

TOOLOX – Pre-hardened Tool Steels Aimed for Die-casting Applications Enabling Faster Mould Manufacturing

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ABSTRACT

Die-casting is an attractive method to produce near-net-shape metallic components. However, in such dies heat-checking is the most common die failure mechanism. To minimize this risk attention must be paid to control die steel strength as well as impact toughness at elevated temperatures, thermal fatigue properties and thermal softening etc. Pre-hardened tool steels, with improved thermal conductivity and control of the above-mentioned properties, are marketed which enables elimination of heat treatment in die manufacturing.

INTRODUCTION

Die-casting moulds are generally manufactured using H11/H13 grades. Using such traditional tool steels has one major drawback, i.e the die has to be quenched and tempered (Q&T) during manufacturing to achieve its final hardness. This results in dimensional changes of the die due to the different phase transformations which takes place in the heat treatment cycle. Furthermore, the cracking risk which can be quite high should not be neglected. As the Q&T is carried out on a near-net-shape machined die there is generally no possibilities to take test samples from the actual die to verify its mechanical properties after the heat treatment.

The last decades have seen rapid development of hard machining in steel having higher hardness, i.e. above approx. 38 HRC. This has enabled development of new not yet standardized tool steel, marketed as TOOLOX 44, being delivered from the steel producer in Q&T

condition with a hardness of 45 HRC. The basic idea, in the development of such steel, is to supply the customer/tool-maker with steel already heat treated to its final hardness (45 HRC) and being dimensional stable in machining. Since no further Q&T is required can die manufacturing be carried out much faster. Another important benefit using such steel is that the steel manufacturer checks and guarantees mechanical properties of the steel, which is not possible when regular tool steels are bought in as soft-annealed condition.

STEEL/PLATE MANUFACTURING

STEEL/SLAB PRODUCTION – The new steel is produced using an integrated steel shop equipped with secondary metallurgy. The use of iron-ore based metallurgy results in extremely clean steel having very low impurity levels. Table 1 shows a comparison in chemical composition between W.Nr.1.2344 (= H13), H13 premium [1], H13 superior [1] and TOOLOX 44.

Table 1. Chemical compositions, all elements are given in weight-%.

Grade	C	Si	Mn	P	S	Cr	Mo	V
W.Nr 1.2344	0.37-0.43	0.90 - 1.20	0.30 - 0.50	Max. 0.030	Max. 0.030	4.80 - 5.50	1.20 - 1.50	0.90 - 1.10
H13 prem.	0.37-0.42	0.80 - 1.20	0.20 - 0.50	Max. 0.025	Max. 0.005	5.00 - 5.50	1.20 - 1.75	0.80 - 1.20
H13 sup.	0.37-0.42	0.80 - 1.20	0.20 - 0.50	Max. 0.015	Max. 0.003	5.00 - 5.50	1.20 - 1.75	0.80 - 1.00
TOOLOX 44	0.31-0.34	1.00 - 1.20	0.75 - 0.85	Max. 0.010	Max. 0.003	1.30 - 1.40	0.75 - 0.85	0.13 - 0.15

As is shown in Table 1 shall the new tool steel be compared with H13 premium with respect to demands on maximum permitted phosphorous and sulfur contents.

Continuous casting of slabs

The liquid steel is solidified using a continuous casting machine equipped with controlled-soft-reduction (CSR) and also with fully protected casting using ceramic tubes between ladle/tundish and between tundish/mould. The CSR-casting technique, in combination with effective secondary metallurgy, enables production of very clean slabs without the when using standard continuous casting typical centre-line segregation.

Lagerstedt [2] has studied solidifying of steel having a chemical composition of 0.48% C, 0.36% Si, 0.88% Mn, 1.5 % Cr and 0.048 % S using;

- Standard ingot up-hill teeming
- Continuous casting without soft-reduction
- CSR-casting

Figure 1 shows a sulfur-print of the up-hill teemed conventional ingot, having a dimension of 746x1089x1700 mm. As is clearly demonstrated shows the central equi-axed part of the ingot heavy V- and A-segregates. The peripheral parts show a columnar zone free from macro-segregations.



Figure 1. Sulfur-print of an up-hill teemed ingot.

The columnar zone also shows short distances between the dendritic arms indicating that solidification has taken place under a relatively high temperature gradient. Continuous casting of slabs solidifies the liquid steel under a high temperature gradient, creating small distances between the secondary dendrite arms. A short solidification time suppresses formation of V- and A-segregates and the crucial point in continuous casting is to cast the melt without the formation of centre-line segregation.

The horizontal zone in the CSR-caster has different back-up roll configuration, when compared with conventional casters, pertaining to compensate the shrinkage of the solidified shell thereby eliminating the inter-dendritic flow of the enriched melt in the two-phase region towards the centre-line. This flow generates the centre-line segregation in conventional continuous cast slabs. In the trials carried out by Lagerstedt [2] was the initial casting speed chosen to secure through thickness solidification of the strand before entering the soft-reduction zone (Horizontal zone) of the caster, see Figure 2 Pos 1. After casting half of the melt the casting speed was increased to position the through thickness solidification to occur in the soft-reduction zone, see Figure 2, Pos 2.

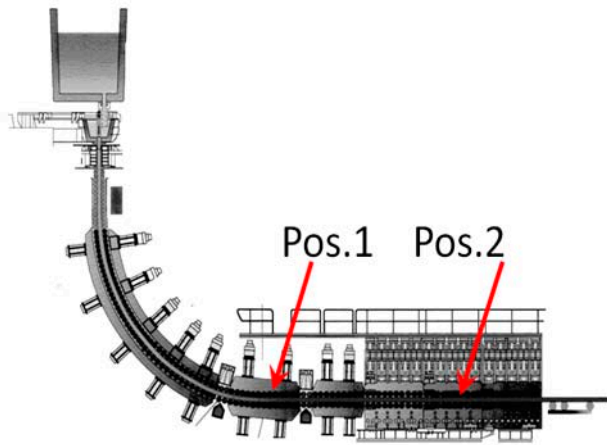


Figure 2. Schematic layout of the CSR-caster.

By this variation in casting speed were slabs produced without the CSR-technique (Pos. 1 in Fig. 2) and also fully using the CSR-technique (Pos.2 in Fig. 2). These different solidified slabs show macrostructures as given in Figure 3.

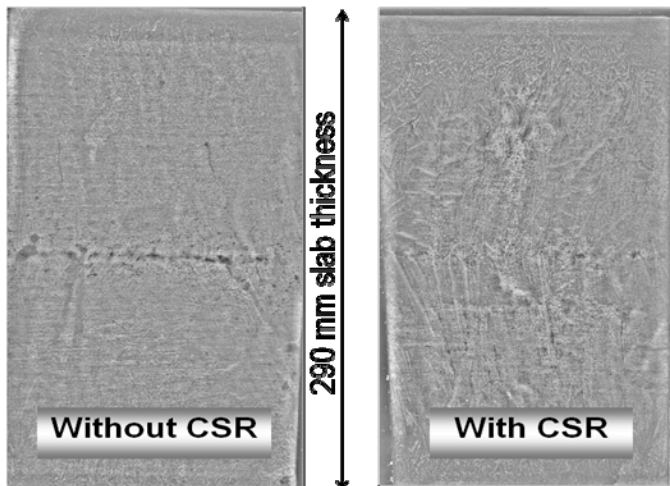


Figure 3. Continuous cast slabs, 290 mm slab thickness.

This experiment [2] clearly shows that the centre-line segregation can be effectively controlled using soft-reduction to compensate the shrinkage of the solidified shell. This compensation eliminates flow of the enriched inter-dendritic melt to the central part of the solidifying slab. Carbon and sulfur profiles see Figure 4-5, measured in the slab thickness direction of the slabs given in Figure 3 also clearly demonstrates the effective segregation control achieved when using the CSR-technique.

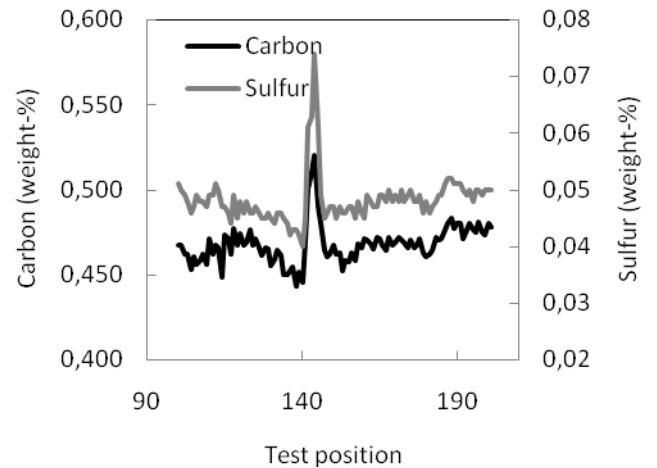


Figure 4. Carbon and sulfur segregation in the conventional CC-cast slab.

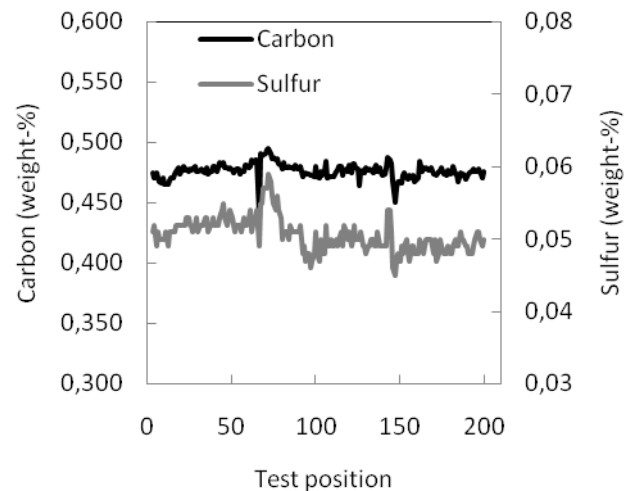


Figure 5. Carbon and sulfur segregation in the CSR-cast slab.

STEEL CLEANLINESS – The steel cleanliness is an important parameter to control pertaining to maximize the fatigue properties in hot-work tool steel. The CSR-casting technique, as described above, in combination with secondary metallurgy results in very clean slabs without the need of ESR-remelting. Figure 6-7 show a comparison in steel cleanliness between conventional up-hill teemed steel (P20+Ni), ingot cast and ESR-remelted steel (Premium H11/H13), and finally CSR-cast steel (TOOLOX 33/44).