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論　文　要　旨
Thesis Abstract

2022 年　8　月　25　日

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主論文題名　（Title）

A Study on Joule Heating and Arc-fault Induced Electrical Fire in Commercial grade Copper and Brass in Low Voltage Electrical system

内容の要旨　（Abstract）

Electrical hazards have been one of the major problems in human society since its introduction into our life. There are many types of electrical hazards that can be extremely life threatening such as a common electrocution or a certain failure that can cause a subsequent mechanical breakdown. One of the most dangerous of all is electrical induced fire hazard. Fire hazards stemming from electrical devices are very common. This type of hazard can happen anywhere as long as there is enough electrical power running through the area. Currently there are two main types of electrical induced hazards. The first type is a joule heating effect which is a dissipation of electrical energy into heat energy due to the power loss by the internal resistance of the conducting material. The second type is an electrical discharge into an unwanted area which is called an arc-fault. An electrical discharge as a spark can accumulate a tremendous amount of heat energy in a small area within a very short amount of time in the comparison to joule heating effect. An electrical spark that discharges into any flammable material can easily start a fire from that material. However in a low-voltage application such as household devices, the electrical power that is used in low-voltage areas is insufficient to create a large arc that can jump between two conductor gaps. Currently there is no research and report that is capable of explaining an arc-fault in a low-voltage setting. This research focuses on this type of arc-fault.

There are two main types of electrode material which are copper and electrical grade brass. These two types of metal are most commonly used in household plug and it is also a common place where electrical fires would occur. The whole experiment setup is monitored by an oscilloscope with current sensor, high speed camera, thermal camera and a laser vibrometer. After the experiment has been done in each step, the samples are then taken to the visual observation apparatuses to investigate the deformation and the damage that was done on the electrode. The result we obtained from all the experiments has concluded that the arc-fault generated by household plug and socket was not actually a true arc-fault as perceived by previous studies done by other researchers. Regular arc-fault is an electrical discharge between two points of conductor where the phenomenon electrifies the air gap and creates an arc jump. The result we got from the experiment is that visually the arc-fault in a low voltage

environment exhibits an arc jump between two points, but it was superheated electrical pathway near the contact point which was exacerbated by the intrinsic properties of copper oxide. Copper oxides is well-known to be a semiconductor that reduces its electrical resistance with high temperature. The perceived arc is actually a current pathway on the surface that was superheated by joule heating effect and meltdown, which changes the current pathway constantly and creates "Look alike" electrical discharges.

According to the conclusion we got from the study. Low voltage arc-fault is not actually an arc-fault, but rather an advanced stage of joule heating effect that is exclusive to copper-base conductors. Therefore, commercial arc-fault detection apparatus that look for high voltage arcing signatures as a detection method is not entirely reliable. It has been proven by users that this type of detection apparatus tends to detect false positives. In our study, we wanted to create a detection method that will detect this type of phenomenon accurately. Since this type of hazard is still effectively a joule heating effect, some amount of power will be lost before it is able to deliver to the main load. Therefore we can detect the amount of power that was lost before it was delivered to the main load. The first method is a voltage disparity (Between two current transformer's output) method. This method basically makes a comparison between normal state and arcing state. If there is any low voltage arc-fault present in the system, the power that is able to deliver the load will be reduced to a certain point. This method has been tested in the experiment successfully. However, this method will only work in a passive electrical device. The device that does not radically change in current draw. The 2nd detection method is to exploit the low-voltage arc fault mechanism. Due to the mechanism of this type of arc-fault. The circuit has a constant fluctuation of power in every period in one cycle. The method uses a saturated current transformer to detect any small changes in the power load. Due to the mechanism of a saturated transformer, any subtle changes in power draw will drastically change the magnetic field that was stored in the transformer core. This method is the most promising as a future research topic.

The conclusion from this research is that copper base electrical connection was believed to be better suited than steel due to its high current carrying capacity. However, our study has pointed out that copper oxide that can be generated by normal uses of the device can create a fire hazard risk that we usually look over. The best case scenario to alleviate this problem in the far future is to change the type of metal from copper into something else that does not contain any copper. The contact coating will be very important to avoid this type of problem. Currently, contact coating is only applied on the plug blade of the appliances but not on the interior of the socket. If changes of contact material and coating is not possible in the near future, the Saturated current transformer detection method that we devised can be developed further in the future.

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