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THE TEMPERATURE DECREASE OF THE TREATED CAST IRON USING AN INJECTION

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An out furnace treatment of the cast iron using compressed air to make up powdered additions is connected with endothermic effects. The results of the cast iron temperature decrease under conditions of the natural self-cooling as well as after the compressed air injection at various depths and time have been presented in the work. It was pointed out that the temperature decrease of the liquid cast iron during a foreblowing is proportional to the depth of the lance draught. An application of the protective coating (a graphite layer of slag as a covering) reduces 20 % of the temperature decrease of the treated cast iron. Some active methods of the experiments planning have been used in the research.

Key words: *thermal treatment of cast iron, additions, quality product*

Smanjivanje temperature obrađivanog lijevanog željeza ubrizgavanjem. Izvanpećna obrada lijevanog željeza komprimiranim zrakom radi uklanjanja dodavanog praha povezano je s endotermičkim efektima. U ovom radu su prikazani rezultati pada temperature lijevanog željeza pod uvjetima prirodnog hlađenja, ali i nakon ubrizgavanja prirodnog zraka na raznim dubinama. Istaknuto je da je smanjenje temperature tekućeg lijevanog željeza tijekom propuhivanja proporcionalno dubini uranjanja koplja. Primjena zaštitnog omotača (pokrov od grafitnog sloja šljake) smanjuje za 20 % gubitak temperature obrađivanog lijevanog željeza. Primijenjene su neke aktivne metode planiranja metoda u istraživanju.

Ključne riječi: *termička obrada lijevanog željeza, dodaci, kvaliteta proizvoda*

INTRODUCTION

An out-of-furnace treatment of the cast iron, eg. blowing powdered reacting substances into the liquid cast iron, in a stream of bearing gas, is a technology, in which endothermic occurrences predominate. Therefore, it is a process, which has a negative energy balance. This fact determines a major limitation of applicability, particularly at a small quantity of the cast iron in the ladle. On the other hand, there are some potential benefits unusually interesting in it. It was clearly given in the article [1]: blowing 2 kg of Fe-Si-Cr into 60 kg of the cast iron loweres the temperature for about 140-160 °C (according to conditions), but the chrome output amounted about 90 %. Those circumstances became a research premise that purposes tracing of directions of the radical warmth losses. The temperature losses of the cast iron in the ladle or in the melting-pot of the induction furnace, during the mentioned out-of-furnace treatment, are connected with such elements as:

- naturals losses (the ladle warming and the heat exchange with the environment),
- losses connected with the immersed lance and with a blowing gas carrier,
- losses connected with powdered substance heating.

The movement (effervescence) of the metal bath during the mentioned process intensifies the heat exchange as well as its losses.

RESEARCH

The temperature loss, in conditions of the natural self-cooling and as a reason of the carrier blowing by the lance immersed in the ladle or in the melting pot of the induction furnace filled with the cast iron, was the main goal of the research. Nominally, the cast iron mass (sub-eutectic composition) in ladle amounted 65 kg, and 60 kg in the melting pot of the furnace.

The cast iron temperature was measured by thermocouple, with an immersion element PtRh-Pt having the numerical index. The natural temperature loss of the cast iron

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was defined as an average of three series of the measurements in a period of 180 seconds, with readouts every 10s. The experiments with the inductive furnace have been done in three variants: an open bath, the bath covered with the natural slag and a swimming graphite cover with an opening (Figure 1.).

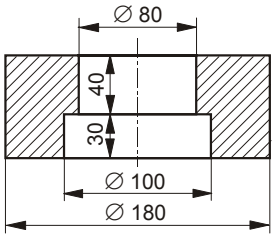

Figure 1. **Shape and dimensions of the protective graphite cover**
Slika 1. **Oblik i dimenzije zaštitnog grafitnog pokrova**

The heat losses caused by a dipped lance and the blowing gas carrier were investigated according to the experiences' planning method, using the Piesoczynski -D- optimal plan of the second degree for two variables (h = 2) [2]. Such parameters as:

X_1 - depth of the lance's immersion h [mm]: 20 (x_1=-1), 110 (x_1=0), 200 (x_1=+1),
X_2 - time of blowing T [s]: 30 (x_2 = -1), 45 (x_2 = 0), 60 (x_2=+1).

Compressed air, drained in the OSP 24 drainer, was used as a gas carrier. The air pressure figured 1471 hPa (1.5 at), the cast iron's mass - 60 kg. In both cases (lance and the melting pot of the induction furnace) an identical graphite lance similar to the one used in the time of the investigation, described in the work, [1] was used.

The regress analysis of the date, given from the measurements of the natural temperature fall of the cast iron's bath without a covering, gave the following relationships:

- for the ladle

$$\Delta T_k = 0.55\ t - 781 \cdot 10^{-6}\ t^2\ [°C] \quad (1)$$

- for the melting pot

$$\Delta T_t = 0.29\ t - 138 \cdot 10^{-6}\ t^2\ [°C] \quad (2)$$

Figure 2. displays the ladle disadvantage. The largest decrease appeared during the first minute: about 31 °C and 16 °C (accordingly to the ladle and the induction furnace melting pot).

As the time goes by, the speed of the self-cooling decreases - average for the period of the first three minutes figured about 25 °C/min and 15 °C /min (accordingly).

Applying the bath cover in the melting pot brings benefits but not essential ones. The regress equations form as follows:

- for the slag covering

$$\Delta T_{tž} = 0.195\ t - 794 \cdot 10^{-7}\ t^2\ [°C] \quad (3)$$

- for the graphite covering

$$\Delta T_{tp} = 0.144\ t - 322 \cdot 10^{-6}\ t^2\ [°C] \quad (4)$$

The lack of the considerable difference between both ways of the liquid cast iron isolation results from the Figure 2. In a further temporal perspective, the presence of the graphite cover will probably increase the heat losses in consequence of the bath carbureting.

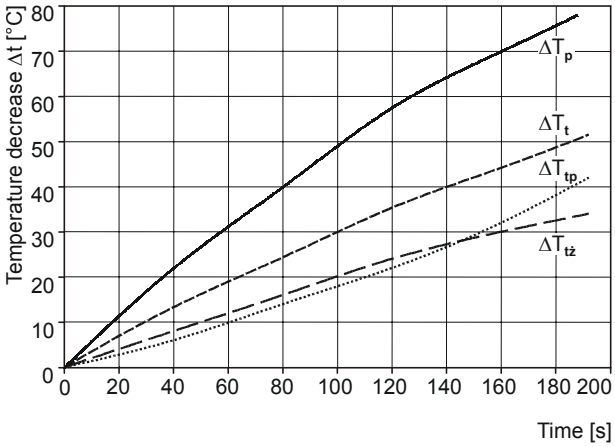

Figure 2. **The natural temperature drop of the cast iron: in the ladle without a protective cover-ΔT_k; in the melting pot of the induction furnace: without a protective cover ΔT_t, under the graphite cover -ΔT_{tp}, under the slag cover -$\Delta T_{tž}$**
Slika 2. **Prirodni pad temperature lijevanog željeza: u loncu bez zaštitnog pokrova - ΔT_k; u talioničkom loncu indukcijske peći: bez zaštitnog pokrova -ΔT_t , pod grafitnim pokrovom - ΔT_{tp}, pod pokrovom šljake - $\Delta T_{tž}$**

The investigation results of the lance immersion depth and the bath blowing time are shown in Table 1. The data elaboration brought the estimation of the following mathematical model (code form):

$$\hat{y} = 148.7 + 85.0\ x_1 + 15.6\ x_2 + 10.0\ x_1\ x_2\ [°C] \quad (5)$$

The temperature fall of the izolines course in the investigated segment of a factor's space is shown as Figure 3. During one minute of blowing the air into the cast iron (x_2=+1) by the lance immersed to the depth of 20 mm (X_1= -1), the temperature drop reached about 54 °C, however the depth of its immersion of 200 mm - already about 260 °C. The heat losses are significant and the influence of the lance immersion is exceptionally large.

In comparison with the natural temperature drop, the losses direction seems to be radical. A question is wheder a protective cover presence (slag, covering) can influence the heat losses during the air blowing into the bath. The method of estimation of the significance of differences between average values, according to the Lord test, was used [3]. The three measurements of the melting-pot of the induction furnace were used for both coverings at con-

Table 1. **Plan and results of the research**
Tablica 1. **Plan istraživanja i rezultati**

No of experiment	The plans factors after the coding		The cast iron temperature [°C]			Comments
	x_1	x_2	before the treatment	after the treatment	difference	
1	0	+1	1450	1284	166	Fundamental experiments of the plan
2	+1	+1	1456	1206	250	
3	+1	0	1460	1224	236	
4	+1	-1	1458	1256	202	
5	0	0	1456	1318	138	
6	0	-1	1460	1334	126	
7	-1	+1	1460	1394	66	
8	+1	-1	1460	1256	204	
9	-1	0	1450	1392	58	
10	-1	-1	1452	1398	54	
11	+1	+1	1458	1204	254	
12	-1	+1	1458	1396	62	
13	-1	-1	1460	1404	56	
14	0	0	1464	1324	140	Supplementary experiments to their variants esstimation
15	0	0	1462	1310	152	
16	0	0	1452	1300	152	

ditions as follows: the cast iron mass 60 kg, the lance immersion depth 110 mm, the air pressure 1471 hPa, the blowing time 45 s. The results as well as the calculations are shown in Table 2. From the fact that the value u_{obl} exceeds the values from the table $u_{(0,\,05;\,3)}$, it can concluded that the graphite cover protects the cast iron from the heat loss a

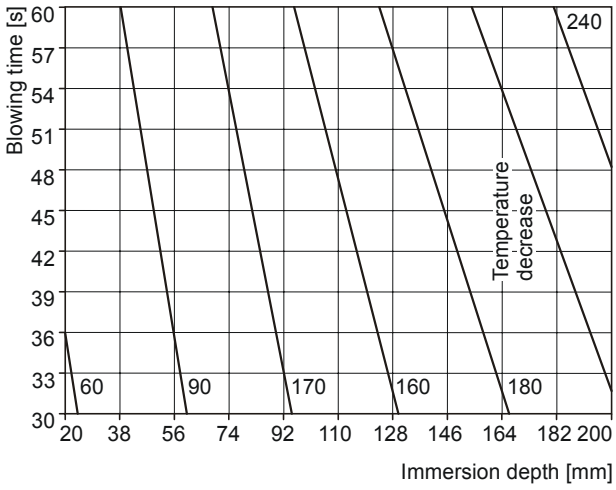

Figure 3. **The influence of the lance depth immersion (x_1) and the blowing time (x_2), (a coded form) on the temperature decrease of the liquid cast iron ΔT**
Slika 3. **Utjecaj dubine uranjanja koplja (x_1) i vremena propuhivanja (x_2), (šifrirani oblik) na smanjenje temperature tekućeg lijevanog željeza ΔT**

bit better. The cover superiority over the slag comes out in range of the environment and the lance protection. The bath blowing under the slag discloses that it has caused the limitation of the cast iron splashes but simultaneously the slag itself was too intensely thrown onto the upper part of the furnace lining, it stucked the lance and its protection. After the treatment many difficulties with the lance liberation from the slag appeared. Presence of the graphite cover caused the calmer course of the treatment. The cast iron splashes were limited to the zone of its edge value, causing a small clot over the metal mirror. The lace remained clean without any clots. Does the protective cover bring such essential effects during blowing the air into the liquid cast iron? The answer may given by the comparison of the discussed data with the results received from the investigation without the protective cover results.

The results received in the experiences based on a basic level were useful for goal reaching. (Table 1., experience 14, 15 and 16) because the results of the investigation were similar. The received average temperature fall of the cast iron figured 148 °C, at a gap, which equals 12. Using the Lord test, successively for a slag and the graphite cover, the values were received as follows:

- for the slag $u_{obI} = 1.225$,

- for the cover $u_{obI} = 2.608$.

In the first case the difference (see: average values in Table 2.) seemed to be statistically unessential, in the second one - significant. Therefore, the protective function

Table 2. **The temperature change of the cost iron under the protective cover and air-blown**
Tablica 2. **Mijenjanje temperature lijevanog željeza pod zaštitnim pokrovom i uz propuhivanje zrakom**

Measurement	Slag cover temperature [°C]		Temperature decrease [°C]	Graphite cover temperature [°C]		Temperature decrease [°C]
	before the treatment	after the treatment		before the treatment	after the treatment	
1	1456	1324	132	1444	1326	118
2	1462	1334	128	1448	1338	110
3	1468	1328	140	1448	1326	122
average			133.3	average		116.7
gap			12	gap		12
$u_{obl} = \frac{133.3 - 116.7}{12} = 1.383 > u\,(0.05;\,3) = 1.272$						

was realized by the graphite cover better then by the slag. Probably the "stiffness" of the cover restrained the metal bath effervescence and the intensity of the heat exchange with the environment, which is connected with this fact.

CONCLUSION

The investigation showed, that the main reason of the considerable temperature drop was the influence of the gas carrier at the lance dipped in the bath.

Taking the natural temperature drop as an example, resulting from the investigation, in 45s, which equals 15 °C (the melting-pot of the induction furnace without a protective cover), and during the air-blowing at the same time, by the lance dipped at the depth of 110 mm and at 1471 hPa - average 148 °C, it is easy to estimate, that the participation of the lance and the air influence in the heat losses estimate the value of almost 90 %.

The depth of the lance immersion enlarges the temperature losses, which in extreme cases would figure the level of about 250 °C. Using the protective covers of the bath diminishes the temperature drop however, the results are not impressive, reaching about 20 % (for the induction furnace melting pot).

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