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QUALITY IMPROVEMENT OF CONTINUOUSLY CAST ROUND BILLETS

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Preliminary Note – Prethodno priopćenje

Paper is focused on the observation of the conditions causing defects origin in continuously cast billets in the first phase of solidification and shell formation in the mould. Work is also focused on the area of casting failures. Experiences were aimed at steel preparation for casting from the viewpoint of desoxidation and modification of inclusions, facility influence on solidification and formation of shell, influence of the taper of the mould, and on vibrations influence and origin within primary cooling system – oscillation mechanism – mould. The method of measurement was tested, incl. the analysis of acoustic spectrum for phenomena assessment within continuous casting. Conclusions resulted in modification and changes of shapes of moulds, incl. casting technology of round billets.

Key words: continuous cast, round billets of steel, solidification, casting failures, mould

Poboljšanje kakvoće kontinuirano lijevanih okruglica. Članak je usmjeren na sagledavanje uvjeta uzroka izvornih grešaka u kontinuirano lijevanim okruglicama u prvoj fazi skrućivanja i formiranju kore u klistarizatoru. Rad je također usmjeren u područje lijevačkih pogrešaka. Cilj je u iskustvu pripreme čelika za liejvanje sa gledišta dezoksidacije i modifikacije uključaka, olakšavanju utjecaja skrućivanja i stvaranja kore, utjecaj zakošenja kristalizatora i na utjecaj vibracija na početak unutar primarnog sustava hlađenja, mehanizam titranja – kristalizator. Metode mjerenja su provjeravane uključujući analizu akustičnog spektra za fenomen 'procjene pojava unutar kontinuiranog lijeva. Zaključni rezultati su u modificiranju i promjeni oblika kristalizatora, uključujući lijevačku tehnologiju okruglica.

Ključne riječi: kontinuirano lijevanje, čelične okruglice, skrućivanje, lijevačke pogreške, kristalizator

INTRODUCTION

Heat flow measurement and research of influence of primary cooling conditions on shell formation at different casting speed that had been carried-out on billet square mould with a parabolic taper were the basis for works dealing with the issues prevailing during round billets casting. Experiments have been carried-out with round parabolic mould by using of which many defects during casting have been detected and removed including some surface defects.

At the same time, use of the same round-shape mould has been investigated for steel with a different carbon content (peritectic steel and medium-carbon steel), and different conditions for casting have been set in order to eliminate breakouts of steel including billets suspending in mould and longitudinal depressions occurrence caused by deformation of billets.

One of prevailing issues having been known for a longer period of time, nevertheless, significance of which growths at higher casting speed, is casting of steel with carbon content in the range of 0,09 – 0,14 vol. % - often incorrectly called peritectic steel (carbon content lies in Fe-C diagram approximately in the area of peritecticum even though peritectic reaction occurs at steel having carbon content in the range of 0,1 – 0,5 vol. %). Such issue is complicated for shapes being difficult to be cast with higher speed e.g. casting of round blooms and billets.

The need to address the issue prevailing with billets quality at higher casting speed and casting of new sizes came out of shut-down of those rolling mills that had re-rolled blooms with greater cross-section to required smaller sizes and shapes. In terms of costs, such technology cannot compete with direct rolling of continuous cast billets on finishing rolling mill – often immediately after casting as the direct-rolling process in hot status.

Efforts to go-around such issue by a change in chemical composition have been successful for one part of product mix only. Customers´ requirements do not allow using such method for the entire production.

Searching for correct mould shape and mould oscillation parameters that resulted at high-speed billet facilities in a convex shape is one of many ways that did enable to eradicate the above-mentioned barriers.

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CARRIED-OUT EXPERIMENTS & ACHIEVED RESULTS

Mould shape influence on heat outlet has been investigated during round billets casting (round billets having ∅ 210 mm).

In such case, literary analysis has proceeded to practical experiments. Under such analysis, mould being of a parabolic shape shall be deemed to be appropriate for casting of peritectic steel of round cross-section [1, 2, 3].

Figure 1 shows temperature course in the wall of parabolic mould during casting through submersion nozzle with various casting powders use and it is subsequently compared with results of a similar measurement on a round-shaped mould with linear taper.

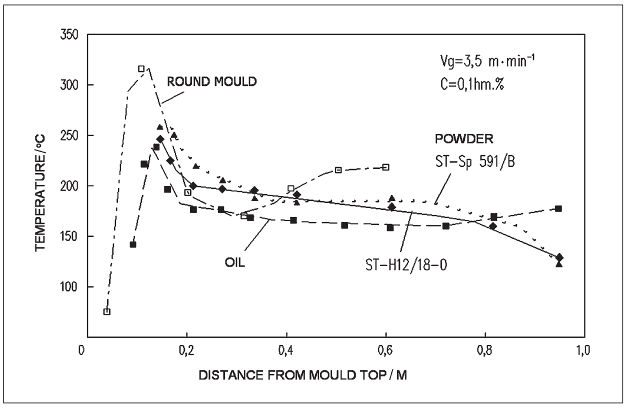

Figure 1. Mould wall temperatures during peritectic steel casting

Figure 1 shows that at parabolic mould, wall temperature is immediately under steel level dropping but its further drop is not as significantly steep as at mould with linear taper. Such fact achieved at peritectic steel casting shows a more equal cooling effect of parabolic mould.

During our experimenting, casting of peritectic steel has often been accompanied by breakouts close below mould caused by longitudinal breaking of cast shell. Cast shell of steel with carbon content close to 0,1 % had non-equal thickness from the very beginning of its formation – see Figure 2.

Both Figure 2 and Figure 3 were taken by samples taken from transversal section of billets, on which breakouts occurred. These cross-sections do enable to ascertain actual thickness of a solidified layer of steel in defined place of casting as after breakout, entire fluid phase (body) will flow-out through breakout crack.

Solidified layer of one casting part up to the distance of about 800 mm from the upper (top) margin corresponds to cast shell in the mould. Breakouts do occur in the places with weakened cast shell – see Figure 3.

For field testing, another mould tube of parabolic taper has been manufactured and tested having the same length as convention tube had. Such mould tube taper in meniscus area was about 4 %.m^{-1}, and in direction towards lower end, taper parabolically decreased.

By such mould tube using, heat had been more equally dissipated along the mould's length with assumed effect of cast shell strengthening at the same casting speed. Such effect was shown (demonstrated) by increased reliability of casting and by decreased share in heats with breakout to level being usual for any other cast cross-sections and steel grades.

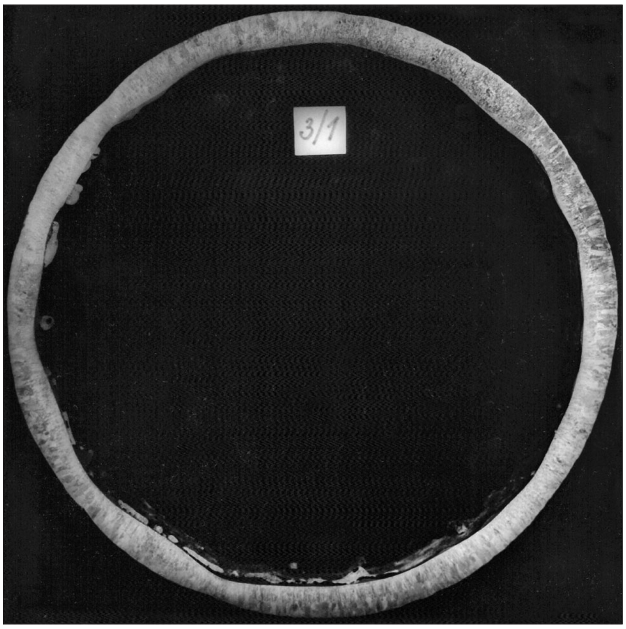

Figure 2. Sectional view through cast shell after breakout (etching), distance from the meniscus – 600 mm, carbon content – 0,1 %

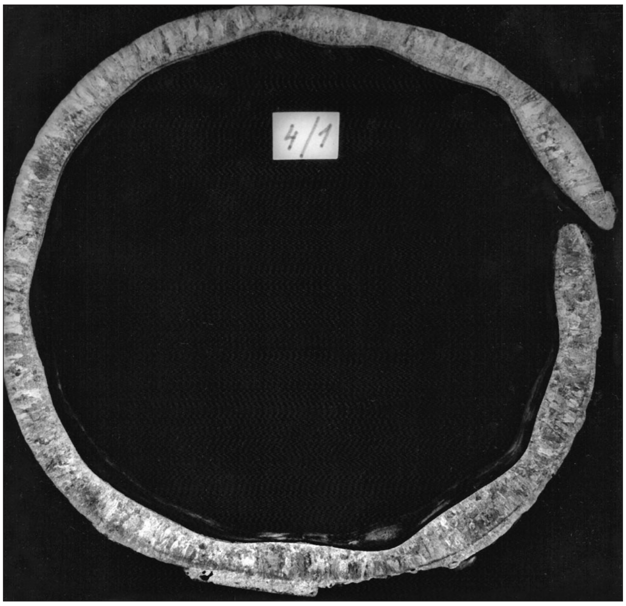

Figure 3. Sectional view through cast shell after breakout (etching), distance from the meniscus – 900 mm, carbon content – 0,1 %

Table 1 shows characteristic chemical composition of steel grades as per carbon content.

Casting of steel with carbon content higher than 0,35 % - characterized by smaller shrinkage – has been from time to time accompanied by cast shell deformation as shell was compressed by mould in form of a narrow caving-in evidently caused by mechanical stress. Such surface defect has been the cause of yield reduction within next round billets processing, nevertheless, it

Table 1. **Average chemical composition of steel groups**

Group	Average specified content, vol. %					
	C	Mn	Si	P	S	Al
Low-carbon steel	0,08	0,47	0,21	max. 0,025	max. 0,025	Non-specified
Medium-carbon steel	0,42	1,12	0,30	max. 0,020	max. 0,020	

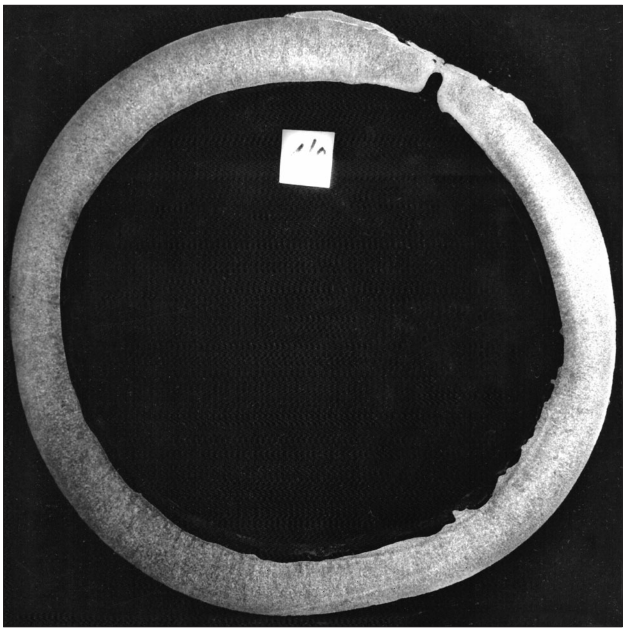

Figure 4. Sectional view through cast shell after breakout (etching), distance from meniscus – 1400 mm, carbon content – 0,35 %

might be the right cause of breakouts occurred at these steel in the lower area of zone of secondary cooling.

Figure 4 shows sectional view through casting in the distance of about 1400 mm from steel level – it has been taken after breakout through a crack in zone of tertiary cooling.

After specified phenomenon elimination, experience in steel casting has been used gained during testing with parabolic mould using being of a square cross-section shape 130 × 130 mm. During testing, draw force has been measured, by means of which casting was drawn from mould. At its increase, steel level has been subsequently reduced, whereby meniscus has got to the area with a lower taper.

Section, in which level height in mould is measured by means of a radioactive sensor, is about 110 mm long. During casting, steel level has been usually set to about 80 % of the height of measured section, and afterwards, at this level, it has been kept by controlled inlet of steel into the mould.

Within parabolic mould usage, such level height has been set and kept for steel quality with carbon content lower than 0,25 %. For qualities with higher carbon content, level has been set to 60 % of measured range, what is about 20 mm lower.

By the application of casting with different levels heights in mould according carbon content in steel, we were successful in removing the described phenomenon of mechanical deformation of billets with higher carbon content.

By monitoring of yield from round billets in tubes production, it has been for example ascertained that at steel quality for tubes production with carbon content of 0,34 % and Mn content of 1,1 %, yield from round billets cast by means of a parabolic mould has been 94,2 % vs. yield of 89,2 % at billets cast to convention mould [4].

CONCLUSION

Testing of casting by means of a mould with a parabolic taper have been carried-out with the aim to achieve increased cooling effect of the mould; to enable casting with a higher casting speed and thus to increase performance of CCM. During testing, assumptions correctness has been proven in relation to their increased cooling effect. Casting speed has been achieved higher vs. casting by means of convention mould without any breakout occurrence due to thin cast shell breaking.

Metallographic research of taken samples has proven their positive impact on both inner structure and shape of billets when at billets cast by means of parabolic mould, no dimensional defects of the type of lateral sway and/or depressions occurring at billets cast by means of convention moulds have been evident.

Gained experience has been applied for parabolic mould putting into operation for casting of round billets. By their usage, the number of breakouts occurred had significantly been reduced particularly at steel casting with carbon content of 0,1 vol. %, at which impact of peritectic reaction on cast shell formation is the most striking. The number of breakouts during casting of these steel grades has been reduced several-fold.

Gained experience in correct metal level adjustment during casting by means of a parabolic mould did enable using of the same mould tube with a parabolic taper for casting of different steel qualities with carbon content in the range 0,07 – 0,55 %.

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