production of double-layer metal plates includes: joining the layers of the bimetal strip and rolling it. The necessity to roll initially joined materials often results from the fact that it is impossible to join materials with relatively small thicknesses. In the rolling process, in most cases, uneven deformation of the layers is often encountered. As a result, after rolling, the plate is often bent towards the layer with the greater resistance to deformation. The second unfavourable phenomenon is the impossibility to predict the exact thicknesses of the layers after rolling. Laboratory tests would, in this case, turn out to be very expensive. For this reason, computer modelling will allow technologists to reduce costs by developing new technologies.

Furthermore, the paper proposes to introduce asymmetrical tangential velocities of the rollers. Through appropriate selection of the rollers' tangential velocities, it will be possible to control the flow velocity of both layers of the bimetal strip – both in the intensive deformations zone and after leaving the roll gap. As a result, it is possible to obtain not only a straight strip, but also greater uniformity of distribution of the total draft between particular layers of the bimetal strip.

Modelling of the asymmetrical double-layer metal plate rolling process

The Forge 2D software package was used for theoretical analysis. Research was conducted for the process of rolling double-layer plates consisting of Al and Cu. The double-layer plates meant for rolling were initially joined using the explosive welding method (fig. 1).

a) parallel setup



b) setup with initial angle α

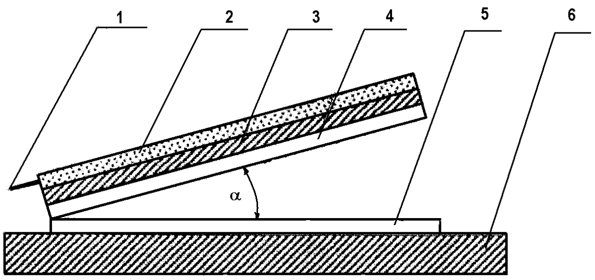


Fig. 1. Diagram of the basic setups fro explosive welding, 1-detonator, 2-explosive material, 3-protection pad, 4-the plate to be blasted onto the base plate, 5-base plate, 6-base, α-value of the angle at which one plate is blasted onto the other, H- initial distance between the welded surfaces.

The explosively welded materials were: a laser of aluminium Al99 and a layer of copper M1E. These are materials that may have a maximum of 1% of impurities in their chemical composition. Due to the differences in the values of resistance to deformation, the copper layer will be called the hard layer (it has a greater resistance to deformation compared to the aluminium layer), while the aluminium layer will be called the soft layer. The following plate thicknesses were taken for tests: aluminium layer Al hM=8 mm, 6 mm and 5 mm, and the copper layer Cu hM=2 mm and 4 mm

Forces of friction during the rolling process were modelled on the basis of solution of content [6] and determined using the following relation:

$$\tau = -m\frac{\sigma_0}{\sqrt{3}}\frac{\Delta V}{\Delta v} \quad (1)$$

where:

- τ – vector of unitary forces of friction,
- σ_0 – basic yield stress,
- $\Delta V/\Delta v$ – parameter describing the slide of metal on the roller (ΔV– tangential velocity of the roller for the given time step,
- Δv – rubbing speed of metal on the tool contact surface),
- m – friction factor,

Parameters of work hardening curves for the considered pair of metals were determined from Arrhenius equation [6]:

$$K(T,\bar{\varepsilon}) = K_0 \cdot (\bar{\varepsilon} + \bar{\varepsilon}_0)^n \cdot e^{-\beta T} \quad (2)$$

where:

- ε_0 – adjusted strain vector for successive steps,
- $\bar{\varepsilon}$ – total strain vector, K_0, n, β – parameters of work hardening curve,

The ratio of the velocity of the upper roller to the velocity of the lower roller, or the ration of the upper roller diameter to the lower roller diameter, is regarded as the measure of symmetry [1-4]:

$$a_v = V_g/V_d = D_g/D_d \quad (3)$$

Numerical tests were to determine the optimal value of the asymmetry coefficient a_v. This coefficient is regarded as the ratio of velocities of the rollers, for which it will be possible to obtain both a straight strip, as well as an even distribution of the total draft for particular layers.

Test results and analysis

Fig. 2 presents the dependency of the relative deformation of the hard Cu layer on the layer thickness ratio in the bimetal plate and on the relative draft. The dependency graphs are based on numerical data obtained for the double-layer metal plate rolling process.

On the basis of the test results presented in fig 2, there is a considerable visible unevenness of deformation of the bimetal layers during the rolling process. The result is bending of the free end of the double layer band after leaving the roller gap. In order to improve the conditions of the rolling process, asymmetry of the tangential velocities of the working rollers was introduced. Fig. 3 presents the linear dependencies between the optimal value of the coefficient of asymmetry av and the relative draft ε for various layer thickness ratios hT/hM.

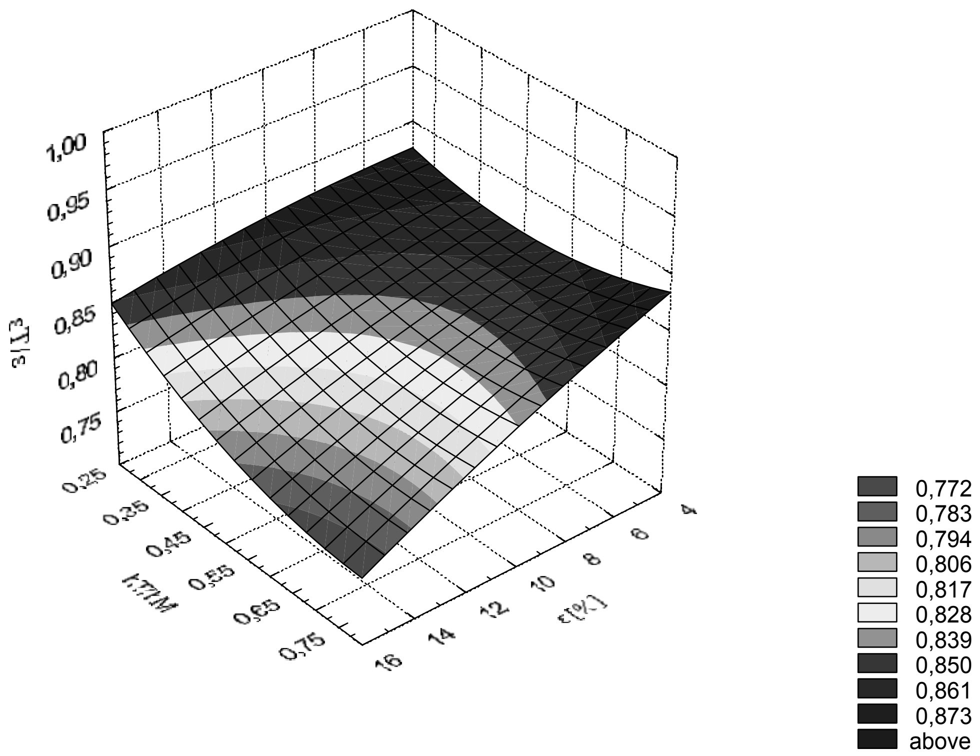


Fig. 2. The relation relative deformation of the hard layer versus layer thickness ratio and total relative draft.

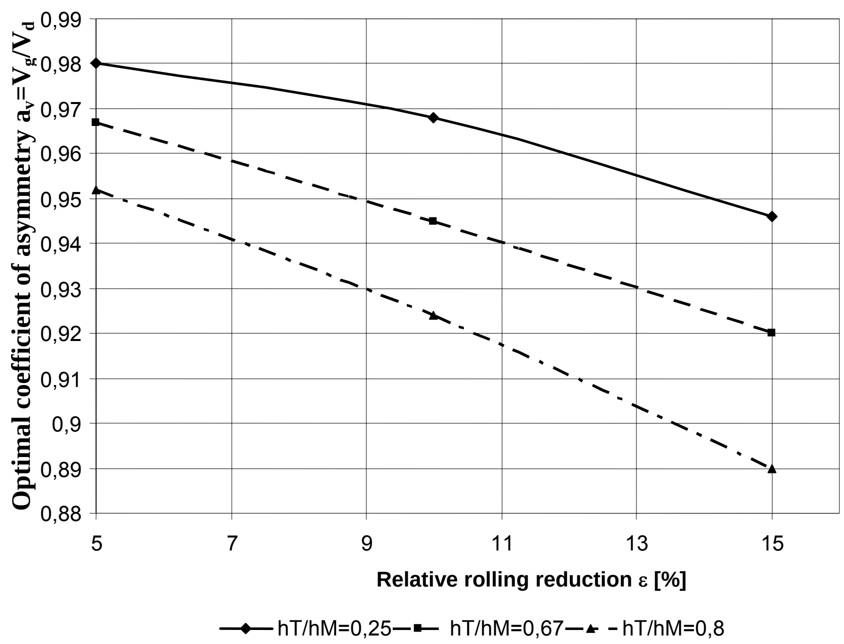


Fig. 3. The relation between the optimal coefficient of asymmetry a_v and the value of rolling reduction ε for different h_M/h_T =10/2

On the basis of the research results resented In fig 3, it was observed that an increase of both the draft value and the hard layer (Cu) share in the double layer plate leads to the need to introduce greater asymmetry of velocities of the working rollers. The possibility of conducting numerical research and relatively precise determination of the optima value of the asymmetry coefficient av, significantly reduces the need for expensive laboratory tests. The introduction of asymmetry of velocity of the working rollers affects the unevenness of deformation of the bimetal plate's layers. Fig. 4 presents results of numerical research for optimal values of the asymmetry coefficient av (a straight band was obtained following the rolling process).

It ensues from research results presented in fig. 2-4 that asymmetry of tangential velocities of the working rollers a_v has a great impact on the unevenness of deformation of the bimetal plate's layers leaving the zone of intensive deformation. After introduction of asymmetry of tangential velocities of the working rollers, the unevenness of deformation of the material's layers decreases. The optimal value of asymmetry coefficient was determined by changing the velocity of the roller contacting the hard layer. Research was conducted until a straight two-layer bimetal plate was obtained at the outlet of the roll gap.

Summary and conclusions

The Forge 2D software package used for numerical calculations allows for the execution of computer simulations of the asymmetric rolling process of double-layer metal plates. Numerical modelling of the bimetal plate rolling process offers the chance to avoid the costs involved in laboratory tests. On the basis of analysis of the numerical test results, conducted in the paper, it may be stated that introduction of asymmetry of tangential velocities of the working rollers leads to reduction of the unevenness of distribution of total draft. As a result, it is possible to determine the thicknesses of the bimetal layers following the rolling process. Furthermore, asymmetry of tangential velocities of the rollers allows us to obtain a straight bimetal strip after rolling.

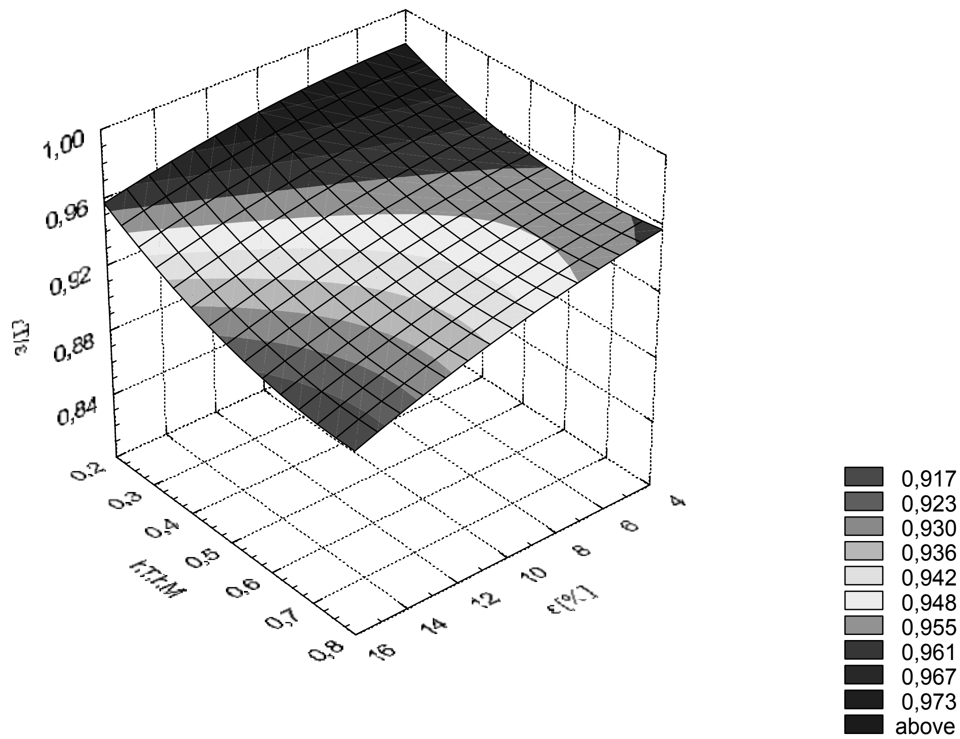


Fig. 4. Relative deformation of the hard layer versus layer thickness ratio and total relative draft for optimal values of the asymmetry coefficients.

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