The Influence of M-effect Metal Arrangment on the overload current Pre-arcing time of DC current-limiting fuses

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***Abstract*—Using a M-effect metal is an efficient method to shorten the pre-arc time of current-limitinging fuse.But the M-effect can't work on high current range. the arrangment of M-effect metal have a significantly influence on the pre-arcing time of current-limiting fuse. The objective of this paper is to determine the influence of the arrangment of M-effect metal on the overload current pre-arcing time of DC current-limiting fuse.A DC test circuit is adopted to acquire the pre-arcing time with and without the M-effect metal. Six designs with different arrangments of M-effect metal are tested to determine the influence on the pre-arcing time.Experimental results show that the M-effect operation takes effect when the overload current is around two times of the rated current. If a short pre-arcing time is needed, the best arrangment of M-effect metal is in one side back on the restrict zone.Double sides or double layers designs of the M-effect metals took longer pre-arcing time than the one side design.The pre-arcing time also became longer as the M-effect metal moved away from the restrict zone.**

***Index Terms*-- DC current-limiting fuse,M-effect metal arrangment, pre-arcing time**

I. INTRODUCTION

DC current-limiting fuse is a protection electric appliance with a high interruption capacity Now DC current-limiting fuse is widely used as the electric protection in the field of electric vehicles, urban railway transportation, semiconductors, photovoltaic power generation and other emerging DC technology field.

In the field of electric vehicles, four or five DC current-limiting fuses are needed to protect the battery pack, motor controller, air conditioning and other DC/DC converters; In the field of urban railway transportation, there are two kinds of DC power supplings, which are pantograph and the third rail current collector, respectively. Both of them need a DC current-limiting fuse to prevent fault current from explosion. In the field of semiconductor protection, such as IGBT, 1ms shut-off time is targeted for the DC current-limiting fuse [1].

A common week point of DC current-limiting fuses is the poor interrupting capacity of overload current. The typical range of overload current is two to five times of the rated nominal current. On the other hand, The capacity of short circuit interruption of DC current-limiting fuse is typically strong. The reason of the weak overload current interruption capacity of DC current-limiting fuse is that the pre-arcing time is too long. M-effect is an efficient method to shorten the pre-arcing time.

The performance of M-effect metal was reported by many researchers. Mu et al. introduced a type of fuse with a M-effect metal [2].Иамито-ков,Харисов and Wang measured the temperature rise, watt lose and pre-arcing time of DC current-limiting fuse [3]. Beaujean, Leach [4]-[6]and other researchers used finite element method to simulate the M-effect. the M-effect can't work in high current range. In addition, there are no report on the influence the of M-effect metal arrangement on the pre-arcing time of DC current-limiting fuse.

The objective of this paper is to determine the influence of the arrangment of M-effect metal on the overload current pre-arcing time of DC current-limiting fuse. The work would be beneficial to improve the overload current interruption capacity of DC current-limiting fuse.

II. EXPERIMENTAL SETUP

A. fuse arrangement

The test fuses are shown in Fig.1. A ceramic body is used, which is cylindrical shape. the diameter of the ceramic body is 8mm and its length is 30mm.The filling silica sand is 60~80 meshes. The size of fuse element is shown in Fig.2.The material of the fuse element is silver,the lonth is 43mm,the width is 1.64mm,the thick is 0.14mm and the radius of the restrict zone is 0.75mm,The rated current of the fuse is 15A. The M-effect metal material is Tin and the fuse element material is silver.

B. Experimental circuit

Fig.3 shows an experimental circuit for overload current pre-arcing time measurement of DC current-limiting fuses. . A DC source is adopted, which is a constant current source. The DC source out is DC current of 30A, 45A, 60A and 75A,

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which is two times to five times of the rated nominal current of the test fuse. the source voltage is set to 10V.

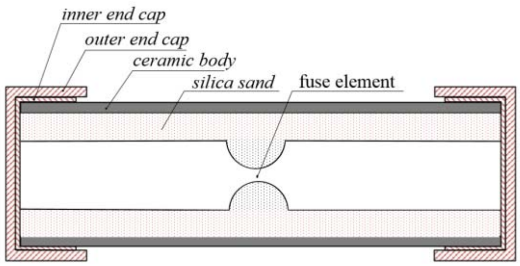

Fig.1. Fuse structure

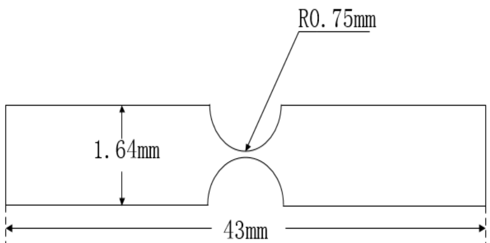

Fig.2. the size of fuse element

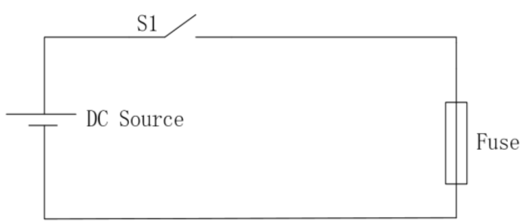

Fig.3 Experimental circuit

C. The six arrangments of M-effect metal

The ohom heating is a key point for M-effect. the M-effect metal is arranged in six arrangments to determine their influence on the pre-arcing time. Fig.4 shows the six arrangments and Table I shows the parameters of the six designs. The width of the metal is the same as the fuse element, which is 1.64mm in all of the six designs.

Fig.4(a) shows Design 1. There are two retanglar M-effect metals with same size locating on the both sides of the restrict zone. The length of the metal L1 is 2mm. The thickness of the M-effect metal is 0.4 mm. This case wants to observe the M-effect when the metals contribute from both sides of the restrict zone, which is a double sides design.

Fig.4(b) shows Design 2. There are two rectangular M-effect metals locating on the left side of the restrict zone. However, the design has double layers. One locates on the front side and the other locates on the back side of fuse element. The length of the metal L1 is 2mm. The thickness of the M-effect metal is 0.4 mm. This case wants to observe the M-effect when the metals contribute from both the front side and the back side, which is a double layers design.

Fig.4(c) shows Design 3. There is a rectangular M-effect metal locating on the left side of the restrict zone. The length of the M-effect metal L1 is 4mm, which is higher than Design 1 and Design 2. However, the thickness of the M-effect metal is 0.2 mm. That means the volume of the M-effect metal of Design 3 is half of Design 1 and Design 2. This case wants to observe the M-effect when the metals is thinner and longer, which can compare with that of Design 4.

Fig.4(d) shows Design 4. There is a rectangular M-effect metal locating on the left side of the restrict zone. The length of the M-effect metal L1 is 2mm, which is equal to Design 1 and Design 2. The thickness of the M-effect metal is 0.4 mm. That means the volume of the M-effect metal of Design 4 is equal to Design 3, and it is half of Design 1 and Design 2. This case wants to observe the M-effect when the metal contribute from only one side. It can be seen as a benchmark as compared with that of Design 1 and Design 2, in which the metals contribute from two sides, including not only the left side and right side of the restrict zone, but also the front side and back side of the fuse element. It can also be compared with Design 3, in which the metals is thinner and longer, but with the same volume of the metal.

Fig.4(e) shows Design 5. There is a rectangular M-effect metal locating on the left side of the restrict zone. The length of the M-effect metal L1 is 2mm. However, the M-effect metal apart a distance L2 from the restrict zone, where the L2 is 1.5mm. The thickness of the M-effect metal is 0.4 mm. That means the volume of the M-effect metal of Design 5 is equal to Design 3 and Design 4, and it is half of Design 1 and Design 2. This case wants to observe the M-effect when the metal is apart from the restrict zone, compared with Design 4, which is as a benchmark.

Fig.4(f) shows Design 6. There is a rectangular M-effect metal locating on the left side of the restrict zone. The length of the M-effect metal L1 is 2mm. However, the distance L2 apart from the restrict zone is longer than Design 5, which is 2.5mm. The thickness of the M-effect metal is 0.4 mm. That means the volume of the M-effect metal of Design 5 is equal to Design 3, Design 4 and Design 5, and it is half of Design 1 and Design 2. This case wants to observe the M-effect when the metal is further apart from the restrict zone, compared with Design 5 and the benchmark Design 4.

Table 1:the parameters of six designs of M-effect metal

design number	L1(mm)	L2(mm)	Thick(mm)
1	2	0	0.4
2	2	0	0.4
3	4	0	0.2
4	2	0	0.4
5	2	1.5	0.4
6	2	2.5	0.4