Experimental verification of different current flow scenarios in laboratory scale DC arcs

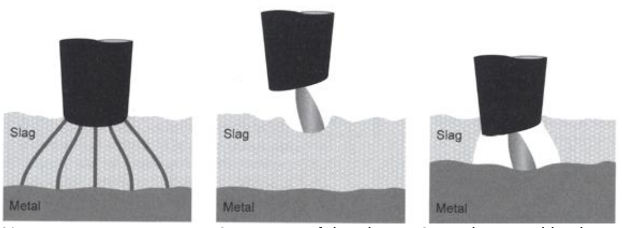
M. Aula[a)], H. Pauna[a)], N. Andersson[b)], C. Jonsson[b)], T. Fabritius[a)]

a) University of Oulu, Process Metallurgy Research Unit
b) KTH Royal Institue of Technology, Materials Science and Engineering
Matti.Aula@oulu.fi

INTRODUCTION

In electric arc furnace the electricity is transmitted from an electrode to steel bath, which conducts the current to another electrode. In AC furnace both the electrodes cyclically change from anode to cathode.

The electricity is transmitted from electrode to steel bath via slag or arc plasma. The different types of arc shapes are presented in Figure 1.



No arc | Arc on top of the slag | Arc submerged in slag

Fig. 1. Possible arrangement of current flows in EAF [1].

The main factors affecting how the current flows are the electrical conductivity of the slag, the depth of the slag and the arc voltage. With high voltage, low slag conductivity and thicker slag layer the shape in which are is on top of the slag becomes more probable. An example of arcs observed on top of the slag from ilmenite smelting is presented in Figure 2.

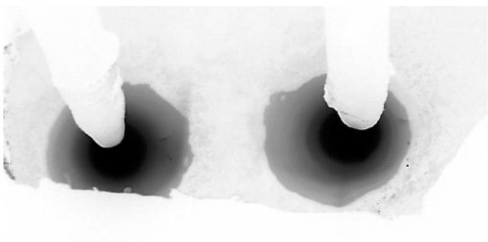


Fig. 2. An example of short, low power arcs observed during ilmenite smelting in pilot DC furnace [2].

The aim of the research was to test if these different arc shapes can be observed in laboratory furnace by manipulating the factors affecting the current flows.

Experimental setup

The tests were conducted with a induction heating furnace situated at Royal University of Technology in Stockholm. The arc was generated on top of the slag with system modified from a welding machine ESAB LHH400 Universal. The behaviour of the arc was observed with two industrial grade cameras. One camera had four green glass filters and 25 ms integration time while the other had single 1050 nm filter with 0.1 ms integration time. The frames were taken with an approximate frequency of 20 Hz for the green filtered camera and 16 Hz for the 1050 nm filtered. The difference in filtering allowed measurement of different phenomenon, the green filtered camera was used to observe arc shapes while the other one had better sensitivity for high temperature slag.

The differences in slag depth were created by adding more slag formers and the foaming slag conditions were generated by injecting oxygen to the furnace. The furnace and foaming tests are presented in Figure 3.

(a) Furnace configuration | (b) foaming tests in action

Fig. 3. Pictures from the measurement campaign.

During the heats slag formers were added in batches and the arc was generated by switching of the heating and moving the arc equipment into the furnace. During the arc tests the voltage and electrode position were varied to test their effect on the arc position.

In slag foaming tests the oxygen was injected to the furnace and the arc was generated simultaneously. The foaming also continued for some tens of seconds after the oxygen injection was turned of, thus exhibiting spontaneously foaming conditions.

RESULTS

The experiments show that with flat bath conditions without foaming the arc is often observed on the top of the slag. This is especially common during the first additions of slag. Two bright arcs from both electrodes can be observed in Figure 4. The figure contains processed images and colour maps, which highlight the intensity of the positions near the arc.

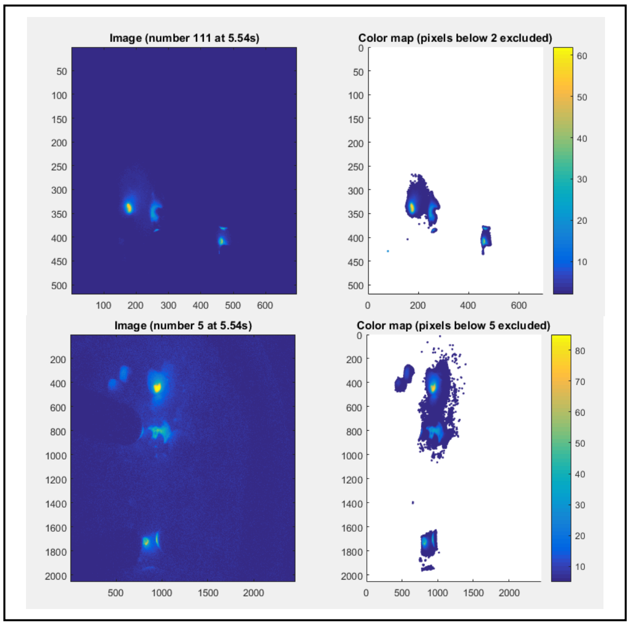


Fig. 4. Images and colour maps obtained from the two cameras (top green filtered, bottom 1050 nm filtered) during early slag additions.

In conditions with visibly low viscosity slag, it was typical to observe only a single arc despite two electrodes. The wear of the electrodes is not uniform, which causes the electrode lengths to start deviate from each other. The results is that while the other electrodes touches the slag, the other has a long arc. This type of an arc is presented in Figure 5.

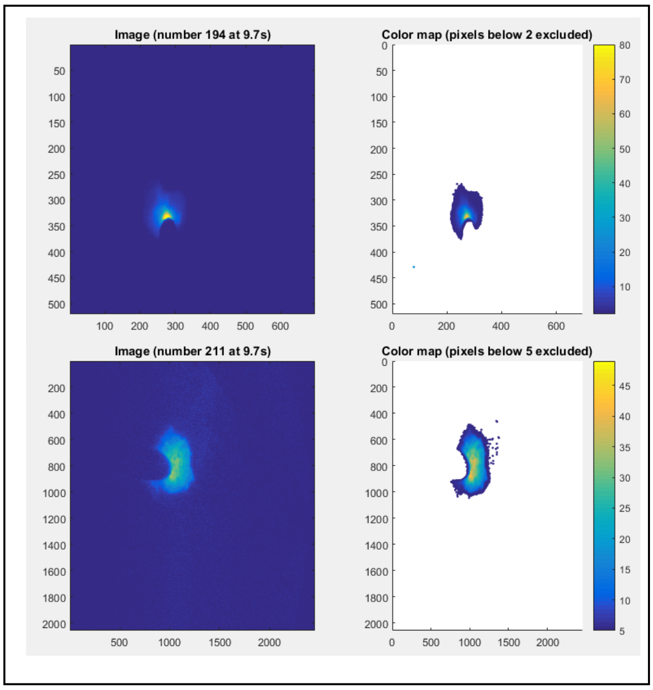


Figure 5. Images and colour maps obtained from a single arc with the two cameras (top green filtered, bottom 1050 nm filtered).

Despite constantly increasing slag amount and slag foaming, arc could be observed on top of the slag when the arc power and electrode position was varied. This can be observed from figure 6, where the shape of the oxygen lance is clearly visible. Without manipulating the electrode position the arc was submerged during the foaming.

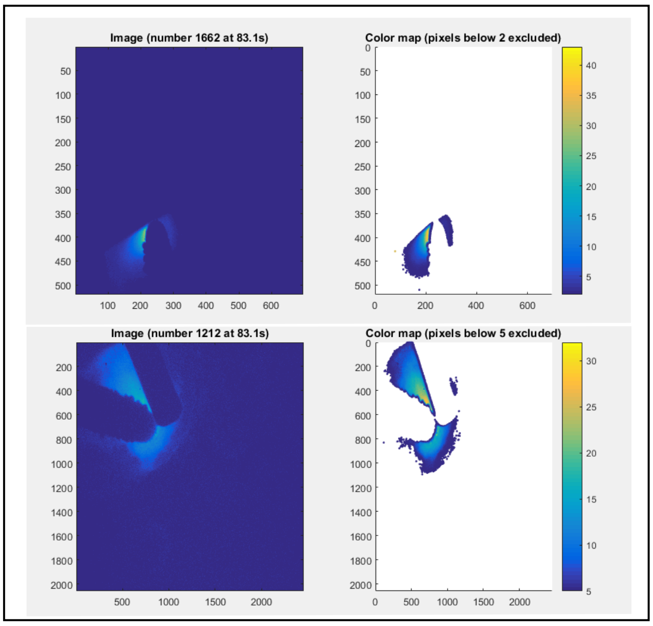


Fig. 6. Images from the two cameras and their colour map during foaming (top with green filter, bottom with 1050 nm filter).

CONCLUSION AND OUTLOOK

The results show that despite varying slag depths and foaming conditions, the arc could be raised on top of the slag. This indicates that with the current experimental setup, the effect of the arc voltage dominates the other effects on the mode of current flow. Even with the foaming slag, a stable arc could be observed on top of the slag. With the high arc voltages, the arc can burn over the foaming slag if the foaming slag conditions are not optimal. Furthermore, this suggests that measurement techniques relying on analysis of light emitted by the arc are feasible even with foaming slag.

REFERENCES

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[2] Q.G. Reynolds and R.T. Jones: Twin-electrode DC smelting furnaces – Theory and photographic testwork. Mintek. [White paper].