The Test Method to Acquire the Optimal Parameter for CL-Fuse

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Abstract

In this experiment, the discharge gap and surface roughness for various peak current and pulse on time were evaluated.
in this paper we choose 7 parameters with weight value based on study and experimentation and analyzed the characteristics of arcing period. In addition, we proposed the experimental method to extract the optimal design parameters with minimal effort as related the mutual effect from each of the parameters.

1. Introduction

The fuse used in the high voltage distribution line often fails due to the active ionization caused by the strong electric field at fuse terminal. To suppress the ionization at the high voltage and high capacity current limiting fuse, the particle size and compactness of silica sand, the design, length, notch number and material of element, the diameter and the length of fuse body must be considered carefully. However, these are not proper that is treated with the inherent interrupting characteristics from many parameters at present. Because of these reasons, time and effort are needed to develop the new type of fuse by the fuse designers in relation with the inherent characteristics from each of parameters. in this paper we choose 7 parameters with weight value based on study and experimentation and analyzed the characteristics of arcing period. In addition, we proposed the experimental method to extract the optimal design parameters with minimal effort as related the mutual effect from each of the parameters.

2. Sample and experiment

In the fig.1, the material of the fuse's outer body includes a composite 87% epoxy and 13% glass fiber, the angle of the glass fiber coiled at outer body is 15•20•. The core of fuse body is ceramic included 70% alumina. The element is 99.9% pure silver. The silica sand is 99.6%, the size is 0.45•1.05[mm]. The test device constructed by charging, interrupting and measuring part is illustrated in the fig. 2.

The experiment is carried out under the condition 1[kV], 50[kA].

3. Results

3.1 the size of silica sand

In the figure 3, the size of the silica sand to the energy generated during the arcing period is the solid line, and the dotted line illustrates the arcing time. The larger size of silica sand, we see the increased energy during the arcing period in the fig 3, When the size increases from 0.45 to 1.05, the arcing energy increases about three times. And the test oscillogram is illustrated the size 1.05, 0.45 in the fig. 4. The amplitude of current in the arcing period from the fig (b) is more decreased than that of fig (a). The arcing time is about 3.3[ms] in the fig (a), 4.5[ms] in the fig (b), but in case of fig (b), The amplitude of current is very small, and it is applied to 4.5[ms]. This result is explained as follows. The arc having the generated conductance when the element melting is absorbed into the silica sand. Its size is smaller because the surface area able to collide with silica sand is larger; it is effected to absorb the heat from the silica sand. Consequently, the arc is not easy to arrive at outer body through the small space of silica sand. In case of the size, 1.05 silica sand, When a metal vapor and a silica sand by arc mixed, the fulgurite is not generated. And the metal vapor is mixed with all silica sands in the inner body. Consequently, the arc has the reaction with all silica sands while the high current is applied. So we can guess the arcing time is very short because the coiling is easy. From these results we can see that the size of silica sand has to be considered as the short of arc current and time means the optimal interrupting.

The fulgurite's structure is illustrated in the fig. 5. When silica sand meets the high temperature arc, it melts, structures the mixed fulgurite. The hole is generated in the center that there is the element, there is the empty space in the hole. There is the silica sand, which is not melted and metal vapor at the edge of the fulgurite. The larger size of silica sand, the melted silica sand is the smaller, and the hole's size is the larger.

3.2 the compactness

The element's length is 60[mm], the diameter is 0.41[mm] which is twisted, and the notch' number is 24, the silica sand's size is 0.65[mm]. This equation is used to decide the compactness.

$$\Delta Q = \frac{Q - Q_O}{Q_O}$$

Q_O : The weight before the vibration

Q : The weight after the vibration

It illustrates the arc energy, the solid line and the arcing time, the dotted line to the compactness in the fig. 6. The compactness is developed about 40[%] when using the vibrator, 60[Hz]. It is shown below x axis as per unit. The arcing energy is about 60[kA^2 ·sec] when the silica sand is inserted without vibration. The outer body is exploded when the compactness increases above 1.1[p.u]. The arcing energy decreases about 4.87 times. This phenomenon is analyzed as follows. The high temperature is generated when the arcing starts after the element is melted. The arcing which has the generated high pressure by the high temperature is progressing toward the outer body through the silica sand during the very short time. In this time, if the arcing arrived at the outer body easily, the arcing is not eliminated completely by surrounding silica sands. Consequently, because the arc's conducting keeps on, the arc energy becomes larger.

The major parameter in order to arrive at the outer body easily is the small space inside the silica sand. The more space, the easier it is for the arcing to arrive by the high pressure. When the compactness is increased. The small space decreases, but the surface area, which is able to collide with arc increases. The arc can not arrive at the outer body by the results, but collides with the surrounding silica sand. When the collision is generated, the arc having the high temperature lose the heat needed to melt silica sand, so the insulation is recovered quickly.

3.3 the thickness of element

The size of silica sand is 0.45[mm], the element's length is 80[mm], the inner diameter of the outer body is 28[mm]. The outer body's length is 40[mm]. And to know the effect of ability of interrupting by the varying the thickness using the press power, we varied the thickness, 0.47, 0.39, 0.32, 0.25, 0.2[mm]. The press extends the notch's width and length. Consequently, the element pressed to equal the resistivity is extended in its length

It illustrates the arc energy and arcing time when the element's thickness is varied in the fig.7. As it gets thinner, the arc energy is decreased to 1 over six and arcing time is decreased to 1 over four So, the thinner, the more developed the ability of interrupting. Because the notch's region is separated with the certainty, the region without the notch region is not melted, only the part of the notch is vapor, the silica sand extinguishes the arc easily. There is a notch which is extend widely, the metal vapor spreads widely also, the interrupting is carried out easily because the vapor has more chances in order to meet silica sand.

3.4 the length of element

The size of silica sand is 0.45[mm], the inner diameter of the outer body is 18[mm]. The outer body's length is 40[mm]. To know the effect of element's length under the notch number is constant, we varied the length 40, 80, 120, 180[mm]. It illustrates arc energy and arcing time to the element length having constant notch number in the fig. 8. From this figure, the arc extinguishing of the element length is optimal at 80[mm]. Although the silica sand absorbs the thermal generated at each notch, under this test condition. The whole region of element is changed to arc because there are close notches very on the element having the shorter length then 80[mm], so because the much melting mass, the interrupting is not easy. And there is a constant distance between notches on the above 80[mm]. But the element's length is extended. Consequently, when it is coiled at core, the distance between the lines are very close, the silica sand didn't control the metal vapor. In this paper, we can get the optimal length of element extinguishing arc under the constant space.

3.5 the number of notch

The size of silica sand is 0.45[mm], the inner diameter of the outer body is 18[mm]. The outer body's length is 40[mm]. To know the effect of the notch's number, we varied it from 16 to 44. We can see that the interrupting carries out easy as the number of notch decrease from the fig. 9. When the notch's number is 16, the energy of arc is the smallest. If the notch's number is decreased, the energy of arc is to increase on the contrary after a critical notch.

If an arcing voltage is higher, the arc can be eliminated effectively. In this paper, we can see that the extinguishing of arc is optimal at the element's length having 16 notches

3.6 the inner diameter of the outer body

The size of silica sand is 0.45[mm], the outer body's length is 40[mm]. To know the effect of varying inner diameter of the outer body We varied inner diameter 18[mm], 33[mm] When the volume is increased 3.5 times, the arc energy is decreased 1 over 4, and the arcing time is decreased 4 over 5 from this fig. 10. These results can be explained as thinking the physical phenomenon, which the generated high pressure arrives at the outer body when the fulgurite is producted. The pressure, which is generated in the center, spreads toward radial. At this time, The silica sand is relaxed to transfer uniformity of the impact by the high pressure. This relaxation is effected by radial size. Consequently the explosion is not generated by the radial size increased 1.8 times. At the same time, because the silica sand's size is 0.45[mm] the arc's high temperature is transferred easily to silica sand, and the interrupting carries out easily

3.7 the length of the outer body

The size of silica sand is 0.45[mm], the inner diameter is 18[mm], the element's length is 80[mm]. To know the effect of the varying outer body's length We varied the outer body's length 40[mm], 60[mm]. There is no difference of the arc energy as the outer body's length increase from fig. 11 but the arcing time is decreased. These results are explained in fig. 12. The generated pressure impact is progress toward r and Z when the fulgurite is producted in the center of notch. The direction of the outer body' length is Z , the length is 20[mm], 30[mm], the perpendicular direction is r. Z is longed 2.2[p.u.], 3.3[p.u.] more then r so the pressure impact generated in the center is progress to the Z

direction as a result, it is the time arrived at the outer body shorter than the time arrived at the end cap. Consequently, the impact arrived at the outer body is higher than that arrived at the Z . So In the case of the fuse can control the pressure impact properly, although the length is longer toward Z , The effect of the interrupting is not difference.

4. Results

Among the many parameters affected by the interrupting characteristics. In this paper, we can get the proper design parameter. Through the experiment about the 7 parameters is under the 1[kV], 50[kA] condition. The arc energy is decreased to 1 over four as increased the compactness 15% by the sequence testing method. There is the optimal extinguishing when the size is 0.45[mm], the notch's number is 16 When the inner diameter of the outer body's is increased 1.8 times the ability of arc extinguish is increased 4 times. But the ability of extinguishing is increased by the increase the inner diameter to toward r, when the length toward Z is extend is not different. When the fuse designer develops the new model. There will be the economical benefit about the time and effort as referring to this paper's experiment results.

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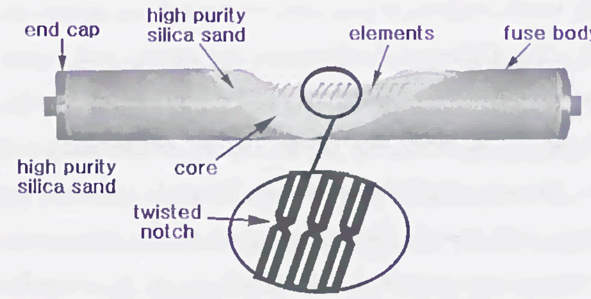


Fig. 1 Cross-sectional view of the tested fuse

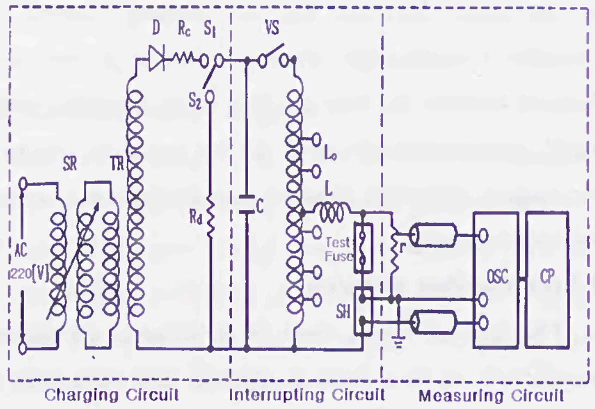


Fig. 2 Schematic diagram of equivalent interrupter

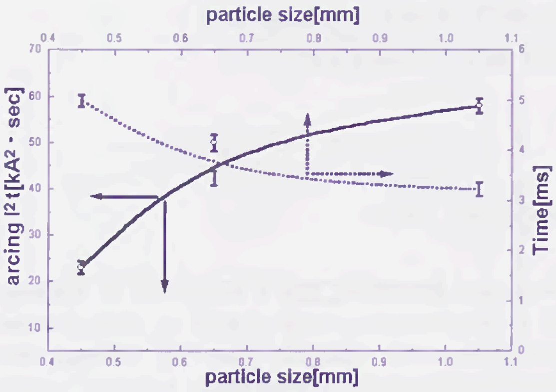


Fig. 3 Particle size effects of silica sand

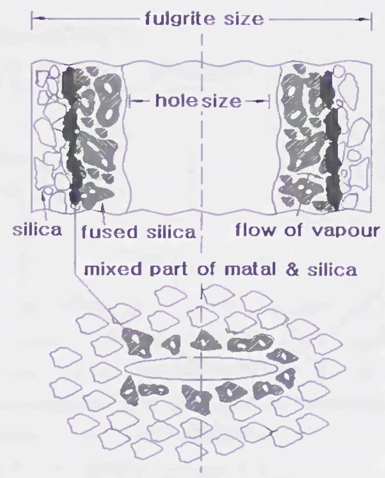
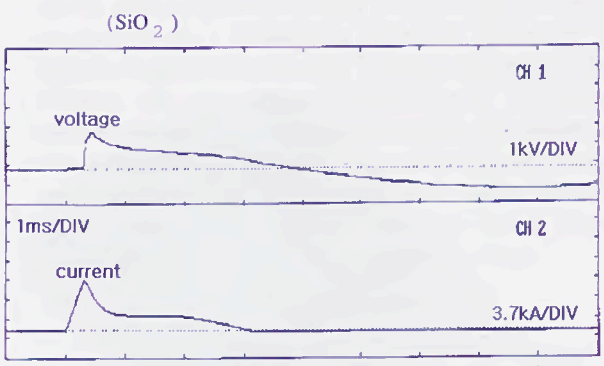
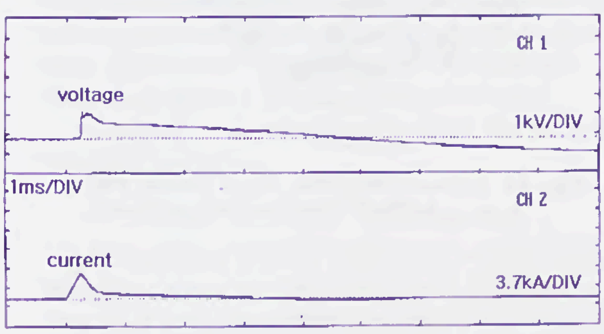


Fig. 5 Structure of fulgurite



(a)Particle size, 1.05[mm]



(b) Particle size, 0.45[mm]

Fig. 4 Interrupting oscillograms of particle size effects

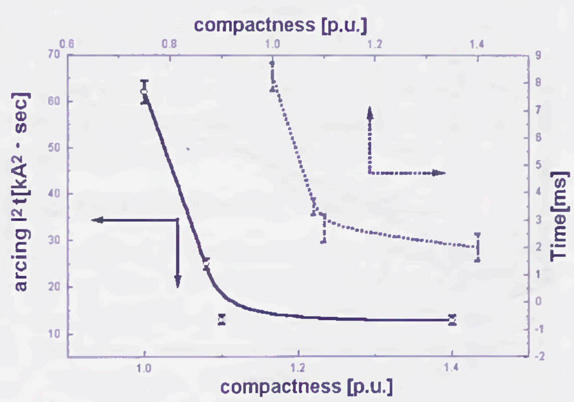


Fig. 6 Compact effects of silica sand (SiO_2)

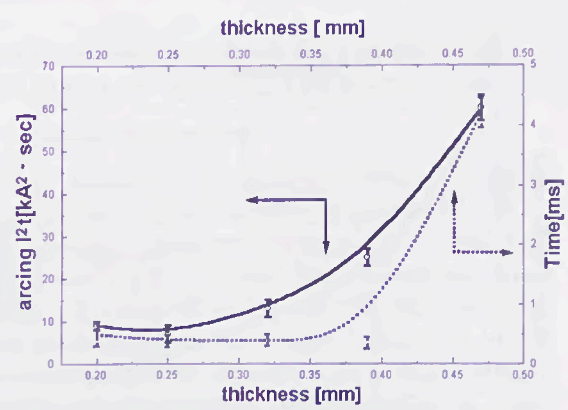


Fig. 7 Thickness effects of element notch

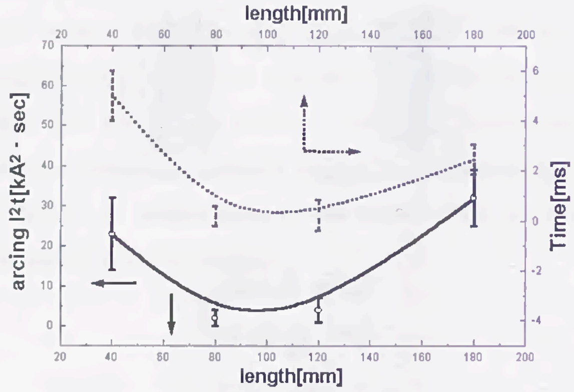


Fig. 8 Length effects of fuse element

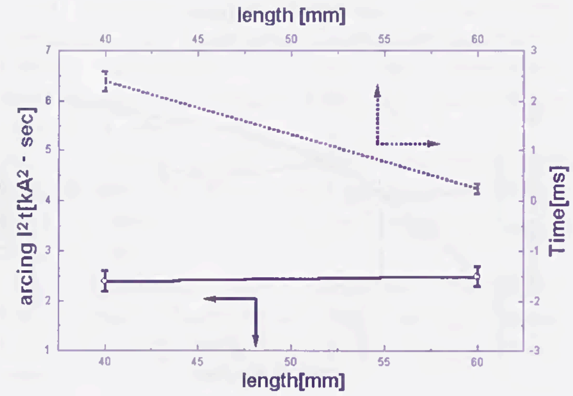


Fig. 11 Length effects of fuse body

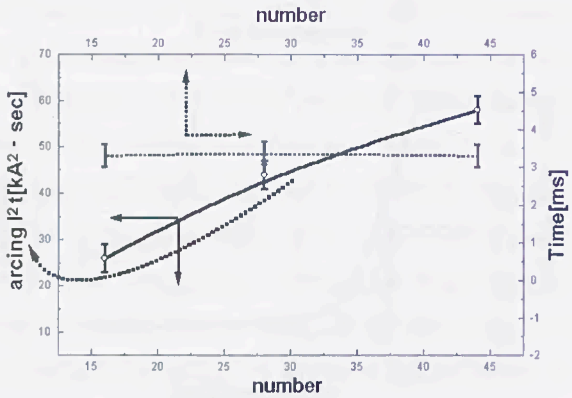


Fig. 9 Notch number effects

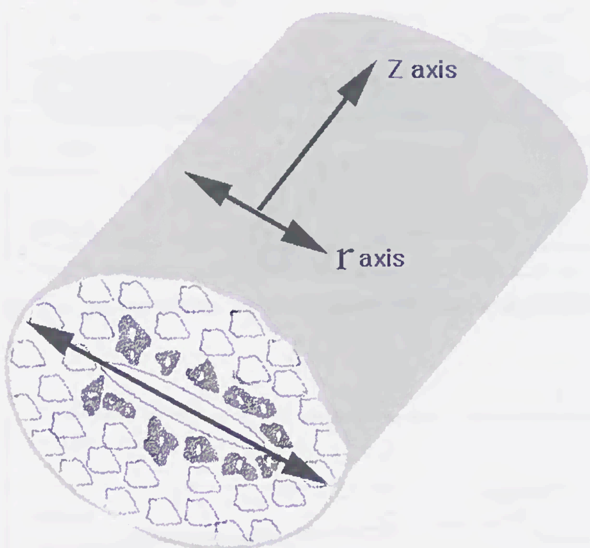


Fig. 12 Forward directions of arc plasma with high pressure

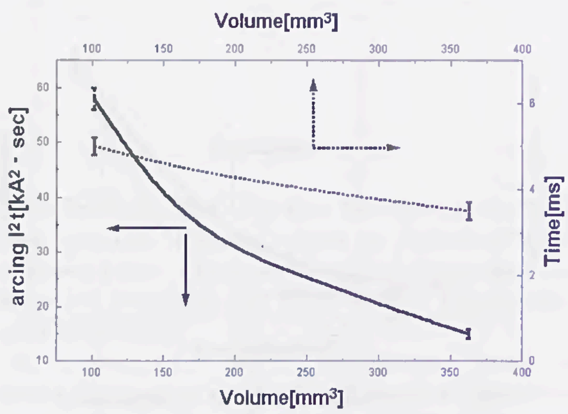


Fig. 10 Volume effects in fuse body