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# Research of the Possibility of Upgrading of the Melted Steel Pumping Out Process

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**ABSTRACT:** In article questions of upgrading of the melted steel are considered. It is noted that on the accepted technology of smelting became at the end of the oxidizing period the content of gases in metal (oxygen, nitrogen and Hydrogenium), being harmful impurity, often it appears above the values admissible for ready steel. It is shown that deoxidation can be carried out by various elements, both in separate application, and in various combinations. However metals the deoxidants applied in the form of ferroalloys are very expensive and increase product cost.

In work the possibility of upgrading is investigated became by removal of a part of gases pumping out. This technology allows to localized production, to refuse partially import of ferroalloys and does products of competitiveness in foreign market.

**KEYWORDS:** deoxidants, the melted steel, gases in metal, ferroalloys, separate, steel, pumping, Hydrogenium, pressure, crystallizer, carbon, gas emission, carbon oxidizing, liquid steel, nonmetallic inclusions.

## I. INTRODUCTION

On the accepted technology of smelting became at the end of the oxidizing period the content in metal of gases (oxygen, nitrogen and Hydrogenium), being harmful impurity, often it appears above the values admissible for ready steel. It causes the necessity of decrease of content of gases in steel or at least their transfer to a state, a having least adverse effects on properties of ready metal. Some elements – deoxidants promote decrease in content of oxygen or an adverse effect also of nitrogen and are gray [1].

Usually understand decrease as steel decontamination the content of Hydrogenium and nitrogen, but these elements have unequal properties. Decontamination generally comes down to reduction of metal in contact with the gas phase having fractional pressure of the deleted gas it is much less, than pressure of its selection from metal [2]. Deoxidation and decontamination of metal, being final operations of receiving the given contact of impurity in ready steel, substantially define quality of an ingot and finished products from it.

## II. LITERATURE SURVEY

Numerous researches of regularities of change of content of oxygen in metal at the end of process of oxidizing refinement allowed to draw a conclusion that oxygen content in metal before deoxidation in any steel-smelting units, mainly, depends on concentration of carbon: the carbon content is less, the oxygen content in metal is more [3,4].

Oxygen concentration is much higher equilibrium with carbon. If to keep this content of oxygen in metal, then in a steel setting time in a crystallizer oxidizing reaction of carbon and fuming of CO and CO<sub>2</sub> will continue. It is admissible only if it is melted boiling and semi-quiet became, and intensity of gas emission in a mold have to be quite particular: when hardening of the boiling metal it is more (but it isn't excessive). When hardening an ingot of quiet steel visible gas emission, i.e. carbon oxidizing reaction course, has to be excluded [5].

Therefore, the first problem of refinement of steel comes down to achievement of the given extent of deoxidation of metal – to receiving in ready liquid steel of such residual content of oxygen which provides normal behavior of metal to its crystallization in time.

Deoxidation of the boiling steel comes down only to some decrease in content of oxygen in metal, at preservation of its level above equilibrium with carbon. It is provided, usually, with deoxidation only manganese at the residual maintenance of its 0,30-0,40%, seldom follow-up enter silicon (residual content no more than 0,02-0,03%) and aluminum (thousand shares of percent).



The second problem of deoxidation consists in ensuring perhaps smaller content in solid steel of products of reactions of deoxidation – the nonmetallic inclusions (NI) and also in receiving NI having the minimum negative impacts on properties of steel. The shallow NI, shaped spheres which are located in volume of metal have such properties.

The third problem of deoxidation comes down to ensuring receiving the fine-grained structure of metal and is solved by receiving the shallow NI which are allocated from a liquid phase in a firm look and playing a role of the centers the beginning of formation of crystals of metal. Such properties nitrides, carbonate of vanadium, niobium etc have. In this case NI positively affect properties of steel.

Eventually the problem of deoxidation – a doping comes down to receiving in ready steel of the given maintenance of the deoxidating and alloying elements. Elements – deoxidants have to have the following properties [6]:

- 1) High deoxidizing ability (a high chemical affinity to oxygen);
- 2) Tendency to formation of the oxides insoluble in liquid steel which are easily removed from it or doing minimum harm to it to properties;
- 3) Ability to improvement of properties of steel (to increase in durability, thermal workability, firmness against action of severe atmospheres etc)
- 4) Low cost and availability (not deficiency). Besides, the element has to reduce deoxidant to influence of such harmful impurity as sulfur and nitrogen on properties became and also remaining in metal have to promote a refinement of grains.

### III. METHODOLOGY

In the presents time isn't present any oxidant who would be the first in all qualifying standards. In a work practice rather large number of deoxidants is applied, each of which is more or less suitable for these or those cases.

Manganese is the most widespread deoxidant. The deoxidizing ability of manganese is sufficient for receiving normal ingots of the boiling steel. Manganese has high chemical affinity to sulfur and significantly reduces the negative influence of sulfur on a internals of steel at introduction it as 0,30 – 0,50% and above.

Silicon is also quite widespread deoxidant. Into steel it is entered in the form of ferrosilicon with the maintenance from 10 to 75% of silicon. Silicon advantage as deoxidant, consists in it with a high chemical affinity to oxygen, allowing a semi-part quiet steel at residual contents it in metal of 0,15-0,30% and also in ability to form nitrides and to prevent an aging became.

Aluminum is applied usually technical clear, on the physical and chemical to internal is one of the best deoxidants since has at the same time high chemical affinity to three harmful impurity to oxygen, nitrogen and sulfur. Besides, aluminum, promotes austenite grain refinement. At the same time positive influence of aluminum on properties of steel appears at residual contents it in metal in the 100-th shares of percent therefore aluminum as deoxidant, in posledny years finds bigger application. Though it is rather expensive.

Vanadium is the valuable deoxidant having a versatile positive impact on properties of steel. For example, production of the non-aging boiling steel is possible with use only of vanadium. Vanadium is entered into metal usually in the form of ferrovanadium which is expensive and scarce material.

Titanium and zirconium is very good deoxidants, but ferrotitanium and ferrozirconium and also alloys in which enter these elements into steel, are very expensive, scarce and are used only by production steel a special purpose.

Calcium and magnesium is the strong deoxidants: their application provides increase in a quality of steel. It is explained by the following circumstances [7]:

1. Their high chemical affinity to the oxygen and sulfur allowing to provide very low residual content of dissolved oxygen (less than 0,001%) are also gray (less than 0,002%) in ready metal.
2. Deoxidation products which remain in metal form mini-globular oxy-sulphidic nonmetallic inclusions, evenly the distributed in metal volume. They have minimum the negative impact on properties of steel. Now broad distribution received deoxidation by the calcium which is a part of complex alloys, for example, of calcium-silicon, a ferrosilicon-calcium, etc. It is characteristic that positive influence of calcium on properties of steel affects already at an expense of its 0,01%, and the expense more than 0,1% isn't required.

Rare-earth metals (REM) have very good deoxidizing abilities, have a high chemical affinity to harmful impurity. Melting point their very low (to 1000<sup>0</sup>C), and boiling point high (to 3000<sup>0</sup>C). It is expedient to apply them in the form of the complex alloy received carbon- thermal by method and containing 40% of REM in repartitions (mainly cesium) and 45 – 50% of silicon.

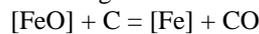
Carbon is ideal deoxidant since the deoxidation product CO is removed from metal. But the high deoxidizing ability of carbon is shown only at pumping out and a purge of metal by indifferent gases when low fractional pressure CO in a

gas phase is provided. In usual conditions with a pressure of 0,1 MPas the deoxidizing ability of carbon can be used only for deoxidation of slag at extraction (diffusion) by deoxidation of metal [8].

It should be noted that not all above-stated deoxidants are manufactured in Uzbekistan and, if necessary, are imported with larger currency expenses. The most available of them is carbon which can successfully deoxidate in the conditions of pumping out. For this reason in our republic begins widely such way of deoxidation of metal takes root [9].

It is known that one of the most reliable and widespread methods of definition of oxygen concentration in steel is vacuum melting in the conditions of which carbon completely restores the nonmetallic inclusions weighed in metal. Pressure of gases in these conditions are supported at the level of 10<sup>-3</sup> – 10<sup>-5</sup> mm Hg (0,133 – 13,3 • 10<sup>-4</sup> N/m<sup>2</sup>) that it isn't enough even in semi-industrial vacuum flowing furnaces and the more so industrially when pouring steel.

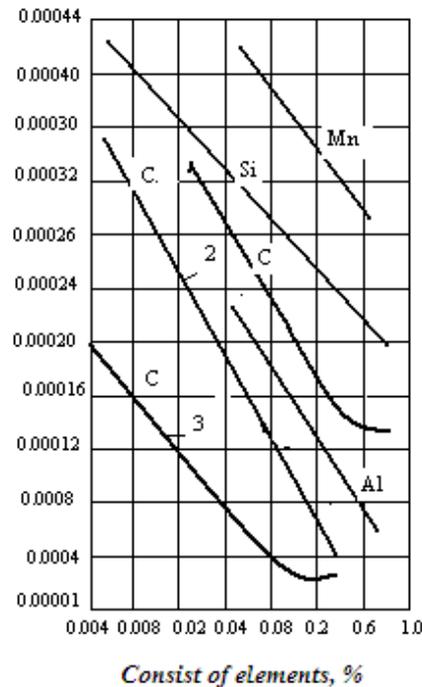
Steel deoxidation by carbon is followed by formation of gaseous white damp on reactions: [10]



From the rule Le-Chatilly it is known what with a pressure pumped down in a surrounding medium, the equilibriums stated above reactions moves from left to right, towards formation of gases. At the same time reactions can take place more stoutly as pressure of P<sub>CO</sub> is supported at the level of several mm Hg.

#### IV. EXPERIMENTAL RESULTS

At department of “Metallurgy” of the Tashkent state technical university researches on determination of deoxidizing ability of various elements and carbon are conducted with different pressure of a gaseous fluid. Results of researches are presented in fig. 1.



**Fig. 1.** Deoxidizing ability of various elements and carbon with different pressure of a gaseous fluid  
1-C (1,01•10<sup>5</sup> Pas), 2-C (0,13•10<sup>5</sup> Pas), 3-C (0,013•10<sup>5</sup> Pas)

Data in fig. 1. show that if fractional pressure of white damp in the field of oxidation of carbon and restitution of inclusions is maintained at the level of 1 mm Hg (133,322 Pas), then even alumina at t temperature = 1600<sup>0</sup>C is fragile and is restored already at [C] = 0,01%.

The made experiments confirm the theoretical assumptions of a possibility of the considerable development of deoxidation of steel and restitution by carbon of the nonmetallic inclusions weighed in it due to pumping out.

In special literature there are very many descriptions of the laboratory and semi-industrial experiments demonstrating noticeable decrease of content of nonmetallic inclusions in steel at its pumping out. Along with it it should be noted



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that in a number of production experiments there were no confirmed high deoxidations of result when using a vacuum [11].

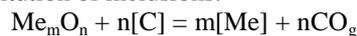
Apparently, kinetic conditions at pumping out of larger mass of metal don't conductivity to restitution of strong oxide inclusions. Besides, and thermodynamic doesn't allow to count conditions of pumping out of larger mass of metals on the considerable development restitutions of  $\text{SiO}_2$  or  $\text{Al}_2\text{O}_3$  even when using perfect rapid pumps.

## V. CONCLUSION AND FUTURE WORK

In our opinion, the reason of this phenomenon can be that researchers control pressure of gases in the recipient (a vacuum chamber, molds or the furnace), but it pressure far doesn't correspond to the white damp selection pressure which it is observed in metal micro-volume, immediately contacting to the restored inclusions. It is known that it is common pressure develops of pressure of a surrounding gaseous fluid and also ferrous - statistical and capillary. At what in the conditions of  $P_{\text{atm}} \leq P_{\text{cap}}$ . Along with it high-heat solid inclusions have rather imperfect contact with reducer – the carbon dissolved in metal that predetermines larger stability of inclusions and small speed from destruction.

From the theory of metallurgical processes it is known that process of destruction of oxides inclusions in vacuum is considered as consisting of the following stages:

1. A carbon mass transfer to the surface of inclusions;
2. Adsorption of carbon on the boundary surface metal – nonmetallic inclusions;
3. Act of chemical reaction of restitution of inclusions:



4. Formation of white damp and removal from metal.

In our opinion it is represented perspective carrying out pumping out in a ladle by means of the rapid high-vacuum modern pumps capable to cause very intensive sparging of metal at larger speeds of removal of white damp. At the same time the mass of metal has to be no more than 15 - 20 tons.

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