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Analysis of the bimetallic bars rolling during a skew rolling

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ABSTRACT

Purpose: Bimetallic bars which possess higher corrosion resistance and mechanical properties, it is the new kind of bimetallic bars which are better than standard bars. The bimetallic bars are more often applied in concrete construction. There are few methods which ensure a good strength of bimetallic layer bond. Hydrostatic extrusion, rotary rolling and explosive cladding are most often used methods.

Design/methodology/approach: The simulations of the bar rolling in a three-high skew mill were carried out using the Forge2005® commercial program.

Findings: The higher value of yield stress of the cladding layer does not produce the effect of "flowing down" of this layer over the core surface and it's folding between the rolls. The use of non-corrosive steel on plating layer assures receipt on a high durability and esthetics bimetallic bars.

Practical implications: Bimetallic bars are chiefly used in the building industry at production of concrete constructions, and as working elements in bridge building in aggressive environment.

Originality/value: Production of bimetallic bars is very difficult. One from many problems during production bimetallic bars is assurance good strength of bimetallic layer bond. A theoretical analysis of bimetallic bar rolling in a three-high skew mill is presented in the paper and the distributions of stress and strain intensities in the bimetallic bar during skew rolling are shown.

Keywords: Numerical techniques; FEM; Rotary rolling; Bimetallic bars; Steel - steel resistant to corrosion

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

An increased interest in the use of bimetallic bars in the building industry has been observed in recent years. One of the most important conditions for the use of bimetallic bars in this industry is to assure the high strength of joint between the individual layers of the bimetal.

One of the bimetallic bar manufacture methods consists in the rolling of bimetallic stock in a three-high skew mill. The bimetallic bar rolling process is similar to the process of rolling seamless tubes. It, however, differs in the conditions of flow of particular bimetal layers in the roll gap due to the different geometrical parameters of the process. If, during skew rolling, the resistance of plastic deformation of the outer layer is less than that of the core, then the outer layer deforms more than the core, as a consequence of which a reduction in wall thickness and an increase in tube perimeter occur [1-15].

One of the most important guaranteeing factors the obtainment the good quality of bimetal bars is the high endurance it joins between components of bimetal. Bimetal bars are characterized by definite properties physics - mechanical, which was not it been possible to get for separate creator bimetal metals.

The method of production of bimetal bars should assure good level of following properties: the ductility, plasticity, endurance, electric conductivity and thermal, the corrosion resistance, proper coefficient of thermal dilatation [1, 8, 10].

2. Production of bimetal bars in a three-high skew rolling mill

The rotary rolling, in general, is used in the elongating process of manufacturing a seamless tube. In this process, the inner tool, such as a mandrel, is inserted into the hot tube, and then the wall thickness of the tube is reduced and the tube is elongated. Figure 1 shows the schematic view of rotary rolling in the elongating process of manufacturing a seamless tube. If the tube is regarded as the outside layer member and the mandrel is regarded as the core member in this rolling process, the tube of outside layer member is separated from the mandrel of the core member so that the outside layer member and the core member are not integrated. If a deformation resistance of the outside layer member is smaller than that of the core member, the outside layer member is deformed more greatly than the core member which reduces the wall-thickness. Thus, as shown in Fig. 1, a wall-thickness was reduced, and a peripheral length got longer, whereby the lengthened portion is jutted out to a gap between the rolls to generate the flaring. As a result, a gap is generated between the core member and the outside layer member, whereby the diffusion bonding layer of both metals, which has been already formed by rolling, is separated. In order to prevent this, the outside layer member is preferably larger than the core member in deformation resistance. 42%Ni-Fe alloy and Cu were used as material, and the assembly (70 mm dia.) was produced in the same manner. The resulting assembly was heated at 900°C and then rolled by rotary rolling in which the cross angle was 3°and the feed angle was 9°. The deformation resistance (MPa) at 900°C is 42%Ni-Fe alloy; 196, Cu; 34.5. Figure 2 shows the result of rolling. Figure 2a shows the result in the case that the outside layer member is 42%Ni-Fe alloy and the core member is Cu. Figure 2b shows the result in the case that the outside layer member is Cu and the core member is 42%Ni Fe alloy. From this result, it is confirmed that the good rolling for diffusion bonding can be carried out in the case that the deformation resistance of the outside layer member is larger than that of the core member. On the contrary, the good rolling for diffusion bonding cannot be carried out in the case that the deformation resistance of the outside layer member is smaller than that of the core member [2, 4-6, 12, 13]. Figure 3 presents a three - high skew rolling mill.

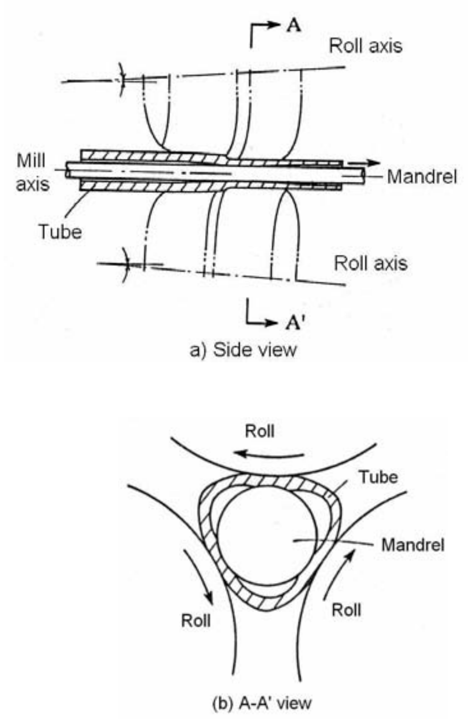

Fig. 1. Schematic view of rotary rolling in elongating process of manufacturing a seamless tube [2]

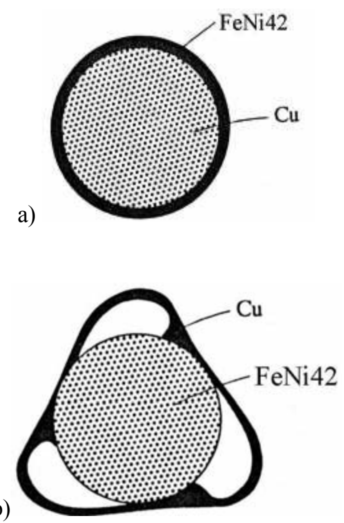

Fig. 2. Effect of deformation resistance on rotary rolling for clad bar[2]; a) Outside layer: FeNi42, Core: Cu; b) Outside layer: Cu, Core: FeNi42

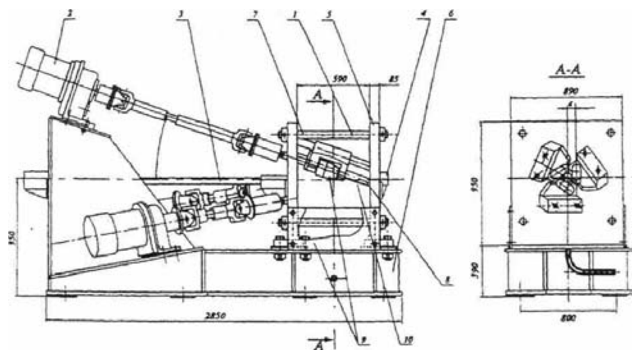

Fig. 3. Three - high skew rolling mill [5],1 - Working stand, 2 - Primary engine, 3 - Entry guide, 4 - Stripper guide, 5 - Steel plate, 6 - Base, 7 - Distance screws, 8 - Cassettes, 9 - Working rolls, 10 - Thrust bearing

3. Numerical modelling of the skew rolling process

The results of theoretical studies on the process of rolling bimetallic bars in a three-high skew mill are presented in the paper. The program Forge2005® was used for the computer simulation of this process.

As a result of theoretical studies carried out, distributions of stress and strain intensities in the bimetallic bar were obtained.

Figure 4 illustrates the rolls and bimetallic band with a finite-element mesh adopted for the simulation of the process of rolling in the three-high skew mill. Figure 5 presents the form and dimension of bimetallic band.

It was assumed in numerical modelling that the bar core was made of steel C45, while the cladding layer was of steel 304L. The mill feedstock was composed of a tube of a diameter of 38 mm and a wall thickness of 4 mm and a 30 mm-diameter round bar. The following initial conditions were taken for numerical studies: feedstock temperature: 1100°C, tool temperature: 60°C, roll rotations: 100 rpm, roll diameter: 60 mm, and friction factor: 0.8. The feedstock was rolled into a bimetallic bar of a final diameter of about 17 mm. As a result of simulations carried out, distributions of stress and strain intensities on the cross-section of the rolled bar were obtained (Figs. 6-7).

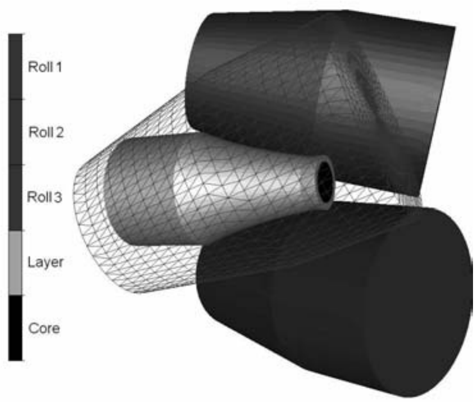

Fig. 4. The rolls and bimetallic band with a finite-element mesh adopted for the simulation of the process of rolling in the three-high skew mill

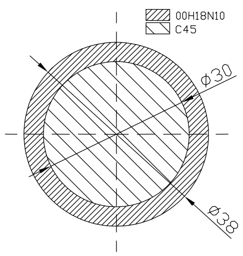

Fig. 5. Form and dimension of bimetallic band

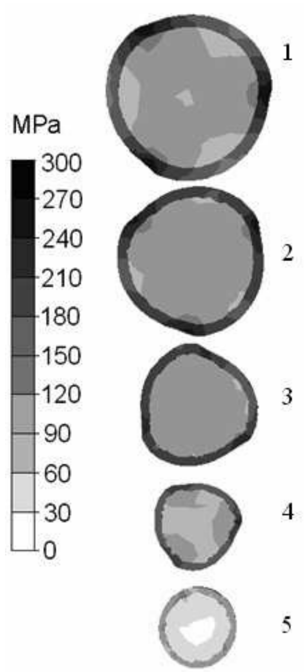

Fig. 6. Distribution of stress intensities: 1) in the plane of entry to the roll gap; 2) in the 1/3 central zone of the roll gap; 3) in the 1/2 central zone of the roll gap; 4) in the 2/3 central zone of the roll gap; 5) in the plane of exit from the roll gap

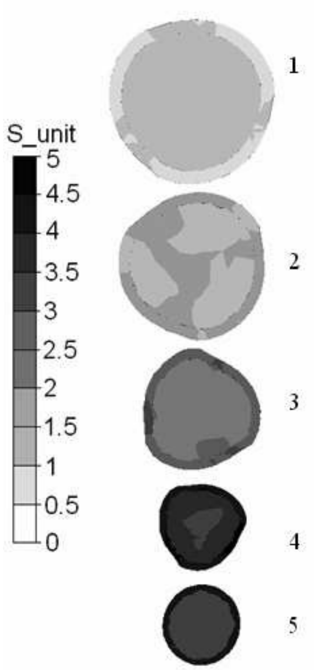

Fig. 7. Distribution of strain intensities: 1) in the plane of entry to the roll gap; 2) in the 1/3 central zone of the roll gap; 3) in the 1/2 central zone of the roll gap; 4) in the 2/3 central zone of the roll gap; 5) in the plane of exit from the roll gap

On the basis of the distributions of stress and strain intensities (Figs. 6-7) obtained in the rolling of bimetallic bars in the three-high skew mill it can be found that the greatest values of stress intensity occur in the locations of contact of the bimetallic band with the rolls and are equal to 220 MPa. The stress intensity values are higher in the cladding layer of the bimetal, which is caused by the lower temperature and rheologic properties of this layer. In the first phase of rolling, in the zone of material entry to the roll gap, the stress increases, and as the band moves through the roll gap, the value of stress intensity increases to reach maximum values in the central part. The inclination of the roll axis in two planes during rolling makes the band to twist and causes large deformations to be obtained during a single pass. In the sizing zone, the values of stress intensity decrease.

4. Conclusions

From the studies carried out it has been found that:

- the high value of stress intensity in the roll gap favours a good bond between particular bimetal layers,
- the higher value of yield stress of the cladding layer does not produce the effect of “flowing down” of this layer over the core surface and it’s folding between the rolls,
- the use of non-corrosive steel on plating layer assures receipt of a high durability and esthetics bimetallic bars.

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