Analysis of the Defect of Crack in Casting

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Abstract: ***This study addresses the different types of internal and surface cracks that can continuously form during steel casting. For each crack type, the operating and metallurgical factors known to influence crack formation are evaluated due to the high temperature mechanical properties of steel and knowledge of the stresses generated in the solidifying shell. The significance of two low ductility zones in steel is shown by this process. One area is above 1340 °C and all internal cracks and longitudinal surface cracks can be formed. The other regions are between 700 and 9000 °C and are associated with the presence of soluble aluminum, niobium and vanadium. In slabs, lateral surface cracks can be connected to the other latter region. This expertise, combined with an understanding of the stresses produced by continuous casting, makes it possible to propose mechanisms of crack formation and relate them to operational and metallurgical variables.***

Keywords: Crack formation, casting, steel, carbon, stress, internal cracks, Metallurgical factors.

INTRODUCTION

Crack formation in the continuous casting of steel has long been considered as a problem. Cracks were observed in cast steel sections at almost every conceivable location as shown in Fig. 1. In the interior, cracks can be seen diagonally at the edges, in the middle line, or between opposite corners. Transverse and longitudinal cracks will occur on the surface in both the mid-face and corner regions [1].

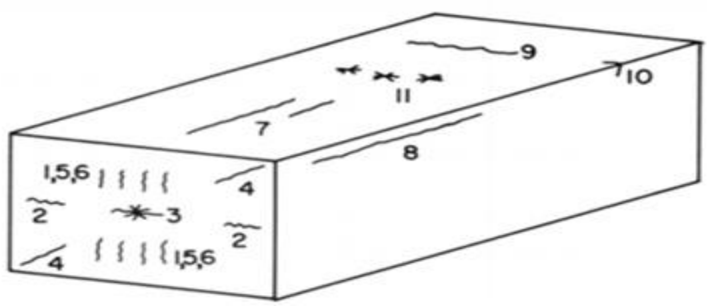

Fig. 1 Schematic drawing of casting showing different cracks

The reason for the proliferation of crack types lies in the nature of the method of continuous casting itself. Continuous casting has gained widespread popularity because it can extract heat by integrating mould, sprays and radiant cooling at a remarkable rate. Nevertheless, high temperature gradients in the solid shell result from rapid cooling, which can also alter quickly as the shell expands or contracts. However, because the semi-solid section is required to move through the process, a number of mechanically induced stresses resulting from friction in the mold, roll pressure, ferro-static pressure, system misalignment, bending and straightening operations are subjected. Depends entirely on the severity of these stresses and strains, crack formation can occur.

Much has been reported about the causes and treatments of these different kinds of cracks. Nevertheless, in this body of literature, which included a number of reviews, there was a tendency to regard each type of crack, mainly from an organizational point of view, as a separate issue. There have been few serious attempts to deeply analyze crack formation in more profound terms by linking the existence of cracks not only to operating stresses and strains, but also to the mechanical properties of steel at continuous casting temperatures. From such a point of view, the present review has been undertaken to examine the cracking problem [2][3].

Attribute To Crack Formation and Characteristics of the Material

Stress and strain in continuous casting:

The essence of the stresses and strains that can create a crack in the shell. In the mould, axial stresses are described in the shell due to friction between the oscillating mould surface and the shell surface. When the mould moves upwards relative to the shell and when the relative motion of the mould is downwards, these stresses, which involve axial and bending stress, become tensile. This has been illustrated in the figure 2.

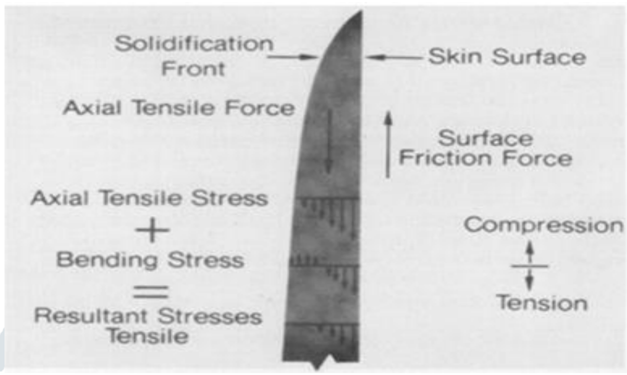

Fig. 2 Schematic Drawing Of Axial And Bending Stresses In The Solid Shell Resulting From Frcition In The Mold

The ferro static pressure provides the normal friction force which, as the shell cools and shrinks, also generates tension in the transverse plane. The transverse stresses are easiest to picture in the mid face region where they are tensile with the highest stresses occurring near the surface. A similar stress pattern is likely near the corner, but less certain about the form of stress is the presence of a well-defined air gap [4]. Thermal stresses in and beneath the mould are created by changing temperature gradients in the shell. These are usually tensile on the front of the solidification, which is coldest and compressive. As shown in Fig. 3, the resulting stresses are tensile at surface and at the solidification front it will be compressive. However, this situation can change rapidly if rolls lower in the process are poorly spaced as they deform the bulged shell on the solidification front and set tensile stresses. If a set of rolls is gapped too narrowly, similar stresses can arise [5] [6].

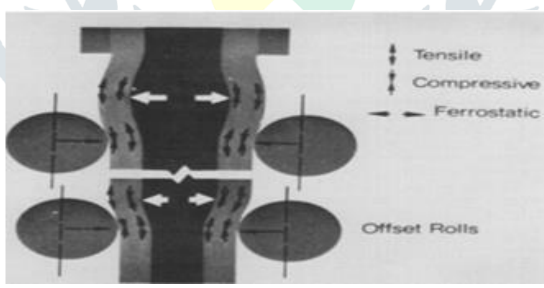

Fig. 3 Axial stresses in the solid shell

High temperature mechanical properties of steel:

At high temperatures, several variables affect the mechanical properties of steel: temperature, chemistry of steel, structure, strain intensity, and thermal background. With the number of variables involved, it is not surprising that the strength and ductility of steel are imperfectly understood under continuous casting conditions. Nevertheless, in understanding crack formation, the studies carried out show a picture of mechanical behaviour of considerable value. Taken together, they show that steel has low strength and/or ductility in three different temperature ranges and is thus vulnerable to cracking [7]. There is ample evidence to suggest that the strength and ductility of steel decreases markedly at temperatures above about 1340 °C.

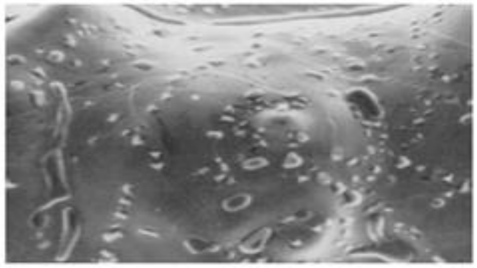

Fig. 4 Scanning Electron Micrograph of Surface of a Crack Formed

The low strength and ductility tends to be due to the presence of liquid films in inter dendritic regions that do not freeze until temperatures well below the solidus are reached. Obviously, the liquid films contain high levels of arsenic, phosphorus, and other elements that have a lower than unity segregation coefficient and are distributed between the rising dendrites as illustrated in figure 4. This is a scanning electron micrograph of the inside surface of a crack developing at the temperature of the solidus [8]. The surface smoothness, without any signs of fracture, is indicative of the presence at crack formation of a liquid film.

Analysis of crack formation:

If the information on stresses and mechanical properties in the two preceding sections is combined with practical knowledge from a continuous casting process, the cause of a particular type of crack can be evaluated. From plant observations, the location and orientation of the cracks can be determined along with the operational factors that have been thought to cause and cure the cracks. It is then possible to analyze and evaluate possible causes of tensile stress to determine if the stresses act on fragile and non-ductile solid shell areas, resulting in cracks in the observed field. With regard to mechanical properties, it is generally possible to consider only the high and low temperature zones with low ductility, as the intermediate temperature zone has not been sufficiently connected to continuous casting [9].

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- *Midway cracks:*

Midway cracks, or as they are often called, can be found in sulfur prints and transverse section macro etches, similar to shown in Fig.5. In an area roughly halfway between the surface and the centerline, they appear as dark lines running regular to a given face [10].

Fig. 5 Sulfur Print of Transverse of Billet

CONCLUSION

This study sought to combine plant expertise on crack formation in continuously cast steel with basic knowledge of stress generation and steel's mechanical properties at high temperatures. This has shown that the observed cracks are likely to be related to two regions of low steel ductility: a high temperature zone above 1340 °C, which tends to be responsible for most cracks, including all internal cracks; and a low temperature zone between 700 and 900 °C, which causes transverse surface cracking issues. Combined with an understanding of the stresses produced in continuous casting, this knowledge allows to propose crack formation mechanisms and relate them to operational and metallurgical variables.

REFERENCES

[1] D. Klobčar, L. Kosec, B. Kosec, and J. Tušek, "Thermo fatigue cracking of die casting dies," *Eng. Fail. Anal.*, 2012.

[2] "Modeling of Stress, Distortion, and Hot Tearing," in *Casting*, 2018.

[3] M. Muhič, J. Tušek, F. Kosel, D. Klobčar, and M. Pleterski, "Thermal fatigue cracking of Die-casting dies," *Metalurgija*, 2010.

[4] K. L. Scotti and D. C. Dunand, "Freeze casting – A review of processing, microstructure and properties via the open data repository, FreezeCasting.net," *Progress in Materials Science*. 2018.

[5] J. Campbell, "Cracks and tears," in *Complete Casting Handbook*, 2011.

[6] B. G. Thomas, "Review on Modeling and Simulation of Continuous Casting," *Steel Research International*. 2018.

[7] D. Tomus, P. A. Rometsch, M. Heilmaier, and X. Wu, "Effect of minor alloying elements on crack-formation characteristics of Hastelloy-X manufactured by selective laser melting," *Addit. Manuf.*, 2017.

[8] S. Kumar, A. Gupta, and A. Arya, *Triple Frequency S-Shaped Circularly Polarized Microstrip Antenna with Small Frequency-Ratio*. 2016.

[9] E. N. Kumar and E. S. Kumar, "A Simple and Robust EVH Algorithm for Modern Mobile Heterogeneous Networks- A MATLAB Approach," 2013.

[10] J. Campbell, "Sixty Years of Casting Research," *Metall. Mater. Trans. A Phys. Metall. Mater. Sci.*, 2015.