J. PIEPRZYCA

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CAST STRAND'S STRUCTURE QUALITY RESEARCH IN RESPECT TO METHOD OF THE LIQUID STEEL FLOW THROUGH CC DEVICE'S TUNDISH

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CC process has great importance on achieving high quality cast strands. On this stage of production last metallurgic interventions are wage, which regards to liquid steel and also primary structure of the solidifying steel ingots forms. This article presents results of the research, that applies to influence of the liquid steel mixing method in tundish on steel ingots' primary structure. Study of the flow conducted on physical model of the triple-stranded tundish, which provided results formed as RTD curves. Generated curves were put together with primary structure's metallographic test results of the individual cast strand 's cast in actual CCM. That listing allows to valuate influence of the liquid steel mixing method in tundish on steel ingots' primary structure quality.

Key words: tundish, steel flow, quality, physical modeling, RTD curve

INTRODUCTION

High quality of the steel is one of the main requirements for its producers. Therefore, the aim is to continuously improve its production of technologies, which are still conducted. This applies to every stage of production. One of them is CC process. This process is particularly important in the development of the steel ingots quality. At this stage of the production final metallurgical treatment of liquid steel are conducted and the structure of the primary solidification of ingots shapes. The Department of Metallurgy at Silesian University of Technology for many years carried out research on the optimization of the CC process. It is carried out using the techniques of physical and numerical modeling. Mainly concerned with issues related to the hydrodynamics of the liquid steel flow through tundish and the mixing phenomenon in the crystallizer. The results of model tests conducted so far lead to the conclusion that there is a relationship between the hydrodynamic conditions of flow of steel through tundish and a way the primary structures of ingots shape. This provides the rationale to undertake research to confirm or exclude the foregoing statement. Model tests were conducted in the three-stranded tundish obtaining results in the form of RTD curves.

These curves are characterized by the conditions of homogenization and the flow of steel for each stroke of tested tundish. The results were compared with the metallographic results of primary structure of the original samples taken from the relevant strands of continuous ingots cast on the actual COS device. This summary allows to estimate the influence of the method of mixing the steel in the tundish and the quality of ingots structure.

DESCRIPTION OF THE COS DEVICE USED IN TESTS

Device used in research is intended for casting molten killed steel in an electric arc-furnace and treated outside the furnace. The obtained ingots (cross-section 100 × 100, 120 × 120, 140 × 140, 160 × 160, 140 × 165 and ϕ 170) are intended for further processing in both steel works branches as well as in external recipients. A characteristic feature of the device is unusual, asymmetric three-strand trough-type tundish with nominal capacity of 10 Mg. View of the tundish is shown in Figure 1. Radius of the device's arc is 6 m, and the production capacity of 350 000 t / year. The length of the sequence depending on the order is from 2 to 15 heats.

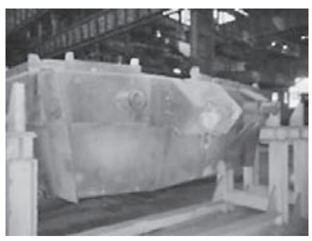

Figure 1 View of three-stranded tundish

MODEL TESTS

Industrial practice related to steel casting with use of described tundish pointed to the process disruption in

J. Pieprzyca: Silesian University of Technology, Department of Metallurgy, Katowice. Poland

the region of extreme stroke - the furthest edge from infusions zone. These issues were caused by the construction of a physical model of described device. The model was made basing on many years of experience with constructing this type of laboratory stands, both own and achieved through collaboration with other research centers [1 – 6]. It has character of the water segment model. To determine the similarity criteria the method of dimensional analysis was used. While for determining the similarity of the kinetic for flow of water to the liquid steel scale method was used. As a tracer the aqueous solution of $KMnO_4$ was used. Thanks to the original construction of concentration of the tracer in the water sensors and the application of the video cameras to register experiment obtained results are twofold: visualization and RTD curves. Model studies are conducted in series, each including several experiments for the same variant of tundish model equipment. The repeatability of model liquid flow parameters is assured by the construction of the physical CC machine model. The hydraulic system of the model is furnished with the following valve pairs:

- a control valve – connected with a flow meter (required model liquid flow rate can be set),
- an opening-closing valve – a binary (zero-one) solenoid valve used during the experiment.

This set valve is installed both on the tundish model inlet and on its individual nozzles. The opening-closing valves are remotely operated. It the makes easier carry out the experiment.

Diagram of tundish model shows Figure.2.

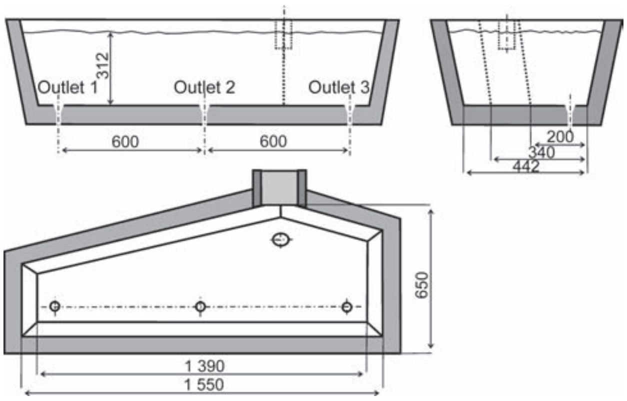

Figure 2 Diagram of tundish model.

The model research aim was to determine the way of flow and mixing of the steel in the tundish. The results of these tests in the form of sample images from the visualization experiment part, and the RTD curves shows Figures 3 and 4.

On the basis of model tests' results can be stated that, although the time to reach the tracer for strokes 2 and 3 is similar, it is much longer in the case of first stroke This leads to the formation of negative phenomenon in the form of large dead zones in tundish's area. The kinetics of steel mixing in this region is also very limited. In industrial conditions the observed phenomenon can cause interference during conduction of the casting process.

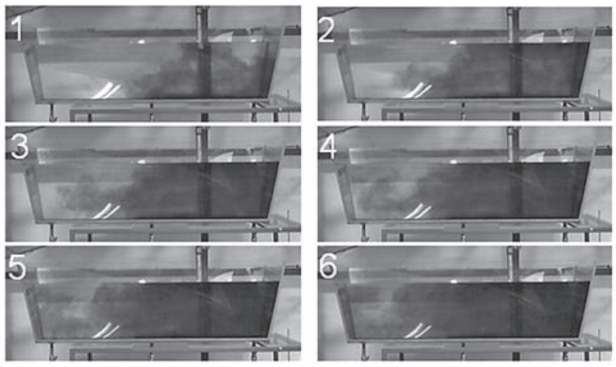

Figure 3 Tracer expenditure in the tundish model (Variant A) after time: 1) 10 s, 2) 20 s, 3) 30 s, 4) 40 s, 5) 50 s, 6) 60 s.

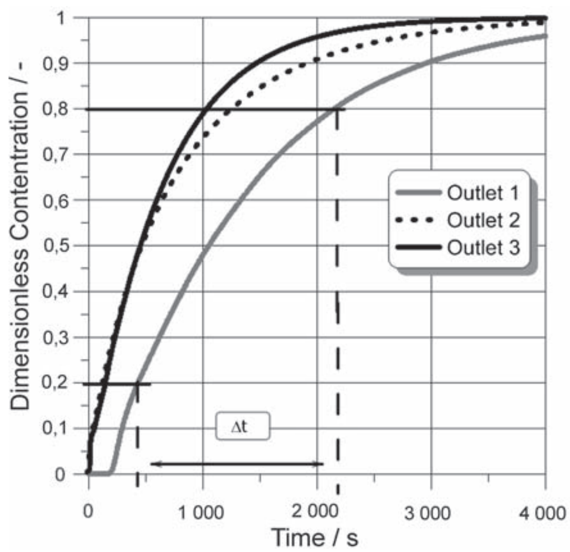

Figure 4 Steel residence time curves type of F in the tundish.

Nozzle number 1 is especially exposed to the obliteration and in extreme cases (as a result of adverse heat's effects) to freeze and ultimately the need to cut the cast vein. It is also expected that the described adverses hydrodynamic and heat observed in the region of number 1 stroke have an impact on the quality of the original structure of the cast ingot. Size of each crystallization zones (frozen crystals, bar and evenly axial) may differ from the surface of these zones in the ingots cast in the veins 2 and 3. To objectively determine the impact of the adverse hydrodynamic events in the area of stroke number 1 observed during the model tests, on the quality of the original structure of the obtained ingot was decided to conduct control tests in industrial conditions.

INDUSTRIAL RESEARCH

Industrial research has had a control character. It rely on taking samples from ingots in the form of template and further processing them to conduct metallographic tests.

In research steel heat No. 68 929 was used, with consist of chemical composition: C = 0,11 %, Mn = 0,55 %, Si = 0,17 %, P = 0,016 %, S = 0,012 %, Cu = 0,29 %, Cr = 0,05 %, Ni = 0,09 %, Mo = 0,01 %, Ti = 0,002 % , V = 0,002 % Sn = 0,018 %, Pb = 0,001 %, Ca = 0,002 %, N = 120ppm. The steel cast's liquidus temperature is 1 517 ^{o}C, and the casting temperature was 1 559 ^{o}C. Cast ingot size is 120 × 120 mm. Smelting cast with use of feeder technique and crystallizer's wall lubricated with rapeseed oil. Feeder's channel diameter was 16 mm. The stream of steel from the main ladle to tundish was protected by a ceramic pipe. Convex crystallizers were used with 801 mm of height and 6000 mm radius of the arc.

From the point of view of the research conditions correctness some of the technological parameters of casting have not been preserved. This was due to the need to ensure a safe process and to avoid losses in the production. As the researches were only conducted in control character there was a decision to carry out experiments according to the crew that operate the device.

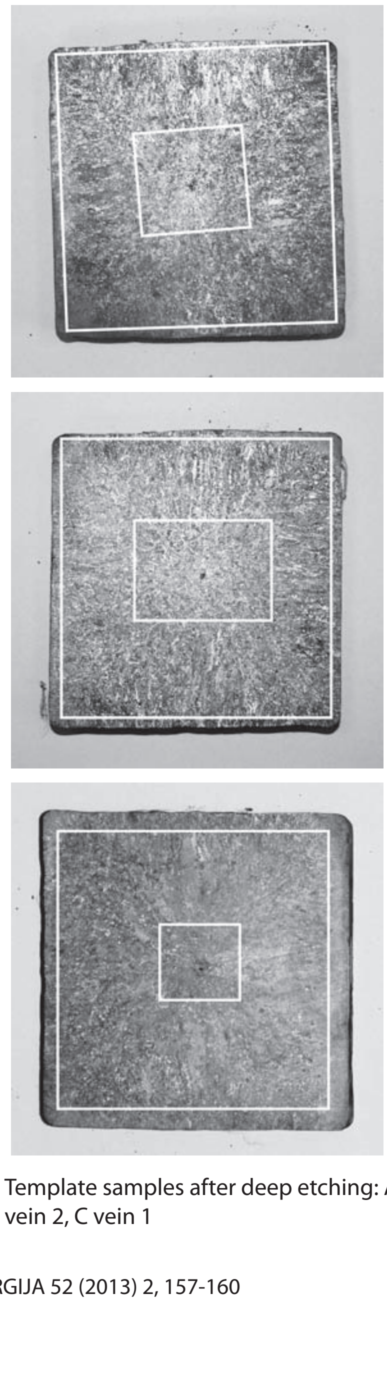

Figure 5 Template samples after deep etching: A vein 3, B vein 2, C vein 1

And so, during casting process electromagnetic mixers were used, which were installed on crystallizers with current strength of 340 A and frequency of 5,5 Hz. Another factor that affected the results was the difference in casting speed of individual veins resulting from the different parameters of the primary cooling (crystallizers). These differences result from many years of experience of the crew on steel casting in asymmetric ladle. Casting speed of the individual veins were: vein 1 = 2,88 m/min, vein 2 = 3,28 m/min, vein No. 3 = 3,00 m/min. Water flow velocities in the relevant crystallizers were: crystallizer 1 = 1 706 m/min, crystallizer 2 = 1 752 m/min, crystallizer 3 = 1 760 m/min. Secondary cooling was the same for all veins. Water flow velocity in particular zones were: spraying ring 187 m/min, the first zone and 278 m/min, the second zone 161 m/min.

From each ingot samples have been taken of length 200 mm for metallographic analysis. Samples were taken from three zones of ingots - beginning, middle and end of melting.

Figure 5 shows examples of the samples prepared for metallographic analysis after deep etching.

After analysis of metallographic images was stated slight deterioration of ingot's primary structure cast from No. 1 vein..

CONCLUSION

Research on improving the quality of the primary structure of the ingots cast in a continuous manner are now essential. Influence on the formation of this structure has many factors. One of them is method of flowing and mixing of the steel in the tundish. The nature of this flow determines the effectiveness of processes in the liquid steel just before it's solidification. This concerns the homogenization of both the chemical and temperature. Especially in the asymmetric tundishes preserve of identical chemical conditions, above all heat in individual strokes poses many problems.

So far this problem has been considered mainly from the technological point of view of the ongoing process. Ensure continuity of its duration in long sequences, ie. fouling risk elimination and freezing of threatened strokes. It should be noted the influence of chemical and thermal heterogeneity of steel, resulting from the improper flow and method of mixing in the tundish, on the quality of cast ingots' primary structure. The results of the researches presented in this article suggest validity of continuing.

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Note: The responsible person for English language is: J. Kuc, Poland