Sci. Bull. Fac. Educ., Nagasaki Univ., No. 36, pp. 73~80 (1985)

Monte Carlo Simulation on Cathode Spot Behavior and Erosion Pattern for Au Contacts by Micro-Computer

Kagehiro ITOYAMA and Yoshitaka KOMORI*

Department of Technology, Faculty of Education,
Nagasaki University, Nagasaki 852
(Received Oct. 31. 1984)

Abstract

Monte Carlo simulation on the cathode spot movement and the erosion pattern for Au contact was carried out by employing the micro-computer. Three factors which were applied to characterize the cathode spot behavior of the break arcs, which are the maximum length moved, the maximum moving width and the velocity distributions of moving cathode spot, and arc duration were established as the restriction conditions for this simulation. The simulation on the cathode spot movement on (x y) surface the contour figures and the cross sections of crater structures were in good agreement with the actual results of the cathode spot behavior and the erosion pattern on Au contacts.

Introduction

In an electric contact operation, the electrode erosion caused by arcing depends not only arc voltage and arc current but also an arc root behavior on the electrode. The arc root behavior depends upon the formation of an oxide film, its decomposition and an adsorption of oxygen molecules (1). The electrode erosion of the cathode forms to a crater structure in a cathode arc. The crater structure, therefore, shows own pattern of each electrode material (2). This means to be able to estimate the erosion pattern of electrode by simulating the arc root behavior.

The authors had tried to simulate the arc root behavior on the breaking of contact by the micro-computer several years ago (3). However, a memory capacity of the micro-computer was so small that its simulation was not so

*The author is a staff of Fukuoka City Office.

satisfactory for the display of results of the simulation. The recent micro-computer, however, develops its memory capacity and enable to treat the simulation of the arc root behavior mentioned above. An employment of a micro-computer needs not to choose "time" and "place" for the simulation and enable to realize a "usefull" simulation.

The cathode spot behavior on the cathode surface was simulated by Monte Carlo method from velocity distributions of the moving cathode spot. The velocity distributions were obtained from the observation of the cathode spot behavior by a high speed camera(1). The erosion pattern of contacts was shown by a contour figure of the crater and was displayed an arbitrary cross section of the crater in this simulation.

Procedure of Simulation

The model of a random walk is reasonable one as the cathode spot behavior on the cathode surface from an observation of breaking arc by a high speed camera(1) and a microscopic observation of the trace of an arcing(4). Namely, if the position of cathode spot in X and Y direction calculated by a fixed probable distribution can be located to next position with a lapse of a fixed time interval, the simulation can achieve our porpose.

Behaviors of the cathode spot can be characterized by three factors(1):

(1) the maximum length moved (l_{mx}) which was defined as a maximum shift distance of the cathode spot in an arcing;

(2) the maximum moving width (l_{mw}) which was the difference between fhe maximum and minimum distances on the motion of cathode spot;

(3) distributions of velocity of the moving cathode spot.

These three factors and an arc duration must be established as the restriction condition for the simulation. In this simulation, the arc duration corresponds to the number of times that the cathode spot can move in one arcing.

Fig. 1-(a) shows an example of the distribution of velocity of moving cathode spot at breaking arc. This distribution corresponds to a distance of which the cathode spot can shift between two arc ignited positions, if the shift time of moving cathode spot between two positions is established resonably. Fig. 1-(b) shows the accumulative frequency distribution of Fig. 1-(a). Therefore, by making a correspondence between the random number which is generated by a computer and each value of the accumulative freqency distribution, we can calculated the moving distance of the cathode spot which corresponds to the random number.

A regression analysis was carried out for the accumulative distribution

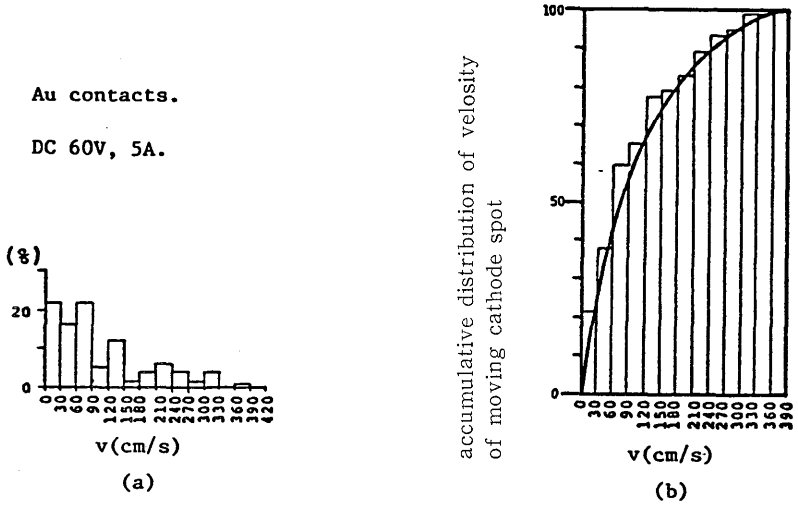


Fig. 1-Velocity distribution of moving cathode spot and its accumulative distribution.

curves on the contact materials of Au Cu and Ni. The logarismic function,

$$y = a + b\log_e x \qquad (1),$$

shows a high correlation for each contact material.

The values of a and b in eq. (1) are shown in Table 1. These values which are calculated for each experimental condition do not show a dependency for each contact material.

The simulation was executed based on four restriction conditions including arc duration and following two assumptions.

(1) The cathode spot moves at random with corresponding to the accumulate distribution function of moving cathode spot. The arc ignition position does not depend upon the previous one.

Table 1-Values of a and b and correlation coefficient

MATERIAL	EXPERIMENTAL CONDITIONS VOLT.	CURR.	a	b	CORRELATION COEFFICIENT
Au	50V	3A	-4.2	17.6	0.980
	50V	5A	-38 0	22.8	0.980
	60V	2A	-57.0	29.4	0.988
	60V	3A	-43.2	27.8	0.982
	60V	5A	-50.0	25.7	0.985
	72V	3A	-67.6	28.8	0.948

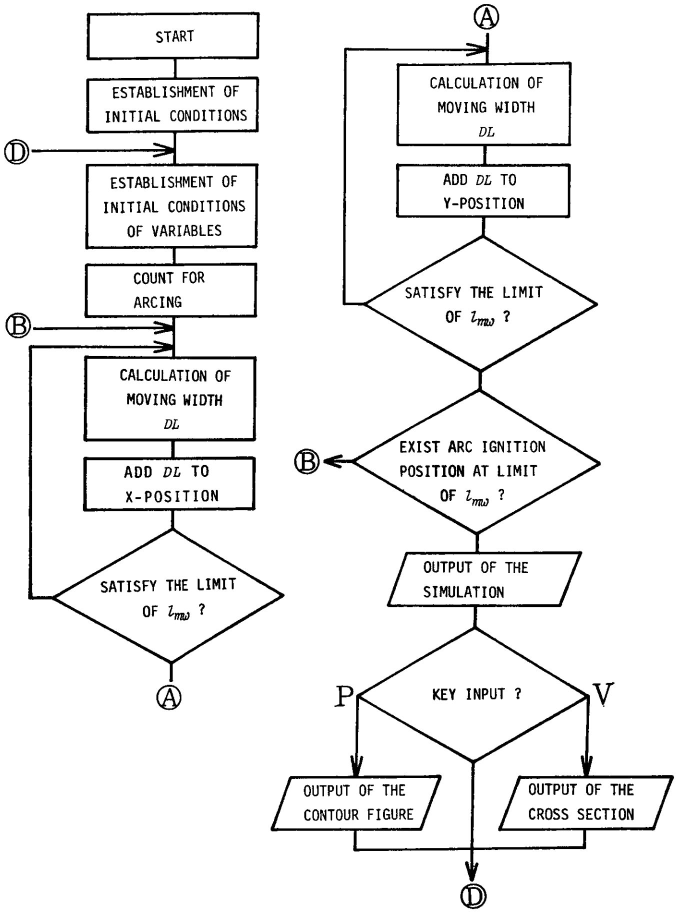


Fig. 2-Flow-chart of the program.

(2) The tendency of the cathode spot behavior at y-direction is as same as one at x-direction. Therefore, the cathode spot behavior at y-direction also conform with the same restriction conditions.

A flow-chart of the program is shown in Fig. 2. The actual program is the construction of sub-rutin call system. This program was executed the movement of cathode spot to the number of movements corresponding to arc duration after the initial conditions were established for a display and some variables. As one moving duration between two arcing positions is established to be 0.2 msec., this means that the cathode spot repeats the movement of 50 times in the case of the arc duration of 10 msec.. The moving width, *DL*, is obtained from the accumulate distribution which corresponds to the random number and the new arc ignition position is held by adding *DL* to the previous arc ignition position. It is judged that the movement of the cathode spot is

Table 2–Values of restriction conditions.

MATERIAL	EXPERIMENTAL CONDITIONS VOLT.	CURR.	$y=a+b\log_e x$ a	b	MAXIMUM MOVING WIDTH l_{mw} (cm)	NUMBER OF MOVEMENT IN AN ARCING
Au	50V	3A	−4.2095	17.6193	0.89	35
	50V	5A	−37.9877	22.7840	1.08	55
	60V	2A	−56.9725	29.4051	0.90	40
	60V	3A	−43.2183	27.8296	1.01	60
	60V	5A	−50.0044	25.7007	1.24	95
	72V	3A	−67.6233	28.8062	1.36	100

over the maximum moving width, *lmw*, or not. If the movement of the cathode spot is not over the maximum moving width, the space between two arc ignition position is tied by dots. By the key input of P or V, the informations of the contour or the arbitrary cross section of crater are displayed and the simulation is repeated until the fixed number of operations.

The micro-computer employed in this work is PC–8001 of NEC and its memory capacity is 24 kbyte on ROM and 32 kbyte on RAM. The programing language is N-BASIC. A picture was constructed by 100 dots in vertical direction and 160 dots in horizontal one. The movement of cathode spot was displayed by a line of unit area. Establishing 1 mm to 20 dots in vertical and horizontal direction, the width of unit dot is equal to 50 micrometers.

Assuming that the trace of the cathode spot behavior means the eroded part, the data on depth must be stored for each unit dot. Therefore, the picture corresponding to the cathode surface was divided by (80×80) unit dots in x-and y-direction. When the trace of moving cathode spot passed through on these unit dots, the number of passage of trace was counted by variables *DP* (I, J) for each unit dot on the picture. Where I and J are integer and satisfy the condition of $0 \leqq I \leqq 80$ and $0 \leqq J \leqq 80$.

On the output of holizontal picture, variables *DP* (I, J) were divided eight stages by one's value. Each stage was shown by colors including "brack" and this means to show contours by colors for the depth of crater. On the output of vertical picture, the values of *DP* (I, J) was displayed as a function of I for an arbitrary J. This means the output of an arbitrary cross section of the crater.

Results and Discussion for Simulation

(a) Simulation on the Cathode Spot Behavior for the Single Break Arc

Fig. 3 is an example of simulation in the single break arc for Au contact at DC 72 V and 3 A. The initial conditions were 1.72 mm for l_{mw} and 20 msec. for the arc duration, which corresponds to the number of a hundred movements of the cathode spot. Assuming that all of the trace of the cathode spot movement is the erosion part, this simulation is in agreement with the actual eroded pattern of Au contact[(5)]. The gross processing time was about 70 seconds for this example.

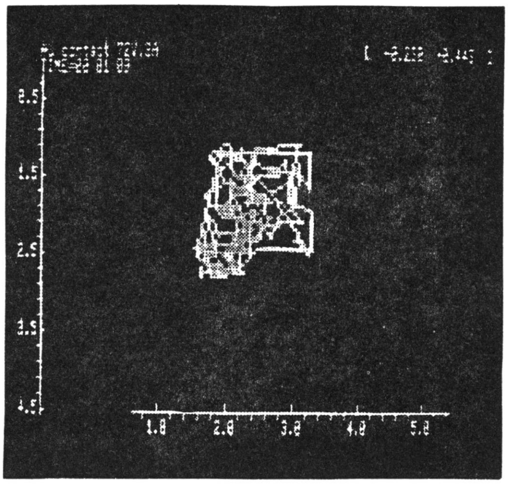


Fig. 3-Simulation of the cathode spot movement in an arcing for Au contact at dc 72 V and 3 A.

(b) Output of Contour for the Crater Structure

Fig. 4-(a) and (b) are the output of the contour for the crater structure of Au contact at DC 50 V and 5 A after 1000 operations and 4000 operations, respectively. As shown in Fig. 4, the contour of the crater shows a concentric circular pattern and is deformed into an eliptic pattern from the concentric circular one with increasing operations. The change of contour pattern is a

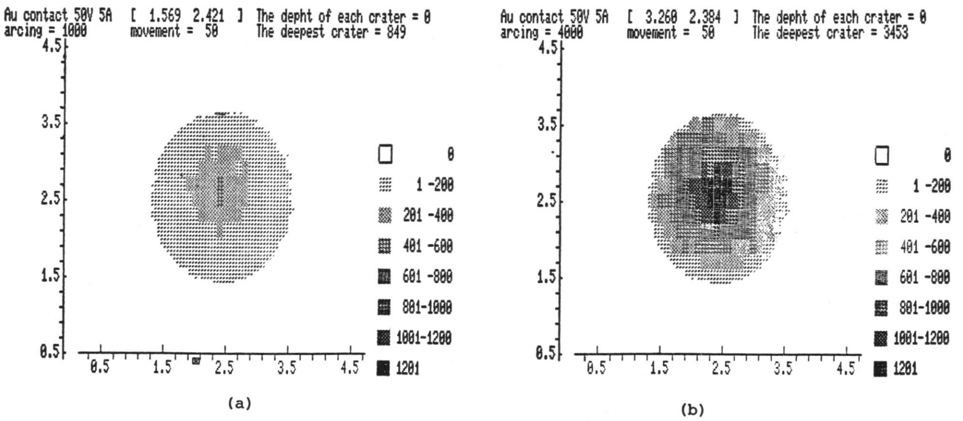


Fig. 4-Output of contour figure of the crater structure for Au contact at DC 50 V and 5 A; (a) 1000 operations, (b) 4000 operations.

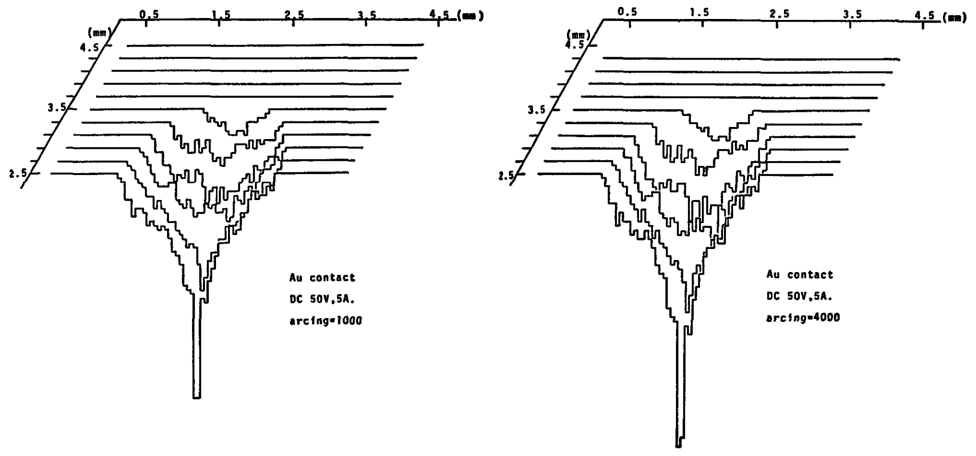
distinctive feature for Au contacts in actual results of the contact erosion(2).

(*c*) *Output of Arbitrary Cross Section for the Crater Structure*

Fig. 5-(a) and (b) are the output of the cross section of Fig. 4-(a) and (b), respectively. These are drawn by overlaping some cross section figures of crater which were obtained at intervals of 0.2 mm from center. The crater shows a conical structure and had a characteristic of the stage structure on Au contacts(2).

As mentioned above some results of this simulation on Au contact are in good agreement with the actual results of contact reosion and deformation on Au contact. This means that the simulation is a reasonable one basically.

In this simulation, the erosion part does not expand with increasing operation, because it is fixed that l_{mw} is constant. Therefore, the relation between l_{mw} and the number of operations must be found to perform the good simulation for the actual contact erosion.



(a) (b)

Fig. 5-Output of cross section of the crater structure for Au contact at DC 50 V and 5 A; (a) 1000 operations, (b) 4000 operations.

Conclusions

Monte Carlo simulation on the cathode spot behavior and the erosion pattern for Au contact was carried out by employing the micro-computer. The maximum length moved, l_{mx}, the maximum moving width, l_{mw}, distributions of velocity of moving cathode spot and arc durations were established as the restriction conditions for this simulation.

(1) The simulation on the cathode spot behavior for Au contact on (x, y)

surface was in agreement with the trace of the cathode spot movement observed microscopically.

(2) The simulation on the contour figure and the cross section of the crater for Au contact were in agreement with the actual results of the erosion pattern for Au contacts.

References

(1) K. Itoyama and G. Matsumoto: "Velocity distribution of the moving cathode spot in breaking contact arcs", IEEE Trans. Compo., Hybrids, and Manufact. Technol., Vol. CHMT-1, No. 2, p. 152 (June 1978).

(2) K. Itoyama: "Contact erosion pattern of dc break arcs", IEEE Trans. Compo., Hybrids and Manufact. Technol., Vol. CHMT-2, No. 4, p. 522 (June 1979).

(3) K. Itoyama, T. Mizoguchi and G. Matsumoto: "Simulation on the behavior of cathode spot at breaking arc of contacts", Paper of Technical Group, TGEMC 77-26, IECE Japan, p. 15 (December 1977).

(4) K. Itoyama and G. Matsumoto: "Discussion on the formation process of the crater structures of Ni electrode at breaking arcs", Paper of Technical Group, TGEMC 79-23, IECE Japan, p. 11 (October 1979).

(5) K. Itoyama and Y. Wakimura: "Estimation on the cathode spot diameter of Au and Ag contacts at breaking arcs", Symposium of National Conference of IECE Japan, 1983, No. S 12-4 (April 1983).