Experimental Research on Current-carrying Efficiency of Arc under Different Polarities

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Abstract. Current-carrying arc got contact surface worse and influenced the transmission of electric energy. Arc burning process and arc characteristics and arc erosion and current-carrying efficiency were tested on a home-made single asperity current-carrying tester under different polarities conditions. Experimental results show: when W probe is anode and copper specimen is cathode, arc mainly belongs to metallic vapour state and arc has long burning times and high arc energy and low electric field intensity. Current-carrying efficiency is high. When W probe is cathode and copper specimen is anode, arc mainly belongs to gas state and arc has short burning times and low arc energy and high electric field intensity. So arc erosion is light and current-carrying efficiency is low.

1. Introduction

Pantograph-catenary system is friction pair which can transmit electric energy during their sliding relatively. When contact surface breaks between pantograph and catenary at high voltage and heavy electric current, current-carrying arc generates inevitably. Current-carrying arc with high temperature could burn and damage the material and makes contact surface worsen, while it can transmit electric energy to satisfy with energy supply of high-speed train because of its electrical conductivity. So pantograph-catenary arc takes on double properties [1-2]. It is necessary to research influence of arc characteristics on arc erosion and arc current-carrying efficiency.

In recent technological developments of current-carrying friction pair, major efforts have been devoted to research of friction-wear property and current-carrying quality. Experimental results show current-carrying arc play an important role. All above researches were carried out on the pin-on-disk tester which kept pin and disk contact all the time, thus friction heat and resistance heat and arc heat damaged commonly materials and electric current transmitted in contact conductivity and arc conductivity manners [3-10]. It is rare that mere arc cause damage and change of electric conductivity quality. Current-carrying arc occurs at random and instantaneously, so it is difficult to control and catch and measure it. To solve above problems a current-carrying tester of a single contact peak has been developed on which arc burning process and arc characteristics were observed and analyzed under different polarities.

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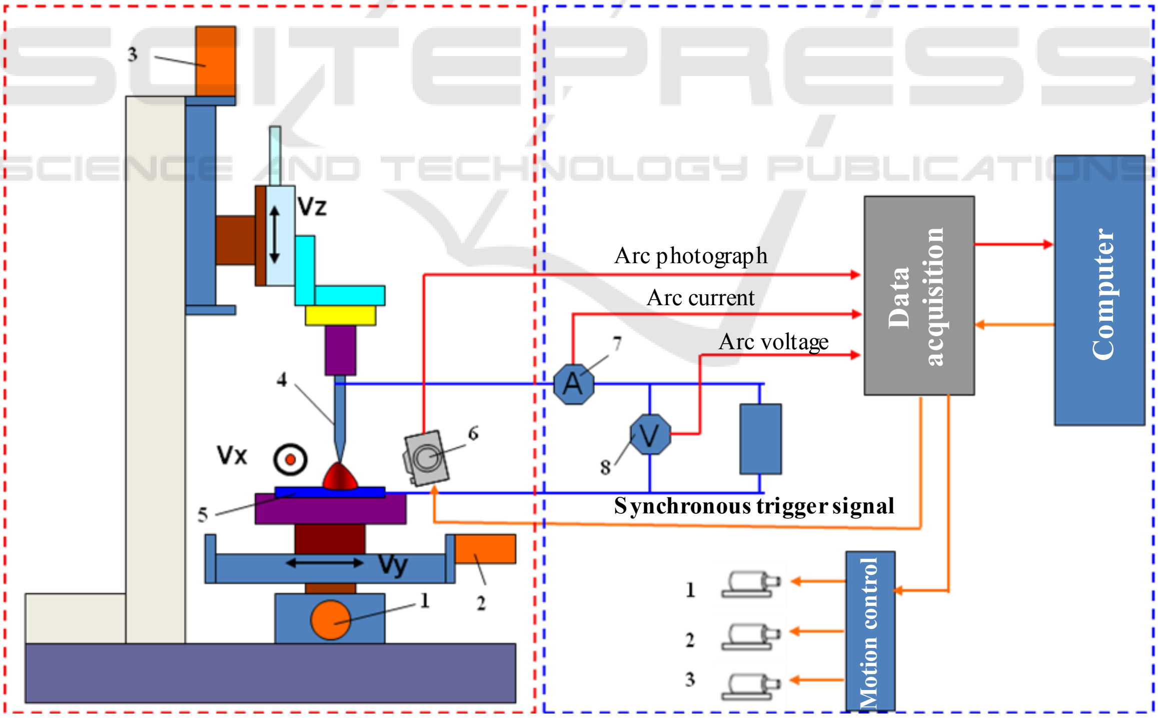
In this paper, arc burning processes were photographed separately under two polarities conditions and arc states were obtained by observing and analyzing pictures. The aviations of arc burning time and arc energy and electric field intensity against voltage were gotten to study on arc characteristics. Microstructure and element distribution on the erosion surface of material were available by SEM and arc erosion mechanism were discussed. Based on arc burning process and arc characteristics, arc erosion and current-carrying efficiency were researched and a method of alleviating arc erosion was put forward.

2. Experimental apparatus and experimental procedure

2.1. Principal of experimental apparatus

Experiment was carried out on the current-carrying tester of single contact peak whose principle was shown in Figure 1. The tester consists of mechanical and measure-control systems. In the mechanical system probe moves up and down at certain speed by adjusting rotation rate and orientation of stepping motor of Z direction, meanwhile specimen moves back and forth at certain speed by adjusting rotation rate and orientation of stepping motor of X direction. When probe slides with specimen, probe and specimen and electric source form a closed electric circuit and current transmission is by the contact surface between probe and copper. When probe separates with specimen, probe and arc and specimen and electric source form a closed electric circuit and current transmission is by arc. In measurement-control system voltage sensor and current sensor and high-speed camera catch respectively arc voltage and arc current and arc pictures of burning process, in addition all these data are collected synchronously and are displayed on the computer screen after treatment of software.



Mechanical **Measurement and control part**

1 stepping motor of X direction 2 stepping motor of Y direction 3 stepping motor of Z direction
4 probe 5 specimen 6 high-speed camera 7 current sensor 8 voltage sensor

Figure 1. Principle diagram of current-carrying tester of the single contact peak.

2.2. Experimental procedure

In the experiment probe adopts tungsten alloy which is made up of W and ThO_2 and the content of ThO_2 is 0.7~0.99%. W probe is 2.4mm in diameter and 45mm in length and its end is processed into cone which is 30 degree in angle and 5mm in length. Specimen adopts copper which is 80mm in length and 40mm in width and 8mm in thickness and copper specimen will be treated with #800 metallographic abrasive papers. Electric source adopts JP50100D source of direct current which can supply constant current or voltage. Experimental current is set 20A and experimental voltage is set at 25V, 30V, 35V, 40V, 45V and copper specimen moves back and forth at 15mm/s along X direction and W probe moves up and down at 3mm/s along Z direction. All above parameters will be preseted before experiment.

2.3 Measurement of experimental results

Arc current and arc voltage is respectively attained by current sensor and voltage sensor. Arc pictures are shot by high-speed camera. Arc burning time is obtained in term of variation regularity of arc current and arc voltage. Arc energy is gotten by product of arc current and arc voltage and arc burning time. Electric field intensity is gained by division of arc voltage and the distance between W probe and copper specimen at this point. The current-carrying efficiency, η, is expressed as:

$$\eta = \bar{I}/I \times 100\% \quad (1)$$

Where is average current during arc burning steadily time and I is normal electric current.

3. Experimental results

3.1. Arc current transmission at different polarities

Authors should try to make economical use of the space on the page; for example: Electric transmission quality is reflected by efficiency and stability of electric transmission during arc burning. Because current-carrying arc is mobile, waveform of arc current contains many interference signals which are shown in Figure 2. Figure 2 shows change of arc current with time which decreases at first quickly and then slowly and quickly again at last.

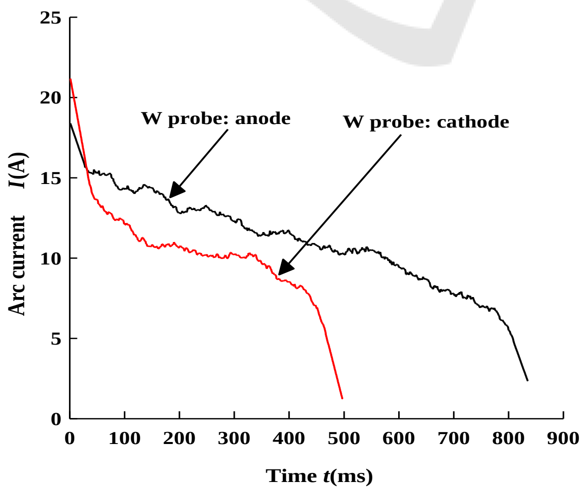


Figure 2. Change of arc current with time at different polarities.

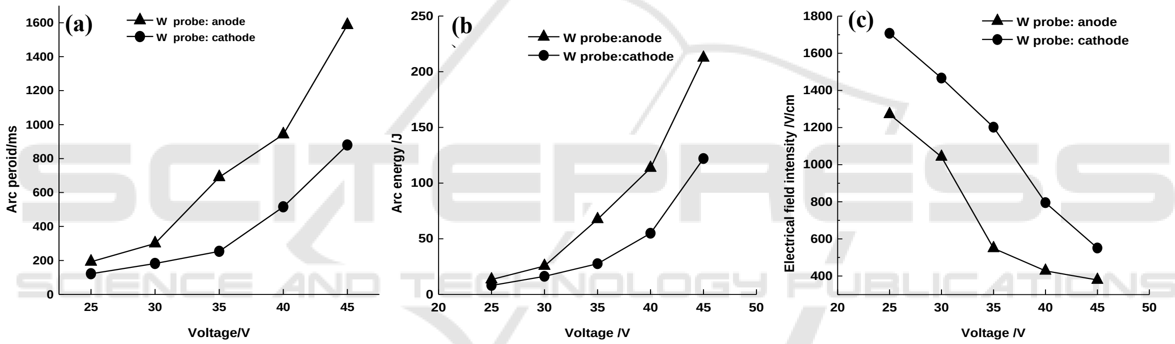
3.2. Arc burning characteristics under different polarities condition

3.2.1. Arc burning characteristics

Arc burning time stands for ability to keep burning. Figure 3 (a) shows the variation of arc burning time against voltage, which is arc burning time increases when voltage increases. But the arc burning time is longer when W probe is anode than W probe is cathode, so the ability to keep burning is better when W probe is anode than W probe is cathode.

Arc energy is the accumulated discharge energy which reflects heat energy in arc. The more arc energy is, the higher arc temperature is. Figure 3 (b) shows the variation of arc energy against voltage, which is arc energy increases when voltage increases. The arc energy is more when W probe is anode than W probe is cathode.

Arc burning process essentially is charged particles move directionally and collides with each other under the action of electric field intensity, thus electric energy turns into kinetic energy and then into heat energy which makes arc temperature go up. At the given electric current and voltage the higher the electric field intensity is, the more difficultly the arc keeps burning, and vice versa. Figure 3 (c) shows the variation of electric field intensity against voltage, which is electric field intensity decreases when voltage increases. The electric field intensity is lower when W probe is anode than W probe is cathode, so the ability to keep burning is better when W probe is anode than W probe is cathode.



(a) Arc burning time; (b) arc energy; (c) electric field intensity

Figure 3. Arc burning characteristics at different polarities.

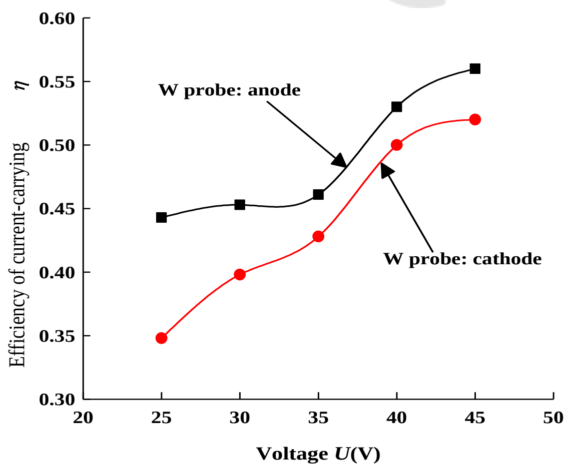


Figure 4. Changes of current-carrying efficiency with voltages at different polarities.

3.2.2. Current-carrying efficiency under different polarities condition

Variation of current-carrying efficiency against voltage is shown in Figure 4, which is known that current-carrying efficiency increases when voltage increases and the current-carrying efficiency is higher when W probe is anode than W probe is cathode.

4. Discussions

4.1. Analysis of arc burning process and characteristics under different polarities condition

Boddy et al scholars found that arc between switch contacts would undergo two stages. The first stage was described as metallic vapor state arc which mainly burned in metallic vapors, while the second stage was described as gas state arc which burned in little metallic vapors and air ionizing took part in arc burning. When arc transferred from metallic vapor state to gas state, arc voltage would jump [11]. When arc is in metallic vapor state, arc motion is slow as charged particles are heavy. When arc is in gas state, arc motion is quick as charged particles are light.

Figure 5 shows variations of arc voltages against arc burning time at 15 voltages under different polarities condition. It is found that time in metallic vapour state is longer when W probe is anode and copper specimen is cathode than W probe is cathode and copper specimen is anode.

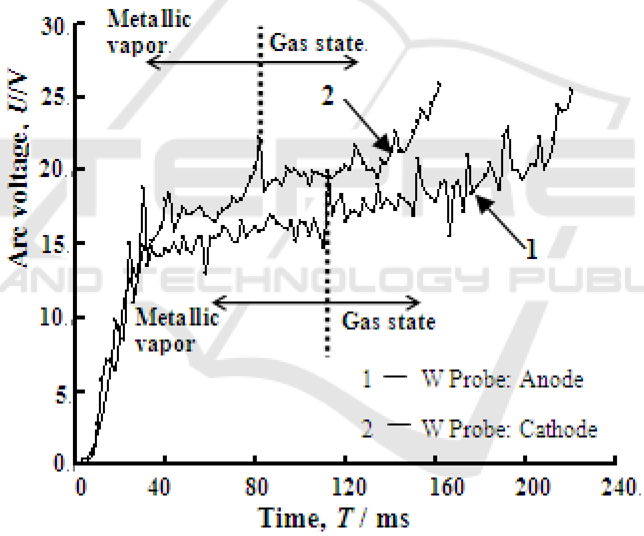


Figure 5. Aviations of arc voltages at 15V under different polarities.

4.2. Analysis of electric conductivity of arc

Document [12] expressed electric conductivity of arc is related with movement of charged particles. Under electric field force movements of electrons and cations in arc form electrons stream and cations stream respectively which form commonly arc currents. Because cations are much heavier than electrons and then cations move much more slowly than electrons, arc currents mainly are made up of electrons. Under the action of electric field force, electrons move in direction of electric field force and meanwhile electrons can collide with each other to move irregularly. Irregular motion of electrons form thermal motion currents and direct motion of electrons form electric field currents. Thermal motion currents are 100 times or so as much as electric field currents, that is, arc currents mainly consist of thermal motion currents. Arc energy is high when W probe is anode and copper specimen is cathode, thus charged particles are not only a great quantity but also at high speed. All these cause much more thermal motion currents and high current-carrying efficiency. Arc energy is low when W probe is cathode and copper specimen is anode, thus charged particles are not only little but also at low speed. All these cause much less thermal motion currents and low current-carrying efficiency.

5. Conclusions

- when W probe is anode and copper specimen is cathode, arc mainly belongs to metallic vapor state and arc has long burning times and high arc energy and low electric field intensity. Current-carrying efficiency is high.
- When W probe is cathode and copper specimen is anode, arc mainly belongs to gas state and arc has short burning times and low arc energy and high electric field intensity. So arc erosion is light and current-carrying efficiency is low.

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