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ANALYSIS OF INTERNAL DEFECTS APPEARED IN THE CONTINUOUS CASTING

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Abstract. *The paper presents the study of internal defects resulting from the continuous casting of steels. The 50 samples were taken from a total of 20 continuously cast bits of different steel grades. The investigation of the causes of internal defects, shown on the analyzed samples, started from the assumption that the secondary metallurgy was performed correctly. The following internal defects have been evident: internal cracks (axial cracks, section cracks), central porosity and marginal punctuation impurities.*

Key words*:* *internal cracks, central porosity, marginal punctures, continuous casting*

1. INTRODUCTION

The economic importance of the hot sectors results from the use of processed products, represented by laminates, forged, molded, cast, sintered parts, etc. in almost all areas of social life, but especially in machine building, civil and industrial construction (bridges, dams, halls, dwellings) [1,2,3]. World trade in steels and products made in warm sectors is a barometer of the overall world economic development, as goods in this category have a wide use. In 2017, Romania's steel production increased by about 50% compared to the same period in 2010, due to the investment policy of representatives of the large steel groups that are present in Romania and have invested in the acquisition of technologies in order to obtain quality steel such as: ARCELORMITTAL, MECHEL, TMK and TENARIS.

Over the past 21 years, world steel production has almost doubled, growth is boosted by emerging and not developed countries (France, the UK now produces less than in 1989, the US, Japan and Germany stagnated, and India's production and China rose 4.5 times, 10 times).

According to the World Steel Association data, 1.4 billion tons of steel were produced worldwide in 2010, and Romania ranks 34th among producer countries (China, with 44% in world production, followed by Japan with 7.8%, the United States with 5.7% and Russia with 4.7.Continuous casting of metals, especially steel, is a process increasingly used nationally and globally due to the major advantages it has compared to conventional casting. Thus, the modernization and optimization of the continuous casting process and equipment, including the extraction facilities for semi-finished products, is an intense concern of the field research .[3,4,5,6,7]. So the development of all industrial branches has led to a growing demand for steel, which has led the steel industry to develop a lot and to seek solutions for modernization, as well as for the production of high quality and precision products.

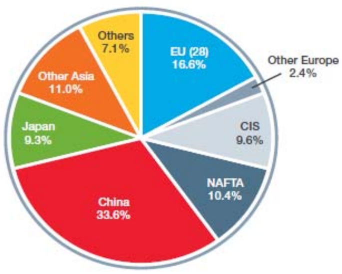

Figure 1. Continuous cast steel production in 2006

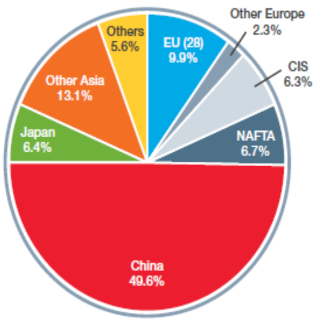

Figure 2. Continuous cast steel production in 2016

Following the continuous cast steel production from 2006 to 2016, worldwide we find that the largest quantity of continuous cast steel is provided by China, as shown in figures 1 and 2. China's share of the world's production is about 50%, and the quantity of steadily cast steel in the EU countries drops from 16.6% to 9.9%.

The upgrading action of the global steel industry is aimed at introducing or expanding more efficient, environmentally-friendly or low-emission technologies, such as the continuous casting process [7,8, 9,10].

The main factors that accelerated the expansion of modern continuous casting technology can be synthesized as follows:

1. Making products that meet the demands of top techniques (cosmonaut, electronics, military, nuclear, etc.).
2. Environmental protection and disruption of biological cycles.
3. Increasing labor productivity.
4. Reduce material expenses.
5. Adaptation of the quality criteria to the increased demands of the users of the products.

In the fully integrated modern steel manufacturing processes, the continuous casting of steel semifinished steel is gaining ground in classical ingot molding due to dimensional precision, surface quality, superior energy recovery, precision of chemical composition control, and the amount of inclusions non-metallic, which results in a material purity of only a few ppm. Through continuous casting process carbon and alloy steels are cast, electrotechnical steels, corrosion-resistant steels etc.

There are still problems, without which it is not possible to achieve the efficient casting of different grades of steel through this process [1, 8, 10]. One of these problems is to ensure the superior quality of continuously molded semifinished products, related to axial segregation, porosity and so-called V-shaped segregation [10-13].

Other problems are related to the appearance of surface defects, internal defects, predominantly determined by suf-fers and non-metallic inclusions. Compared to classical cast ingots, for continuous casting of the same steel brand, the total amount of non-metallic inclusions in continuous castings is usually higher.

2. DEFECTS APPEARING ON CONTINUOUS TURNING

Internal cracks occur in areas with low mechanical strength of the material, under the individual or combined action of mechanical, thermal and phase transformations. The greatest likelihood of internal cracks is in the liquidus solidus transition area. These are generated by exceeding the limit values of plating or elongation, during metal stress due to the fluorescence pressure of the column of liquids, as well as the drive and straightening forces in the extraction-straightening unit.
In the free spaces created thus penetrates the liquid metal enriched in segregation elements, forming interdentritic zones of composition different from the rest of the metallic mass.

The crack susceptibility increases with the increase in the content of the elements: C, Mn, Sn, P, S. Increasing the carbon content of the steel, especially over 0.7% increases also the risk of cracking, increasing the difficulty of casting. In the carbon content of 0.17-0.25% the decrease of the elongation causes a tendency of cracking [1, 7, 8, 10].

Particularities of elaboration: insufficient boiling or decarburization beyond the indicated limits as well as molding characteristics such as: the degree of turbulence of the steel jet in the crystallizer, influence the formation of the cracks [1, 4, 10, 14].

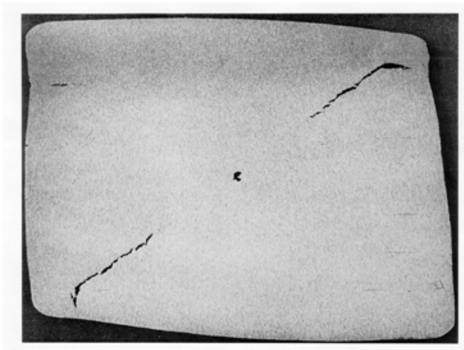

Figure 3. Cracks on diagonal

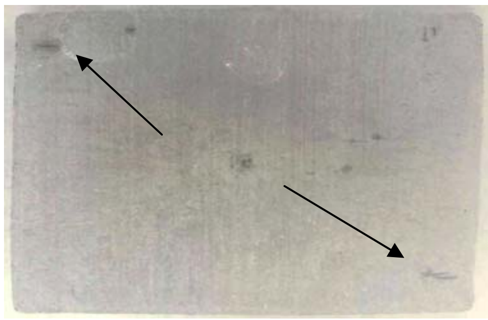

Figure 4. Surface cracks

Figure 5. Central cracks

The origin of retardation and porosity is in the solidification process. Their occurrence is caused by a too sharp angle of the solidification cone due to excessive casting speed and too intense cooling. By reducing the casting speed the porosity is reduced and dispersed.[10] Retaining and porosity depend on: steel composition, casting speed, overheating of steel and the size of the blank [1, 10].

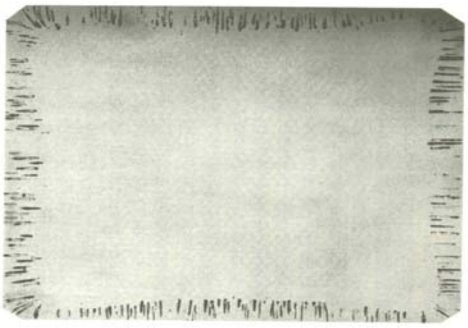

Figure 6. Retaining

3. EXPERIMENTAL PART

Sampling was done from continuous casting billets under normal conditions, ie excluding the bits from the beginning and end of the batch. Samples of 20 continuously shielded castings were sampled over a calendar month of the following steel grades listed in Table 1:

Table 1. Steel brands analyzed

Brands	No. sample	No. charge
AH36	11	4
BST500S	9	3
S235J2	3	1
S355J2	6	2
C40E	2	2
C45E	2	1
45	2	2
20MNV6	3	1
18HGT	3	1
40H	6	2
40CR10	3	1

The investigation of the causes of internal defects, shown on the analyzed samples, started from the assumption that the secondary metallurgy was performed correctly.

After analyzing the 50 samples, the following internal defects were highlighted: internal cracks (axial cracks, cracks per section), central porosities and marginal punctual impurities.
The central porosity can form if there is insufficient liquid to feed the contraction that occurs during solidification. Chances of occurrence are increased by high casting velocity and intense secondary cooling which can generate equiaxial grain crystals at the center of the billet before the column crystal growth front.

For the ease of highlighting internal defects in figures and graphics, the 20 batches were denoted in letters from A to U as shown in Figure 7.

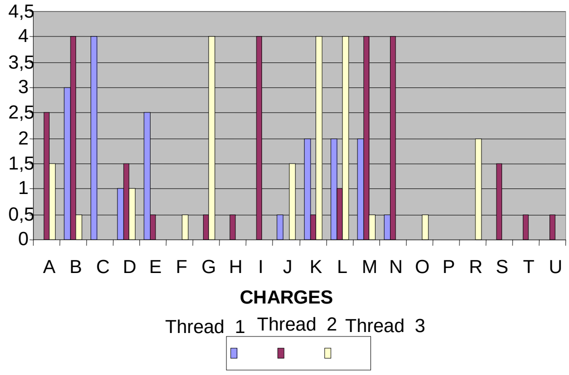

Figure 7. How to allocate central porosity for the 20 charges

It is noted, according to figure 7, that after continuous casting, thread 2 and yarn 3 have maximum points.

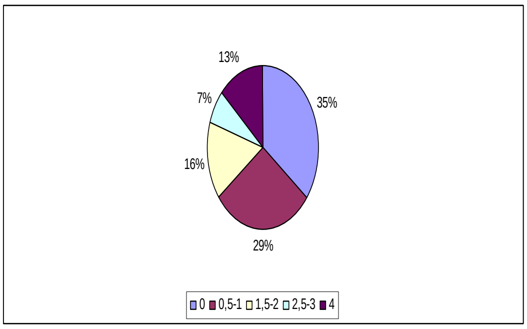

Figure 8. The central porosity score for the 50 analyzed samples

According to figure 8, it is found that for 35% of the analitic balls the score is zero and for the remaining 65% the central porosity score was between 0.5 and 4. The main cause of IPM (Marginal Punctuation Impurities) is reoxidation. Anywhere in the system there is the possibility of reoxidation, there will be a macroinclusion.

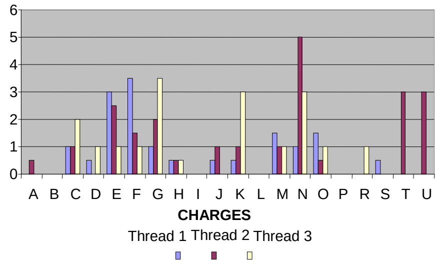

Figure 9. PM analysis for the 20 charges

Figure 9 shows how marginal point impurities are distributed over the 20 batches analyzed where it is found that the largest share of these defects is at thread 2.

From Chart 10 it is found that 28% of the analyzed samples have no impurities and the remaining up to 100% have this type of defect with scores ranging from 0.5 to 4.

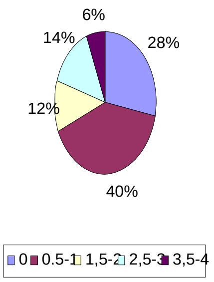

Figure 10. IPM score for the 50 samples analyzed

Between the casting pot and the distributor, the steel protection is made with a submerged tube. There are cases where the opening of the casting pot requires the use of oxygen when the tube is removed and there is a risk of reoxidation.

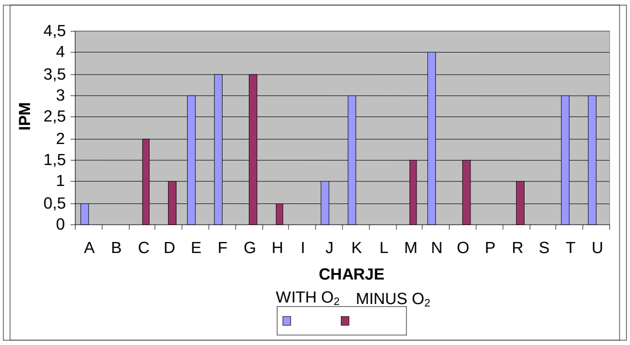

Figure 11. How to open the pouring chamber

Figure 11 shows that the emergence of IPMs is most common in oxygen-exposed charges.

The steel protection between the distributor and the crystallizer is achieved by means of immersion tubes and crystalliser dusts.

The immersion tubes are made of graphite-based composite materials with a protective insert.

This insert contains ZrO, which has a melting temperature of 2700° C and is not wetted by slag.
During casting, erosion of refractory materials in the distributor, including protective tubes that cause the production of inclusions in steel, occurs.

The durability of these tubes is relatively short of a maximum of 10 castings.
Another cause for the emergence of IPMs is the entrainment of coating dusts from the distributor and the crystalliser dusts into the liquid steel due to their incorrect immersion and due to the eddy currents.

4. CONCLUSIONS

After the research of the causes of the internal defects encountered in the analyzed samples, some actions are required to diminish the quantity of these defects and increase the productivity.

Internal cracks and central porosity do not pose any problems because the hot plastic deformation process disappears, but non-metallic inclusions cause great damage to finished products.

The injection of casting powder into liquid steel when it is cast at high speed is a problem with respect to the number of non-metallic inclusions in the continuous casting, electromagnetic stirrers, and the electromagnetic braking process as a solution to reduce the number of inclusions.

The use of primary electromagnetic agitators reduces the content of non-metallic inclusions, and the use of final electromagnetic stirrers (located below the secondary cooling zone) reduces the occurrence of central porosity.

The implementation of electromagnetic braking technology would lead to some advantages such as:

- favoring the exit of the meniscus surface of the Ar bubbles and non-metallic inclusions, which can be captured in the casting powders,
- preventing the casting of the casting powder in the liquid steel by stabilizing the fluctuating level of the steel in the crystallizer.
- stabilizing the meniscus of the liquid steel in the crystallizer,
- increasing the temperature of the steel under the meniscus,
-controlling the flow of molten metal through the immersed tube by reducing the flow rate,
- uniformization of the melt slag thickness as a result of the reduction of the meniscus movement speed.

REFERENCES:

[1] O. Florea s.a., Teoria Proceselor Metalurgice, Ediția a-2-a, Editura Didactică și Pedagogică București, 1984.

[2] C.O. Rusănescu, M. Rusănescu, F.V. Anghelina, V Bratu, The influence of the micro-alloying elements on physical and structural characteristics of the some steel destined for manufacturing the oil pipes, Romanian Reports in Physics, Vol.68,no.1, 278-293, 2016

[3] J. H. Chesters, Refractories for iron & steelmaking, The Metals Society, London 1974, pp. 406-407.

[4] V. Bratu, Metode experimentale și procedee privind îmbunătățirea calității semifabricatelor turnate continuu, Editura Științifică F.M.R., București, 2003.

[5] C.O. Rusănescu, M.Rusănescu, Traian Iordanescu, V. Anghelina, Mathematical relation ships between alloying elements and technological deformability indexes, Journal of optoelectronics and advanced materials, Vol.15, No.7-8, 718-723, 2013.

[6] E. Popa, T. Heput, E. Ardelean, A. Socalici, Identifying the main defects appeared in the structure of continuous blanks, International journal of systems applications, engineering & development Issue 1, Volume 6, 2012.

[7] N. Oargă, T. Heput, E. Ardelean, E. Popa, Study on internal defects continuously cast blanks, Annals of Faculty of Engineering from Hunedoara, tom III, fasc.1, 2001.

[8] E. Ardelean, M. Ardelean, A. Socalici, T. Heput, Simulation of continuous cast steel product solidification,Rev. Metal.Madrid 43, 181– 187, 2007.

[9] V. Bratu, I.N. Popescu, The Mathematical Model Applied to Solidify and Segregation of Ledeburite Tool Steel Ingots, Scientific Bulletin of Valahia University-Materials and Mechanics 15 (12), 28-31, 2017.

[10] V.Vrabie, C.Bratu, I.Chira, Tehnologia Elaborării şi Turnării Oțelului, Editura Didactică şi Pedagogică Bucureşti, 1979.

[11] S.Mckay, N.S. Hunter, A.S. Normanton, V.Ludlow, P.N. Hewitt, B.Harris, Powder evaluation for continuous casting , Ironmaking and Steelmaking 2002, vol. 29, Nr. 3, p. 189.

[12] K. Kim, H. N. Han, T. Yeo, Y. Lee, K. H. Oh, D. N. Lee, Analysis of surface and internal cracks in continuously cast beam blank, Ironmaking and Steelmaking 1991 Vol. 24 NO. 3 p.249

[13] Y. Tanizawa, Factors of decarburation in continuous casting of ulc steels and the remedies. Camp Isij, vol. 4, 1991, p. 257.

[14] Ghe. Ioniță, E.V.Stoian, Heat flow in solidification, Buletinul Universității Petrol-Gaze din Ploieşti,ISSN 1224-8495, 87-92, 2006.

[15] K.Koyama, Y.Nagano, K.Nagano, T.Nagano, Physico-chemical properties of powders used for continuous casting, N.S.T.R. nr. 34, July 1987.

[16] Yu, X., Pomfret, R. J., Coley, K. S. Dissolving alumina in the crystalliser powder , Metallurgical and Materials Transaction B , vol. 28, 1997.