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Development of 3-dimensional strip rolling analysis

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ABSTRACT

Through right deduction of theoretical equations and some disposal technique, a 3-dimensional strip rolling coupled analysis software has been successfully developed in this paper, which considers strip plastic deformation and roll elastic deformation simultaneously. The calculated examples with different kinds of rolling conditions all conform to the reality, and results show that the developed 3-dimensional program is applicable to the wide strip.
Keywords: 3-dimensional analysis, strip rolling, roll deformation, strip profile, edge drop

1. Introduction

With the increasing demands on the quality of strip shape from customers, strip shape control becomes more important. For solving this kind of problem, it is necessary to build the mechanical model which can truthfully reflect the actual strip deformation. In such case, 2-dimensional analysis can't get the right answer. We must take the strip lateral deformation into consideration, which means that the metal deformation in width direction can not be negligible, 3-dimensional strip rolling analysis should be considered.

2. Building of 3-dimensional strip rolling analysis model

Considering that FEM is difficult to apply to large production mill for its time consuming and difficulty in disposal of boundary condition, slab method [1)] is adopt here. There were many researchers [2~4)] who had ever used this method to solve 3-dimensional strip rolling problem, but most of their work concentrated on the research of narrow strip, and their methods were invalid to be applied to wide strip analysis. Until now there is no publication for systematic research on wide strip. In view of such facts, the coupled model is proposed by considering strip plastic deformation and roll elastic deformation simultaneously, which can be applied to wide strip analysis. As Fig.1 shows, after running the program of strip plastic deformation, the distribution of rolling force across strip width is calculated. Then, with the aid of the calculated rolling force, running the program of roll elastic deformation can obtain strip profile. In comparison with assumed rolled strip profile, if profile deviation is less than the standard value, the final strip profile and rolling force distribution are obtained and the program ends; if not, the assumption of rolled strip profile will be modified, and the foregoing calculating procedure is continued until the above condition is satisfied.

3. Calculation results and analysis

In order to certify that the developed 3-dimensional strip rolling analysis program is suitable to different kinds of rolling conditions, both narrow strip mill and wide strip mill have been selected for calculation. Compared with wide strip calculation, calculation for narrow strip is relatively easy. So here, calculation mainly concentrates on the wide strip. Fig. 2 shows the specifications of a wide strip mill. The calculation conditions are defined in Table 1.

Fig. 3 shows the result of rolling pressure distribution by using 3-dimensional coupled analysis. In rolling direction, there exists a friction hill. In width direction, there is a peak value of rolling pressure near strip edge area, i.e. from strip center to edge, rolling pressure increases smoothly, only at strip edge exists a quick decrease. This result is similar to that from the experiment by the pin-method [5].

Fig. 4 shows the influence of strip reduction on the distribution of rolling force per unit width. There all exists a peak value of rolling force near strip edge area for each width strip. The same phenomenon appears in different reduction cases. With the reduction increasing, rolling force increases for different width strip.

The reason why the peak value of rolling force exists near strip edge area for all width strip is that, the edge area is far from its center area for wide strip, so the difference for the states of force acting between the area of strip center and edge is changed smoothly, then the roll deformation effect is higher than the rigid roll effect, which results in that the rolling force increases smoothly from strip center to edge. At strip edge there exits a free surface, so strip in that area is easy to be deformed, which results in a quick decrease of rolling force.

Fig. 5 shows the tension effect. In each case, whether tension is added or not, the rolling force at strip edge doesn't change, but the distribution of rolling force decreases for different width strip in the order of no tension case, only front tension added case, only back tension added case and both front and back tension added case. This indicates that back tension is more effective to decrease the rolling force.

The main reason why rolling force decreases with the action of tension is that the added tension changes the state of force acting on the strip, tension is acting on the strip in tensile state, which is good for metal elongation and makes metal being deformed easily. Because the acting area for back tension is larger than that for front tension, back tension is more effective to decrease the rolling force.

Because of the above distribution of rolling force, the corresponding distribution of exit strip profile is obtained as Fig. 6 shows. Here the exit strip profile is expressed as the thickness deviation between strip center and each point. Results show that the exit strip profile increases with the reduction increasing, decreases with the tension increasing, and back tension is more effective to decrease the exit strip profile.

4. Conclusions

Three-dimensional strip rolling analysis for wide strip has been successfully developed, which can be used as a virtual mill to do many experiments with different rolling conditions and provide useful information for plant production.

5. References

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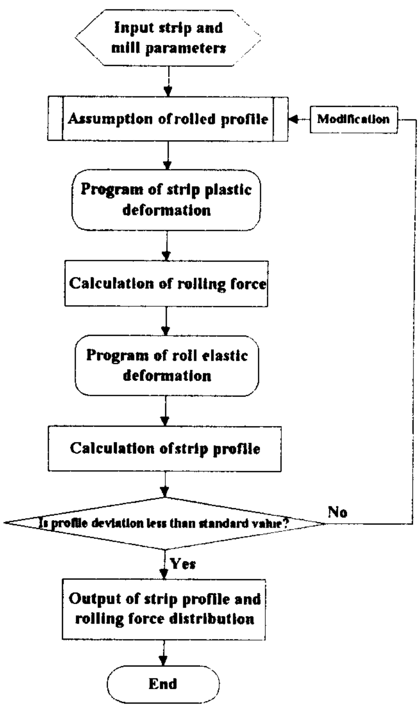


Fig. 1 Flowchart of 3-D coupled program

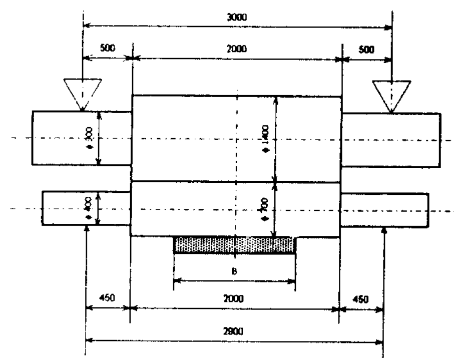


Fig. 2 The wide strip mill for calculation

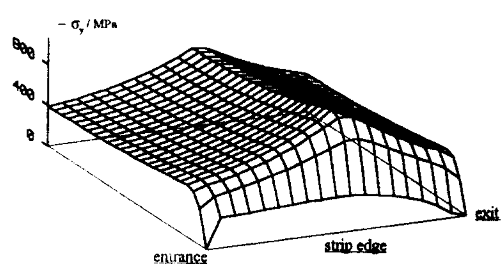


Fig. 3 Distribution of rolling pressure $-\sigma_y$ (B = 800 mm)

Table 1 Calculation conditions for wide strip

Item	Unit	Data	Item	Unit	Data
entry strip size	mm	3.0 × 800, 1200, 1600	reduction	%	10, 20, 30
strip shear yield stress	MPa	210	Young's modulus	MPa	210000
coef. of elasticity in shearing	MPa	81000	friction coef.		0.1
front tension	MPa	0, 120	back tension	MPa	0, 125

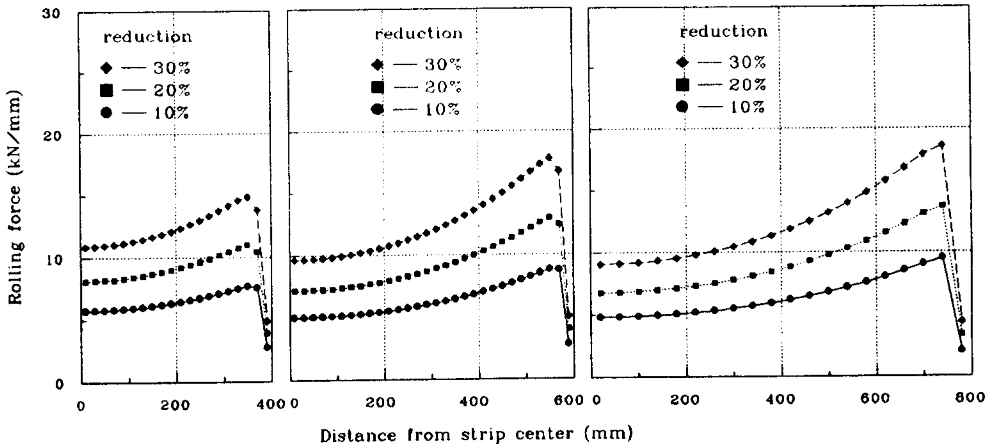


Fig. 4 Influence of strip reduction on the distribution of rolling force per unit width

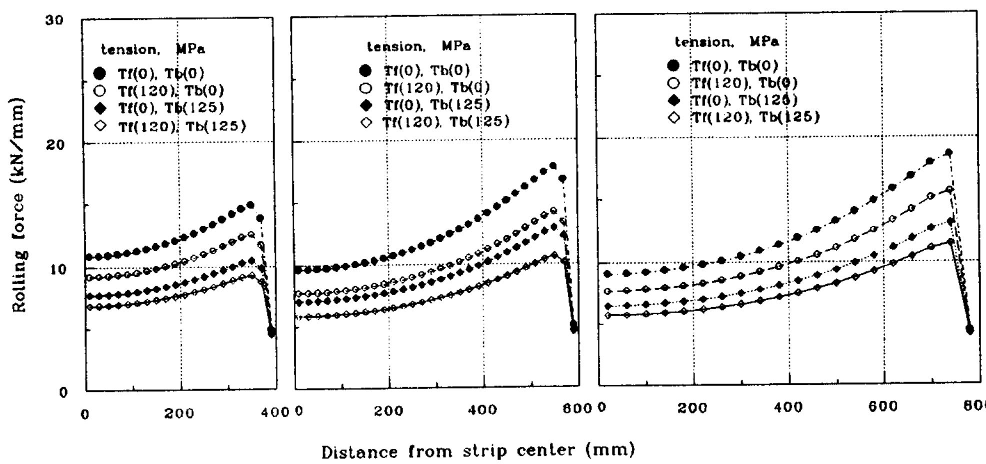
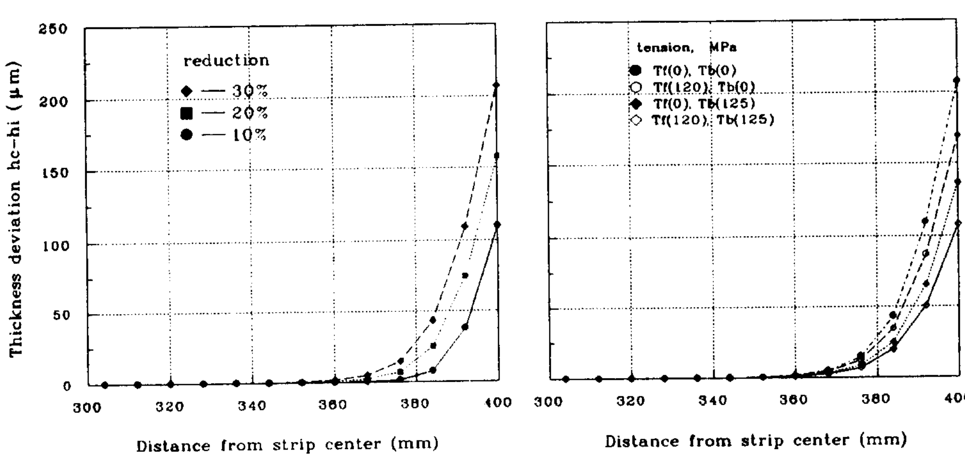


Fig. 5 Influence of strip tension on the distribution of rolling force per unit width (ε = 30%)



a) strip reduction effect

b) strip tension effect (ε = 30%)

Fig. 6 The distribution of exit strip profile (B = 800 mm)