Quality of synthetic cast iron manufactured in plasma-induction furnace

W. Łybacki
Poznań University of Technology, Piotrowo 3, 61-138 Poznań, Poland, E-mail: wojciech.lybacki@put.poznan.pl

1. Introduction

A basis for the classification of grey cast iron, both according to the Polish Standard PN-92/H 83106 and to the standards of other countries, is its minimal tensile strength determined on a sample of diameter \( d_0 = 20 \text{mm} \), produced from a separately casted roller of the diameter \( \varphi = 30 \text{ mm} \) and length 300 mm. Although tensile strength provides a basic criterion for cast iron quality, the opinion that the problem of cast iron quality is of more sophisticated character and the problem of cast iron strength \( \sigma_u \) should be considered together with its other features, e.g. hardness, modulus of elasticity \( E \), and impact strength \( K_C \), becomes more and more common. W. Patterson and A. Collaud have introduced some following indexes determining the quality of cast iron according to chemical composition: relative hardness \( HB_w \), relative strength \( \sigma_{u,w} \), and complex quality index \( L_J \) or \( Q_i \). According to chemical composition optimal values of the modulus of elasticity have been defined, characterizing a cast iron of good quality [1,2].

At present crucible induction furnaces are more often applied for cast iron melting. The essential disadvantages of these furnaces is low temperature of slag limiting the course of reaction between the slag and metal. Melt in an induction furnace consist of suitably chosen charge materials remelting and overheating of liquid alloy till required temperature.

As a result of co-operation between The Foundry Laboratory and The Institute of Electrical Engineering (both Poznan Technical University) induction-plasma installation for melting was built.

Plasma, as an additional source of energy in an induction furnace shows the following features:
- does not pollute the liquid metal with undesired impurities;
- provides good stability of electrical parameters, which enable control process and simplifies its course;
- gives high temperature (up to 14000ºC in argon plasma) and energy concentration;
- enables refining and intensifying of melting processes;
- according to the kind of used plasma-generating gas the melt may be effected in any atmosphere.

Laboratory research showed positive influence of induction-plasma melting on mechanical and plastic properties of cast ferrous alloys. An increase of strength was found out especially for impact strength of such cast ferrous alloys as: grey cast iron, carbon cast steel and stainless cast steel [3,4]. The results of this research were confirmed in a foundry in an induction furnace with the capacity of 300 kg. Moreover it was shown that induction-plasma melting increased the efficiency of induction furnace two times with less consumption of electrical energy by about 25 % [5].

Basic raw materials used for grey cast iron manufacturing are foundry irons, ferrous and iron scrap. The cheapest raw material that may be used in production of cast iron is ferrous scrap. The cast iron obtained in the result of steel carbonizing is called synthetic cast iron. The main obstacle to the wide use of ferrous scrape in synthetic cast iron manufacturing is low effectiveness of known methods of iron and steel carburizing.

Research on the kinetics of iron and steel recarburization was the subject of number of papers [6, 7]. It shows that recarburizing of liquid ferroalloys depends on the following factors:
- temperature of the process;
- chemical composition of liquid metal;
- mixing of liquid metal;
- kind of carburizer;
- furnace atmosphere.

There are two main ways of recarburization during steel melting in foundries. Strewing the liquid metal surface with carburizer or blowing any powdered carburizer by means of nitrogen or air fluxes. The first method assures efficiency of the process from 30 to 50 % the second from 50 to 70 % [6].

2. Experiments

The research on obtaining synthetic cast iron in induction-plasma furnace was carried out in Foundry Laboratory by means of installation consisting of induction furnace PI50/8 and plasma torch together with plasma supply and control systems. The scheme of laboratory induction-plasma furnace is presented in Fig. 1.
Melting of synthetic gray cast iron in the induction-plasma furnace was followed by the research on efficiency of recarburizing of Armco iron and cast steel. As a charge material Armco iron or steel with chemical composition given in Table 1 was used. Kind and chemical composition of carburizers are presented in Table 2 (carbon and sulphur contents was analysed by means of automatic analyser METALYT CS ELTRA Gmbh).

### Table 1

**Chemical composition of Armco iron and steel**

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.012</td>
<td>0.02</td>
<td>0.015</td>
<td>0.0065</td>
<td>0.086</td>
<td>0.0005</td>
</tr>
<tr>
<td>0.21</td>
<td>0.360</td>
<td>0.600</td>
<td>0.014</td>
<td>0.020</td>
<td>0.170</td>
</tr>
</tbody>
</table>

### Table 2

**Chemical composition of carburizers**

<table>
<thead>
<tr>
<th>Kind</th>
<th>Mar-Kind</th>
<th>Carbon</th>
<th>Sulphur</th>
<th>Ash</th>
<th>Volatile matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite A</td>
<td>I</td>
<td>96.88</td>
<td>0.136</td>
<td>1.03</td>
<td>1.95</td>
</tr>
<tr>
<td>Graphite B</td>
<td>II</td>
<td>94.78</td>
<td>0.556</td>
<td>4.44</td>
<td>0.22</td>
</tr>
<tr>
<td>Anthracite A</td>
<td>III</td>
<td>75.85</td>
<td>0.799</td>
<td>15.61</td>
<td>7.74</td>
</tr>
<tr>
<td>Anthracite B</td>
<td>IV</td>
<td>88.45</td>
<td>0.853</td>
<td>4.38</td>
<td>6.32</td>
</tr>
</tbody>
</table>

Results of recarburization of Armco iron and steel point at high efficiency of recarburizing in induction-plasma furnace especially for the carburizer marked as I. It should be underlined that about 90% of total carbon content was assimilated during overheating of the liquid metal at the temperature 1460°C.

### Table 3

**Recarburizing rate of the liquid Armco iron at the temperature 1460 - 1480°C**

<table>
<thead>
<tr>
<th>Time, min</th>
<th>Carbon, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.012</td>
</tr>
<tr>
<td>5</td>
<td>1.67</td>
</tr>
<tr>
<td>10</td>
<td>2.99</td>
</tr>
<tr>
<td>15</td>
<td>3.12</td>
</tr>
<tr>
<td>20</td>
<td>3.56</td>
</tr>
</tbody>
</table>

Results of studies of steel carburization in an induction-plasma furnace, using argon as plasma-generating gas, have shown high, exceeding 90%, effectiveness of the process. Carburizer carbon utilization reached even 100% (Table 3). Taking into account current prices of charge materials, i.e. steel scrap, carburizer, and pig iron, the cost of manufacturing 1 ton of synthetic cast iron might be lower by about 40% as compared to the foundry iron [8].

Results of the research give an evidence that without a modification process cast iron having the strength from 150 to 350 MPa may be obtained. Inoculation process allows to produce cast iron of the strength from 300 to 400 MPa.

The research allows to ascertain that synthetic cast iron is characterized by better mechanical properties than the cast iron melted of traditional raw materials. This is confirmed by quality coefficient $LJ > 1$ (according to Patterson) shown in Table 5. The chemical composition of synthetic cast iron is presented in Table 6.
4. Conclusions

The research performed in laboratory with plasma-induction furnace allows to formulate the following conclusions:

1. In plasma-induction furnace all grades of grey cast iron may be manufactured of ferrous scrap.

2. Without inoculation a synthetic grey cast iron of strength up to 300 MPa may be produced, while inoculation process enables to improve the strength of the cast iron up to 400 MPa.

3. The synthetic cast iron produced in a plasma-induction furnace is distinguished by its improved quality as compared with the cast iron produced of traditional raw materials.

References


W. Lybacki

SINTETINIO LIEJAMOJO KETAUS, GAMINAMO PLAZMINĖS-INDUKCINĖS KROSNYSE, KOKYBĖ

Reziumé

Straipsnyje pateikiami sintetinio liejamojo ketaus gamybos plazminės-indukcinės krosnyse tyrimo rezulta- tai. Nustatyta, kad plazminis-indukcinis procesas sudaro palankias sąlygas gaminti aukštos kokybės, gerų mechaninių savybių pilkajį sintetinį ketą.

W. Lybacki

QUALITY OF SYNTHETIC CAST IRON MANUFACTURED IN PLASMA-INDUCTION FURNACE

Summary

The work presents the results of research of synthetic cast iron production in an plasma-induction furnace. It was ascertained that the plasma-induction process provides advantageous condition for manufacturing of synthetic grey cast iron of high grade and good mechanical properties.

V. Льбашки

КАЧЕСТВО СИНТЕТИЧЕСКОГО ЧУГУНА, ПРОИЗВОДИМОГО В ПЛАЗМЕННО - ИНДУКЦИОННЫХ ПЕЧАХ

Резюме

В статье представлены результаты исследования качества синтетического чугуна производимого в плазменных - индукционных печах. Определено, что плазменно - индукционный процесс создал благоприятные условия при производстве серого синтетического чугуна высокого качества с хорошими механическими характеристиками.

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