INVESTIGATION OF THE PRE-ARCING BEHAVIOUR OF DISSIMILAR UNIFORM DOUBLE-ELEMENTED FILLED FUSES, USING FE CAD TECHNIQUES

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Summary

Dissimilar uniform strip elements in filled fuses have been studied using Finite Element CAD techniques to investigate 'M effect' time-current type fuse melting behaviour. The results of simulations indicate significant time delay operation is feasible for Ag-Ag and Ag-Sn element material and that FE CAD techniques may be used with confidence to analyse this class of problem.

Introduction

The use of low-melting point alloys to produce 'M effect' in fuses is known to introduce conditions where the fuse can operate outside its declared time-current characteristic. The use of parallel elements of different material and dimensions, to produce the similar time-delays in the overload region of time-current characteristics without the shortcomings of 'M effect' was considered to be feasible but very difficult to investigate experimentally. The FE CAD simulation technique (1), which could be verified by experiment, was considered to be the most suitable method for investigating the time-lag performance of dissimilar elements.

Finite element CAD simulation studies were consequently used to investigate the time-delay low-overload pre-arcing performance of fuses containing two dissimilar uniform strip elements of different materials, surface area and relative positions in filler.

Fuse Models

Two fuse models were developed to simulate the transient heating of two parallel current-carrying uniform strip elements, in filled fuses. The period of interest was over the region 1s to 10s, consistent with the 'M effect' overload time-delay region of fuse time-current characteristics. Over this time range, the model has to take account of heat conduction to end terminations, convection from all fuse surfaces and the temperature dependency of the electrical and thermal properties of all the fuse components (2).

A simple model was developed, which eliminated the external heat transfer effects. The model was useful, and is recommended, for quick assessment of the accuracy of representation and for estimating the assumptions of the model, since it requires fewer nodes and much shorter computer run times.

A more detailed model fig 1 had to be limited to 1000 nodes. The model includes variations in thermal conductivity, specific heat and electrical conductivity with temperature change, of all the fuse components. The fuse modelled was a DIN standard NH00 fuse (maximum external body dimensions 30 x 30 cm in section and 46 cm long). The filler was granulated silica quartz and the body was made of ceramic material. The end plates were brass and knife blade contacts, made of copper, were assumed to be connected to standard lengths of cable held at 20°C, 50 cm from the cable/fuse terminations.

At the end of each time step of the computation, the redistribution of the current between the two elements is determined by computing the electrical resistances of the elements, until one of the elements reaches its melting temperature. When one of the elements reaches its melting temperature, the whole current is transferred to the other element.

The detailed model required 990 nodes, which enabled solutions to be obtained using a Personal Computer fitted with a mathematics co-processor.

Results

Simulation studies were undertaken with the detailed model for pairs of similarly dimensioned strip elements made from silver, copper, aluminium, tin and zinc combinations. The Cu-Ag, Cu-Al and Ag-Al combinations shared current almost equally and consequently produced virtually no time delay effect compared with the Ag-Sn combination. Similarly, element combinations of similar low melting point metals produced no noticeable 'M effect' type characteristics.

Simulation studies were undertaken on pairs of Ag-Ag element of same cross section, but different widths and thicknesses and therefore different surface areas. The results of the respective simulation studies given in Table 1 and fig 2, indicate 'M effect' type melting time-current behaviour.

Ag-Sn element combinations indicated the most promise so studies were concentrated on this pair of element materials. Simulation studies were undertaken on Ag-Sn strip of different widths and thickness but with the same combined cross sections. These results are also given in table 1 and figures 3 and 4 for two samples carrying a current of 300A.

Table 1 - Operating Melting Time for Sample Parallel Elements

Sample	Element Material 1 / Dimension	Element Material 2 / Dimension	Operating Time (s) (I = 300A)
A	Ag W = 3.18 T = 0.1	Ag W = 3.18 T = 0.1	8
B	Ag W = 3.18 T = 0.1	Ag W = 0.56 T = 0.56	4
C	Ag W = 3.18 T = 0.1	Sn W = 0.56 T = 0.56	1.25
D	Sn W = 3.18 T = 0.1	Ag W = 0.56 T = 0.56	0.7

W = width (mm)
T = thickness (mm)
csa = 0.318 mm^2

The four fuse samples, Table 1, were simulated for current-carrying conditions approaching their estimated rated currents. The simulation temperature profiles of a section through the fuse at the hottest point, is shown in fig 5 for the fuse samples A, B and C.

In order to check the accuracy of these latter simulations the respective fuse combinations were made up and voltdrop and temperature measurement tests performed. Correlation better than ± 5% was obtained between the experimental and simulated results.

Conclusions

The studies indicate that 'M effect' time-delay type operation can be obtained without using low melting point alloys by varying the element geometry of parallel fuse elements comprising similar or dissimilar material. The FE CAD studies were undertaken on uniform strip elements in order to examine basic principles and to assess the accuracy of the simulations in predicting the performance of practical filled fuses in the 1s to 10s time-current characteristic region. The results of all the simulations compared sufficiently well with experimentally derived results to establish a high degree of confidence in the FE CAD technique.

It is considered that the 'M effect' type characteristic may be further improved by varying the relative disposition of elements and for practical dissimilar strip elements with reduced sections. These latter investigations are to be followed up in the next stage of the studies, although practical problems are anticipated in fixing low melting element material to fuse end plates.

References

1 Gomez J.C. and McEwan P.M., Determination of the Time/Current Characteristic of FusesUsing Finite Element Methodology, 6th IntSAP Conf, Lodz, 1989.

2 McEwan P.M., Numerical Prediction of the Pre-arcing Performance of HRC Fuses, PhD Thesis, Liverpool Polytechnic, 1975.

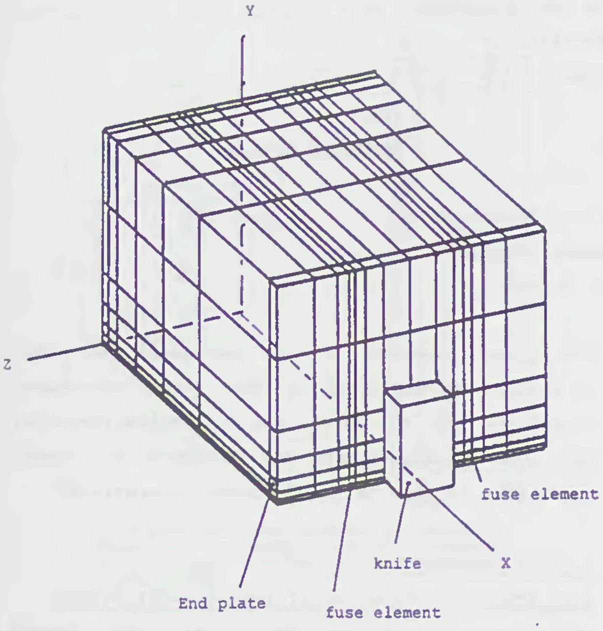

Figure 1 Finite Element Fuse Model

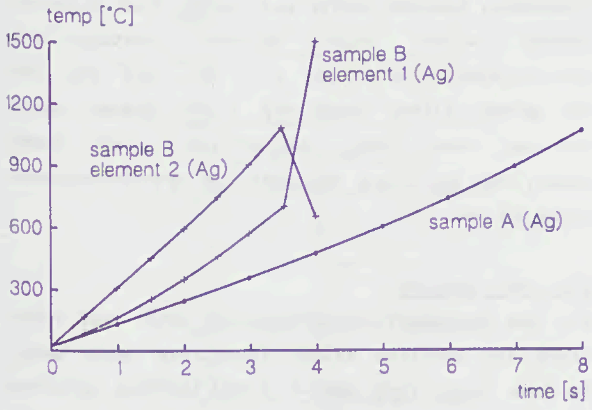

Figure 2 Critical Time-current Temperature Rise of Sample A and Sample B Silver Strip Elements (I = 300A)

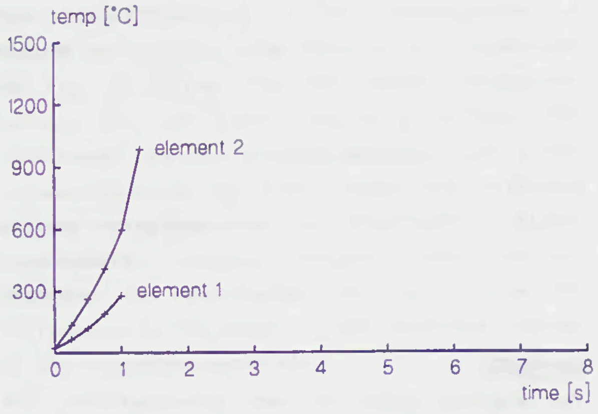

Figure 3 Critical time-current Temperature Rise of Sample C Sn-Ag Strip Elements (I = 300A)

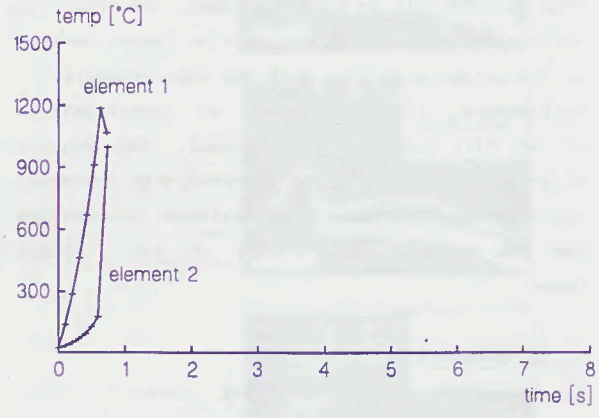

Figure 4 Critical Time-current Temperature Rise of Sample D Ag-Sn Strip Elements (I = 300A)

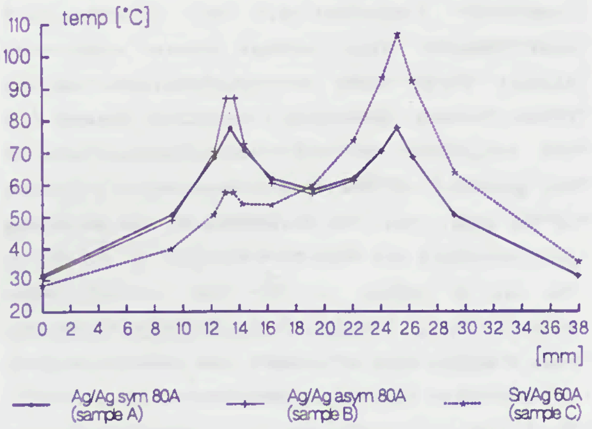

Figure 5 Section View of Fuse Steady-State Temperature Profile of Sample Parallel Elements Types A, B and C