ELECTROSLAG CASTING OF FLANGE TYPE BILLETS BY USING METAL MODIFYING WITH SYNTHETIC ULTRADISPERSED PARTICLES

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Method of producing high-quality billets of flange type using the centrifugal electroslag casting with metal modifying by synthetic ultradispersed particles of titanium carbonitride is described. In this case the level of mechanical properties of castings is not almost differed from properties of a forged billet, that makes it possible to use the cast electroslag castings instead of forgings. Results of comparative analysis of cast metal are given and advantages of the method are shown.

At the present time the products in the form of ring-shaped billets of a flange type are widely used at the enterprises of gas and petroleum refining industry for joining different pipelines. These products are produced by GOST 12820-80, GOST 12821-80 from 20, 09G2S, 10G2, 2Kh13, 08Kh18N10T grade steels and others and operate at high pressures and under severe climatic conditions, at abrupt drops of temperatures of transporting media.

These products can be manufactured using different technological processes. Forging, stamping, casting by traditional methods (open methods of melting) with a post mechanical treatment of billets are most widely used. These standard technologies have both advantages and drawbacks.

Advantages of the traditional technology of casting are the high accuracy of billets with minimum tolerances for machining and a high factor of metal utilization. Its drawbacks refer to a poor quality of metal and difficulty in producing dense billets, because the molten metal during melting and pouring is saturated with gases, non-metallic inclusions, harmful impurities and prone to structural and chemical inhomogeneity. Therefore, the cast billets for manufacture of critical components are not used in principle.

Products, made by forging, have the higher metal quality, though they can inherit the defects of cast billets and ingots used in this case. The important drawbacks of this technology are the high cost of billets, stipulated by the use of a large number of intermediate operations (forging of ingots for billets, their cutting, piercing and expansion), a low factor of metal utilization and the need in expensive forging and rolling equipment. Thus, the hot working in manufacture of flange billets is a forced procedure which is used due to a poor quality of casting.

The challenging trend in the solution of this problem is the replacement of forged billet by high quality castings with minimum tolerances for machining. As these components have central through holes, then it is rational to use a promising technology for their manufacture: a centrifugal electroslag casting which is free from many above-mentioned drawbacks owing to its technological features [1].

The principle of the technology consists in electroslag remelting of electrode in a melting unit, providing accumulation of molten metal and slag in required amounts and its subsequent pouring into a rotating mould. Consumable electrodes of any shape and cross-section can be used as remelting metal. It is this technology that was used for manufacture of critical flange billets.
Remelting of the consumable electrode was performed under the flux, representing a mixture of calcium fluoride, electric corundum, magnesite and silica. Such flux provides the molten metal refining in a melting unit from sulphur and phosphorus, protection from a harmful effect of surrounding medium, and is characterized also by a significant fluidity at high rate of cooling [2].

Method of electroslag casting is simple and efficient. Equipment for the realization of this technology includes serial installations of A-550U or EShP-0.25 types, a skull melting unit of a special design, a centrifugal machine with a vertical axis of rotation and a casting mould.

Accuracy of the produced casting is defined a casting mould. Therefore, a composite metal chill mould, manufactured using a method of a lathe machining of ring-shaped billets, each of them repeats a part of an external configuration of the piece being cast, was used. During pouring out of a slag-metal jet into a mould its separation is occurred under the action of centrifugal forces. Slag prevents the casting sticking to the cast mould walls, thus spreading by a thin and uniform layer over its surface. A larger part of the slag is forced out inside and upward the casting where it is a hot top and does not allow formation of cavities. With a general reduction in temperature of metal and slag, a skull, separated from billet only after its withdrawal from the mould, is formed. As an example, the Figure 1 shows a general view of a dismantled metal chill mould with a casting.

![Figure 1. General view of dismantled metal chill mould with casting in a skull](image)

The important advantage of this technology is the feasibility of billet metal hardening owing to its modifying. The modifier was selected in accordance with a procedure described in work [3]. It was established that an integrated modifying with synthetic ultradispersed particles of titanium carbonitride in the amount of 0.3-0.5% of the melt mass is most effective. The modifier was produced by mixing the powdered components with a subsequent cold pressing into tablets of 25-30 mm diameter and 8-15 mm thickness. Sizes of tablets were selected from the condition of their dissolution in a molten metal being modified during 20-30 s. The modifier was added at 1650 °C temperature for 2 min before the pouring out that provided the uniform distribution of dispersed particles-inoculators in the entire volume of the molten metal in the melting unit. Metal pouring into a metal casting chill mould was made at 1600 °C temperature.

Billets of flanges, produced by the centrifugal electroslag casting with a modifying (CESCM), satisfy all specified requirements to the products: this is a geometric accuracy of casting and also high properties of the metal. Thus, the tolerance for machining as to the external surface is 2.0-2.5 mm, in height – up to 4 mm, as to the internal diameter – 8-15 mm. Here, the metal utilization factor is 0.6-0.8. This reduces significantly the metal content of the product and power consumption for its manufacture.
The electroslag modified metal is differed from metal, produced by an open melting, by a fine-grain structure, high chemical homogeneity, absence of foreign oxide inclusions, air bubbles, pores, cavities, cracks, low content of harmful impurities of sulphur and phosphorus, uniform density of metal in the entire volume and, consequently, also by the isotropy of physical-mechanical properties in all the directions.

Thus, for example, the analysis of structure of castings produced from 2Kh13 steel proves that non-modified metal has a directed transcrystalline structure with long primary axes of dendrites. Metallographic analysis showed that coarsening of martensite structure is occurred in this case accompanied by a significant increase in hardness with a intercrystalline form of metal fracture (Figure 2).

Figure 2. Structure of cast non-modified steel 2Kh13: a – macrostructure; b – microstructure (X200); c – fracture relief

Adding of 0.4 % of modifier into metal leads to a noticeable change in structure and properties of the cast metal. Zones of transcrystallization in ring shaped castings are eliminated, sizes of dendrites are abruptly decreased, acquiring a favourable shape in the entire volume of the metal solidified. Structure of castings is characterized by the presence of ferrite martensite matrix with compact carbides arranged mostly in micrograins, and fracture of impact samples has mainly a transcrystalline nature (Figure 3).

Figure 3. Structure of cast modified steel 2Kh13: a – macrostructure; b – microstructure (X200); c – fracture relief
In this case the level of mechanical properties of castings is not almost differed from properties of a forged billet. Results of mechanical tests of some grades of steels used for the manufacture of flanges are given in the Table 1.

Table 1

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Heat treatment conditions</th>
<th>$\sigma_t$, MPa</th>
<th>$\sigma_y$, MPa</th>
<th>$\delta$, %</th>
<th>$\psi$, %</th>
<th>$KCU^{+20}$, MJ/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>09G2S 09G2S (induction melting) 09G2S (CESCM)</td>
<td>Normalizing at 930°C, air</td>
<td>505</td>
<td>332</td>
<td>34</td>
<td>62</td>
<td>1.34</td>
</tr>
<tr>
<td>2Kh13 2Kh13 (induction melting) 2Kh13 (CESCM)</td>
<td>Quenching at 1050°C, oil, tempering at 660°C, air</td>
<td>808</td>
<td>636</td>
<td>21</td>
<td>68</td>
<td>1.42</td>
</tr>
<tr>
<td>08Kh18N10T 08Kh18N10T(induction melting) 08Kh18N10T(CESCM)</td>
<td>Austenization at 1050°C, air</td>
<td>546</td>
<td>278</td>
<td>55</td>
<td>67</td>
<td>2.62</td>
</tr>
</tbody>
</table>

The comparative analysis shows a significant advantage of the electroslag metal over the metal of the onen induction melting and small differences as to the properties of the forged metal. Ultrasonic testing and magnetic flaw detection showed a dense cast structure, absence of microcracks and any defects. After mechanical treatment these flanges have passed successfully hydraulic tests for air tightness under 32 MPa pressure. As an example, Figure 4 shows a general view of casting and ready flange $D_n$ 200 at pressure of working medium $P_n$ 10 MPa.

As a whole, the properties of electroslag metal satisfy the requirements of TS26-0157-24-69 that makes it possible to use the cast electroslag castings instead of forgings. In addition, this technology provides high flexibility in the production of different types and dimensions of the flange billets.

REFERENCES: