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# The optimal conditions for production of bimetallic plates in asymmetrical hot rolling

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In the elaborated of new the technologies for rolling of bimetallic plates there are many problems both with ensuring a uniform strain distribution and producing a straight band as well. The analysis of bimetallic plate production is a complex and difficult problem to solve in a theoretical way. In the paper was presented a problem of hot rolling St36K+0H13J plates. Computer analyses for asymmetrical rolling process has been performed in this work to optimize the conditions for production of bimetallic plates. A Finite Element Method – Forge2 program has been applied in the computer simulation.

## 1. INTRODUCTION

The design of new technologies of rolling bimetal sheets poses a lot of problems with obtaining a uniform distribution of rolling reduction onto the layers and a straight band at the exit from the roll gap. The analysis of bimetallic plate production is a complex and difficult problem to solve in a theoretical way. The main reason is that layers of bimetallic band deform non-uniformly [1÷3, 7]. Variety of the strain intensity is related to different properties of bimetal components, which is strictly connected with their chemical composition. Different chemical composition of the layers influences on their hardness that brings about bending of the strip due to unequal state of stress over their its thickness. Industrial and a lot of experimental research have proved that the ratio of strains in the layers can vary substantially within the range of 0.57 - 1.3 [1, 2] (depending on the chemical compositions of welded steels and rolling process parameters). A soft layer flows around a hard layer due to a higher degree of deformation. As a result of its higher plastic properties, the soft layer undergoes greater deformation, which manifests itself in its flowing around the hard layer. As a consequence of the non-uniformity of deformation of the layers of two-layered sheet, the band bends on exit, which may lead to a the damage of the rolling mill or its equipment. For this purpose, an asymmetry of roll peripheral speeds is introduced. The asymmetry of roll peripheral speeds is introduced to make the velocity of flow of layers in the plane of exit from the roll gap uniform. The problem is, however, to determine a roll speed ratio (asymmetry factor) for which a straight two-layered band will be obtained. In order to reduce the costs of experimental investigations, these are often substituted with computer simulations of these processes.

## 2. AIM AND SCOPE OF NUMERICAL ANALYSES

A presented in the paper the process of rolling St36K+0H13J plates was considered both numerically. The purpose of investigations carried out within the present study was to determine the effect of roll peripheral speed asymmetry on the non-uniformity of deformation of bimetal sheet layers. By appropriate selection of the roll speed asymmetry factor, $a_v = V_g/V_d$ or $a_v = D_g/D_d$, a straight bimetal band with a greater uniformity of distribution of rolling reduction into band layers can be obtained [1, 2, 4, 5]. In the work considered asymmetry of peripheral speed of roll. In fig. 1 presented schema of asymmetrical rolling of bimetallic plate for $a_v= V_G/V_D=1$ (fig. 1a) where stripe bending at the exit roll gap and for $a_{vopt}= V_G/V_D<1$ (fig. 1b) where obtained linear stripe at the exit roll gap.

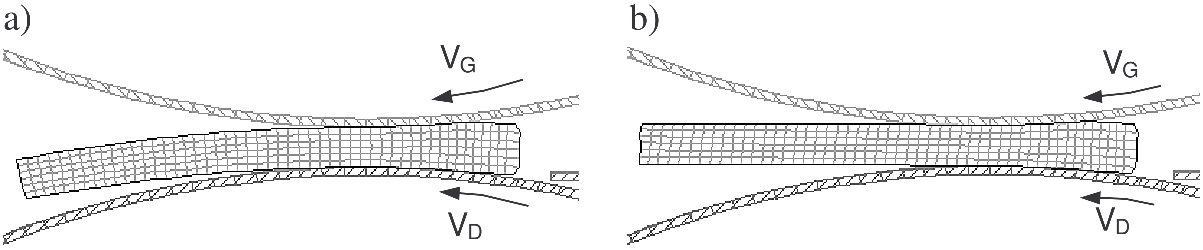


Figure 1. Schema of asymmetrical rolling of bimetallic plate a) $a_v= V_G/V_D=1$ b) $a_{vopt}= V_G/V_D<1$

For numerical examinations, the St36K steel was taken for the basic layer and the 0H13J steel for cladding layer. The parameters of work-hardening curves for particular steels were determined from their chemical composition. Computer simulations were performed for a rolling temperature of 1000°C. The Treska solution enables intrinsic fixing of the position of the neutral surface on the basis of the rolling process parameters. The problem of friction on the stripe and rollers' surface contact was simulated using the solution by Treska [8]:

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

where:

$\tau$ – vector of unitary friction forces,
$\sigma_0$ – base plastifying strain,
m – friction factor,
$\Delta V/\Delta v$ – slide quantity parameter

The value of friction factor equal to 0.4 was assumed for computations. Computer simulation was carried out based on the Forge2 program that enables any technological processes to be accomplished within the flat state of deformation by using the rigid-plastic and the elasto-plastic models. Forge2 programme is based on Finite Element Method [8]. It makes it possible to analyse a lot of processes applying to symmetrical and asymmetrical plastic working by numerical way. The elastic–plastic model was used for asymmetrical process in this work. The bimetallic strip came into being from separately formed layers.
Diameter of the rolls was R=500 mm and the rolling speed 1.6 m/s. The bimetallic stripe thickness was H= 12, 18 and 24 mm.

The optimal value of asymmetry factor, for which a straight two-layered band was obtained, is designated by $a_{vopt}$. During simulations of the process of rolling the hard layer was in the lower part of the band, which resulted in it's bending downwards. The investigations were performed for ε=10%, 20% and 25% relative rolling reduction.

## 3. RESULTS OF COMPUTER SIMULATION

As a result of investigated calculations, the changes of band curvature ratio and of separate bimetallic layers at the exit from the roll gap were obtained.
The results were used to find the optimal value of asymmetry ratio of the roll velocity $a_v$ for various band thickness and rolling reduction. The optimal value of asymmetry factor $a_{vopt}$, for which a straight two-layered band presented in table 1.

Table 1
The optimal conditions for production of bimetallic plate St36K+0H13J in asymmetrical hot rolling

| H [mm] | ε [%] | H/R | $H_T/H_M$ | $a_{vopt}$ | 1/R' [1/m] |
|---|---|---|---|---|---|
| 12 | 10 | 0,048 | 6/6 | 0,9412 | 0,1058 |
| 12 | 10 | 0,048 | 4/8 | 0,9467 | 0,1152 |
| 12 | 10 | 0,048 | 2/10 | 0,9510 | 0,0169 |
| 18 | 10 | 0,072 | 9/9 | 0,9414 | 0,0271 |
| 18 | 10 | 0,072 | 6/12 | 0,9484 | 0,0610 |
| 18 | 10 | 0,072 | 3/15 | 0,9581 | 0,0424 |
| 24 | 10 | 0,096 | 12/12 | 0,9467 | 0,0950 |
| 24 | 10 | 0,096 | 8/16 | 0,9524 | 0,0112 |
| 24 | 10 | 0,096 | 4/20 | 0,9639 | 0,0440 |
| 12 | 20 | 0,048 | 6/6 | 0,8205 | 0,0528 |
| 12 | 20 | 0,048 | 4/8 | 0,8556 | 0,0218 |
| 12 | 20 | 0,048 | 2/10 | 0,8791 | 0,0145 |
| 18 | 20 | 0,072 | 9/9 | 0,8888 | 0,0996 |
| 18 | 20 | 0,072 | 6/12 | 0,9040 | 0,0376 |
| 18 | 20 | 0,072 | 3/15 | 0,9412 | 0,0792 |
| 24 | 20 | 0,096 | 12/12 | 0,9357 | 0,0849 |
| 24 | 20 | 0,096 | 8/16 | 0,9412 | 0,0669 |
| 24 | 20 | 0,096 | 4/20 | 0,9440 | 0,0751 |
| 12 | 25 | 0,048 | 6/6 | 0,8040 | 0,0713 |
| 12 | 25 | 0,048 | 4/8 | 0,8421 | 0,0065 |
| 12 | 25 | 0,048 | 2/10 | 0,8579 | 0,0318 |
| 18 | 25 | 0,072 | 9/9 | 0,8648 | 0,0365 |
| 18 | 25 | 0,072 | 6/12 | 0,8939 | 0,0613 |
| 18 | 25 | 0,072 | 3/15 | 0,9106 | 0,0356 |
| 24 | 25 | 0,096 | 12/12 | 0,9302 | 0,0485 |
| 24 | 25 | 0,096 | 8/16 | 0,9304 | 0,0369 |
| 24 | 25 | 0,096 | 4/20 | 0,9423 | 0,0277 |

where:

1/R' – curvature of bimetallic plate
$H_M$ – initial thickness of basic layer
$H_T$ – initial thickness of plating layer

The band curvature was determined as 1/R' reverse of radius curvature. On the basis of the simulations, the lowest strip curvature was obtained. Fig. 2 ÷ 4 show the distribution of bimetallic band curvature that depends on asymmetry ratio and relative rolling reduction.

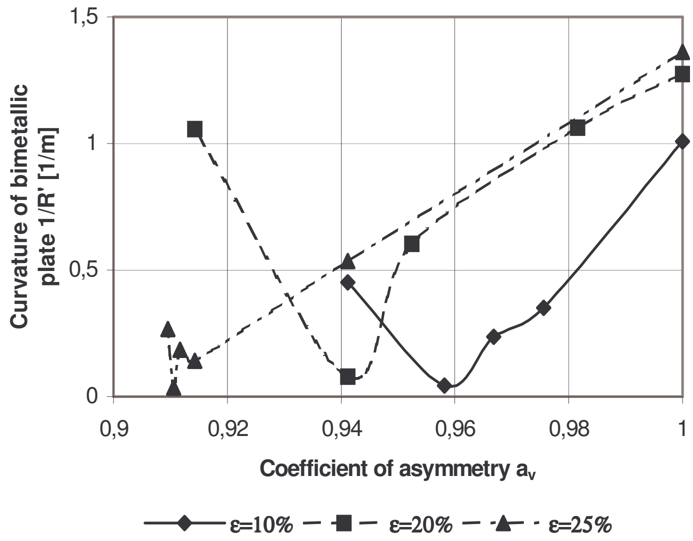


Figure 2. Distribution of bimetallic plate curvature for asymmetrical process rolling for thickness layer ratio value of $H_T/H_M$=3/15

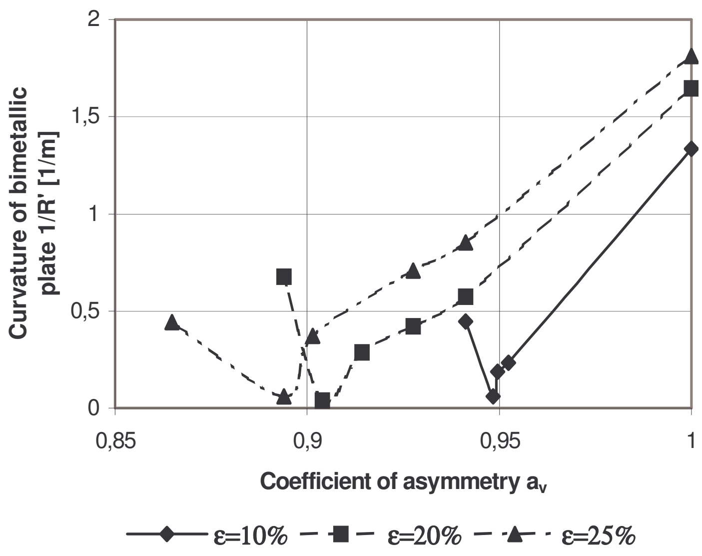


Figure 3. Distribution of bimetallic plate curvature for asymmetrical process rolling for thickness layer ratio value of $H_T/H_M$=6/12

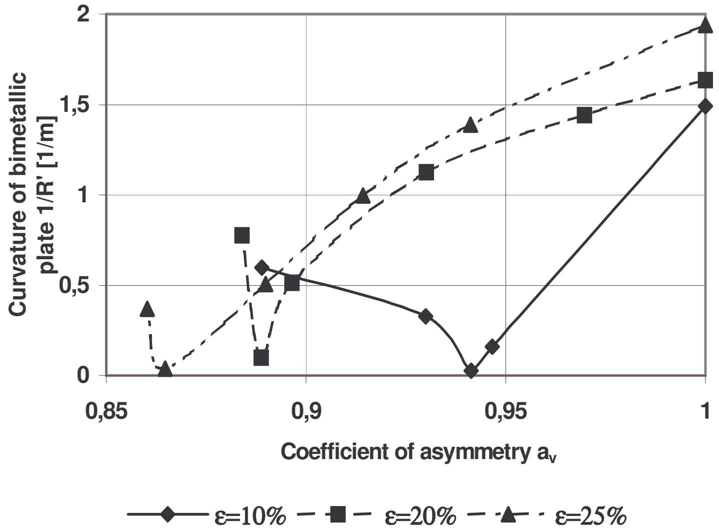


Figure 4. Distribution of bimetallic plate curvature for asymmetrical process rolling for thickness layer ratio value of $H_T/H_M$=9/9

Above presented figures 2÷4 have proved that with increase of the hard layer ratio it is necessary to introduce greater asymmetry of the rotational speed of the rolls. The optimal value of the coefficient of asymmetry is value, which haves the lower value of the band curvature. On the basis of presented distributions of the bimetallic plate curvature it can be obtained that existence of meaningful influence of the layer thickness ratio $H_T/H_M$ and rolling reduction on the optimal value of asymmetry coefficient. Three ranges of layer thickness, with particular attention on participation of the plating layer were taken into account in the work. In all cases both the increase of the rolling reduction and the hard layer thickness causes an increase in searching area for optimum-value of the asymmetry ratio. As was mentioned earlier, the optimal asymmetry ratio is the ratio of rotational speed of rolls $V_G/V_D$, for which the straight band can be obtained.

## 4. CONCLUSIONS

On the basis of the computer simulations it can be stated that:

- with increase of the hard layer ratio and the value of relative rolling reduction, is necessary to introduce greater asymmetry of the rotational speed of rolls to obtain the straight bimetallic plate,
- the curvature of bimetallic plate depends on process parameters; in case when hard layer ratio was lower the optimal conditions of the process were easier to find; in other cases a bigger failure of this regularity was observed,
- with increasing value of the roll radius factor, H/R, the region of searching for an optimum reduces, which indicates that sheets of increased thickness show less sensitivity to bending upon flowing out from the roll gap,
- with increasing layer thickness ration, $H_T/H_M$, the band curvature increases and the uniformity of deformation of bimetal sheet layers decreases.

## REFERENCES

1 Dyja H., Symetryczny i asymetryczny proces walcowania dwuwarstwowych wyrobów płaskich, seria monografie nr 12, Częstochowa ,1990,

2 Dyja H., Wilk K.: Asymetryczne walcowanie blach i taśm, Prace Naukowe Wydziału Metalurgii i Inżynierii Materiałowej Politechniki Częstochowskiej, 1998,

3 Dyja H., Rydz D., Pilarczyk J. W., Krakowiak M.: Effect of asymmetric rolling on distribution of flow rate of bimetallic band, 1998, Baltic sea metal forming and cutting seminar, Bamfac'98, 2-3 June 1998, Vilnius, Lithuania, s. 159-165.

4 Dyja H., Pietrzyk M.: 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, 12.1 – 12.7.

5 Dyja H., Stoiński D.: Investigation of Symmetrical and Asymmetrical Rolling of Sandwich Flat Products. Modelling of Metal Rolling Processes, eds., Beynon J.H., Ingham P., Teichert H., Waterson K. London, 1996, 422 – 431.

6 Dyja H., Pietrzyk M.: On the Theory of the Process of Bimetal Plate and Sheet Hot Rolling, J. Mech. Work. Technol., 1983, 8, 309 – 325.

7 Dyja H.: Nowe aspekty procesu walcowania blach platerowanych. Politechnika Częstochowska, Seria Monografie, Częstochowa, 24, 1982.

8 Manual of programmes Forge 2/96, Transvalor S.A.