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Resource and energy saving technology for producing high-quality steel castings with heat-time treatment

D A Lubyanoy[1], R O Mamedov[2,3], S V Knyazev[3], B M Sokolov[2,3] and N V Oznobikhina[2,3]

[1]Kuzbass State Technical University, 7 Ordzhonikidze Street, Novokuznetsk, 654000, Russia
[2]"Kuznetskoye Litye" LLC, 7 Ferrosplavniy proezd, build. No. 1, Novokuznetsk, 654034, Russia
[3]Siberian State Industrial University, 42 Kirova Street, Novokuznetsk, 654007, Russia

E-mail: Lubjanoy@yandex.ru

Abstract. Today, the current direction in the development of steel production is resource and energy saving. So, one of the problematic issues in the steelmaking process is to reduce the consumption of ferroalloys. The possibility of improving the quality of castings, due to the heat-time treatment of the melt is considered. The melt is overheated to high temperatures by holding in the furnace. Because of that, the yield of suitable products increases, the metal consumption of products decreases.

1. Introduction

In modern conditions of industrial production, the improvement of the technological and service properties of metal products, the achievement of a world-class level of quality indicators, is possible only if the fundamental scientific research is deepened and new technological solutions are developed on their basis. The production of the vast majority of metallic materials is associated with their smelting. Therefore, the issues of obtaining fundamental data on the structure and properties of liquid metal, their changes as a result of various external influences are of significant importance.

As a rule, the classical technology of steel production from a fresh batch includes an oxidative melting period in which 0.2 – 0.5 % C is oxidized [1]. When iron oxides are added to the bath with a melt, in the form of iron ore concentrate, metal oxidation is also performed at the same time. It was found that during the oxidation period of the smelting during the carbon burnout process, not only harmful gases are removed, but also useful elements such as manganese, chromium and silicon.

2. The problem and its solution

Resource and energy saving is currently the most important direction in the development of steel production. Reducing the consumption of ferroalloys in the process of steelmaking is an urgent task. For this reason, if possible, it is necessary to reduce the oxidation period during smelting. From the data analysis in [2], it can be seen that when burning 0.1-0.15% C from the initial value, the maximum removal of hydrogen is achieved. Then, the hydrogen content decreases less intensely. Its final content depends on the raw lining of furnaces, an undried chute and a casting ladle, charge materials, ferroalloys and various additives introduced into the metal or into slag during melting and casting, the atmosphere surrounding the liquid metal during the production and casting of metal, etc.

According to the published data [2], the carbon content in the metal by melting should be 0.1 – 0.2% higher than in the finished steel. From the point of view of P.Ts. Peshev and R.P. Todorova high-quality deoxidation of steel is the most important means of preventing sieve shells. To deoxidize one tonne of steel, it is recommended to introduce 1 – 1.3 kg of aluminum. The residual amount of aluminum in steel should be more than 0.03% [3].

This means that the deoxidation of steel and the presence of residual aluminum in it have a decisive influence on the most important indicators of steel quality such as mechanical properties and sieve-like shells [4]. For this reason, one of the main tasks of the oxidation period to remove hydrogen in the metal becomes less significant [5]. As a result, oxidation of a high carbon content from the melt, which is accompanied by the oxidation of useful impurities such as silicon, manganese, and chromium, is not rational in meltings for castings.

In the conditions of modern production, it is often not possible to obtain castings of the required quality without additional processing. This is due to many factors, for example, metal heredity, crystallization rate, etc. Many years of production experience suggests that one of the most important reserves for reducing structural and chemical heterogeneity of steel, improving the quality of steel products in steel production, is the improvement of the technology of the smelting process to obtain an equilibrium, most uniform melt before crystallization [6]. Crystallization of the metal occurs from a nonequilibrium state, which enhances the chemical and physical heterogeneities of the solid metal, reduces its service characteristics and leads to significant deviations of its quality from melting to melting.

There are different ways to transfer the melt into equilibrium. The most affordable way to obtain equilibrium melt is a high-temperature effect. Classical heat treatment does not always allow castings with the necessary structure to be obtained. The authors of [6, 7] revealed that the preparation of a melt for crystallization by heat-time treatment has an effect on the solidification process and helps to improve the structure and properties of solid metal.

Extensive research conducted at Zlatoust and other metallurgical plants showed that the use of heat-time treatment for the production technology of a number of alloyed steel grades gives good results, leading to improved mechanical properties, reduced scrap, etc. [7].

Heat-time treatment of the melt leads to a decrease in its chemical and physical heterogeneity, a reduction in the size and number of shrinkage defects. Thermal treatment allows the modes of heat treatment to be significantly reduced and simplified and the energy costs for heat treatment of steel castings to be reduced. The mentioned above phenomenon, as a rule, is accompanied by an increase in ductility, corrosion resistance and other characteristics of the quality of the alloys. The structure becomes more uniform, and the hardness is maintained at the same level, which allows higher mechanical properties of the castings to be obtained. There is a recrystallization and ordering of metal grains. This structure helps to increase the hardness and wear resistance of steel, which are practically not inferior to those obtained with standard hardening. The yield of suitable products increases, the metal consumption of products decreases.

In order to improve the quality of products and reduce their cost in the conditions of LLC “Zavod Gidromash”, melting was performed using thermal heat-time treatment on DSP-1.5 furnace with acid lining. Quite interesting results were obtained by remelting the “returning” low-alloy steel grades (40KhL, 35 KhGSL), etc. With the melting technology without an oxidizing period, with a carbon content 0.24%, in the melt there is 0.26% of manganese (figure 1). And using the melting technology with an oxidizing period, with a decrease in carbon content from 0.52% to 0.34%, the manganese content decreases from 0.34% to 0.08%. This shows that the manganese of the melting period, according to the technology with oxidation, is actually almost completely oxidized.

Moreover, with the technology of melting with an oxidizing period, part of the hydrogen is also introduced by slag-forming additives. Therefore, it is considered advisable to use technology with minimal oxidation of carbon during the melting process, a slight oxidation period and the maximum use of slag from the melting period [5]. Part of the hydrogen is removed during the oxidation of carbon by the oxidized slag of the melting period. This technology ensures a minimum loss of useful impurities, as a result of which, the consumption of ferroalloys for a number of melts is reduced by almost two, and in some cases the addition of ferromanganese is completely eliminated, while acceptable mixing of the metal, which is one of the main tasks of the oxidation period, is nevertheless carried out, due to the fact that the metal in the furnace in some cases corresponds to either boiling or semi-quiet (the silicon content in the metal is up to 0.11%), which ensures its sufficient mixing in the bath volume of the furnace [8].

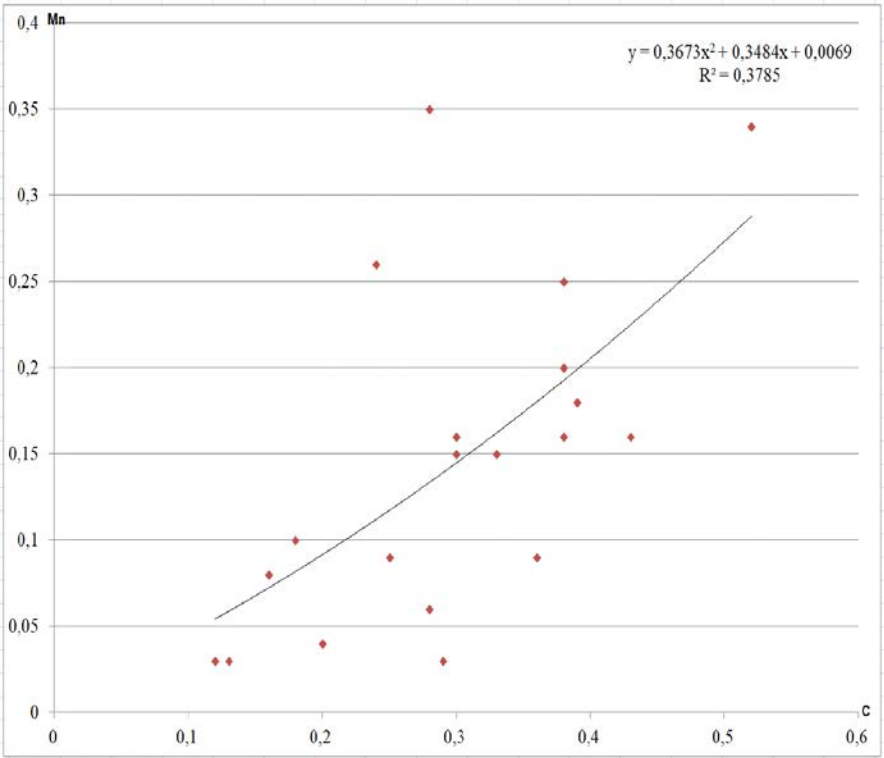

Figure 1. Dependence of Mn content on the C content by melting.

In the period from December 2017 to February 2018, comparative tests of steelmaking technology without an oxidizing period with heat-time treatment and smelting technology usind a fresh batch with full oxidation were conducted. From the conducted melts, we see that there is a decrease in the consumption of cast iron and ferroalloys during smelting of steel 35L in DSP–1.5 (figure 2).

From the histogram, the saving in consumption by the new technology can be seen:

- cast iron 12%;
- ferromanganese 14.6%;
- ferrosilicon 12.7%.

Also, the exclusion of holding time for express analysis and the duration of the smelting of “fresh” carbon charge with oxidation reduces significantly (up to 1 hour or more) the duration of the entire melting.

In addition to effective metal deoxidation (figure 3), when using the studies performed, the optimum quality of the castings is achieved by conducting thermal treatment of the melts, in which the melt is overheated to a temperature of 1650-1700 ^{0}C (for hydro-castings 1680-1710 ^{0}C) with a holding time in the furnace 10 -15 min, which is an effective heat-time treatment and improves the quality of castings. Aluminum, at the end of the heat, is fed to the bottom of the ladle, thereby producing the final deoxidation [8, 9, 10, 11, 12].

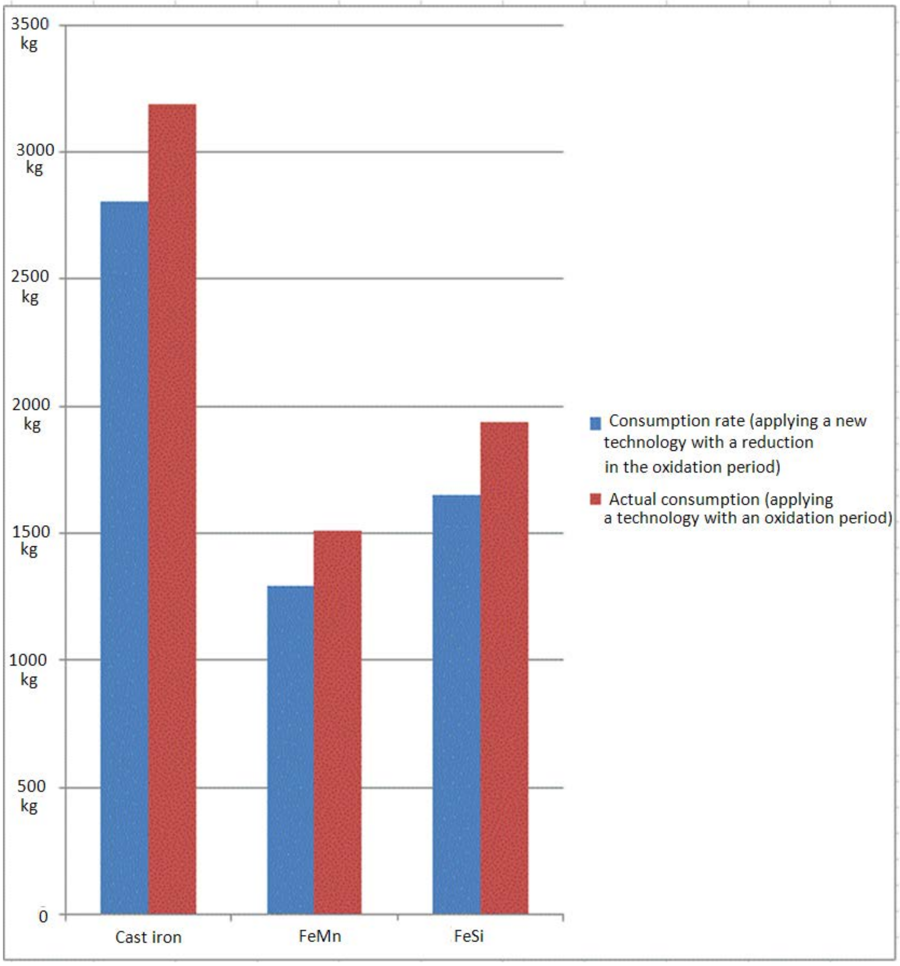

Figure 2. Differences in the technology of smelting without an oxidizing period from the technology of smelting with an oxidizing period.

Figure 3. Casting (bearing housing) with effective metal deoxidation and heat-time treatment.

Figure 4. Responsible casting (rotor disk) without blown holes.

3. Conclusion

Implementation of this metal smelting technology allows obtaining acceptable quality of steel castings with minimal formation of blown holes (figure 4). The described technology has been tested and implemented at LLC "Plant Gidromash" in Novokuznetsk.

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