CORRELATION BETWEEN ARCING PHENOMENA AND ELECTROMAGNETIC NOISE OF OPENING ELECTRIC CONTACTS

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ABSTRACT

The authors observed the electromagnetic noise and surface change for Cu-C electric contact as a simulation model of a commutator motor. In case of Cu(anode)-C(cathode), the duration of sporadic burst noise generates from arc discharge. The patterns of the burst noise at the start of arc are classified into three types, and the pattern of surface change correspond to each patterns. When duration of burst noise become longer, melted area has wide distribution on electrodes surface and the authors have found the correlation between burst noise and the surface area of electrode. From these results, the authors proposed the method of noise control by controlling the melted area and showed a fundamental technique of noise control by the design of electrode in consideration of electrode form.

INTRODUCTION

An electric contact in a small electric appliance is considered as an electromagnetic noise source in HF(3MHz to 30MHz), because of arc discharge which is generated between commutator(Cu) and carbon brush(C) in the commutator motor. To develop the technology for control of noise generation from the electrodes, investigation on the relationship between arc discharge and electromagnetic noise is necessary. The waveforms of electromagnetic noise which is caused from Cu-C electrodes depends on electric current polarity. In the case of Cu(anode)–C(cathode) electrodes, sporadic burst noise occur repeatedly [1]. On the other hand, traces of discharge on the electrode surface are formed by movement of the cathode spot and the anode spot of arc [2][3]. Intensive observation in relationship between electromagnetic noise and trace of discharge on the electrode surface is effective in solving the noise control [4][5].

In this paper, the authors observe the electromagnetic noise and surface change for Cu-C electric contact as a simulation model of a commutator motor. From these results, a fundamental technique of noise control has been proposed.

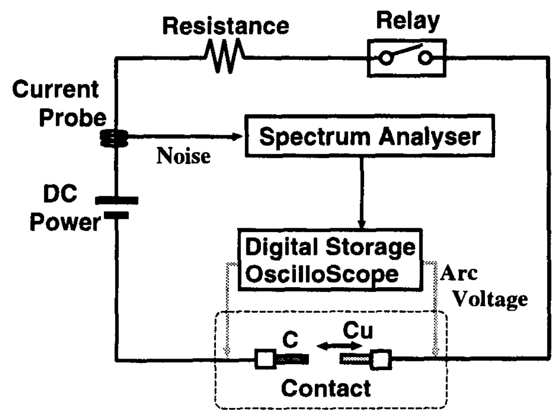

Fig.1. Schematic diagram of the measurement system.

Table 1. Experimental condition.

Electrode	Cu(1mmϕ), C(6mm$\times$7mm)
Electrode length	10mm
Circuit voltage	DC48V
Circuit current	4A
Circuit load	film resistor
Opening speed	40mm/s
Opening number	1 time

EXPERIMENTAL METHOD

The schematic diagram of measurement system is shown in Fig.1. It measures an arc voltage and a noise waveform generated by an opening electric contact. In this measurement, high frequency component of circuit current on the power line is measured with a spectrum analyzer, and referred as an index for electromagnetic noise. The noise on the power line is detected by a electric current probe, and measured with a spectrum analyzer(scan width=0[Hz]). Center frequency f_c=5[MHz] is selected in this measurement, because the effect of propagating noise from electric contact on power line is large in range from 3MHz to 30MHz[6]. The characteristic of the probe is stable at this frequency. The time scale of the oscilloscope is 2[ms/div], and the resolution band width and video band width of the spectrum analyzer are set to 300[kHz] and 10[kHz]. The calibration of noise amplitude is not made,

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and it is referred as a relative value. The measurement of the circuit inductance is 0.7[μH]. This value is so small that there is no effect on the arcing phenomena.

The microphotographs of both electrode surfaces are taken after the first opening operation. The experimental condition is shown in Table 1.

CORRELATION BETWEEN BURST NOISE AND CHANGE OF ELECTRODE SURFACE

Overview of electromagnetic noise and surface change

An example of opening arc voltage and noise waveform(relative value) for Cu(anode)-C(cathode) are shown in Fig.2. Multiple times of sporadic burst noise generate in the arc discharge. Burst noise is always observed at the start of the arc, and the duration of noise is longer than that of noise which occur in latter half.

Microphotographs of the electrode surfaces after arc discharge are shown in Fig.3. Traces of discharge are observed at the edge of contact surface on Cu surface. It is considered that surfaces of both electrodes of contact in this experiment are not parallel, and contacted at edge of Cu electrode as shown Fig.4. In Fig.3(a), several circular traces of discharge(diameter 50μm ~ 100μm) exist on cathode surface. Circular traces are distributed on cathode surface and there is a outside the distribution shiny melted area. From the result, patterns of surface change are classified into two areas as shown in Fig.3.

In this paper, circular traces of discharge is defined as area A, and melted area is defined as area B. The authors discuss the relationship between burst noise at the start of arc and these areas of surface change.

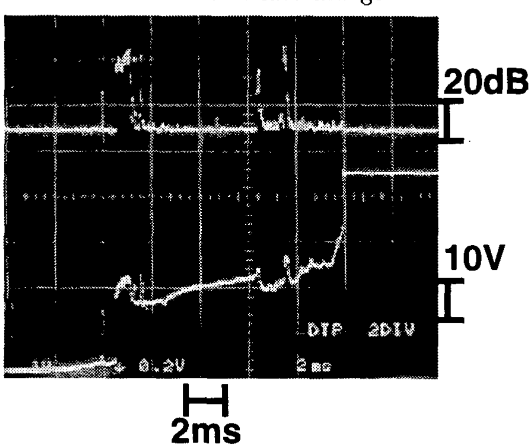
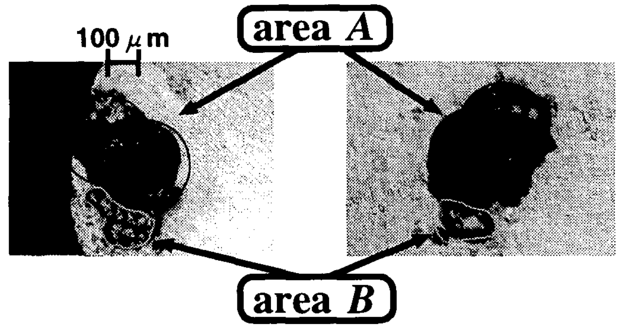


Fig.2 Noise(the top) and arc voltage(the bottom)

Pattern classification of burst noise in the start of arc and surface change

In this section, the relationship between burst noise and surface change is discussed on burst noise at the start of arc. Burst noise at the start of the arc are classified into three patterns in consideration of burst noise duration t_{na} and generation forms.



(a)Cu(anode) surface (b)C(cathode) surface

Fig.3. The microphotograph of electrode surface.

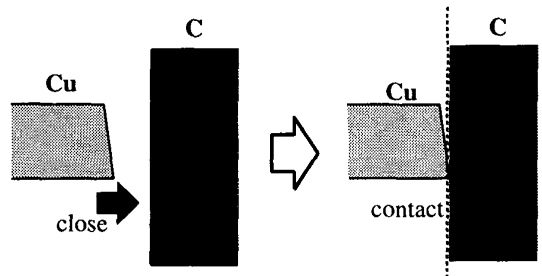


Fig.4. Contact condition of electrode.

(1) Pattern **S** : $t_{na} < 0.5$[ms]

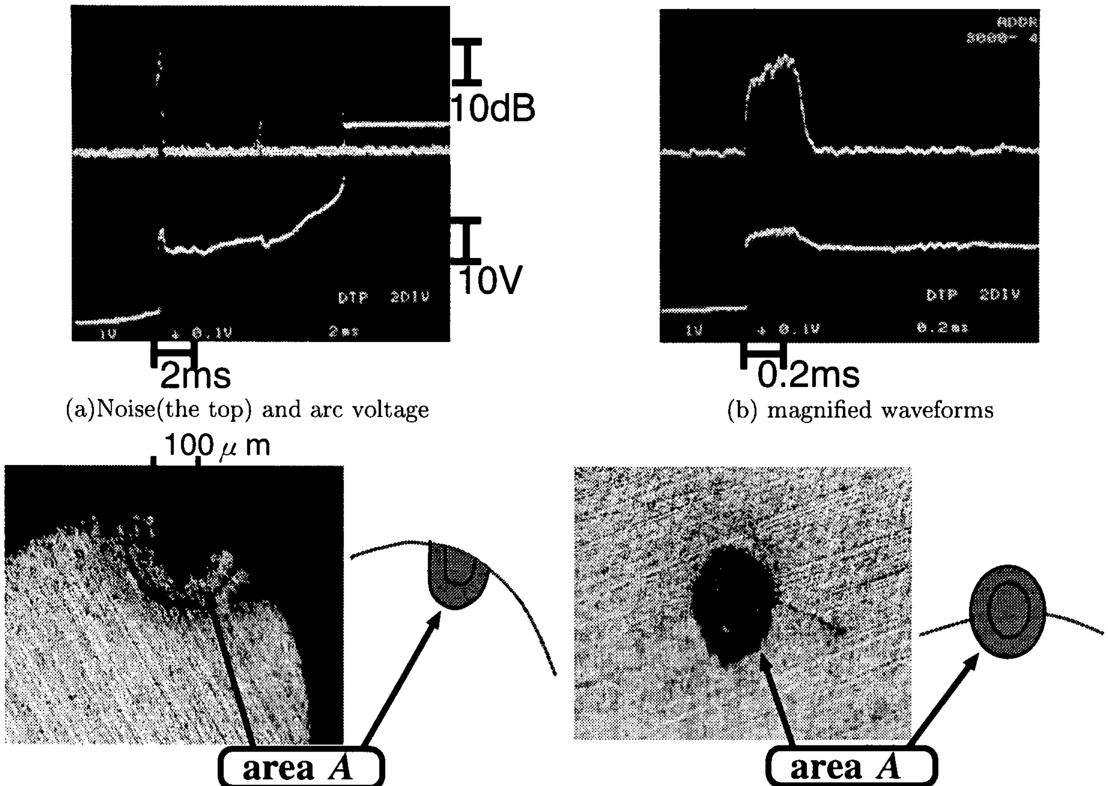
(2) Pattern **L** : $t_{na} > 0.5$[ms]

(3) Pattern **LC** : $t_{na} > 0.5$[ms] and multiple burst noise

For each of patterns **S**, **L**, **LC**, the result of noise(the top) and arc voltage(the bottom) waveform in opening are shown photographs (a) in Figs.5, 6, 7. Photographs (b) in Figs.5, 6, 7 are magnified on horizontal axis from photographs (a) in Figs.5, 6, 7. The microphotograph of the electrode pair (Cu(anode) and C(cathode)) are shown photographs (c) and (d) in Figs.5, 6, 7.

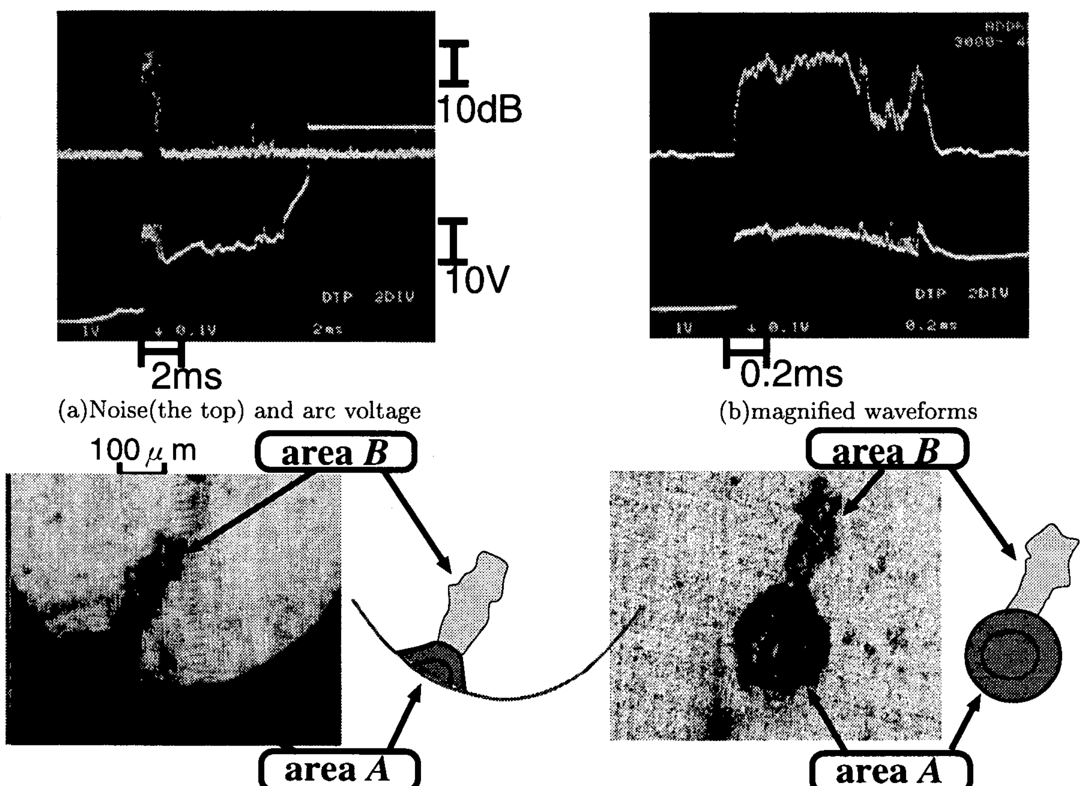
In the case of the pattern **S**(Fig.5), an area A exists on surface of the electrode, but area B is not observed, The position of area A is at the edge of Cu (anode) electrode. It is considered that the surface of both electrodes are not parallel as illustrated in Fig.4, so they contacted at the edge of Cu electrode. In the case of pattern **L**(Fig.6), Area B has wide distribution, and one area A exists on surface of anode. In the case of pattern **LC**(Fig.7), though area B is distributed, it have several area A which have different size.

From these observation results, the authors summarized the relationship between burst noise and trace of discharge in Table 2. It can be assumed that the area B corresponds to generation of burst noise. In the next section, the authors have discussed on a close correlation between burst noise and area B.



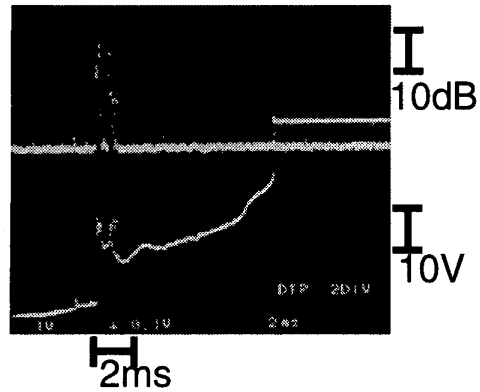
(a)Noise(the top) and arc voltage
(b) magnified waveforms
(c)Cu(anode) surface
(d)C(cathode) surface

Fig.5 Pattern **S**

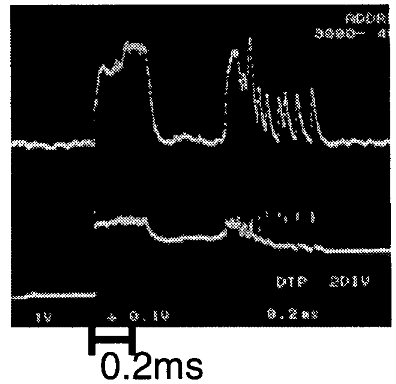


(a)Noise(the top) and arc voltage
(b)magnified waveforms
(c)Cu(anode) surface
(d)C(cathode) surface

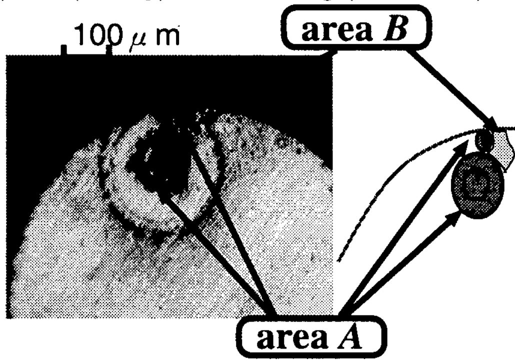
Fig.6 Pattern **L**



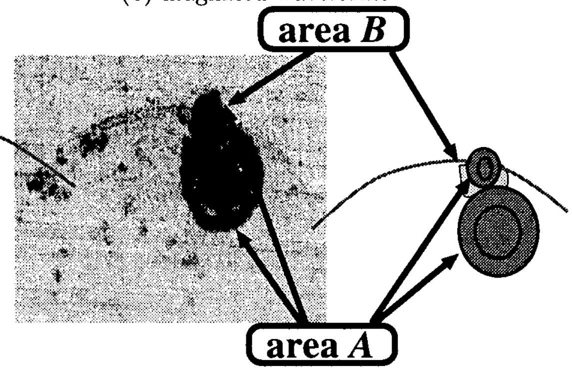
(a)Noise(the top) and arc voltage(the bottom)



(b) magnified waveforms



(c)Cu(anode) surface



(d)C(cathode) surface

Fig.7 Pattern **LC**

Table 2. The classification of patterns.

Burst noise	Surface change	
	area A	area B
S	one exist	no exist
L	one exist	distribute widely
LC	multiple exist	distribute widely

Correlation between burst noise and surface change

The authors discuss on relationship between burst noise and the change of electrode surface. Magnified typical waveforms of arc voltage and noise in the cases that only just one burst noise is generated are shown in Fig.8. The duration of burst noise in Fig.8(b) is longer than (a). Microphotographs of a pair of electrodes are shown in Figs.9(anode) and 10(cathode).

Area A is marked with thick gray in the illustration with, and the area in Fig.9(a) and (b) are almost equal. In fig.9(b), arc duration with large fluctuation is long and thin gray brilliance is seen around areas A and B (light gray area in illustration) exists. The shapes of this area on both electrodes correspond to each other. As surface color is thin gray, it is considered that C from melted or softened area is transferred and sticked on Cu surface. From these results, occurrence of arc with large fluctuation is related to generation of area B on electrode surface.

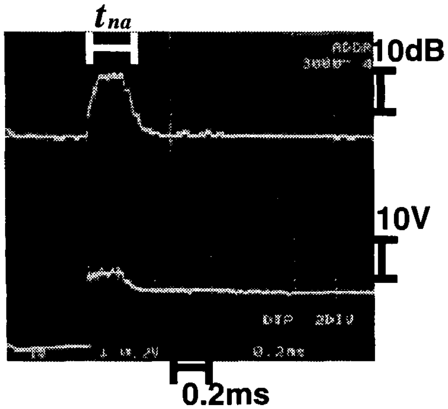
The size of area B is denoted as S_B. The relationship between t_{na} and S_B is shown in Fig.11, with gradient r and correlation coefficient a of regression line by the method of least square. When t_{na} becomes longer, S_B will increase as shown in Fig.11.

The value t of a Student-t distribution with degrees of freedom N-2=16 is 3.30 for measured data shown in Fig.11. As $t = 3.30 > 2.92 = t_{16}(0.01)$, this result shows that the correlation between t_{na} and S_B is statistically significant by a P-value of 0.01 or less.

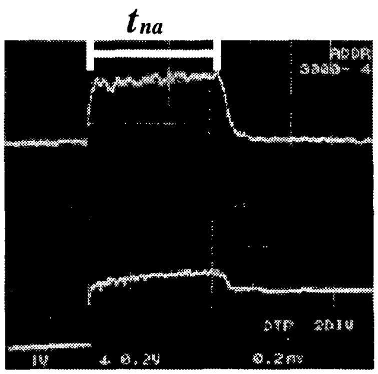
From these results, the authors showed the correlation between burst noise and area B.

CONTROL OF BURST NOISE FROM ARC DISCHARGE

The authors showed that area B(shiny melted area) is formed on electrode surface in the period of sporadic burst noise. If we can find the way to control area B, it may be possible to find a new approach of noise control. To control generation of area B, the authors proposed the method by changing surface area of electrode. In this experiment, Cu electrode of three types were used to change the contact area of Cu electrode and its effect was observed.

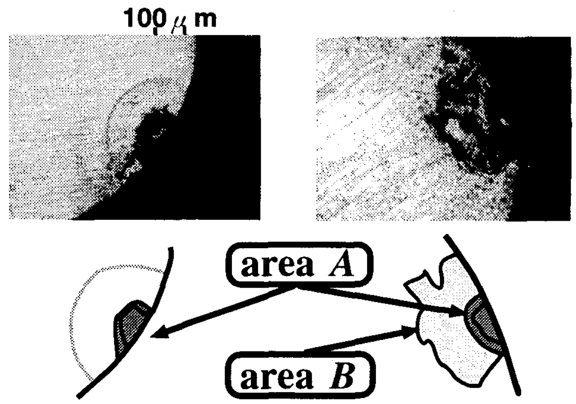


(a)Burst noise is short



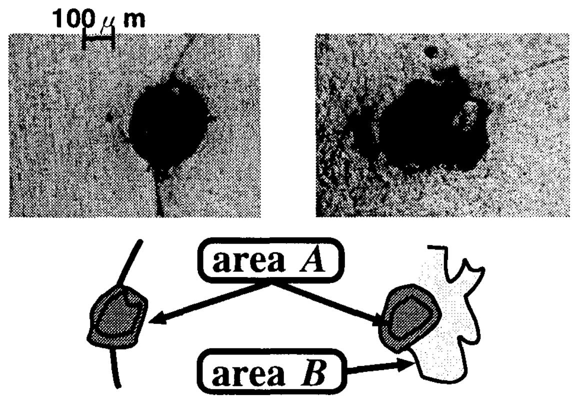
(b)Burst noise is long

Fig.8 Noise(the top) and arc voltage(the bottom) waveforms.



(a)Burst noise is short (b)Burst noise is long

Fig.9 The microphotographs of Cu(anode) surface.



(a)Burst noise is short (b)Burst noise is long

Fig.10 The microphotographs of C(cathode) surface.

Measurement result of opening arc voltage and noise waveform(relative value) for (a)Cu: 4.5[mmϕ], (b)Cu:1[mmϕ] and (c)Cu: 0.7[mm□] are shown in Fig.12.

Microphotographs of the electrodes surface after an operation for Cu(anode) and C(cathode) are shown in Fig.13. Area A exists on surface of cathode. Area B distributes around the area A as Fig.13(a) whose noise duration is relatively long. The areas A of anode and cathode correspond to each other, so do the areas B of the pair of contacts. It is considered that carbon of the melted part of C(cathode) stacked on the Cu(anode) surface. The area B for Fig.13(b) is smaller than that of Fig.13(a) and the area B for Fig.13(c) is not observed. From this result, when electrode diameter become shorter, distribution of area B on surface become smaller.

The measurement for each condition shown in Table 1 was repeated for 40 contacts, and the average of burst noise duration $\overline{t_{na}}$ and the standard deviation σ were measured for various cases of surface area of the Cu (anode) electrode. The results are shown in Table 4 suggesting that the smaller the area of Cu surface is, the shorter the burst noise duration at the start of arc becomes.

From these results, the authors showed a fundamental

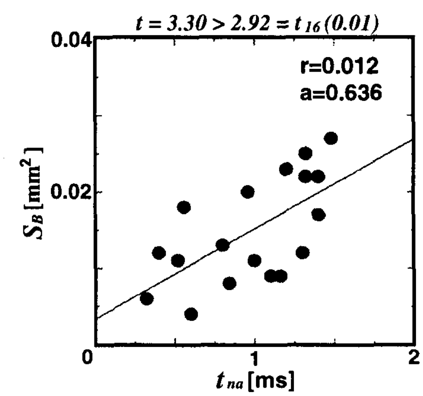
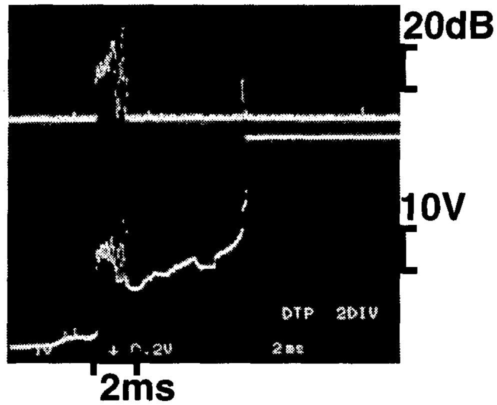
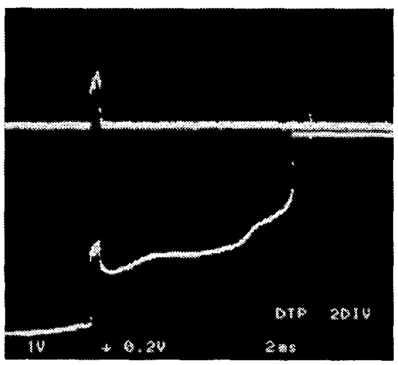


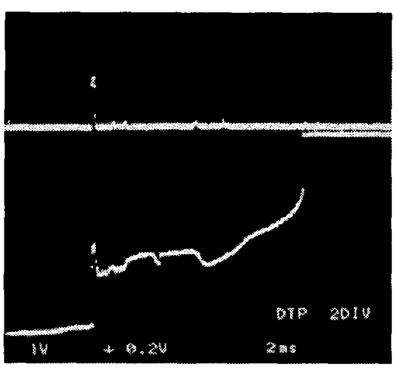
Fig.11 Relationship between t_na and S_B



(a)Cu:4.5mmϕ

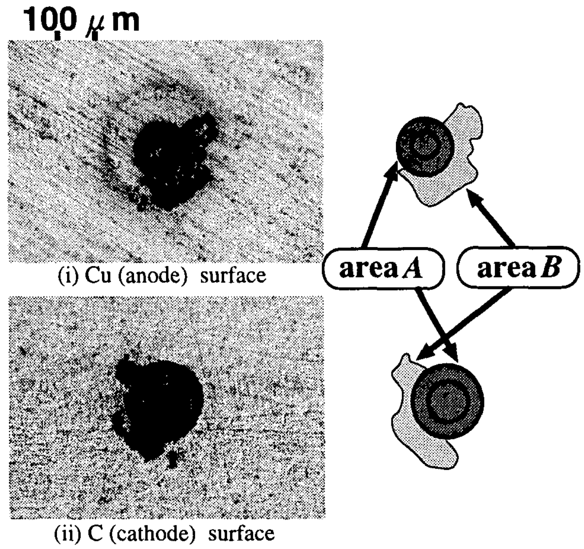


(b)Cu:1.0mmϕ

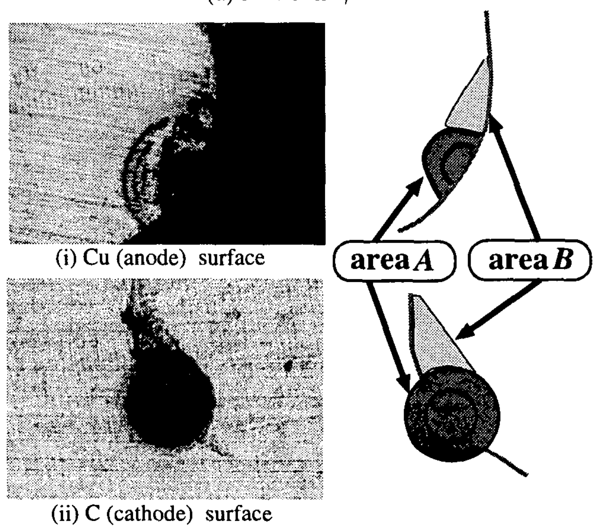


(c)Cu:0.7mm□

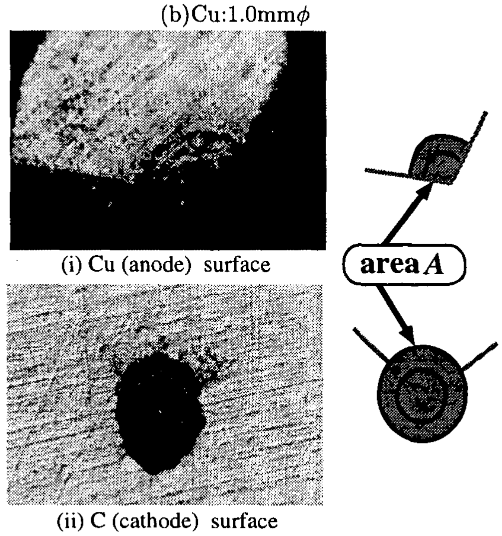
Fig.12 Noise(the top) and arc voltage(the bottom)



(a)Cu:4.5mmϕ



(b)Cu:1.0mmϕ



(c)Cu:0.7mm□

Fig.13 The microphotograph of electrode surface technique of noise control by the design of electrode in consideration of electrode form.

Table 3. Relationship between burst noise and Cu electrode area.

Cu surface	$\overline{t_{na}}$[ms]	σ [ms]
4.5mmϕ	1.16	0.245
1.0mmϕ	0.57	0.275
0.7mm□	0.41	0.102

CONCLUSION

In this paper, the authors have observed the electromagnetic noise and surface change for Cu-C electric contact as a simulation model of a commutator motor. From these results, a fundamental technique of noise control has been proposed. The following findings have been obtained from the experimental result.

(1) The forms of the burst noise in the start of arc are classified into three types, and surface change correspond to the type. When duration of burst noise become longer, melted area(area B) has wide distribution on electrodes surface. Accordingly, the authors have found the correlation between burst noise and the surface area of electrode.

(2) From these results, the authors proposed the method of noise control by the control of generation of area B and showed a fundamental technique of noise control by the design of electrode in consideration of electrode form.

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