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STEEL REFINING IN INDUCTION FURNACE BY PRESSURE

RAFINACJA STALI W PIECU INDUKCYJNYM POPRZEZ CIŚNIENIE

The induction furnace (1700 kg) built in caisson 26,5 m^3 in volume was designed in VÍTKOVICE – Research and Development in the frame of the project of Ministry of Education Youth and Sports MSM2587080701 "Research and verification of new methods of manufacture of metallic materials". This facility makes possible melting and ingot mould casting in vacuum or under pressure of nitrogen or argon.

The present paper summarizes necessary repairs carried out on the above mentioned facility during trial operation and its use for detrimental elements elimination from the molten steel in conditions of vacuum and argon of the steels at argon pressure.

Keywords: Pressure, Argon, Calcium, Manufacture of metallic materials, Induction melting

Piec indukcyjny (1700 kg) zbudowany w kesonie o objętości 26,5 m^3 został zaprojektowany przez firmę VÍTKOVICE – Research and Development w ramach projektu Ministra Edukacji i Sportu MSM2587080701 „Badania i weryfikacja nowych metod wytwarzania materiałów metalowych". To urządzenie umożliwia topienie i odlewanie wlewków do wlewnic w próżni lub pod ciśnieniem azotu albo argonu.

Przedstawiony artykuł podsumowuje konieczne naprawy wykonane na wyżej wymienionym urządzeniu podczas prób w celu wyeliminowania szkodliwych substancji z roztapianej stali w warunkach próżni i stosowanego ciśnienia argonu.

1. Introduction

Research and development of new methods of manufacturing of metallic materials is carried out from the point of view of elimination of some detrimental elements. New vacuum and pressure induction furnace was designed in VÍTKOVICE - Research & Development, Ltd, manufactured in Prvni zelezarska spolecnost Kladno, Ltd. and put into service in VÍTKOVICE - Research & Development, Ltd. This facility makes possible melting and ingot mould casting in vacuum (50 Pa) or in pressure (0,5 MPa) of nitrogen or argon.

Works summarizes necessary repairs carried out on the above mentioned facility during trial operation and the experiments realized in VÍTKOVICE-Research & Development, Ltd. for detrimental elements elimination from the molten steel in conditions of vacuum and argon of the steels at argon pressure.

2. Parameters of VPIM

The basic parameters of vacuum and pressure induction melting furnace (VPIM) are as follows:

• Electric melting power	600 kW
• Weight of molten metal	1750 kg
• Frequency of inductor	1000 Hz
• Porous quarl in a bottom of a furnace	Ar: 1-50 $l.min^{-1}$, N: 2,4-120$l.min^{-1}$
• Dimensions of melting crucible	diameter 590 mm, height 880 mm
• Volume of melting crucible	245 dm^3
• Volume of caisson	26,4 m^3
• Diameter of caisson	3000 mm
• Height of caisson with a cover	4250 mm

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- Working vacuum 50 Pa (0,5 mbar) abs.
- Working pressure (Ar, N) 0,5 MPa (5 bar) abs.
- Maximum height of ingot mould set 2800 mm

3. Trial operation and rectifications of VPIM

During the melting process in the induction furnace the electromagnetic field is induce inside and outside of the inductor. Metallic charge is melted by internal electromagnetic field. External electromagnetic field is spread out to space. If the induction furnace is situated into the caisson, as in the case of VPIM, external electromagnetic field is concentrate between inductor and caisson wall. This concentration of electromagnetic field entailed the warming of furnace components manufactured from austenitic and ferrite steels above the allowable temperature (Tab.1).

TABLE 1

Temperatures of individual parts of atmospheric induction furnace and VPIM (trial operation) during melting

Material	Atmospheric induction melting furnace	VPIM before rectification
Austenitic steel	Connecting rods 50°C Forward shield 120°C Connecting materials 50°C	Connecting rods 50°C Sideboards 250°C Connecting materials 50°C
Ferritic steel	Columns 70°C Hydraulic cylinders 50°C Connecting materials 60°C	Columns 140°C Hydraulic cylinders 150°C Connecting materials 100°C
Aluminium	Sideboards 75°C Front shield 80°C	–
Vermiculite	–	Front shield 20°C

On the basis of melts carried out during the trial operation, the following rectifications of VPIM were realized:

- The inductor built-in the heatproof concrete. Due to the thermal degradation of epoxid, the former inductor was mechanically damaged.
- Replacement of the material of furnace sideboards and columns (austenitic steel) for hard aluminium. The replacement entailed the significant decrease of temperature of these components. Sideboard temperature to 80°C, temperature of columns to 84°C.
- Installation of front hard aluminium shield (see Fig.1)
- Replacement of a material of hydraulic cylinders. During the furnace operation, these cylinders made of ferritic steel were heated to high temperature (150°C). For this reason new cylinders were designed and made of hard aluminium, in cooperation with IVV Engineering, Ltd. The operating temperature of new cylinders does not exceed 55°C now.
- Replacement of material of bushing of electrical cable through the wall of caisson. Original bushing material had a very good isolation characteristics (internal electric resistance as well as electric resistance against crawl current in vacuum), but bad mechanical properties. New bushing was made of Tecapeek, material with very good electric resistance and mechanical properties up to 260°C.

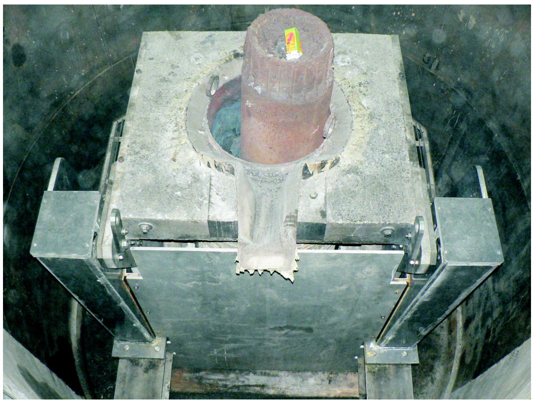

Fig. 1. Front view on VPIM after modification and installation to caisson with aluminium columns and front aluminium shield

4. Use of VPIM for elimination of detrimental elements from steel

Refining of liquid steel in a strong reducing atmosphere under interaction of calcium and pressure of argon was used for elimination of detrimental elements from liquid steel with higher content of chromium and manganese. (> 1 weight %). For the first experiment magnesite rammed lining was used. Melting, dosing and pouring was carried out under pressure of argon (0.5 MPa).

The course of the melt is summarized in Tab. 2. First sample for analysis of chemical composition was obtained after melting down of 1700 kg metallic charge (Tab. 2). CaF_2 and CaC_2 dosing on the surface of molten metal was followed by immersion of CaFe into the volume of molten metal. Samples 2 and 3 were obtained after 10 and 30 minutes respectively.

TABLE 2

Chemical composition of steel under investigation (first experiment)

Sample	C	S	Mn	Si	P	Cu	Ni	Cr	Mo
1	0.54	0.011	0.42	0.23	0.014	0.13	0.11	6.08	0.028
2	0.68	0.006	0.46	0.30	0.014	0.13	0.10	5.24	0.023
3	0.63	0.006	0.46	0.32	0.012	0.13	0.10	5.22	0.024

Sample	V	Ti	Nb	W	Co	As	Sb	Sn
1	0.024	0.005	<0.003	<0.005	0.007	0.005	0.003	0.008
2	0.024	0.007	<0.003	<0.005	0.007	0.005	0.003	0.007
3	0.024	0.007	<0.003	<0.005	0.006	0.005	0.003	0.008

As you can see, significant reduction of sulphur content was reached using above mentioned refining procedure. Lining at the slag line was completely destroyed after melting. Internal volume of caisson was filled up with smoke after addition CaFe was inserting.

For the second experiment damaged magnesite rammed lining was repaired by fire clay. Smaller charge was used for the second melt to prevent the molten metal to reach the level of slag line of the first melt (1000 kg). The steel quality was the same as with the first melt, but with double content of C. Melting, dosing and pouring was carried out under pressure of argon (0.5 MPa).

The course of the melt is summarized in Tab. 3. First sample for analysis of chemical composition was obtained after melting down of metallic charge without alloy FeCr and FeCrC (Tab. 2). CaF_2 and CaC_2 dosing on the surface of molten metal was followed by immersion of CaFe into the volume of molten metal. Samples 2 and 3 were obtained after 10 and 30 minutes respectively.

TABLE 3

Sample	C	S	Mn	Si	P	Cu	Ni	Cr	Mo	V
1	0.14	0.011	0.66	0.18	0.017	0.17	0.062	0.085	0.013	0.007
2	1.17	0.003	0.63	0.24	0.014	0.16	0.079	5.23	0.006	0.016
3	1.11	0.004	0.63	0.23	0.013	0.16	0.078	5.18	0.010	0.016

Sample	Ti	Nb	W	Co	As	Sb	Sn
1	<0.005	<0.003	0.005	0.003	0.007	0.004	0.011
2	0.009	<0.003	0.005	0.003	0.003	0.001	0.007
3	0.009	<0.003	0.005	0.003	0.003	0.001	0.008

More significant reduction of sulphur and phosphorus content was reached using above mentioned refining procedure than at the first melt.

5. Conclusion

New aluminium hydraulic cylinders, aluminium sideboards, aluminium column, aluminium front shield, new inductor in heatproof concrete and new bushing of Tecapeek on caisson improved operating parameters of VPIM substantially.

These experiments made in VPIM with the molten steel, CaF_2, CaC_2 and CaFe under argon pressure 0,5 mpa demonstrated that detrimental elements elimination from steel is on principle possible. Experiments will continue and we expect they confirm and extend these first results.

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