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Relations between Cathode Spots Behavior and Inter Electrode Phenomenon in Low Vacuum Arc Discharge

低真空アーク放電での陰極点挙動と電極間現象との関係

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Inter electrode phenomenon in low vacuum arc discharge between a copper anode and a steel plate sample covered with oxide layer is visually observed and is investigated with a single probe. Cathode spots move on upper surface of the sample until removal of oxide layer on the upper surface is completed, and then they turn to lower surface and start removing the oxide layer there. The cathode spot behavior changes before and after this movement between both surfaces of the sample, which causes the variation of probe current flowing from the inter electrode plasma.

1. Introduction

Descaling or decontamination process for steel products is important to realize adhesive painting or coating layer on their surfaces. Authors have studied about an application of low vacuum arc discharge to such processes for steel surfaces. This method depends on some characteristics of cathode spot. When an arc discharge is initiated under the pressure of about several tens Pascal, bright tiny regions, which are called "cathode spots", appear and move around all over the cathode surface disorderly. There are some previous researches about inter electrode plasma with some cathode spots using single probes [1-3]. The spots have tremendously high density energy due to electric current concentration and the scales or contaminations on the cathode surface can be vaporized. One of the problems to be solved is improvement of its efficiency and the authors are studying the behavior of cathode spots removing oxide layer on the steel surface.

Recently, experiments on whole oxide layer removal of a steel plate by one time arc treatment with single anode are conducted and some curious cathode spots behavior are observed. In this research, the relation between the cathode spots behavior and the inter electrode plasma is investigated with a single probe.

2. Experimental Setup

Figure 1 is a schematic of experimental arrangement used in this research. Arc discharge is initiated with a test piece as cathode and an anode in a stainless-steel vacuum chamber. The 250 mm inner diameter cylindrical vacuum chamber has 300 mm axial length. The cylindrical copper anode is

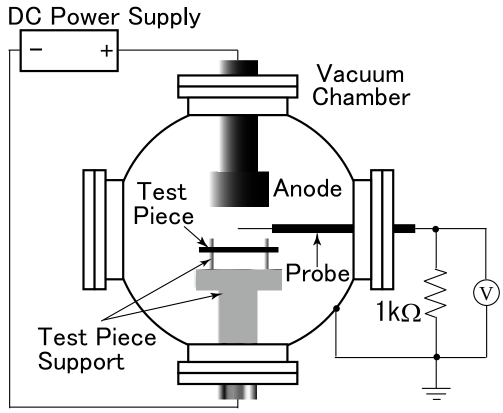

Fig.1. Schematic of experimental apparatus.

100 mm in diameter and inserted through upper side of the chamber. The test piece is a SS400 steel plate, which is a square of 100 mm ×100 mm and 3 mm in thickness. Both upper and lower surfaces of the test piece are covered with about 5 μm in thickness oxide layer. It is set on a test piece support, which is covered by insulators and inserted through lower side of the chamber. An inter eletrode gap is 50 mm. In addition, there is room of 40 mm under the test piece. The vacuum chamber is exhausted to less than 10 Pa before the initiation. The arc is sustained with electric power from a DC power supply. The arc current can be changed from 40 A to 120 A. A single probe, which is made of tungsten, is inserted between the anode and the test piece. The exposed part to the plasma is 1 mm in diameter and 3 mm in length, and is grounded through a resistor of 1 kΩ. Temporal evolution of the probe current is measured with a sampling frequency of 1 kHz.

3. Experimental Results

An arc discharge is initiated between the anode and the upper surface of the test sample. Cathode spots appear on the upper surface of the test sample right after the initiation. All of them move and remove the oxide layer on the upper surface. As the oxide layer reduces, the cathode spots movement becomes quicker [4]. Eventually, all oxide layers are removed and the cathode spots go to the lower surface through the edges. Then, they begin to remove the oxide layer there. However, they sometimes go back and stay on upper surface moving at large velocity. When they are on the lower surface, the inter electrode gap is filled with a bright plasma which is not observed while the cathode spots are on the upper side (See Fig. 2).

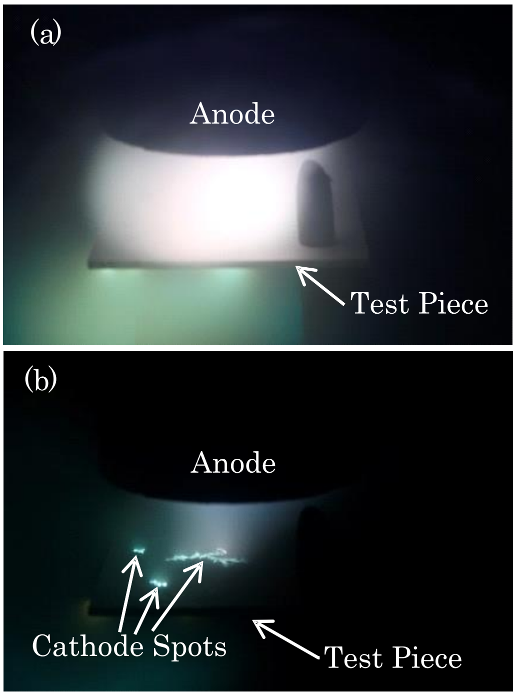

Fig.2. Inter electrode plasma after oxide layer on the upper surface is removed. All cathode spots are on lower surface (a), and on upper surface (b), respectively.

Figure 3 shows a temporal evolution of probe current and its averaged values in every 10 seconds during a discharge. While the cathode spots remove the oxide layer on the upper surface, negative current flows into the probe from the inter electrode plasma. In this case, the current intensity is about 2 mA and the fluctuation level of probe current is about 2～3 mA, which gradually increases as the oxide layer on the upper surface decreases. After the cathode spots move to the lower surface and begin to remove the oxide layer, that is the same situation as Fig. 2,

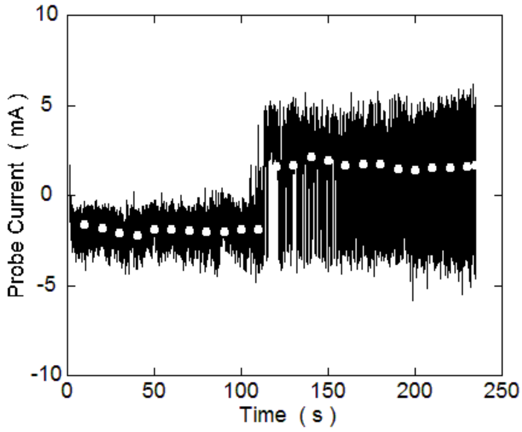

Fig.3. Temporal evolution of probe current in 60 A arc operation. Open circles stand for its averaged values in every 10 seconds.

the fluctuation level drastically increases to about 5 times higher than that of which the spots are on the upper surface. Additionally, the averaged values of probe current in every 10 seconds change to positive current. The authors consider that the change of the probe current average depends on existence of high energy electrons which possibly originate from the cathode spots.

4. Summary

Arc discharge is initiated between anode and upper surface of test sample, and all cathode spots stay on the upper surface until removal of oxide layer is completed. After that, they turn to lower surface and remove the oxide layer, getting back to the upper surface occasionally. Measurement using a single probe shows that negative current flows from the inter electrode plasma while they are on the upper surface, and its fluctuation level drastically increases after they move to the lower surface.

Acknowledgement

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