Magnetic Finite Element Analysis for a Motor Protector and Edge Arcing Elimination

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Abstract. Undesired electric arcing has been problematic for many electro-mechanical switches and relays. In this paper, we first study the physics behind the arc damage, and then use a magnetic finite element analysis tool to determine best location and orientation for AC motor protectors. At the suggested mounting position, the damage resulted from edge arcing is minimized and the life of motor protector is extended significantly

1. Introduction

The physics of the electric arcing is very complicated, and is beyond the scope of this paper. The ignition, maintenance and reignition of an arc depend on many factors, such as, air/gas content, pressure, temperature, and humidity. The arc also depends on contact material, flowing current, and electric field strength in the vicinity of contacts. For DC problems, the arc is not desired as the circuit starts to open or close. While for most AC applications, the arc is intended to exist between two contacts until the current reaches zero.

An increasing imperative in all commercial manufacturing enterprises is increased effectiveness of the design process and robustness during manufacturing of the resulting design. In Sensors and Controls of Texas Instruments, one of the tools utilized to improve the quality of the products is multi-physics finite element analysis for mechanical, thermal, electromagnetic, and coupled problems [1,2,3].

For the product we are studying, the arc is also subjected to a strong magnetic field. Thus, the magnetic force generated on the arc (charges moving at high speed) is usually much larger than the electrostatic force that ignites and maintains the arc. This magnetic force drives arc away from its designed arc path and may cause severe damages to the bimetal beam structure. A typical damage at its early stage is depicted in Fig. 1.

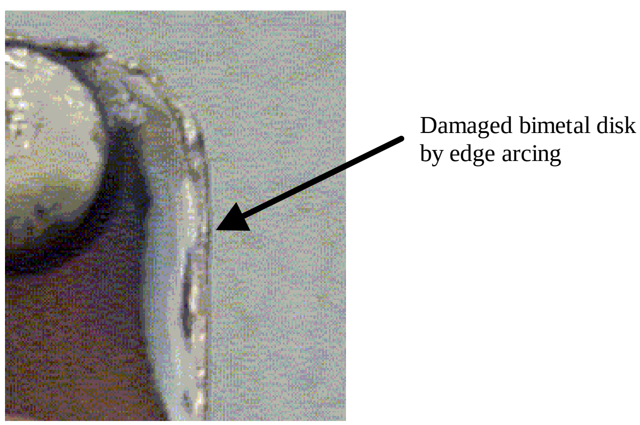

Fig. 1 A typical damage to the bimetal disk

2. Electric and Magnetic Forces

When the condition permits, the electric field (voltage across the two electrodes) would stimulate electrons move from the negative (with lower potential) electrode to the positive electrode. If there is no magnetic field presents, there are two forces acting on a charge, they are gravity and electrostatic forces. In the event of arcing, the gravity would be much smaller than the electrostatic force, and may be neglected.

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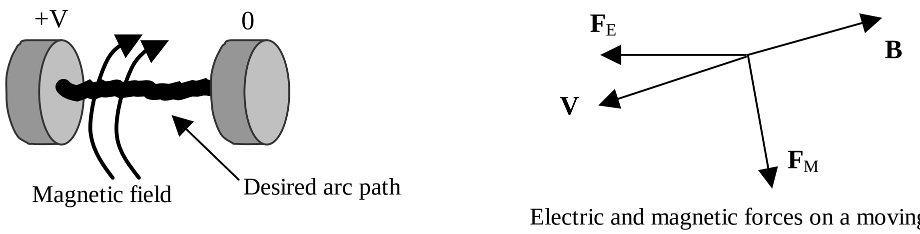

Electric and magnetic forces on a moving charge

Fig. 2 Electrostatic and magnetostatic forces

If there is no magnetic field, the desired arc path is shown in Fig. 2. However, with a magnetic field presented, there are two possibilities,

- magnetic field has no effect to the arc path,
- magnetic field has an effect to the arc path,

which depends on the angle between magnetic field and the velocity as shown in Fig. 2. If the magnetic field is parallel to the velocity, the magnetic force F_M equals zero, therefore the electrons would continue to accelerate along its moving direction. However, if the magnetic field is at an angle to the velocity, the magnetic force won't be zero and will have an effect to the arc path. The worst case is when two vectors are normal to each other.

3. Magnetic Field Computation and Best Mounting Position

Based on the electric and magnetic force analysis, the best orientation is when the desired arc path is parallel to the magnetic field. A 3D magnetic finite element model [4,5] was built to find the best mounting location and orientation. The best location is at where the magnetic field is the weakest among the available mounting space. The best orientation is determined by the flux direction at the mounting location. Shown in Fig. 3 is the magnetic flux density contour and the vector field which are used to determine the best location and orientation.

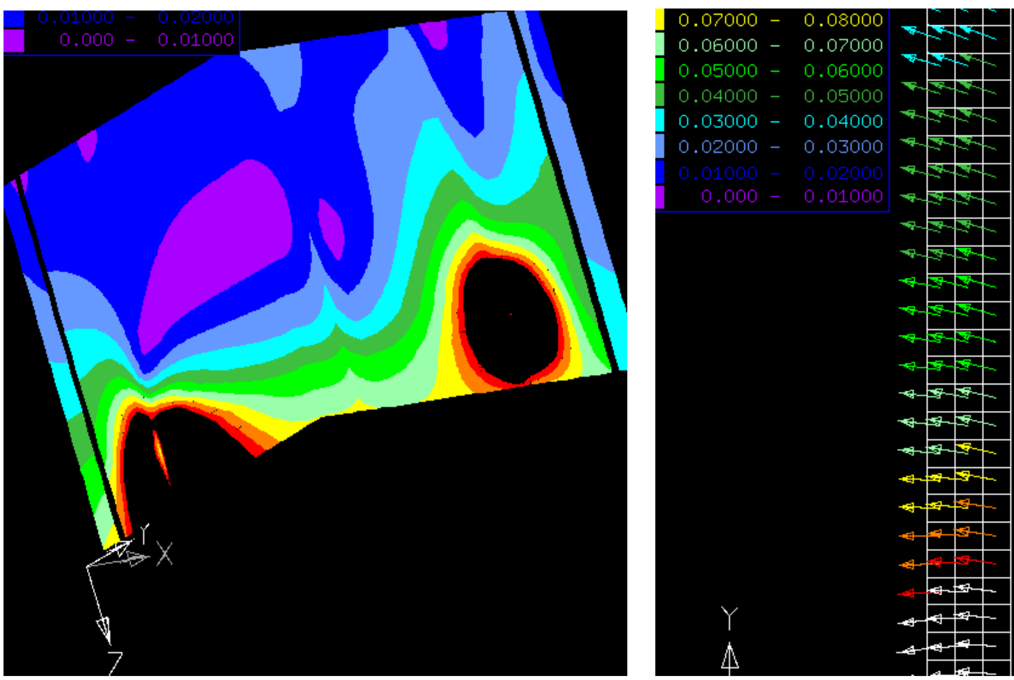

Fig. 3 Magnetic field behavior to determine the best location and orientation for motor protectors

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