International Journal of Engineering & Technology, 7(4.16) (2018) 225-228

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Application of Inverted Cathode Transverse Magnetic Field in Vacuum Arc During Surface Treatments Reusable Metals

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Abstract

The application of transverse magnetic field to control the vacuum arc cathode spot in surface treatment applications was conducted and analyzed its performance. An inverted cathode method of transverse magnetic field is proposed in this paper to serve as an alternative for the normal method of controlling the behavior of cathode spots during the treatment process. Experiment setup was designed to conduct and compare the behavior of the two methods. Several important parameters were considered such as the splitting frequency of the cathode spots, the number of droplets during the process, the linearity of the movement of the cathode spots and the surface roughness of the metal after the treatment process. It was shown that the proposed method (inverted method) gives better linearity in terms of movement and suffers from increased roughness.

Keywords: *vacuum arc, transverse magnetic field, switching electrodes, cathode spot,*

1. Introduction

Vacuum Arc technology had become an important methodology in electrical engineering. It can be used in a number of different applications such as power interrupters or circuit breakers [1,2]. Thermal Spraying technology is also becoming more and more popular in developing countries and cities that promote re-use of old and used materials. This technology can be used to roughen the surface of used material and to increase its adhesive strength. Spray paint can also be used in cleaning oxide films and paint. However, surface treatment remains are causes of secondary waste and particles. For this reason, some people prefer to use surface treatment using vacuum arc cathode spot that potentially has almost no secondary waste particles and offers the possibility of fast processing of the materials. In order to improve its performance, the full characteristics are controllability of the cathode spot must be well understood.

The movement and direction of the cathode spot under the application of high current and low current control input were observed to be almost the same and they are both dependent on the magnetic flux density applied at the input [3].

Vaporization is also one factor that can be observed during the presence of the vacuum arc cathode spots. More vapor can be observed when the cathode spot moves towards the boundary of the metal [4]. The speed of the cathode spot is also responsible for the temperature of the molten pool and the evaporation speed of the metal [5].

Splitting in the direction of travel is also a common problem in vacuum arc cathode spots. At a frequency between 400 Hz to 800Hz, no splitting can be observed using a current of 3.3kA rms. However, when the current is increased to 5kA rms, splitting occurs at a speed of 20m/s [6]. During descaling process, cathode spots are observed to move towards the center in contract motion [7]. Better control to improve the behavior of the vacuum arc cathode spot is still an important aspect that needs to be addressed. One important parameter to consider is the application of the heating or cooling effects of vacuum arcs during the welding process. The working temperature of the cathode spot affects the strength of mechanical properties of the metal joints [8, 9]. The ultimate tensile and yielding strengths of the metals depend on the heating procedure used during the welding process.

2. Problem Statement

Surface treatment using vacuum arc cathode spot minimizes secondary wastes that are usual results of traditional surface treatment methods. This method is commonly used in spraying technology to recycle used materials by removing oxide films from its surface. However, surface treatment using this method has several problems that need to be addressed. During the treatment, cathode points may move randomly in all directions. There are several cases wherein splitting occurs which results to many directions of travel of the cathode points. These movements are undesirable and sometimes are due to constant change in the movement speed of the cathode spots.

When vacuum arc cathode point is applied to remove the oxide film of re-usable materials, the typical behavior of a cathode point on an oxide film is to move freely in many directions. The direction of movement of the cathode point is random and sometimes split into many other different directions. This splitting behavior can be currently controlled by the application of transverse magnetic field to the vacuum arc. The movement of the cathode spot is greatly improved by increasing the magnetic field density of the transverse magnetic field.

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During the application of transverse magnetic field, improvement in the straightness in the direction of travel of the cathode spot can be noticed proportional to the increase in the magnetic field density applied at the input. In low magnetic flux density applications, more splitting of the cathode spots can be observed in random directions. Increasing the magnetic flux density at the input minimizes the number of splitting of the cathode spots, thus improving the linearity in the direction of travel of the cathode spot.

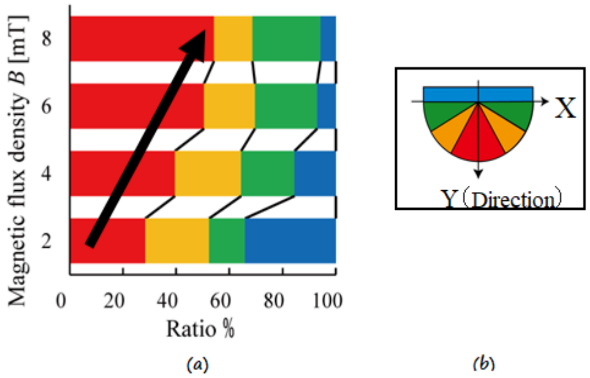

Fig. 1: Effect of Changing Magnetic Flux Density to Direction of Movement of Cathode Spot.

Figure 1 shows the effect of increasing the magnetic flux density to the direction of movement of the cathode spot. The lower the magnetic flux density, the more variations in the straight path can be experienced by the cathode spot. Figure 1(a) shows that the ratio of the straightness in the direction of movement of the cathode spot is lower in applying 2mT magnetic flux density than in applying a magnetic flux density of 8mT. The higher the magnetic flux density applied, the more the cathode spot remains in its straight path. Figure 1(b) shows the indicator in the direction of movement of the cathode spot in vacuum arcs.

Figure 2 shows the result of surface treatments to metal using vacuum arc cathode spots to remove the oxide films. The images are experiment results using a digital camera after removing the oxide films using vacuum arc cathode spots. Figure 2(a) shows that during the treatment, little sparks can be seen scattering in random directions. These sparks produce hot little droplets that leave residues to the surface of the metal. In figure 2(b), an example of a droplet or residue is shown. The number of droplets, their positions and sizes are random. These droplets, once touched by the cathode spots, cause them to split in direction. During the splitting of the cathode spots, mounds, as shown in figure 2(c) are developed due to the surface tension of the molten metal due to the splitting of the cathode spots.

This paper proposes an alternative way of applying magnetic flux density to the vacuum arc cathode spot. It aims to investigate the effect of application of inverted cathode transverse magnetic flux density to the splitting of cathode points and direction of movement of the cathode spot.

3. Experiment Setup

The application on transverse magnetic flux density in controlling vacuum arc cathode spots was performed using the normal model and the inverted cathode model (proposed model). The experiment setup for the two models are shown in figure 3. Figure 3(a) is the setup for the proposed inverted cathode model to improve the controllability and behaviour of the vacuum arc cathode spots in terms of the frequency of splitting of the cathode spots and the linearity in the direction of movement. Figure 3(b) is the normal method being used to control the behaviour of the vacuum arc cathode spots. The working parameters used in the experiments are shown in table 1.

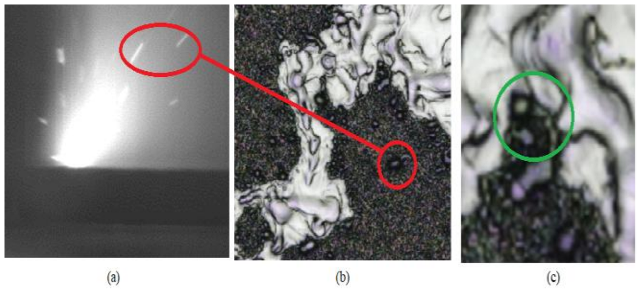

Fig. 2: Results after the Application of Vacuum Arc Cathode Spot in Removing Oxide Film

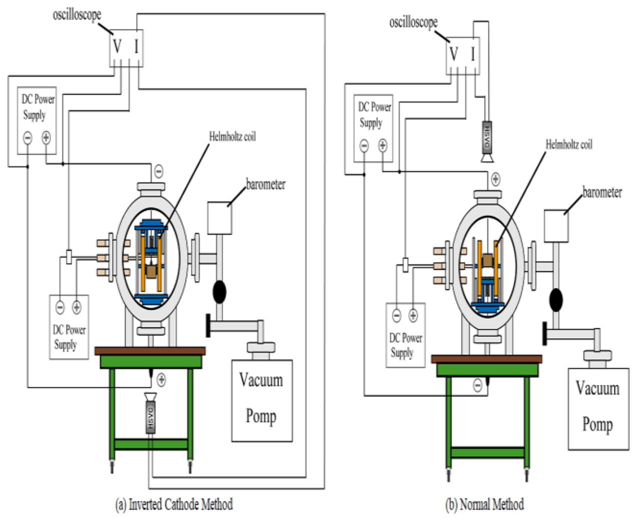

Fig. 3: Experiment Setup

Table 1: Experimental conditions

Parameter	Item/Value
Atmospheric gas	Ar
Pressure	100 Pa
Cathode	SUS 304
Oxide film thickness	2 μm
Anode	Cu
Arc current	10 A
Magnetic flux density	2mT/8 mT
Distance between electrodes	20 mm

4. Discussion of Results

Several experiments and observations are done in this research. The following are important results taken from actual experiments. Some of the pictures shown came from video files taken during the process.

4.1. Effect of Increasing the Magnetic Flux Density to the Splitting Frequency

Experiments are conducted using the two experiment setup models and a constant oxide film thickness of 2 μm. The number of splits or divisions in the movement of the cathode spot was counted using both models under a magnetic flux density of 2mT and 8mT from the transverse magnetic field controlling the vacuum arcs. Figure 4 below shows the comparison of the Normal model and the proposed Inverted cathode model in the frequency of splitting of cathode spots during the treatment of vacuum arc cathode spots Figure 4(a) shows that when the magnetic flux density is small, the normal model yields more splitting frequency than that of the inverted cathode model. When the magnetic flux density is high, both models have almost the same amount of splitting frequencies. Figure 4(b) shows a notable relationship, in terms of the splitting frequency, between the normal model and the proposed inverted cathode model.

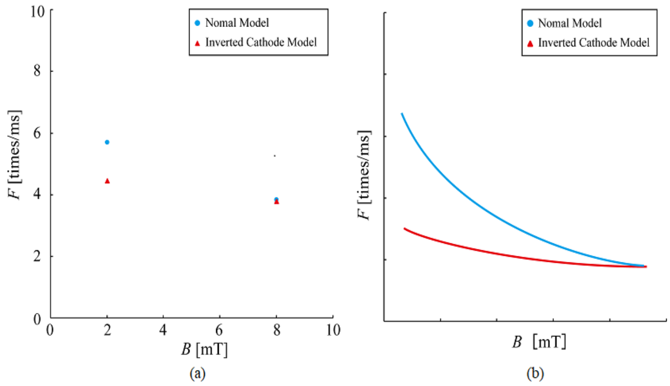

Fig. 4: Frequency of division of cathode spot to magnetic flux density

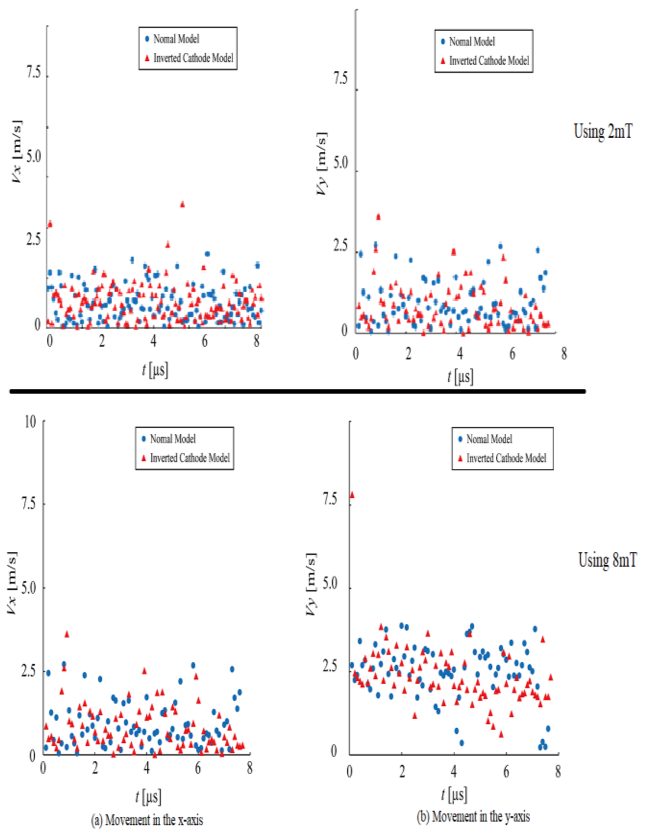

Fig. 5: Moving Speed of Cathode Spot Relative to time (8mT)

4.2. Effect of Droplets in the Movement of Vacuum Arc Cathode Spots

It is known that during the treatment, sparks are observed that cause droplets to scatter in random directions. These droplets have some effect in the frequency of splitting and velocity of movement of the cathode spots

Figure 5 shows a comparison for velocity of the cathode spots between the normal model and the inverted cathode model. It is observed that the velocity of the cathode spot does not change in the normal model, whereas in the inverted cathode model, the velocity decreases as the magnetic flux density increases. Also during the treatment process, it is observed that the behavior of the cathode spots is influenced by the presence or absence of droplets. Splitting occurs when the cathode spot experiences reattachment to the droplets. Thus, splitting frequency varies directly proportional to the number of reattachments of droplets and cathode spots.

The linearity of the movement of the cathode spots is also affected by the change in the magnetic flux density. The results in the linearity test is shown in figure 6.

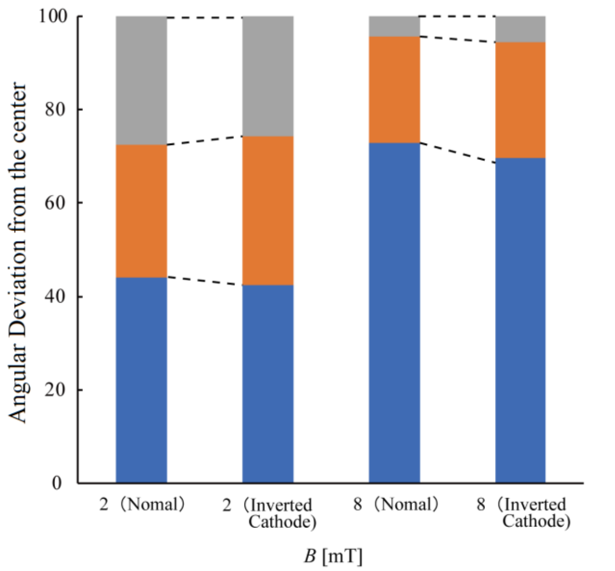

Fig. 6: Comparison of Movement Angles of Cathode Points Due to Change in Magnetic Flux Density

Figure 6 shows that the linearity in the movement of the cathode spots is almost identical for both the normal model and the inverted model under low applied magnetic flux density. The graph also verifies that the linearity improves when the magnetic flux density in increased.

4.3. Comparison of surface roughness of cathode surface

The surface roughness of the metal after the treatment is also taken into comparison. Figure 7 shows the results from the normal method and the inverted cathode method after the removing the oxide films.

Figure 7 shows that the surface of the metal using the inverted cathode method after the treatment has more high residues compared with the surface of the metal using the normal method. These high residues relate to roughness on the surface area of the metals after the application of vacuum arc cathode spots.

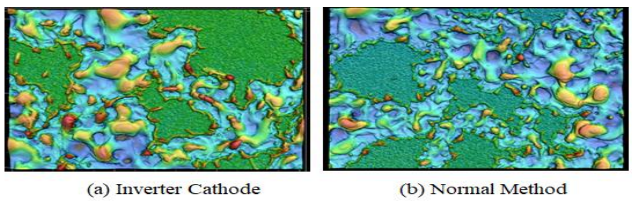

Fig. 7: Surface Roughness Result

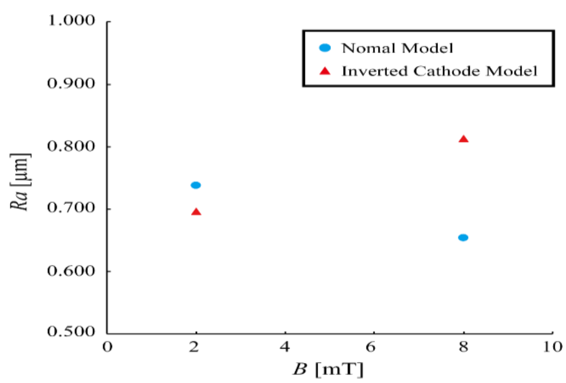

Fig. 8: Comparison Surface Roughness Due to Change in Magnetic Flux Density

Figure 8 shows the comparison of surface roughness between the normal method and the inverted cathode method. This shows that using the normal method, the surface roughness decreases when the magnetic flux density increases while in the inverted cathode method, the surface becomes rougher as the magnetic flux density increases. In this aspect, the normal method is better than the inverted cathode method.

5. Conclusion

Surface treatment using vacuum arc cathode spot controlled by transverse magnetic flux density was used in this research. Performance analysis is done between the normal method and the inverted cathode method. Both methods are used to show the difference in the quality of treatment in terms of the roughness of the surface after treatment and the linearity in the movement of the cathode spots during the treatment. Table 2 shows a summary of the observed performance of the two methods.

Table 2: Summary of Performance of Surface treatment using Normal Method and the Inverted Cathode Method

Parameter	Effect of Increasing Magnetic Flux Density	
	Normal Method	Inverted Cathode Method
Splitting frequency	decreases	decreases
Number of cathode spots	decrease	decreases
Cathode point area	increases	Increases
Number of droplets on the surface	Increases	Decreases
Moving velocity	No change	Decreases
Surface Roughness, Ra	decreases	Increases

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