QUENCHING PERFORMANCE OF AIR ARC DISCHARGE WITH POLYMER INSULATORS

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ABSTRACT

When arcs touch insulators in air circuit breakers, ablation gasses are generated and emitted into the arcing space. As well known, ablation gasses may affect the arc characteristics [1].

As a first step of our study, we used parallel plate insulators. The fixed electrodes are connected by a copper thin wire which passes between the insulator plates. When the discharge is started, the arc touches insulator plates and ablation gas is emitted. We tested the 10 kinds of polymer insulators.

Using arc current and voltage measurement data, we compared the following items such as the number of current cycles, voltage wave forms, and arc conductance, arc time constant and arc loss. In addition, appearances of the arc were observed by using high speed camera, and the length of emitted gas was compared.

1. INTRODUCTION

Polymer insulators are widely used in arc chambers of air circuit breakers. When arcs touch insulators in air circuit breakers, ablation gasses are generated and emitted into the arcing space. As well known, ablation gasses may affect the arc characteristics. Using many types of insulators, we investigate the relations between ablation gasses and arc interruption capability in order to improve the interruption capabilities of air circuit breakers.

2. EXPERIMENTAL METHOD

The experimental circuit is shown in Fig.1. The capacitor bank of 90μF-10kV is used for current source. The current is a decaying alternate wave form (about 60Hz). Fig.2 shows the arrangement of parallel plate insulator. The fixed electrodes are connected by a copper thin wire which passes between the insulators. 10 kinds of insulators are shown in Table.1.

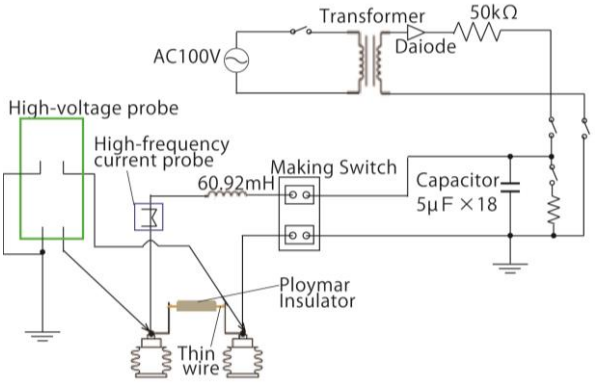


Fig. 1 Experimental circuit

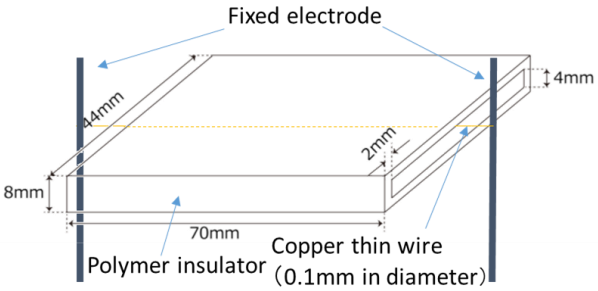
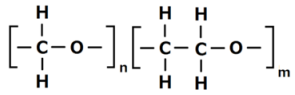
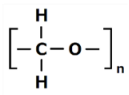
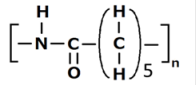
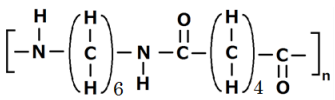
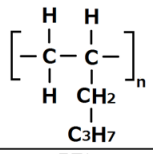
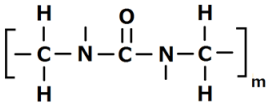
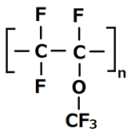
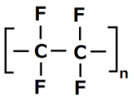


Fig. 2 Arrangement of insulator

Table.1 Kinds of insulator of unit structure

Co-POM①	Co-POM②	Homo-POM
		
PA6	PA66	PA66+fire retardant
		
PMP	Urea resin	
		
PFA	PTFE	
		

3. THE NUMBER OF CURRENT CYCLES

Fig.3 shows voltage and current wave forms of PFA. As shown in these wave forms, the current waves are constantly decayed. The arc voltage rapidly rises and falls just before and after the current zero. We compared the quenching performances of every insulator by counting the number of arcing cycles. Case of Fig.3, the number of the cycles of PFA was 2.5.

Fig.4 shows comparison of the number of the cycles. The number of cycles is in inverse proportion to quenching performance.

From Fig.4, the number of cycles of fluorocarbon polymer insulators (PFA, PTFE) was larger than that of any other insulators.

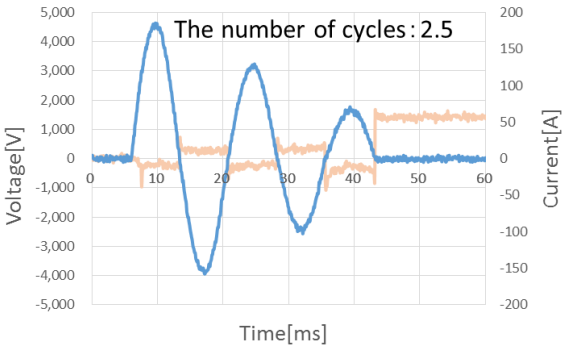


Fig. 3 Voltage and current wave form (PFA)

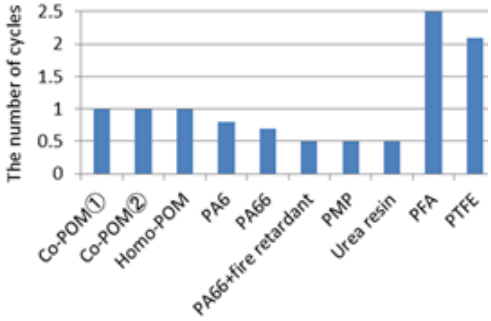


Fig. 4 The number of cycles

4. VOLTAGE WAVE FORM

Fig.5 shows that the waveform of voltage rises rapidly before current zero. Conductance will become small if voltage is high. Therefore, we can mention that the higher the peak voltage is, the better the quenching performance is.

We consider the peak value of voltage of PMP is the largest and that of fluorocarbon polymer insulators (PFA, PTFE) are by far the smallest.

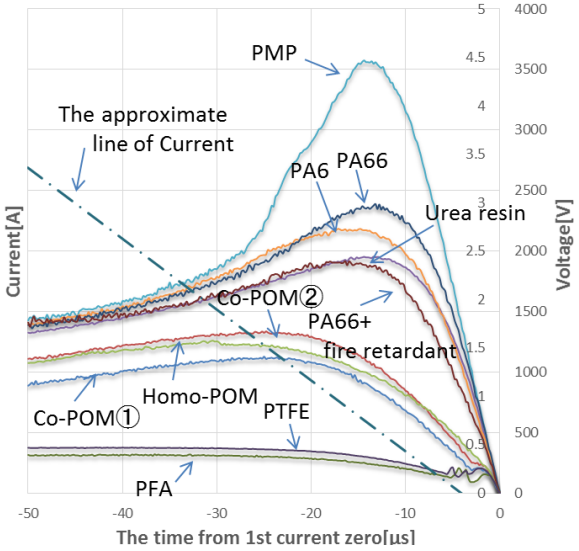


Fig. 5 Voltage wave form

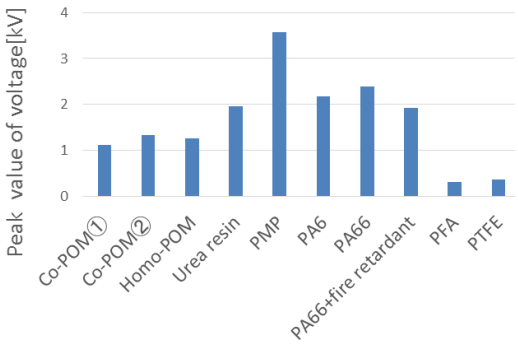


Fig. 6 Peak value of voltage

5. ARC CONDUCTANCE AND ARC PARAMETER

The values of calculated conductance are shown in Figure7. We consider conductance of PMP and PA based insulators are lower than those of others, and that of fluorocarbon polymer insulators (PFA, PTFE) are largest.

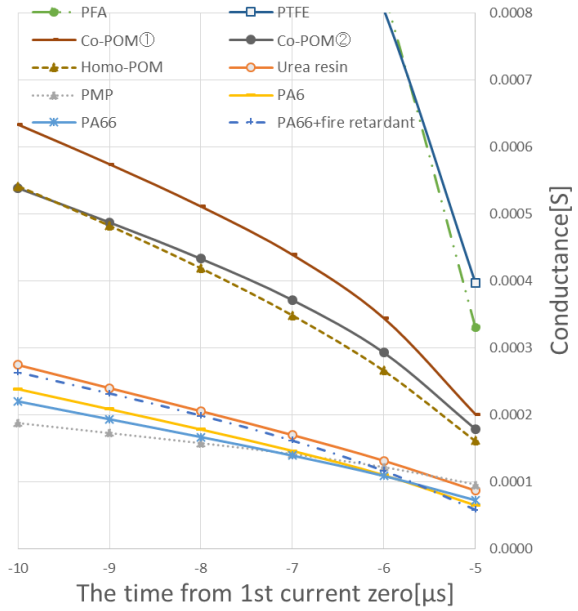


Fig. 7. Time responses of Arc conductance

As first step of calculation of the arc loss and arc time constant, η-Pin curve is plotted by using the Mayr arc model equation (1).
"g" is the arc conductance, "θ" is the arc time constant, "P_{in}" is the input arc power and "P_{loss}" is the arc loss. "η" is defined in equation (1).
From tangent line of η-Pin curve (Fig.8), we can obtain value of the arc loss and arc time constant [2].

Fig.9 and 10 show calculation results of the arc loss and arc time constant respectively. In generally, insulators with high quenching performance show high arc loss and small arc time constant [3]. From Fig.9, we consider arc loss of PMP is the largest, and that of fluorocarbon polymer insulators (PFA, PTFE) are the smallest. From Fig.10, we consider arc time constant of PMP is the longest. And that of fluorocarbon polymer insulators (PFA, PTFE) are the smallest.

$$\eta = \frac{1}{g}\frac{dg}{dt} = \frac{1}{\theta}\left(\frac{P_{in}}{P_{loss}} - 1\right) \qquad (1)$$

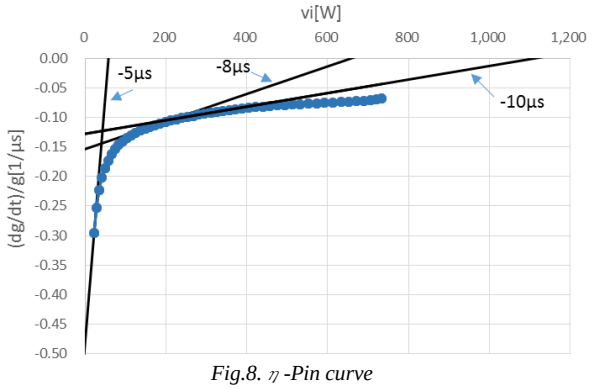


Fig.8. η -Pin curve

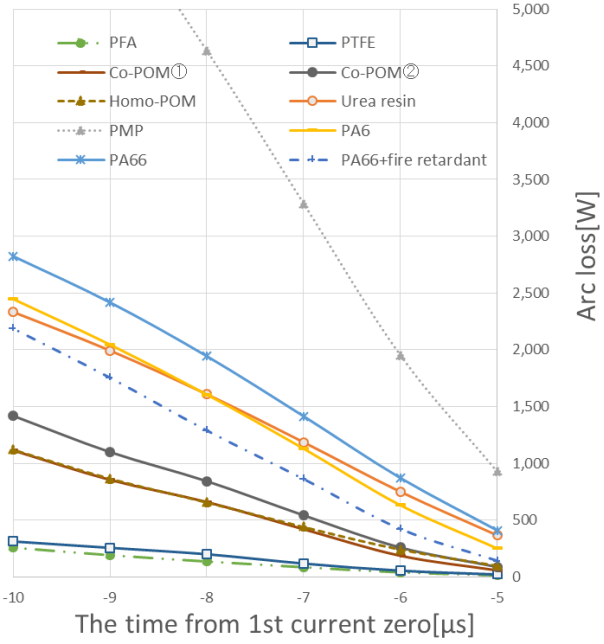


Fig.9. Arc loss

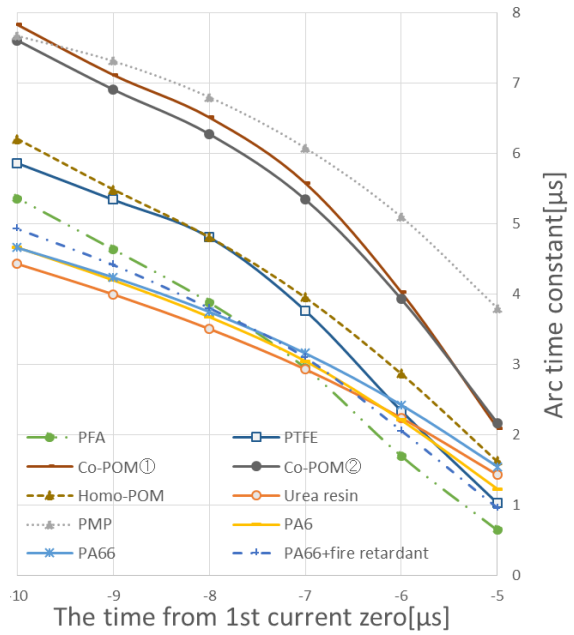


Fig. 10. Arc time constant

6. THE PHOTOGRAPHY BY A HIGH SPEED CAMER

Appearance of the arc is observed by using high speed camera (1000fps, 1/40000), and we compared the length of light emitting region of gas. Fig.11 shows the timing of high speed camera framing and Fig.12 shows the result of appearance of the emitted gas. As shown in fig.12, we consider light emitting region of each material is different.

As next step, we measure length of the emitted gas with Fig.12 and summarized it Fig.13. And comparison of the number of cycles is added to Fig.13.

From Fig.12 and 13, we consider emitted gas is affecting the quenching performance. For example, a large amount of gas is emitted from PMP (Arcing time of PMP is the shortest). But, emitted gas of fluorocarbon polymer insulators (PFA, PTFE) is by far the smallest (Arcing time of fluorocarbon polymer insulators are the longest.)

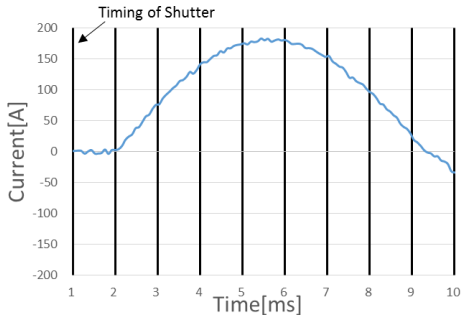


Fig. 11. Timing of high speed camera shutter

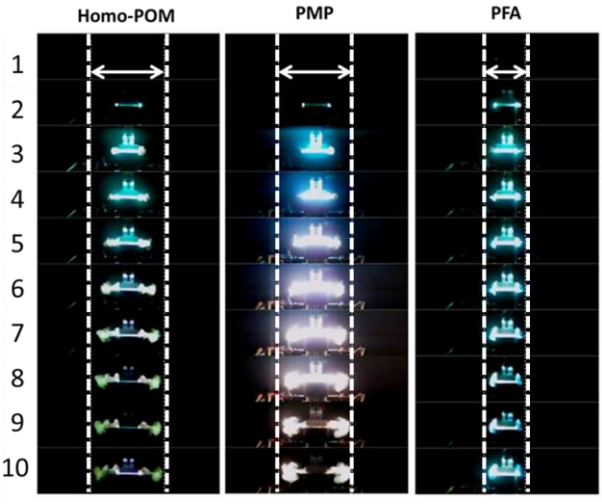


Fig. 12. Photograph of the emitted gas (1000fps, 1/40000)

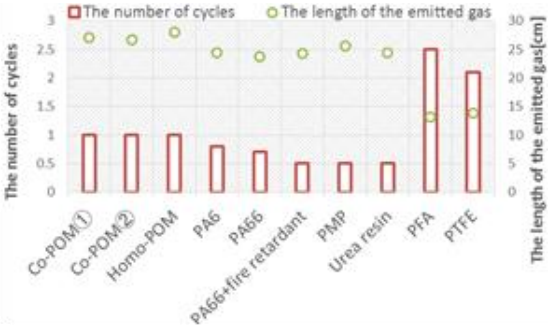


Fig. 13. Relation between the length of the emitted gas and the number of cycles

7. CONCLUSION

We investigated quenching capability of 10 kinds of insulators.We compared the number of current cycles, voltage wave form, and arc conductance, arc time constant, arc loss. In addition, appearance of the arc is observed by using high speed camera, and we compared the length of emitted gas.

Conductance of PMP and PA based insulators are lower than those of others, and that of fluorocarbon polymer insulators are largest. Arc loss of PMP is the largest and that of Teflon-based insulators are the smallest. Arc time constant of PMP is the longest and that of fluorocarbon polymer insulators are the smallest. From relation between the amount of gas of the emitted gas and the number of cycles, we prove the amount of gas is proportional to quenching performance.

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