Production of Titanium Sponge Ingots with Increased Chlorine Content

YU.V.LATASH, I.V.SHEIKO, M.L.ZHADKEVICH, V.S.KONSTANTINOV
A.N.PETRUNKO, A.E.ANDREYEV, A.YA.DEYNEGA
V.V.TELIN, L.YA.SHWARTZMAN

*Institute of electric welding, Ukraine, 252650 Kiev, ul.Bozhenko, 11
**Titanium Institute, Ukraine, 330035 Zaporozhye, pr.Lenina, 180
***Zaporozhye Titanim and Magnesium Plant, Ukraine, 330106 Zaporozhye

ANNOTATION

The major constituent of the ingot cost is the cost of titanium sponge, which is attributed to considerable consumption of electric power to run the vacuum separation process. The investigations showed that the shorter separation period by 20-30% had essentially reduced the expenses required for production of titanium sponge. The residual chloride compounds are removed from titanium sponge during the subsequent remelting. Application of an arc, an electron beam, a plasma flame as a heating source to remelt the titanium sponge with increased residual chlorides content is actually impossible because of heavy evolution of magnesium chlorides into the melting chamber. The induction remelting in a sectional copper water-cooled mould had been tried out as a method for melting a gas-saturated titanium sponge.

Key words: underseparated, sponge, melting, ingots, heating sources, induction, sectional mould.

The vacuum separation process used for production of titanium sponge is one of the power-intensive and expensive processes, basically due to the requirements to the chlorine content in the commercial metal. It is known that in the reaction mass vacuum separation the bulk of magnesium and magnesium chloride is removed at the beginning of the process. It takes 25-30% of the total process cycle. Several ten-hour periods are required to distill negligible portion of magnesium and magnesium chloride. This results in unjustified consumption of electric power, decrease of furnace output, fast wear of the equipment, worsening of titanium sponge quality due to air entry to the unit [1-3].

Production of titanium sponge with increased chlorine content will allow to avoid the above disadvantages. Our investigations and calculations showed that production of titanium sponge containing 0.12% (mass) chlorine allows to increase the reduction furnace capacity by 15% and the capacity of vacuum separation furnace- by 6.8%. Total consumption of electric power for production of titanium sponge and titanium sponge ingots in the vacuum-arc furnaces is reduced by 480 kW·h/t. When producing titanium sponge with 0.3-0.5% (mass) chlorine content, vacuum separation period is reduced by 16.5%, the furnace output increases by 19%, and when producing titanium sponge with chlorine content up to 1.0% (mass), the vacuum separation period is reduced by 24%, the furnace output increases by 25.5%.

Nevertheless, when titanium is exposed to atmosphere at ambient temperature, its quality deteriorates. This attributes to moistening of titanium sponge which contains magnesium chlorides readily hydrolyzed. The increase of moisture content in titanium sponge results in increase of oxygen content in it which, during melting, is transferred to the ingot thus deteriorating its quality. The major features indicating the extent of titanium sponge moistening are residual content of magnesium chloride, duration of contact with air, air moisture, microstructural sponge characteristics. The studies showed that the titanium sponge moistening increases with the increase of chlorine content. Rate of moistening is maximum during the first 1.5 hours and then it decreases sharply. Total saturation is achieved in 8-10 days, the process is irreversible. The sponge drying before melting allows to reduce content of moisture in it and thus to improve its quality. On the other hand, to prevent moistening of titanium sponge, it is necessary to reduce the time of its contact with air.

Since titanium sponge is a raw material for production of titanium ingots, there is a need to design the equipment and to develop the process for remelting of such a titanium sponge. Let us review the prospects of the existing and potential methods for remelting of underseparated titanium sponge. Currently, 90% of titanium ingots and titanium alloys are produced in the vacuum remelting furnaces [4]. With a vacuum-arc furnace, direct current arc, burning between a consumable electrode and metal bath in the mould, is a heat source. It is known that the electric arc burns in the vacuum-arc furnace in the medium of vapours of remelted metals. Depending on
vapour concentration and pressure of vapours within the interelectrodes space, the electric arc can be of pinched, diffusion or transition shape. The pinched shape is the most preferable one (Fig. 1).

![Fig. 1. Vacuum arc furnace with consumable electrode](image)

1 - water cooled copper tray; 2 - consumable electrode; 3 - water cooled mould; 4 - electrode remainder to which a consumable electrode is welded; 5 - titanium ingot; 6 - electrode holder.

In the course of remelting of the consumable electrode, pressed out of underseparated titanium sponge with increased chlorine content, the uncontrolled emission of magnesium and chloride vapours can occur in the arc burning zone. It can cause origination of ionized cloud of vapours not only between the end of consumable electrode and metal bath mirror but also between the side surface adjacent to the electrode end and the mould wall. The volume ionization in the interelectrode space can result in an arc discharge between the consumable electrode and the mould wall. As a result, the water-cooled wall of the mould in the zone of arc action can melt and cause explosion when water enters the metal bath.

The above disadvantage, to the same degree, relates other processes based on the arc heating: vacuum-arc melting with inconsumable electrode, vacuum-arc melting in a skull furnaces, type ГРЭ with water-cooled crucible [5]. Therefore, in the vacuum-arc furnaces, the high-quality titanium sponge with the residual chlorine of not more than 0.12-% (mass) is remelted.

Along with a widely used vacuum-arc melting of titanium, in the industrially developed countries, including Ukraine, the activities are carried out on electron-beam melting of titanium sponge [6]. While the melting of titanium ingots in the electron beam remelting furnace from secondary titanium is successfully brought to a commercial level, the remelting titanium sponge, even of high grades, is conjugated with significant technical difficulties, caused both by specific features of electron beam melting and properties of the charge of this type.

The specific features of electron beam process consist in the fact that metal melting is carried out under high vacuum ($10^{-3} - 10^{-5}$ mm Hg). Therefore, while remelting the gas-saturated charge i.e. titanium sponge, large amount of gases and chlorides is given off into the melting chamber causing disturbance in steady operation of electron guns and vacuum systems (Fig. 2). The case becomes worse when titanium sponge with increased content of magnesium and magnesium chlorides is remelted since, along with gas emission, a considerable amount of magnesium and magnesium chlorides vapours will enter the melting chamber, causing premature destruction of the electron gun electrodes. In addition, the condensate of finely dispersed conducting particles created inside the melting chamber can cause the electric breakdowns in high-voltage components of electron guns and disturbances in operation of all high voltage apparatus. Therefore, with electron beam units, the titanium sponge containing not more than 0.12-% (mass) of chlorine is remelted.
In industry, for a long time the activity has been carried out on application of plasma technology during remelting of titanium sponge of various grades including TG - TV [7] (Fig. 3). The magnesium chloride vapours given off during remelting are condensed on the water-cooled components inside the melting chamber including the chamber walls, plasma generator cases, mould, etc. With this, chlorine compounds get onto the plasma generator electrodes of high melting materials, heated to high temperature. The low-melting compounds, formed with this, cause quick erosion of electrodes and, in addition, can entry a metal bath thus contaminating the remelted metal. That is why, titanium sponge with residual chlorine not more than 0.15% (mass) is used to melt the ingots in the plasma furnaces.

So, the analysis of traditional methods of titanium sponge remelting shows that it is difficult, from the technical point of view, to put into practice the means for remelting of titanium sponge with chlorine content higher than 0.15% (mass). It seems that the arcless heating source is more promising for this purpose.

High-frequency electric field having the following technological advantages in comparison with other types of electric heating can serve as a heating source:
- independent heating source which does not contaminate metal;
- proper agitation of hot metal during melting which provides homogeneity of chemical composition in the bath volume;
- possibility to maintain the melt temperature within the required range;
- low loss of metal and alloying elements in burning;
- possibility to remelt loose charge without preparing the consumable billet or electrode.

The merits of the induction heating source are realized to the most degree in the melting units with a cold crucible or cooled sectional mould which do not have a crucible of refractory material which is a major contaminating source of molten metal [8-10]. The experimental melting of titanium sponge with high chlorine content (up to 1.57% mass) were carried out at the induction unit with a Ø 70 mm sectional mould (Fig.4).

The unit comprises a vacuum melting chamber, an ingot chamber, a screw feeder, a charge bin, a mould, and induction heater, high frequency generator, vacuum and viewing systems.

The process of ingot melting includes the following major process operations: loading of charge into the bin, putting of seed of the metal to be melted onto the tray, vacuum evaporation of charge and melting space, filling up the melting chamber with inert gas up to the remelting pressure, induction of bath in the mould on the seed by means of high-frequency electromagnetic field, feeding of charge batch, melting of charge and removal of ingot from the mould after filling it with molten metal.

During melting, the melting bath was noticeably pressed out from the mould walls forming a dome-shaped bath mirror. With this, the charge lumps under action of the powerful electromagnetic field created by the induction heater current in the mould, fell basically onto the top of the dome where they got melted.

The dome-shaped metal bath has an open surface which provides effective degassing of the charge being melted.

The gases, vapours, chlorides given off in large quantities were evacuated from the melting chamber by inert gas flow through the melting chamber.

The surface of the melted out ingots was completely fused, in the upper portion of the ingot there was a thin layer of finely dispersed sublimates which were readily removed with a metal brush or by washing in the flow-through water.

The evaluation of the ingot metal quality showed that content of iron, carbon, silicon, nitrogen remained actually at the same level that was present in the initial titanium sponge. To evaluate the oxygen behavior the additional studies are to be carried out.
Table

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<th>Sample</th>
<th>Hardness, HB</th>
<th>Fe</th>
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<th>Cl</th>
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The results of investigations showed that induction heating in a sectional mould was one of the most perspective trends for melting out the ingots from underseparated titanium sponge. It will contribute to reduction of titanium sponge cost and the cost of titanium products in the end. The ingots obtained after induction melting can be used as consumable electrodes in the vacuum-arc furnaces of the second remelting. The design of induction furnace with a sectional mould needs a detailed improvement.

REFERENCES: