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ASPECTS CONCERNING PRODUCTION OF DEFECTS OF SUPERFICIAL FISSURES TYPE IN CONTINUOUS STEEL CASTING

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Abstract. *In this paper, there is shown the mechanical process for the making of the superficial fissures to the continuous cast slabs by high strong steels. Also, there is presented the influence of the structure non-uniformity and chemical steel composition in the fissures making process. There are presented the principal measures for the prevention of appearing of the superficial fissures.*

Keywords: *continuous casting; fissures; embrittlement.*

1. INTRODUCTION

Presentation of the formation process of the fissures in continous casting plate slabs

The mechanic process that produces tension stresses is shown in figure 1. A bending process takes place at entering of the plate slab into curved wire zone and a straightening process takes place at exiting of the plate slab from the curved wire zone. This fact leads to states of stresses and successive deformations of ntension and compression which may favor production of fissures in the superficial layers of plate slab in conditions of low plasticity of steel.

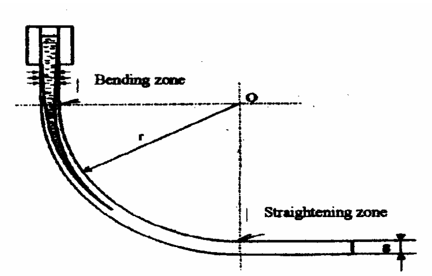


Figure 1. Diagram of steel passing into curved wire of continous casting machine

The ratio (**r/g**) is high (the necessary condition is that **r/g** > 6) so that the neutral fibre is overlapping the median fibre in the bending/straightening zone. So, the curvature radius of the neutral fibre is:

$$\rho_n = r + (g/2) \tag{1}$$

In the bending zone, state of stresses and deformations is analysed with respect to figure 2 diagram. The maximum deformation develops at the level of outside layer of the solidificated crust at the entering into the curved wire and it is calculated by relationship:

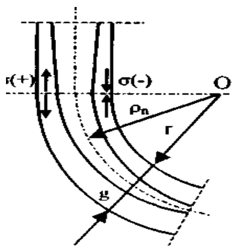
$$\varepsilon_{max} = g/(2\rho_n) = g/(2r+g) \tag{2}$$

The minimum deformation is:

$$\varepsilon_{min} = - \varepsilon_{max} = - g/(2r+g) \tag{3}$$

The tension stress develops in the outside marginal layers of the plate slab and it is calculated by equation of material strain hardness in given conditions:

$$\sigma_{max}(+) = \sigma_0(T) + A(\varepsilon_{max})^n \tag{4}$$



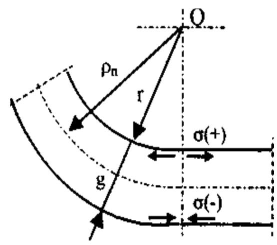


Figure 2. Bending diagram **Figure 3. Straightening diagram**

where: $\sigma_0(T)$ is the material deformation resistance in given conditions (at temperature of solidificated crust in the bending zone) ;

A – material constatnt;

n – strain hardness exponent.

In bending zone, the marginal material layers' temperature is high, from this point of view, material plasticity being quite high. In addition, in this zone, inside plate slab, in a large part of section, steel is found in liquid state.

So, local material deformation corresponds to bending of a tube having recatngular cross-section and filled by a fluid having the same density .

High material temperature in this zone and also reduced rigidity of the core favor deformation with no fissure. However, it should reminded that:

- marginal layers of the solidificated material develop plastic deformations which will be used as starting bases for the deformation that will take place in straightening..
- in bending process, there are developping tension stresses in exterior layers of solidificated crust and also there are developping compression stresses in

interior layers (located towards curvature center of curved wire). In straightening zone, state of stresses and deformation is analysed with respect to figure 3 diagram. At the exit from the curved wire, maximum deformation develops in the interior layer level of plate slab and it is calculated by relationship (3).
In straightening zone, marginal material layers' temperature is much more reduced and so, material plasticity is more reduced. In addition, in this zone, in the entire cross-section, steel is in solid state.
In straightening process, like it was shown there are developping compression stresses in the exterior marginal layers and tension stresses in the interior marginal layers. So, bending and straightening is alternant loading process specific to mechanic fatigue and although at high temperatures, adequation of stress takes place, plastic deformations still remain recorded in bending/straightening series, which, in certain conditions, may determine production of fissures nets in action zone of the straightening tension stresses.
Total deformation in the interior marginal layers of the plate slab, shown in figure 4, will be the sum between maximum and minimum deformation:

$$\varepsilon_{total} = \varepsilon_{\max} + \left|\varepsilon_{\min}\right| = 2\varepsilon_{\max} = 2g/(2r+g) \qquad (5)$$

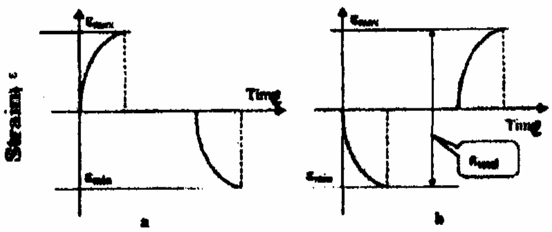


Figure 4. Deformation variation of marginal layers: a – exterior level; b – interior layer

In case of 250mm thickness plate slabs and considering ***r*** – radius of curved wire being equal to 10000mm there will be obtained a total deformation ε_{total} = 0,02439, meaning that total deformation is 2,439%. Apparently total deformation is not high. However, in conditions of low plasticity steel casting having limits of grains embrittled by presence of some inclusions and secondary phases on this limits and having in mind strong unlevelness of the structure in plate slab cross-section, fissures' nets could develop in solid crust. In reality, solid crust supports effective strains higher than the calculated ones. Total deformation calculus was made considering the fact that the material structure is uniformly and does not influence strain repartition on the plate slab thickness.

2. CAUSES THAT LEAD TO LOCAL EMBRITTLEMENT OF STEEL

Steel may have a fragile behaviour in marginal layers of continous casting plate slabdue to the following principal causes:

Chemical composition of Steel.
Constructions' steels having fine granulation, high resistance proprieties and alloyed by manganese, chromium, molybdenum, nickel, niobium, vanadium, titan, boron, aluminium have low plasticity. In state of material as supplied, these steels have the cracking elongation in amount of minimum 16-20%. These steels have cracking elongation by 3-4 times lower ,in casting state, so that the continous casting conditions should be severe and strictly respected. For some steels' grades, continous casting on regular casting machines, in normal technologic casting regime, may lead to an increased percent of plate slaby with fine superficial fissures, which are difficult to be observed in current control devices checking. For this reason, in case of these steels, there are necessary some special technical measures regarding functional-constructive principle of the continous casting machine and technological regime of casting.
Separation on grains' limits of the precipitation phases like carbides, carbonitrates, borides.
Precipitation phases on grains' limits have the role of stresses' concentrators and fissures' primes and, so, these have a negative influence over steel plasticity.
Local segregation, in crust, of carbon and other accompanying elements.
Steel's purity. Presence of fragile inclusions like sulphides, oxides, silicates, nitrides in marginal layers.
Unlevelness of structure.
In the cross-section of continous casting plate slab, there is a strong structure unlevelness, from the crust to the marginal layers, characterized by relative low dimensions of the crystalline grains, in the central zone of equi-axial crystals, passing through columnar crystals' zone. The structure unlevelness leads to strain behaviour variation. Columnar crystals behave like rigid solids which rotate in the time of bending and straightening, practically without to deform, and the crust should take over these rotations by deformation of grains in this zone. The consequence is high probability of producing fissures in plate slab crust.
In figure 5, it is shown this process by which there will be distinguished the rotations which are supported by columnar crystals the more accentuated as bending/straightening zone curve is higher.

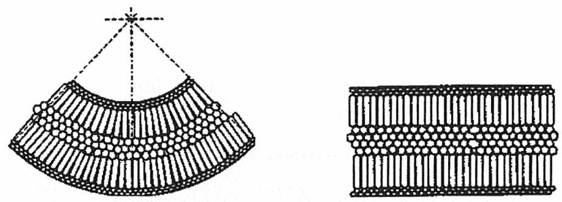


Figure 5. Modifications of plate slab structure in beding

Taking into account that bending and straightening processes are not reversible, namely, in straightening, columnar crystals do not return in initial positions, it results that strains supported by crust are higher and are

cumulating.
In addition, due to columnar ctrystals' rotation and curvature, tension stresses which act against crust are higher, like it is observed in figure 6, and determining relative high strains and, so, its possibility to fissure.

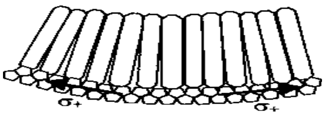


Figure 6. Tension stresses due to columnar crystals' rotation in bending and straightening.

3. PRACTICAL MODES OF PREVENTING OF PLATE SLAB CRACKING IN CONTINOUS CASTING

The necessary measures for preventing production of fissures cin continous casting plate slabs are the followings:
- Ensuring of an appropriate purity of steel
- Ensuring of mixing and corect degasing by argon bubbling in steel in the laddle
- Continuity and uniformity of steel jet in casting
- Crystalliser dust quality and corect distribution of this
- Active surface quality of crystalliser
- Uniformity of cooling water circulation in crystalliser
- Cooling uniformity, in plate slab cross-sections, in secondary cooling zone
- Avoiding of overcooling in secondary cooling zone
- Avoiding of undercooling in secondary cooling zone
- Avoiding of critical tension stresses, specially, in the straightening phase.

From the above causes, the more viable in continous casting process, in conditions in which the other causes act in acceptabile limits, is the las tone: avoiding of critical tension stresses in the straightening phase .
The modes by which critical tension stresses should be avoided in straightening zone can be:

- Vertical continous casting of plate slabs and blooming.s
- Increasing of curvature radius in straightening zone. This leads to high dimensions of continous casting machine.
- Progressive straightening of plate slab by series of straightenings and pauses. So, during a straightening phase, there is developping a stresses' state and a strain state having stresses and undercritical strains. In time of pause, relaxation and stress relief processes take place. The processes are successively repeating until the total straightening of continous casting product.
- Modification of state of stresses of continous casting product in the marginal layers by induction of compression stresses in order to reduce tension stresses' intensity and also, to determine even small compression stresses. .

It results that the most safest solution for total elimination of superficial fissures' devlopment danger, causes of discontinuities in thick plates, ist hat of controlling of tension stress developed in interior marginal layers of the continous cast product by induction of some superficial compression stresses.

4. CONCLUSIONS

Studies and researches have brought an important contribution for distinguishing of essential and real causes which lead to occuring of discontinuity defect.
So, there were resulted the following conclusions:

- Discontinuity defect manifest in one of the thick plate surfaces;
- Defect is producing, as preference, in case of thick plates made of steels having high mechanic resistance and low plasticity;
- Discontinuity defect aspect is of superficial tensioned fissures' type in rolling deformation process;
- Cause of defect is superficial fissures developed as consequence to critical tensile stresses developed in straightening proces sat exit of plate slab from curved wire zone;
- Superficial fissures are favored by reduced plasticity of high mechanical trength steels;
- The safe solution for elimination of superficial fissures in continous casting plate slabs and by this for ensuring of thick plates' quality, ist o modify the character of states of stresses developed in in straightening zone of continous csting plate slab.

5. REFERENCES

[1]. Butnariu, I. Continous Casting of Steel' Semi-products, Ed. Tehnica, Bucuresti, 1995.