IMPROVING OF HEATS' THERMAL PROPERTIES IN THE PRODUCTION OF TOOL STEELS IN ELECTRIC ARC FURNACE AND DURING THEIR SECONDARY METALLURGY PROCESSING

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Abstract

This article deals with production technology and secondary metallurgy processing of tool steels in electric steelworks of VÍTKOVICE HEAVY MACHINERY a.s. with the focus on thermal and slag regulation of heats. During the production and secondary metallurgy steel processing of a trial heat so-called „programme thermo-time steel processing technology" (PTVO) was used.

In its evaluation, the attention was mainly focused on the steel production - technological parameters of 100CrMo7 steel. At the trial melting based on the liquidus temperature, the optimal degree of overheating of the steel melt, and also in the framework of the evaluation comparison with the thermal regime of heats of the same kind of steel with common technology was performed.

When evaluating the slag regime, the attention was mainly focused on the composition of refining slags and the course of desulphurisation of the steel melt.

Keywords: Tool steels, programme thermo-time steel processing technology, refining slags, desulphurisation

1. INTRODUCTION

The objective of the production optimalisation and of the secondary metallurgy steel processing in the ladle furnace (LF) and during vacuum degassing (VD) of highly alloyed tool and bearing steels was to provide suitable thermal regimes both during their production and mainly during secondary metallurgy of selected kinds of these steels.

The tapping temperatures from the electric arc furnace (EAF) and the temperatures of secondary metallurgy are given by chemical composition of the selected kinds of steel, which coheres mainly with higher ingredients of the individual alloying ingredients, especially FeCr, FeMo, Ni, etc.

The main attention was focused on possibilities of use of programme thermo-time processing technology of steel processing of selected kinds of tool and bearing steels with low liquidus temperature with the objective of minimizing the number of inclusions [1, 2].

At the same time the analysis of findings focused on production optimalisation and secondary metallurgy steel processing in the ladle furnace and during vacuum degassing of highly alloyed tool and bearing steels of selected grades was made, especially from the point of view of thermal regime [3-5].

In the practical part, a testing heat with reducing re-heat for the selected brand of bearing steel with chrome content app. 2 wt.% was produced.

2. THE PTVO TECHNOLOGY WITH HIGHER OVERHEATING AND DWELLING ON HIGHER TEMPERATURES

During the new thermal technology we used experience asserted by Baum and co. [1]. Schematic representation of thermal regime of the X12 steel made with common and testing PTVO technology is showed in **Figure 1.**

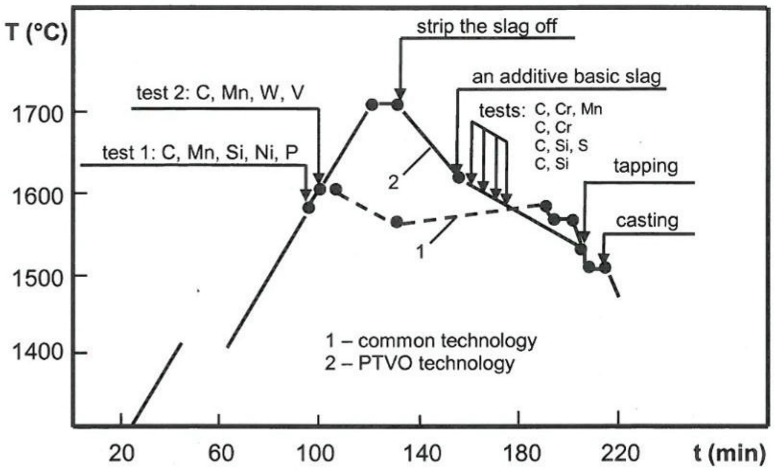

Figure 1 Schematic representation of thermal regime of the X12 steel heat in EAF

The authors [1] state that from the point of view of forging it is possible to gain the best structure while producing the X12 steel during the following regime:

a) maximal temperature of melt from 1650 to 1680 °C,
b) liquid steel dwell at this temperature from 20 to 30 min.,
c) acceleration of cooling to the temperature of 1450 to 1480 °C,
d) dwell during vacuum degassing in the course of 10 to 15 and the following casting.

These parameters were used during an industrial production of the X12 steel. The liquidus temperature of this kind of steel ranges from 1385 to 1398 °C. It means that after a heavy cooling of the melt the overheat temperatures above the liquidus temperature usually range from 65 to 88 °C.

During the evaluation of quality and macrostructure of the ingots made with the PTVO, the following advantages were ascertained:

a) the depth of the defect placement gets smaller during contraction in the riser (in the ingot top part). This enables to lower the volume of the riser by 2 % without lowering the metal macrostructure quality in the zone under the contraction. Aside from this it is also possible to exchange the expensive lunkerit preparation for a cheaper one, e.g. fireclay powder.
b) The incidence of all types of non-metallic inclusions gets lower at small lowering of concentration of oxygen and nitrogen.
c) The PTVO technology decreses the volume of total oxygen from 0.0029 to 0.0026 wt. % against common technology.

d) The elongated oxide got lowered from 2.25 to 2, the non-deformable silicates from 2.0 to 1.0 and sulphides from 1.25 to 1.0.
e) The density of cast metal gets higher along the entire cross-section of the ingot.
f) The ingot and deformed semiproduct surface quality improves.
g) The steel plasticity during forging improves.

The above mentioned assets led to the increase in metal yield by ca 6 or 7 % against the serial production. The main reason for this increase is the absence of wasters due to cracks and lowering metal losses during forging and during clearing semiproducts. Minor defects during forging were reduced by 3.6 %.

The PTVO technology has positive influence on the structure and properties of deformed steel [1, 2]. The macrostructure of semiproducts meant for further processing showed to be more compact than when processed with common technology. Semiproducts produced with the PTVO technology had practically no defects, the centric porosity and spot heterogenity did not exceed 0.5 point (for the common heats it is 1.5 point). The testing steel density was 7 666 kg/m^3, while the common technology steel density was 7 642 kg/m^3.

The specialities of the new technology used to produce the X12 steel are as follows:

a) melt heating to 1660 or up to 1 680 °C,
b) dwelling on this temperature 10 to 20 minutes,
c) removing of foamed slag and adding slag ingredients, namely lime, fluorite and fireclay were in 5 : 1 : 1 ratio, 3 to 4 % of the amount of the metalliferous batch,
d) liquid slag roaming with coke in the amount of 1.5 to 3 kg/t of steel,
e) after gaining carbide slag (during 15 to 40 minutes) difuse deoxydation with the mixtures of 65 to 75 % FeSi and fine-graned lime was performed, which was added to the furnace in amounts of 1.5 to 2 kg/t of steel every 5 to 10 minutes (5 to 6 scoops). After the steel deoxydation a correction of the steel composition as to silicon was made, but more than 5 minutes before the tapping. Furthermore, 2 to 3 minutes before the tapping, the deoxydation with aluminium was made. The tapping was done at temperatures of 1470 to 1490 °C.

The complex meassures for the condition optimalisation according to PTVO must also anticipace sufficiently fast cooling of liquid steel from the meeting temperature to the casting temperature, and in accordance with the preformed production test, isothermic dwell longer than 10 minutes at the last high temperature.

Together with thorough slag deactivation and metal deoxydation this dwell on the stated temperature ensures additional melt degassing and removal of non-metallic inclusions. Metallographic analysis of the X12 steel sample showed that increasing the melting temperature from 1410 up to 1650 °C leads to disintegrating of the dendritic structure and further increase in temperature has practically no effect on linear dimension of the dendritic cell. The increase in dendrit dispersion causes homogeneous distribution of eutecticum along the ingot body. Its structure is more disintegrated. In the specimens heated to temperatures ranging from 1410 to 1 570 °C the eutecticum is characterized with non-homogeneous dimension of the carbidic phase, parts of the fine differencing of phases neighbouring with big carbide crystals.

As a part of the production test was performed a testing melt of the 100CrMo7 steel grade performed in the electric steelworks of VHM a.s. This heat was produced with the PTVO technology, where experience from specialized literature [1] was used, and also calculations of cooling steel waste to ensure fast cooling of the overheated steel bath in the casting ladle were performed. Before the production test a technology direction with the use of the PTVO technology was formulated**.** The melt analysis of the 100CrMo7 steel is stated in **Table 1.**

Table 1 Melt analysis of the 100CrMo7 steel (wt. %)

C	**Mn**	**Si**	**P**	**S**	**Cu**	**Ni**	**Cr**	**Mo**	**V**
1.03	0.32	0.24	0.013	0.010	0.13	0.11	1.84	0.17	0.01
Ti	**Al**	**N**	**Nb**	**Ca**	**B**	**Sn**	**As**	**Sb**	
0.003	0.019	0.0045	0.004	0.0012	0.0005	0.009	0.005	0.0026	

During the production of the testing melt, increased attention was paid to thermal and slag order.

For the thermal order, the focus was on ensuring sufficient overheating of the steel melt, while the increased overheating was performed in the ladle furnace. According to the calculation of the liquidus temperature with a VHM a.s. equation, the liquidus temperature of the 100CrMo7 steel ranges from 1460 to 1469 °C.

During the testing melt in the ladle furnace we reached the temperature of 1714 °C, i.e. steel melt overheating ranged from 245 to 254 °C.

After a 20-minute dwell on this temperature, where the stated temperature was maintained by heating in the LF, 2000 kg of cooling steel waste was added at the temperature of 1713 °C. After the scrap melted during intensive bath mixing with argon, the temperature of the steel bath was changed to 1612 °C. From the results stated above that after adding 2000 kg of steel waste the melt cooled down by 101°C. The weight of the melt was 44.5 tonnes.

The temperature behaviour from the tapping from the EAF and during processing in the LF and VD of the 100CrMo7 steel with the use of PTVO is obvious from **Figure 2.**

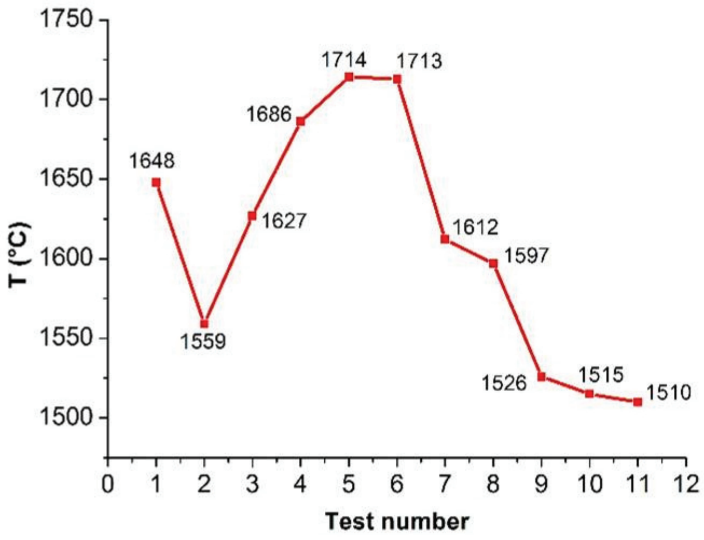

Figure 2 The temperature behaviour during processing the 100CrMo7 steel with PTVO

Legend to **Figure 2:**

1= Steel temperature in EAF before tapping

2= Steel temperature in casting ladle after tapping

3= Steel temperature in LF - 1st test

4= Steel temperature in LF after 16 minutes of heating

5= Steel temperature in LF after 10 minutes of heating - 2nd test - the beginning of the temperature dwell

6= Steel temperature in LF after 10 more minutes of heating - the end of the temperature dwell

7= Steel temperature in LF after adding 2000 kg of cooling scrap

8= Steel temperature in VD - 1st test after adding

9= Steel temperature in VD

10= Steel temperature in VD after adding 6 kg Al-S wire

Figure 3 shows the temperature behaviour of the 100CrMo7 steel produced with the common technology.

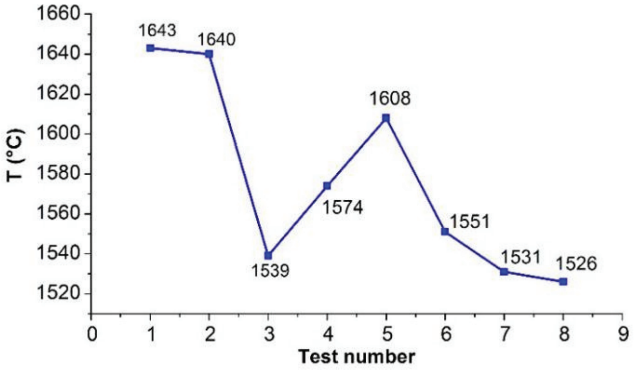

Figure 3 The temperature behaviour during processing the 100CrMo7 steel with common technology

Legend to **Figure 3:**

1 = EAF
2 = Tapping
3 = LF1
4 = LF2
5 = LF3
6 = VD1
7 = VD2
8 = TV - melt

For the slag order the main attention was mainly focused on steel desulphurisation and the following correction of sulphur volume in the vacuum degassing process. The sulphur content course in the steel from the tapping to the melt analysis is stated in **Figure 4**.

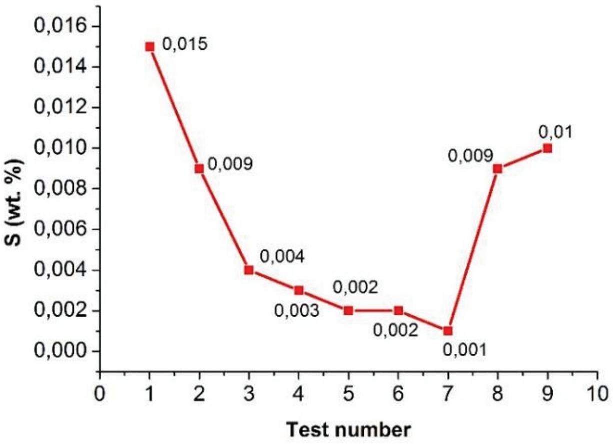

Figure 4 The sulphur content behaviour in the 100CrMo7 steel tapping from the EAF, during PTVO processing, to casting

Legend to **Figure 4:**

1= Sulphur content in steel in EAF before tapping
2= Sulphur content in steel in casting ladle after tapping
3= Sulphur content in steel in LF - 1st test
4= Sulphur content in steel in LF after 10-minute heating - end of temperature dwell
5= Sulphur content in steel in LF after further 10-minute heating - end of temperature dwell
6= Sulphur content in steel in LF after adding 2000 kg of cooling scrap
7= Sulphur content in steel in VD
8= Sulphur content in steel in VD after adding 18 kg of Al-S wire
9= Sulphur content in steel after adding 6 kg of Al-S wire and after 13 minutes of waiting for leaving to casting

Sulphur content course during processing 100CrMo7 steel with common technology is stated in **Figure 5.**

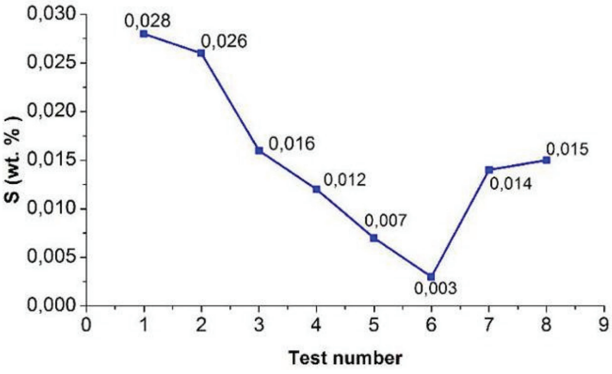

Figure 5 Sulphur content course during processing 100CrMo7 steel with common technology

Legend to **Figure 5:**

1= EAF
2= Tapping
3= LF1
4= LF2
5= LF3
6= VD1
7= VD2
8= TV - melt

3. CONCLUSION

Using the PTVO technology for production of the X12 and 100CrMo7 steels leads to increasing the number of columnal eutectic carbides. The ratio of plastic modifications is decreased at the same time.

In cast steel samples of X12 and Fe melts - 12 wt. % Cr and 2 wt. % C the PTVO technology decreases the distributing Cr factor between primary dendrits and eutectic carbides, and at the same time increases distribution homogenity of chrome in eutecticum.

The application of the testing technology leads to carbon distribution between dendrits and eutecticum. Decrease in volume portion of eutectic carbides shows decreased carbon concentration in eutecticum.

The stability growth of overcooled austenite in intermediate state of conversion and increase in microhardness of the grainy perlite attest to the increase in carbon content in primary dendrits.

Steel smelted with the testing PTVO technology in the forging temperature interval is characterised by smaller dimentions of austenite grain, increased thermic stability of the eutecticum, and growth of some plastic traits.

During the testing melt, the temperature in the ladle furnace rose to 1714 °C, i.e. steel melt overheating ranged from 245 to 254 °C.

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