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THERMODYNAMIC CONDITIONS OF TITANIUM OXIDES AND TITANIUM NITRIDE FORMATION IN MICROALLOYED STEEL

Titanium, vanadium and niobium influence the properties of microalloyed steel, which stems from the temperature dependence of thermodynamic stability of the formed precipitates: nitrides, carbides and carbonitrides. Titanium nitride TiN, similar to Ti_2O_3 and Ti_3O_5, is formed in liquid steel during refining processes after adding an alloy-additive containing titanium and during solidification. The analysis of formation of nonmetallic inclusions containing titanium in liquid steel should be preceded by the analysis of interaction of titanium and gases (O and N) dissolved in liquid steel [1-2].

The equilibrium constants in the reaction of titanium oxides and titanium nitride formation determined from the free energy of reaction given by Pak et al. [1-2] are as follows:

$$2\,\underline{Ti} + 3\,\underline{O} = Ti_2O_3(s) \qquad \log K_{Ti2O3} = 44\,238/T - 13.0 \tag{1}$$

$$3\,\underline{Ti} + 5\,\underline{O} = Ti_3O_5(s) \qquad \log K_{Ti3O5} = 72\,813/T - 21.32 \tag{2}$$

$$\underline{Ti} + \underline{N} = TiN(s) \qquad \log K_{TiN} = 19\,790/T - 7.78 \tag{3}$$

The thermodynamic conditions of titanium oxides and nitride formation in liquid steel can be presented on the example of Ti_2O_3:

$$K = \frac{a_{Ti_2O_3}}{(a_{Ti})^2 \cdot (a_O)^3} = \frac{a_{Ti_2O_3}}{f_{Ti}^2 \cdot [Ti]^2 \cdot f_O^3 \cdot [O]^3} \tag{4}$$

The formed oxides and nitrides can be solids or a part of the liquid solution. The prerequisite of liquid oxidic solution formation at the steel-casting temperatures is the presence of such oxides as FeO, MnO and SiO_2. Oxygen is completely removed from steel before casting, therefore Mn, Si and thus primarily Fe oxides cannot be formed in a low oxygen concentration. This it is assumed that titanium, oxides and nitrides are solid and do not form a solution. If the value of the product, being a result of actual concentrations of Ti and O or Ti and N, does not exceed the equilibrium value, a nonmetallic inclusion will be produced. The calculations reveal that the precipitation of

Ti_2O_3 at a given temperature requires a higher titanium concentration in liquid steel than in the case of Ti_3O_5 (fig. 1).

Titanium nitride formed in liquid steel prior to solidification is mostly removed from it and thus useless as far as the control of austenite grains is concerned. The quantitative characteristic of effects taking place in the course of secondary metallurgy of microalloyed steel containing titanium is available in many works, e.g. [3-4]. Much more titanium gets to steel at a low nitrogen concentration. The influence of the deoxidation degree defined by the amount of added aluminum, is also visible. When the steel deoxidation is poorer, part of titanium takes the form of oxides, therefore its concentration in steel is lower. The plot in Fig. 2 shows the change of oxygen and nitrogen concentration in liquid steel depending on the initial concentration of nitrogen and aluminum for the varying amount of introduced titanium. In both cases the entry oxygen concentration in steel was 100 ppm.

At a low concentration of nitrogen more titanium is transported to steel. There can be also observed the influence of deoxidation degree defined by the amount of added aluminum. When the deoxidation is weaker, part of titanium takes the form of oxides, and so its concentration in steel is lower. Importantly for the production costs, titanium introduced at the final stage of the metallurgical process should be maximally preserved in steel as it plays a significant role in austenite grain control.

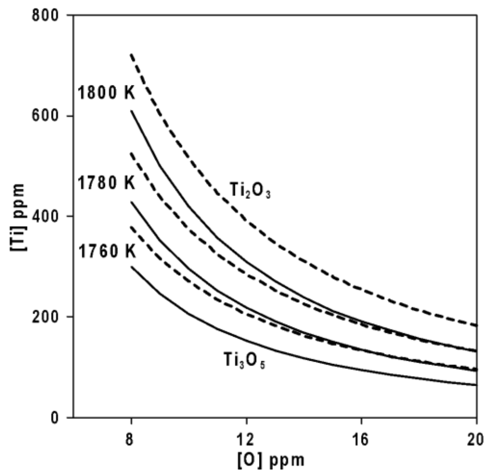

Fig. 1. Equilibrium titanium concentration in liquid steel vs. oxygen concentration for Ti_2O_3 and Ti_3O_5

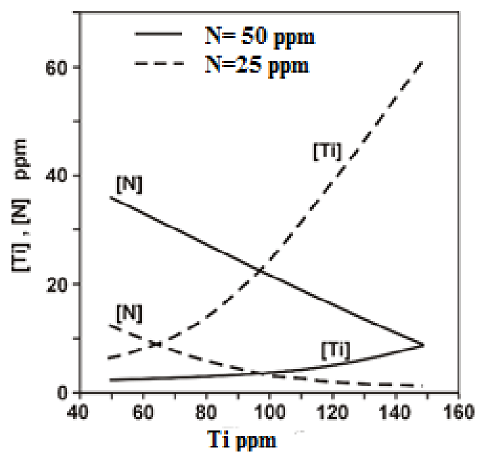

Fig. 2. Titanium and nitrogen concentration in liquid steel at 1805 K depending on added titanium. Added aluminum: 100 ppm

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ИЗГОТОВЛЕНИЕ ДЕТАЛИ СЛОЖНОЙ ГЕОМЕТРИИ ПО SLM-ТЕХНОЛОГИИ ИЗ ЖАРОПРОЧНОГО НИКЕЛЕВОГО СПЛАВА INCONEL 718

SLM-технология – один из видов аддитивного производства, при котором изделие создается методом послойного проплавления порошка металла с помощью лазерного луча, который двигается по заданной траектории согласно трехмерной модели.

Цель эксперимента: Построение модели и элемента форсунки для ЧК «ДТЭК» с толщиной слоя 30 мкм для оценки качества внутренних поверхностей.

Полная модель и вырез форсунки (рисунок) подвергались визуально-оптическому контролю (визуальному анализу).

При визуальном анализе была проведена оценка вида поверхностей элемента «вырез» напечатанного по таким же режимам, что и форсунка.