# (180) MATHEMATICAL MODELLING AND EXPERIMENTAL STUDY OF SLAB UNBENDING ON USINOR'S # 12 CASTER IN DUNKIRK

o JL. JACQUOT*, JP. BIRAT*, JC. DHUYVETTER**, JP. MARKEY**, JD. WEBER***

*Research Institute of the French Iron and Steel Industry (IRSID)
**USINOR, Dunkirk Works ***University of Metz

## 1) Introduction

To avoid internal cracks, hight-quality grades (e.g. pipe grades) are generally straightened on solid core. This leads to a decrease in productivity and to a low surface temperature at the unbending point, and hence to the risk of surface transverse crack formation. In the present work, we have studied techniques to avoid internal crack formation during straightening on liquid core.

## 2) Mathematical modelling

In the temperature range corresponding to CC conditions, the steel is viscoplastic, the stress $\sigma$ is a function of strain $\varepsilon$ and strain rate $\dot{\varepsilon}$

$$\sigma = \lambda\, \varepsilon^{n}\, \dot{\varepsilon}^{m}$$

where the coefficients $\lambda$, n and m depend on steel grade and temperature.

The stress at a distance y from neutral axis is

$$|\sigma| = \lambda\, |C_0 - C|^{n}\, |C'|^{m}\, V^{m}\, |y|^{n+m}$$

where $C_0$ is the initial curvature, C is the local curvature, C' is the derivative of C and V is the casting speed.

Assumptions have to be made concerning the actual shape of the slab in straightening zone. These assumptions where checked by measuring the unbending moment on industrial casters.

Then it is possible to compute the operating conditions of unbending with differential cooling (1) or compressive straightening (2). For the latter case, we measured friction coefficient between slab and driven rolls (Fig. 1)

## 3) Experimental study on USINOR'S # 12 slab caster

The main features of USINOR'S # 12 slab caster in Dunkirk are given in table 1.

From measurements of electric consumption of driven rolls, it is possible to calculate the line resistance (Fig. 2) which increases when the upper rolls are not wedged in the straightening zone. This increase is caused by rolling of the slab, leading to internal crack formation.

The calculation of longitudinal forces (Fig. 3) shows that during standard operation (11 driven rolls) the slab is slightly compressed, but not enough to avoid internal crack formation during straightening.

## 4) Conclusion

The main results are :

- an equiaxed zone obtained by electromagnetic stirring divides by 4 the number of internal cracks ;
- in order to avoid rolling of the cast slab, it is necessary to wedge the upper rolls down to the crater end ;
- a confirmation that compressive straightening and differential cooling are very efficient in decreasing internal crack frequency.

1) T. MASAOKA et al, Tetsu to Hagane, 64, n°11, S 622
2) H. NAKAGAWA et al., Tetsu to Hagane, 64, N°8, A131-134

This research has been conducted with the partial financial support of the ECSC.

| | |
|---|---|
| Manufacturer | : FIVES-CAIL-BABCOCK |
| Start up | : march 1977 |
| Type | : 2 strands, curved |
| Ladle capacity | : 160 t |
| Slab size | : 210~300 x 1040~2100 mm |
| Radius | : 12 m |
| Metallurgical length | : 23 m |
| E.M.S. | : IRSID-CEM stirring rolls |

Table 1.

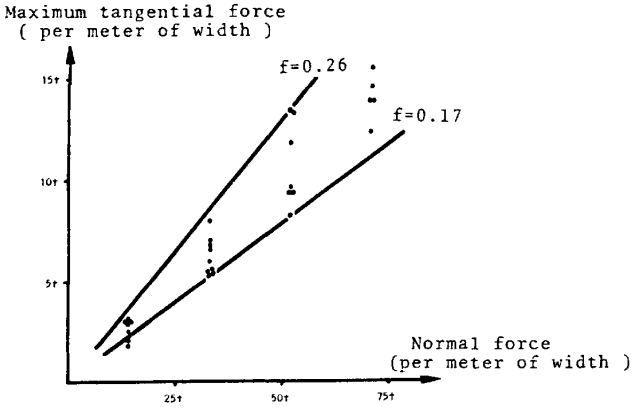


Fig.1 Friction coefficient between roll and slab

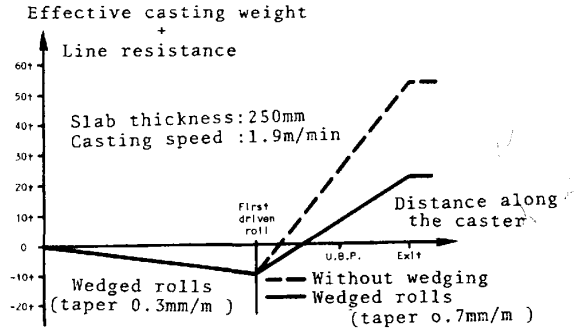


Fig.2 Weight + resistance along the caster

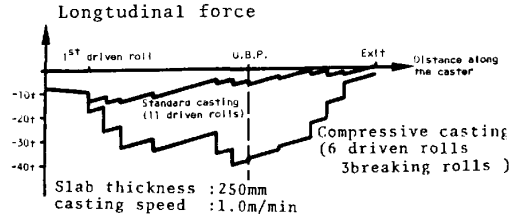


Fig.3 Longitudinal forces in the strand