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BIMETAL PLATE St3S+Cu

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The paper presents a theoretical analysis of the asymmetrical process of rolling bimetal plates composed of the base St3S layer and a Cu cladding layer. Investigation carried out aimed at determining the curvature of bimetal band depending on the value of roll peripheral speed asymmetry factor a_v. Computer simulations were performed on three different layer thickness ratios, H_S/H_H. Numerical studies were based on computer simulations carried out using the Forge 2D software. For computations, this program uses the finite-element method. The asymmetry of the process resulted from a non-uniform distribution of rolling reduction into the bimetal band layers, which caused the band to bend at the rolling mill exit. To counteract this behaviour, an asymmetry of working roll peripheral speeds was introduced.

Key words: *asymmetrical rolling, bimetal plate, numerical analysis*

Bimetalni lim St3S+Cu. Članak daje teorijsku analizu učinka odnosa debljine sloja bimetalnih limova sastavljenih od osnovnog sloja St3S i sloja presvučenog bakrom. Provedena istraživanja su imala za cilj odrediti zakrivljenost bimetalne trake ovisno o vrijednosti faktora asimetrije a_v periferne brzine. Izvedene su kompjuterske simulacije tri sloja s različitim omjerima H_S/H_H debljine. Numeričke studije su se zasnivale na kompjuterskim simulacijama provedenim pomoću softvera Forge 2D. Za izračune, ovaj se program služi metodom konačnih elemenata. Asimetrija procesa rezultira od nejednolikog rasporeda redukcije u slojeve bimetalne trake koje uzrokuju savijanje trake na izlazu iz valjačkog stana. Kao protuteža takvom ponašanju uvedena je asimetrija perifernih brzina radnog valjka.

Ključne riječi: *asimetrično valjanje, bimetalni lim, numerička analiza*

INTRODUCTION

The constant development of numerous branches of industry is the reason, for which ever newer, better and cheaper constructional materials are searched for. Such materials include bimetals that combine the properties of two different metals, owing to which an intermittent interest in these products has been observed in recent years. A major drawback of homogeneous materials resistant to high temperature, large and variable loads, or aggressive media is the high cost associated with the necessary use of expensive alloy additions. A reduction in the costs of materials and improvement of some of their characteristics is possible by, for example, using bimetal products, where, as a rule, the base layer is made up from a cheaper material of lower properties, but having suitable strength properties. Flat bimetal products, such as two-layered plates and bands, have unquestionably had the widest application. The production of bimetal plates is composed of two main stages. The first of them is the process of joining the band layers together [1, 2]. This process can be carried out by different methods, of which the explosive welding method is particularly noteworthy owing to the high properties of the bond that it assures [1]. The second stage includes the often necessary rolling of bimetal plates [2, 4, 5, 7 - 12], which results from the impossibility of joining band layers of smaller thickness. Bimetals are often used for the manufacture of heat exchangers, bearings and containers, and for the production of coins and many other articles.

During rolling bimetal plates, the most frequently encountered problem is associated with non-uniform bending of the layers of bimetal band. The effect of a non-uniform flow of the bimetal at the roll gap exit is a bent band. To counteract this behaviour, an intentional difference in the peripheral speeds of working rolls was introduced. Due to the high costs of experimental tests, an extremely useful tool in the design of rolling materials composed of two or more layers are suitable computer programs offering a

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possibility of simulating those processes. The results presented in this paper have been obtained from computer calculations performed using the Forge 2D program whose operation relies on the finite-element method.

CHOICE OF MATERIAL AND SCOPE OF INVESTIGATION

The study considers the process of asymmetrical rolling of Cu–St3S bimetal band. The process was conducted hot at a temperature of 900 °C. The parameters of material work-hardening curves were defined on the basis of chemical composition of the materials constituting bimetal plate and determined from the Arrhenius equation [10]:

$$K\left(T,\bar{\varepsilon}\right)=K_0\cdot\left(\bar{\varepsilon}+\bar{\varepsilon}_0\right)^n\cdot e^{-\beta T} \quad (1)$$

where:

- $\bar{\varepsilon}_0$ - vector of deformation regulated for successive steps,
- $\bar{\varepsilon}$ - vector of total deformation,
- K_0, n, β - parameters of the work-hardening curve.

Friction forces in the asymmetrical rolling process were modelled on Tresci's solution and determined from Equation [10]:

$$\tau=-m\frac{\sigma_0}{\sqrt{3}}\frac{\Delta V}{\Delta v} \quad (2)$$

where:

- τ - vector of unit friction forces,
- σ_0 - base yield stress,
- $\Delta V/\Delta v$ - parameter describing metal the slip of metal on the roll,
- m - friction factor.

The process of rolling two-layered products is a complex process, where a non-uniformity of deformation of both bimetal band layers usually occurs, which is caused by different deformation resistances of layers making up the bimetal [4 - 6, 9, 11 - 13]. The soft layer deforms more, which can be written as:

$$\varepsilon_{\mathrm{M}}>\varepsilon>\varepsilon_{\mathrm{T}}$$

or

$$\frac{\varepsilon_{\mathrm{M}}}{\varepsilon}\geq 1,\ \frac{\varepsilon_{\mathrm{T}}}{\varepsilon}\leq 1 \quad \text{and} \quad \frac{\varepsilon_{\mathrm{M}}}{\varepsilon_{\mathrm{T}}}\geq 1,\ \frac{\varepsilon_{\mathrm{T}}}{\varepsilon_{\mathrm{M}}}\leq 1 \quad (2)$$

where:

- ε_{T} - relative rolling reduction of the layer of higher plastic deformation resistance,
- ε - total relative rolling reduction of the bimetal band,
- ε_{M} - relative rolling reduction of the layer of lower plastic deformation resistance.

The irregular deformation of particular bimetal layers has been discussed in numerous studies [2, 6, 7, 9, 14, 15].

The ratio of deformations of the layers of most commonly manufactured clad plates, depending on their chemical composition, may change in the range of 0,57 to 1,3 [1] during rolling. The non-uniformity of the distribution of total rolling reduction e into particular platelayers is the cause of occurring differences in the values of their elongation.

As a result, a bending of the band and "flowing out" of the soft layer around the hard layer take place at the roll gap exit.

In this study, the layer with the lower stress yield value is referred to as "soft", whereas the layer with the higher deformation resistance is called "hard" [12, 13].

Computer simulations were performed for bands with the following dimensions:

- H = 14 mm, L = 200 mm and soft-to-hard layer ratios of H_M/H_T = 2/12, 4/10, 6/8;
- H = 28 mm, L = 200 mm and soft-to-hard layer ratios of H_M/H_T = 4/24, 8/20, 12/16;
- H = 56 mm, L = 200 mm and soft-to-hard layer ratios of H_M/H_T = 8/48, 16/40, 24/32.

where:

- H_S - thickness of the (soft) lower deformation resistance layer,
- H_H - thickness of the (hard) higher deformation resistance layer,
- H, L - respectively, the height and length of the two-layered plate.

ANALYSIS OF EXAMINATION RESULTS

Within the study, several computer simulations were performed for bimetal plates with the identical soft-to-hard layer thickness ratio, H_M/H_T, but with different thickness. Figures 1. to 3. illustrate the effect of the value of asymmetry factor on the magnitude of bimetal plate curvature.

Figures 1. to 3. show the dependence of variation in the magnitude of bimetal band curvature on the value of asymmetry factor. As can be observed, the least susceptible to bending on exit from the roll gap was the thicker band with H = 56 mm. This results from the fact that thicker materials are less prone to bending. With decreasing height, a significant increase in bending of specimens was noted.

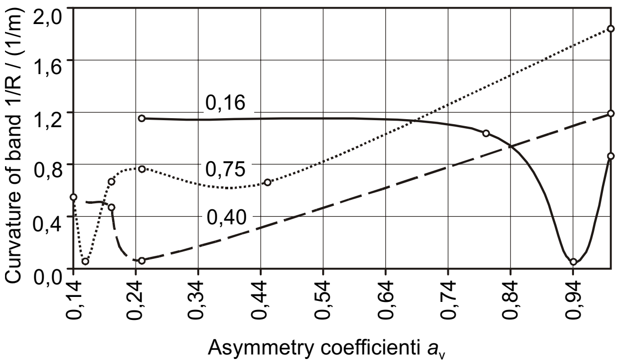

Figure 1. **Diagram of the dependence of CuSt3S bimetal band curvature on asymmetry factor a_v and effect of thickness ratio for H = 56 mm high specimens for a rolling reduction of ε = 20 %**

Slika 1. **Dijagram ovisnosti zakrivljenosti bimetalne trake CuSt3S o faktoru simetrije a_v i utjecaju omjera debljine H = 56 mm uzoraka za redukciju valjanja ε = 20%**

The influence of the magnitude of rolling reduction was also accounted for in the tests. The magnitude of bending is the least for a relative rolling reduction of ε = 20 %. Furthermore, low susceptibility to bending is exhibited also by plates with a soft-to-hard layer thickness ration of H_S/H_H = 0,16, regardless the value of rolling reduction, for small levels of asymmetry. On the other hand, rolled plate

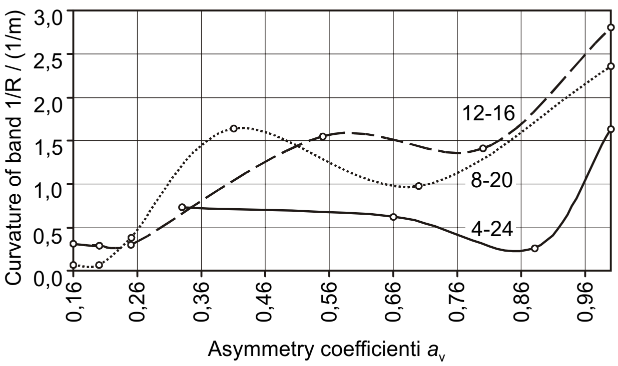

Figure 2. **Diagram of the dependence of CuSt3S bimetal band curvature on asymmetry factor a_v and effect of thickness ratio for H = 28 mm high specimens for a rolling reduction of ε = 20 %**

Slika 2. **Diljagram ovisnosti zakrivljenosti bimetalne trake Cu-St3 S o faktoru simetrije a_v i utjecaju omjera debljine H = 28 mm uzoraka za redukciju valjanja ε = 20%**

with a higher layer thickness ratio of H_S/H_H = 0,75 are characterized by a large curvature on exit from the roll gap. That considerable share of the cladding layer creates much greater engineering difficulties finding an optimal value of the asymmetry factor. This is most clearly noticeable for specimens with a ratio of H_S/H_H = 0,4 and 0,75.

The following conclusions can be drawn from the investigation results:

- An increasing value of total rolling reduction e and a growing percentage share of the cladding layer are the cause of an increase in the curvature of bimetal band;
- For greater values of two-layer plate thickness, H, a smaller band bending is observed;
- Asymmetrical rolling allows the equalization of the flow velocities of bimetal component materials, and thus the straightening of the band at the roll gap exit;
- The Most favorable for this pair of materials is to conduct an asymmetrical rolling process with small rolling reductions and for a small possible share of the soft layer.

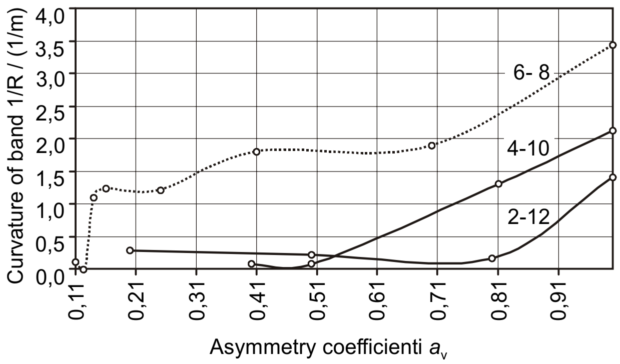

Figure 3. **Diagram of the dependence of CuSt3S bimetal band curvature on asymmetry factor a_v and effect of thickness ratio for H = 14 mm high specimens for a rolling reduction of ε = 20 %**

Slika 3. **Dijagram ovisnosti zakrivljenosti bimetalne trake CuSt3S o faktoru simetrije a_v i utjecaju omjera debljine H = 14 mm uzoraka za redukciju valjanja ε = 20%**

REFERENCES

[1] H. Dyja: Symetryczny i asymetryczny proces walcowania dwuwarstwowych wyrobów płaskich, Politechnika Częstochowska, seria monografie no. 12 Częstochowa 1990.
[2] H. Dyja, K. Wilk: Asymetryczne walcowanie blach i taśm WWMiIM Politechniki Częstochowskiej, Częstochowa 1998.
[3] H. Dyja, A. Maranda, R. Trębiński: Technologie wybuchowe w inżynierii materiałowej, Seria:Metalurgia Nr 20, Częstochowa 2001, 101.
[4] H. Dyja, S. Mróz, D. Rydz: „Technologia i modelowanie procesów walcowania wyrobów bimetalowych" Seria Metalurgia No. 33, Prace Naukowe Wydziału Inżynierii Procesowej, Materiałowej i Fizyki Stosowanej, Częstochowa 2003, 96, 98, 101.
[5] H. Dyja, M. Pietrzyk: A study of Deformation During Rolling of Bimetal Plate and Sheet. W: 4th International Steel Rolling Conference The Science and Technology of Flat Rolling Vol. 2, Deauville, 1987.
[6] H. Dyja: Symetryczny i asymetryczny proces walcowania dwuwarstwowych wyrobów płaskich, Politechnika Częstochowska, seria monografie no. 12 Częstochowa 1990.
[7] Y. M. Hwang, H. H. Hsu, Y. L. Hwang: Analytical and experimental study on bonding behavior at the roll gap during complex rolling of sandwich sheets, International Journal of Mechanical Sciences 42, 2000, 2417.
[8] Instrukcja obsługi programu FORGE 2D
[9] PN-63/H-92140: Blacha stalowa jednostronnie platerowana stalą odporną na korozję

[10] S. Qingnan, Z. Shuhong, Z. Daiming: The characteristics of the deformation and flow process in the rolling of metal sheets and metal powders of composite materials, Journal of Material Processing Technology 1997.

[11] D. Rydz, T. Dyl: Wpływ asymetrii prędkości walców na intensywność prędkości odkształcenia warstw blachy bimetalowej, III Międzynarodowa sesja naukowa, „Nowe technologie i osiągnięcia w metalurgii i inżynierii materiałowej", Częstochowa 2002.

[12] D. Rydz, R. Skoblik: Analiza procesu walcowania blach bimetalowych Al.-Cu z prostowaniem o samotok, III Międzynarodowa sesja naukowa, „Nowe technologie i osiągnięcia w metalurgii i inżynierii materiałowej", Częstochowa 2002.

[13] D. Rydz, H. Dyja: Numeryczna analiza wpływu współczynnika promienia walca i stosunku naprężeń uplastyczniających na odkształcenie warstwy twardej bimetalowego pasma, Hutnik – Wiadomości Hutnicze, 7, 2002.

[14] D. Rydz, H. Dyja, S. Wiewiórowska: Zastosowanie programu Forge 2D do przewidywania krzywizny pasma bimetalowego, WALCOWNICTWO'99, Procesy-Narzędzia - Wyroby, Ustroń, October 20 - 22, 1999.

[15] D. Rydz: Numeryczna analiza wpływu asymetrii prędkości walców na krzywiznę blachy bimetalowej, Sesja Naukowa, „Nowe technologie i osiągnięcia w metalurgii i inżynierii materiałowej", Częstochowa 2000.