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Automation of metal and alloy melting processes using spectral analysis data on the composition of exit gases

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Abstract. The methodology has been developed for determining the physical chemical parameters of real-time metal and alloy melting to identify the correlation between the intensity of the analytical lines of exit gases and the intensity of the lines which are generated in the workshop laboratory by analyzing the samples cast by the furnace operator at the same time, which enables automation of melting process.

1. Introduction

Today, low temperature plasma is generated mainly by a dual-jet arc plasma generator which serves as a spectrum excitation source for solutions and powder materials, as well as for heat treatment of metals and alloys. From the point of view of spectral analysis, the drawback of a dual-jet arc plasma generator is its inability to control the composition of gas flows that do not reach glowing areas. This drawback is eliminated by using a six-electrode device based on three high-voltage transformers powered from a three-phase network [1 - 7].

2. Body text

The production tests were performed in KAMAZ foundry plant to identify the capability to monitor the melting status in real time by the composition of exit gases. The tests showed that the usage of this device in the electric-arc steelmaking furnace DSP-50 made it possible to correct the alloy composition during its production by re-blending the required components; to reduce the power consumption by 10% and electrode consumption by 3%; to control the temperature of molten metal during melting and furnace downtime; to reduce the losses of metal resulted from burnt-off disperse waste by more than two times; to decrease the “time constant” for the process of chemical composition measurement in a produced alloy up to a few seconds, i.e. by two orders of magnitude; the number of defects was decreased from 22% to 15% in the aluminum alloy casts made in the holding furnace Dozomatic 400 by controlling the modifier content in the melt [8].

However, automation of a melting process is not possible with a high-voltage six-electrode discharge due to a low temperature of this source (4800°C), which cannot excite atoms with an excitation energy of higher than five electron volts, that is typical for most elements. This problem can be addressed by using a six-jet plasma generator [9] as a spectrum excitation source for exit gases. It heats exit gases up to 15,000°C, and it is based on three dual-jet plasma generators, which are powered by a three-phase rectifier or electrocar storage batteries. This electric vehicle also carries a spectrum



analyzer between the controlled furnaces equipped with offtakes from the main exhaust duct, and displays to provide a furnace operator with melting status data in real time.

A six-jet arc plasma generator is shown in Figure 1. The plasma forming copper heads (1) are mounted on the nonconductive plates (2), and secured rigidly to the brackets (3) to enable travel along the axes of the heads (1) in the direction perpendicular to the pipe supports (4). Above them there are annularly positioned tube chamber (5) responsible for argon supply to the heads (argon protects electrodes against oxidation), and a chamber (6) responsible for distribution of working gas (air) via the flexible hoses (7). Protective gas is supplied to copper anodes with contacts A1, A2, A3 and tungsten cathodes with contacts K1, K2, K3 via the flexible hoses (8). Above the supports (4), the chamber (9) for addition of cooling water and chamber (10) for water discharge to the passage (19) are positioned axially to the chambers (5) and (6). Cooling water is added to the head compartments from the vertical passage (17). The chamber (10) for water discharge to the passage (19) is near the tube chamber (9). The chambers (9) and (10) are connected with head compartments via flexible hoses (11) and (12). The water flow (19) (heated by the plasma generator) is directed to the radiator to be cooled, and then the cooled water returns to the passage (16). The supports (4) are positioned on the mounting table (20), and between them the tube (14) is rigidly mounted to form an analyzed gas flow or processed powder material (15). The cylinder (13) is mounted axially to the tube (14). This cylinder provides the uniformity of change in angle of convergence of six heads with the help of the articulated joint system (21) which ensures the synchronous change in inclination of the heads in relation to the plane of the table (20). The system (21) includes the plates (22) with the brackets (3) which are mounted loosely on them. The plates are responsible for adjustment of the interelectrode gap between the plasma forming heads in the plasma generator, which are mounted on the nonconductive plates that are secured rigidly to the brackets to enable travel along the axes of the heads in the direction perpendicular to the pipe supports. Above the supports are annularly positioned tube chamber for argon supply to the heads, chamber for distribution of working gas and chamber for water cooling, which are connected to the heads via the flexible hoses. Between the supports (installed on the mounting table), there are rigidly mounted tube which forms an analyzed gas flow or processed powder material, and cylinder which provides the synchronous change in angle of convergence of six heads' axes with the help of the system shown in Figure 1. The system includes the plates with the loosely mounted brackets to ensure synchronous adjustment of the interelectrode gap between each pair of plasma forming heads.

At the first stage, the water cooling and gas supply systems of the plasma generator are started, the water, argon and air flow rates are set during pre-commissioning. At the second stage, the power supply system is activated in the normal operation mode of dual-jet plasma generators: arc discharge is triggered in each head by a momentary high voltage supply to the gap between the electrode and the nearest orifice plate, then the arc column is transferred by an argon stream to the auxiliary counter electrode to form a plasma flux which combines cathode and anode jets into the main plasma flow. At the third stage, the system for separating plasma forming heads is activated to form a plasma dome at an angle of convergence of plasma jets. The angle is defined during the optimization of gas dynamic properties to enable fulfillment of specific tasks when it comes to development of spectrum analysis techniques or development of heat treatment processes for powder materials. At the fourth stage, the system for supply of heat treated powder material or controlled gas flow is started, for example, exit gases for monitoring the status of melting in real time with data recording. At the fifth stage, all the systems are turned off one by one, repeating the plasma generator starting procedure in reverse order.

In order to prevent a significant argon consumption during the operation of six-jet plasma generator, the controller of ratios of two gas flow rates [10] has been developed. It reduces argon consumption by two orders of magnitude (the consumption may remain significant only at the start), and ensures a constant total flow rate of mixed media when their ratios change by a few orders of magnitude, the controller design and operation is simplified.

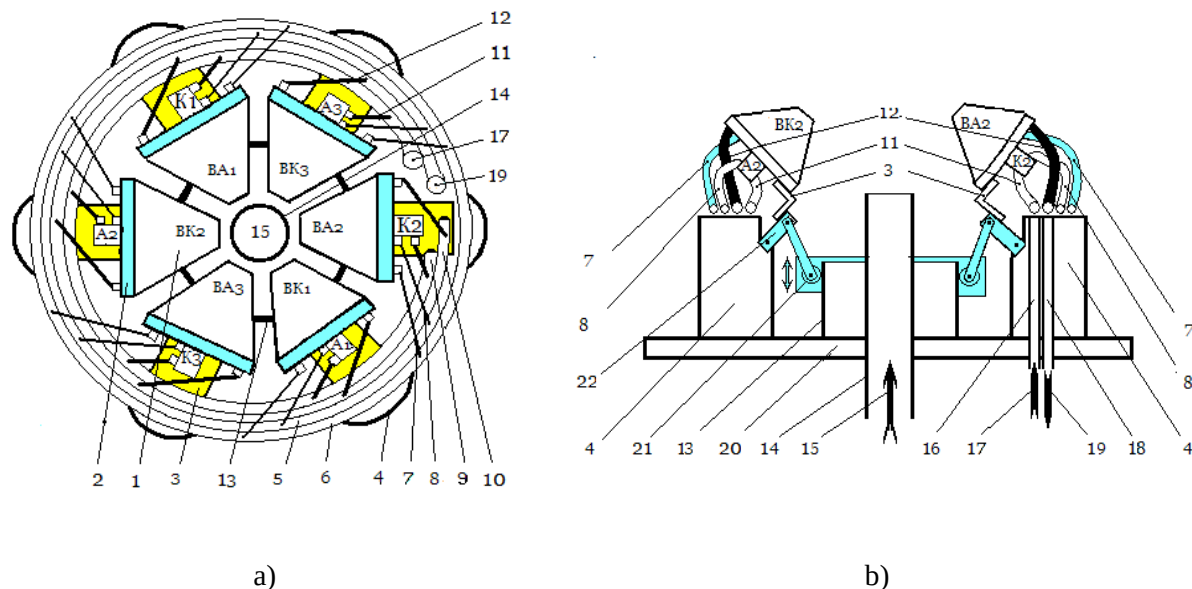


Figure 1. Six-jet arc plasma generator: a) top view; b) side view: 1 – copper heads; 2 – plate; 3 – brackets; 4 – pipe supports; 5, 6, 9, 10 – chambers; 7, 8, 11, 12 – hoses; 13, 14 – tube; 15 – powder material; 16, 17, 19 – passage; 20 – mounting table; 21 – articulated joint system; 22 – plate

3. Conclusions

The developed six-jet arc plasma generator can be used to control the quality of a produced alloy in real time, which enables automation of metal and alloy melting processes.

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