MATHEMATICAL MODEL OF THE STRIP ROLLING MADE OF THE SINTERIZED METALLIC POWDERS

Ionel PETREA, Sorin Miltiade ISTRATE

"Dunarea de Jos" University of Galati
e-mail: petrea.ionel@ugal.ro

ABSTRACT

The minimum-power method has been used to investigate the final ratio soft-layer thickness to tough-layer thickness in bimetals with porous layer rolling. The velocity fields has been determined and the total deformation power has been calculated: the rolling force and roll torque have alsobeen estimated, using the energy method.

KEYWORDS: reduction per pass, the power for internal deformation

1.Introduction

A prime objective of the mahematical analysis of rolling processes is to predict rolling force, roll torque and power, as well as strain distribution in the deformation zone.The problem is especially important in bimetal plate rolling, when the reduction of the tough layer is less than that of the reduction of the soft layer ($\varepsilon_M > \varepsilon > \varepsilon_T$). The reductions of the layers are depedent on the initial soft layer thickness to tough layer thickness (H_M/H_T), the ratio of the yield stresses (Y_M/Y_T), the mean thickness-to-length ratio of the plastic zone (Δ), the friction coefficient (f) and the reduction per pass (ε).

2.Velocity field in bimetal plate rolling

In order to determinate the velocity field the following assumptions have been made:
- a state of plane strain exists in the deformation zone;
- the arc of contact can be replaced by a chord;
- the function $v_x = v_x(y)$ is linear;
- the friction force is constant along the arc of contact;

Figure 1 shows the geometrical configuration of the rolls and the bimetal plate with an infinitesimal element in the deformation zone.

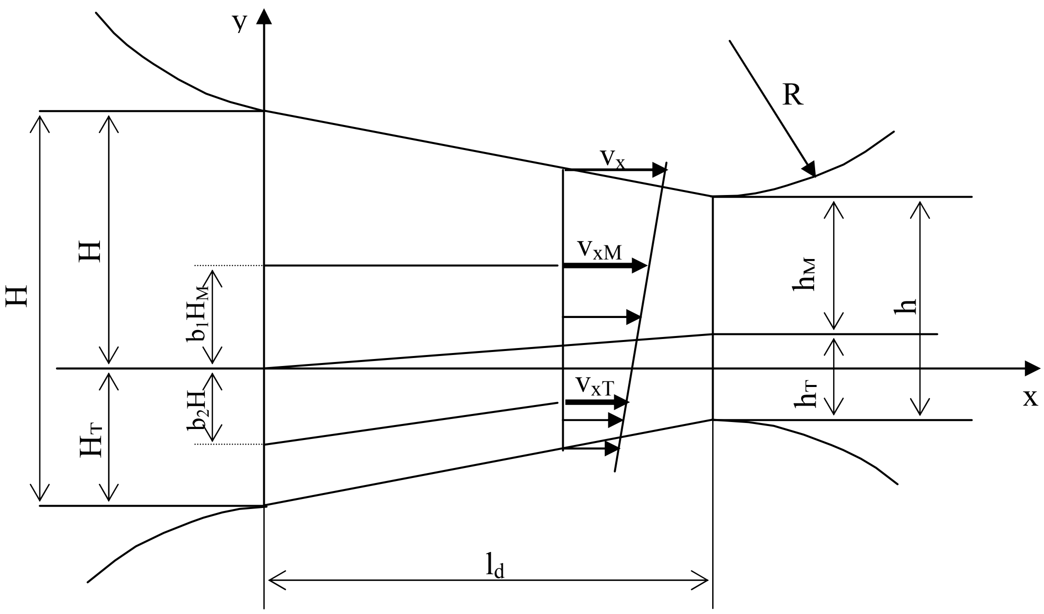

Fig. 1. *Geometry of the rolls and bimetal plate, showing the infinitesimal element.*

Notation:
a – variational parameter = h_M/h_T
H, h – initial and final thickness of the plate
H_M, h_M – initial and final thickness of the soft layer (the porous strate)
H_T,h_T – initial and final thickness of the hard layer (the steel strip support)
l_d – length of the deformation zone
R – roll radius
v_o – initial plate velocity
v_{oM}, v_{oT} – initial velocity in the soft and hard layer
v_r – peripheral roll velocity
v_{xM}, v_{xT} – metal velocity in the soft and hard layer
α - angle between a chord of the arc of the contact and the x axis
β - angle between an infinitesimal element and the x axis
Δ - the mean thickness –to-length ratio of the plastic zone
$\Delta y0$, $\Delta y1$ – initial and final thickness of infinitesimal element
ε – reduction per pass
ε_M,ε_T – reduction in the in the soft and hard layer
λ_M, λ_T – elongation coefficient in the soft and hard layer

If the layers should not be bonded, their elongation coefficients would be:

$$\lambda_M = H_M / h_M ; \quad \lambda_T = H_T / h_T; \tag{1}$$

For a given pass geometry, the velocities are determined from the continuity condition for an infinitezimal element by the following relationships:

$$v_{xM} = \frac{v_0}{1-(1-1/\lambda_m)(x/l_d)} = \frac{v_0}{1-z_M(x/l_d)}$$
$$v_{xT} = \frac{v_0}{1-(1-1/\lambda_T)(x/l_d)} = \frac{v_0}{1-z_T(x/l_d)} \tag{2}$$

where:

$$z_M = 1 - a\frac{(1-\varepsilon)H}{(1+a)H_M} \qquad ,z_T = 1 - a\frac{(1-\varepsilon)H}{(1+a)H_T} \tag{3}$$

Bonding of layers involves changes of velocity in the y direction, and the function $v_x=v_x(y)$ is assumed to be linear. The coordinates of the infinitesimal elements in which velocities are $v_x=v_{xM}$ and $v_x=v_{xT}$ are, respectively: $y = b_1H_M$ and $y = -b_2H_T$ (b1 şi b2 are coefficients, $0 \le b1 \le 1$; $0 \le b2 \le 1$). This results in the following relationship from (2):

$$v_x = \frac{v_{xM} - v_{xT}}{b_1H_M + b_2H_T}(y - b_1H_M) + v_{xM}$$

$$\frac{1}{A}\ln\frac{AH_M(1-b_1)+1/(1-z_M)}{1/(1-z_M)-Ab_1H_M} - \frac{ah}{1+a} = 0$$
$$\frac{1}{A}\ln\frac{1/(1-z_M)-b_1AH_M}{1/(1-z_M)-A(H_T+b_1H_M)} - \frac{1}{1+a} = 0 \tag{5}$$

where:

$$A = \frac{1/(1-z_M)-1/(1-z_T)}{b_1H_M + b_2H_T} \tag{6}$$

The non-linear equations (5) are solved by Newton-Raphson iterative method, enabling determination of coefficients b_1 and b_2.

By differentiation of the velocity field the strain-rate components are obtained in the form:

$$\dot{\varepsilon}_x = \frac{v_0}{l_d}\left\{\frac{y-b_1H_M}{b_1H_M+b_2H_T}\left[\frac{z_M}{(1-z_M(x/l_d))^2} - \frac{z_T}{(1-z_T(x/l_d))^2}\right] + \frac{z_M}{(1-z_M(x/l_d))^2}\right\}$$

$$\dot{\varepsilon}_x = \frac{v_0}{l_d}\left\{\frac{y-b_1H_M}{b_1H_M+b_2H_T}\left[\frac{z_M}{\left(1-z_M\left(x/l_d\right)\right)^2}-\frac{z_T}{\left(1-z_T\left(x/l_d\right)\right)^2}\right]+\frac{z_M}{\left(1-z_M\left(x/l_d\right)\right)^2}\right\}$$

$$\dot{\varepsilon}_{xy} = v_0\left\{\frac{1}{1-z_M\left(x/l_d\right)}-\frac{1}{1-z_T\left(x/l_d\right)}\right\}\frac{1}{b_1H_M+b_2H_T}+\varepsilon_x tg\beta$$

where angle β is defined by:

$$tg\beta = \frac{1}{l_d}\left[y+H_T-\frac{1}{2}H\varepsilon-\frac{1}{A}\ln\frac{A\left(y-b_1H_M\right)+1\left(1-z_M\right)}{1\left(1-z_M\right)-A\left(H_T+b_1H_M\right)}\right]$$

3. Mathematical model of rolling (the power balance equation)

The purpose is the obtaining of a dynamic function (F – rolling force, M – roll torque) in correlation with the initial plate velocity, with the reduction per pass, with the friction in the deformation process, with the behavior at deformation of the material. The mathematical model is obtained from the virtual power principle (the power balance equation):

$$P_D + P_S = P_M + P_F \qquad (9)$$

where:

P_D – the power for internal deformation

P_S – shear power over surfaces of velocity discontinuity

P_M – the driving power of the rolls

P_S – the power dissipated with the friction

4.Calculation of the process parameters of the rolling of bimetal plate

On the basis of equations shown in Section 3, computations of power for internal deformation, power for friction losses and power over the surfaces of velocity discontinuity have been carried out. The results of these computations are exemplified in Fig. 2., in terms of change of the power components as functions of the variational parameter a= h_M/h_T.

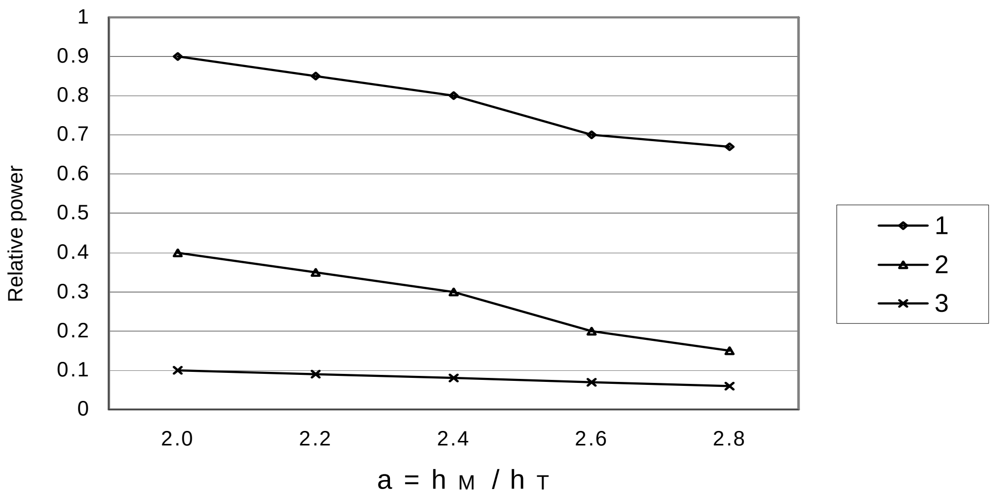

Fig.2. *The relationship of the power components to the h_M/h_T.ratio (H_M/H_T =3, ε = 0.3)*
1 – relative power for internal deformation; 2 –power for friction losses; 3 - power over the surfaces of velocity discontinuity.

5.Conclusions

The method described in the present paper enables the determination of the total power in the rolling of bimetal with porous layer. For any given set of rolling conditions, variational parameter (a)can be computed using the minimum power method, and rolling force and roll torque can be computed using the energy method. A range of computations has been carried out to illustrate the effect of variation of the different rolling parameters on the h_M /h_T ratio, as well as on the rolling force and the roll torque. The accuracy of the present method has been confirmed experimentally.

References

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