COMPARISON OF ARC EROSION COEFFICIENTS

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Abstract: The problem of nonunified approaches to giving arc erosion ratios is addressed for the application of molded case circuit breakers (MCCBs) in the range 6.5-10 kA. Charge, Joule's integral and arc energy are compared as possible quantities to use for ratios of mass loss. The linearity of the relationship of mass loss to those quantities was used as the main metric.

By this metric the ratio to charge was chosen as the most reliable one. But this relation was constant only for fixed contacts with arcrunners. For the moving contact, the mass loss ratio was a linear function of the effective value of the passing current.

Keywords: arc erosion, MCCB, mass loss, erosion ratios

1 INTRODUCTION

The design process of a switching device contact system needs to address a number of things, ranging from delivering low enough contact resistance to prevent softening and welding of the contacts to providing suitable environment for arc root movement.

To accomplish all of these functions, the contacts should ideally remain the same during the whole life cycle of the device. Alas, this is not achievable due to several factors. Namely corrosion, fretting and arc erosion. All of these need to be taken into consideration when designing a new product.

In circuit breakers, the main stress on a contact material occurs during breaking of high short circuit currents and therefore, is mainly influenced by arc erosion. And as such, there is a high demand for ways to calculate or estimate the mass loss during the life time of the device.

However, the rate of erosion still has not been described even approximately close to provide enough support in designing a contact system without previous experience with a similar construction.

To provide comparable data from measurements for different breaking operations, different ratios of mass loss to a quantity corresponding to energy absorbed by the electrode are used. The most commonly used ones are: charge passed during the switching time $\int i\mathrm{d}t$, Joule's integral $\int i^2\mathrm{d}t$ or total power losses in arc $\int iu_a\mathrm{d}t$.

The reasoning behind using different ratios is that different device heat up the contacts via different mechanisms. For example, the Joule's integral is being used when the predominant power losses are in the contacts themselves. The total power losses are used when radiation heat transfer from the arc causes the greatest part of contacts heating up. But there are yet no clear distinctions to which are to be used when. [1]

In order to tackle this problem, several tests were carried out on MCCBs in current range 6.5-10 kA. The measured mass losses were compared in different ratios with the quantities mentioned above. These ratios were determined for future development of the contact dimensions and contact overtravel of the particular MCCB used for testing.

2 EXPERIMENTAL SETUP

The tests were carried out as one phase shortcircuit tests on a MCCB in current range 6.5-10 kA, power factor 0.5, frequency 50 Hz, switching angle 60°, voltage 731 V and the instantaneous tripping current was set to 1.25 kA. Current and voltage were measured. Before and after each test, all contacts were removed from the breaker and weighed.

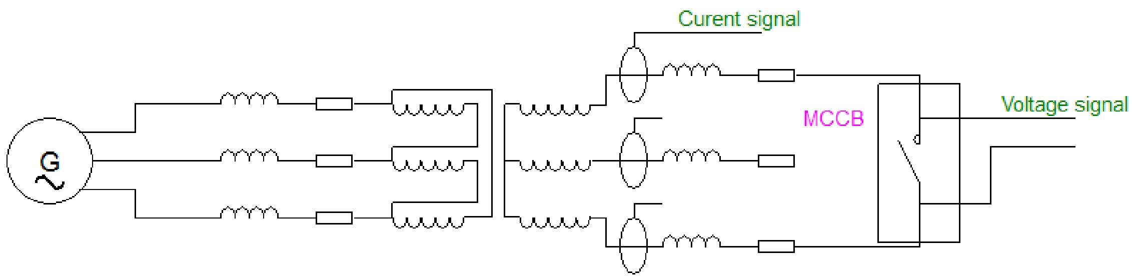

Figure 1: Experimental setup

The contact system of the MCCB consisted of one moving contact (2) and two fixed contact (1) pieces as shown in fig. 2. The upper fixed contact was is further labeled as cathode and the lower one as anode. All test were carried out with the same polarity and all occurrences of arcs burning for more than one half-period were removed from the data.

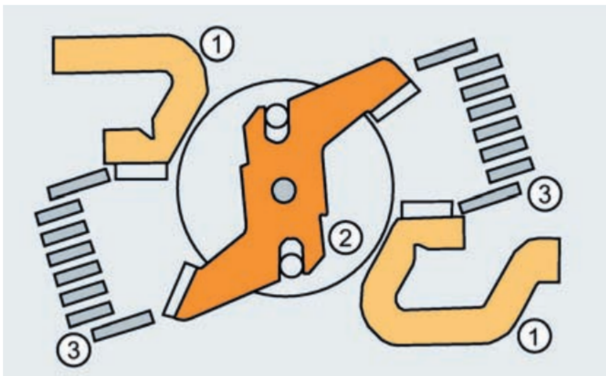

Figure 2: Contact system [2]

The moving contacts had area 5x5 mm and were made of Ag-W. Both fixed contacts were made of Ag-C and had area 7x7 mm. And both fixed contacts had additional 7x7 arcrunners situated towards the arc chute.

3 RESULTS AND DISCUSSION

The first three graphs plot mass losses as functions of $\int i\mathrm{d}t$, $\int i^2\mathrm{d}t$ and $\int i u_a \mathrm{d}t$. The used current was not taken into consideration in these graphs.

Most authors [4] were trying to express the mass loss as a function in the following form:

$$\Delta m = K \cdot \int i^n \cdot u_a^m \mathrm{d}t \tag{1}$$

Where K is a parameter given for the design of the contact system.

To validate if there is this linear relationship, linear regression was used, Pearson correlation coefficient was calculated and compared with the critical value for significance level 0.05, the value being 0.514 for the number of measurements. [3]

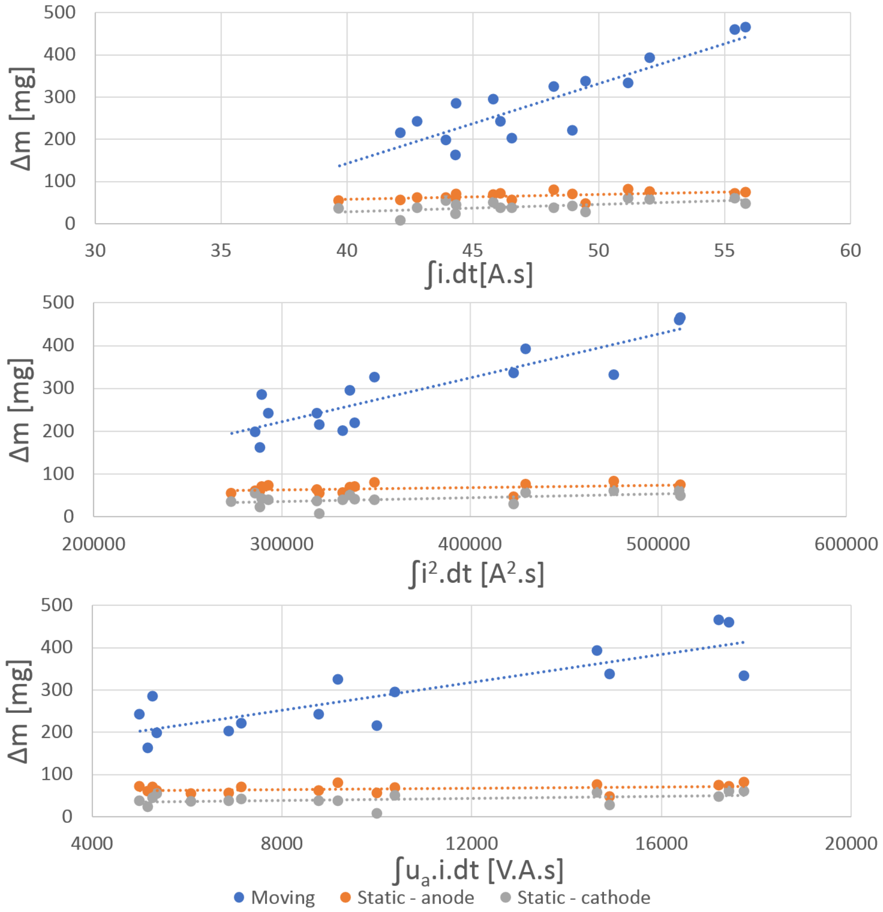

Figure 3: Comparison of used quantities

	$\int i.dt$	$\int i^2.dt$	$\int u_a.i.dt$
Moving contact	0.875	0.890	0.852
Fixed contact - anode	0.548	0.413	0.331
Fixed contact - cathode	0.576	0.501	0.420

Table 1: Correlation coefficients

Only when plotted as a function of passed charge, the data give a reliable linear relationship. But this still does not check fully if the mass loss behaves as stated in (1). This is due to the fact that (1) does not account for the constant coefficient b in the general linear function $y = ax + b$. This was checked by plotting the ratio of mass loss and $\int i dt$ as a function of effective value of the switching current.

The presumable reasons for overall lower correlation coefficients for fixed contacts is lower mass loss in comparison to the moving contact. Therefore any phenomena like re-deposition of metal from contacts or splitter plates, creation of metal oxides or deposition of carbon from the plastic casing will have higher impact on the total mass loss. Additionally the arc is partially transferred onto the first plate of the splitter plate array (see (3) fig. 2) and thus is not exposed to the arc for the full duration.

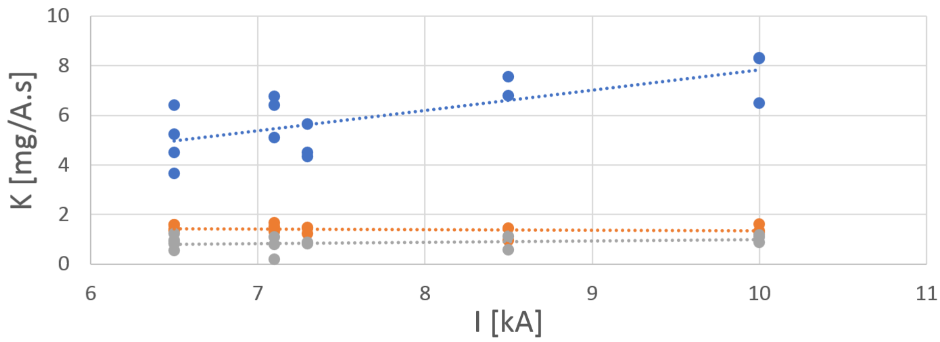

Figure 4: Ratio of passed charge as a function of current

For the fixed contacts, the value of ratio over the whole interval 6.5-10 kA is close to constant. For anode the change between value at 6.5 kA and 10 kA is 6.2 % with variation coefficient of 12.0 % and for the cathode the change is 22.5 % with variation coefficient of 30.0 %. However, the moving contact ratio still exhibits linear behaviour. For this, the equation (1) was altered to:

$$\Delta m = K_f \cdot I \cdot \int i \cdot \mathrm{d}t \tag{2}$$

With this, coefficient K_f as a function of current yields a function with the change of 2.4 % and variation coefficient of 16.4 % over the whole interval.

The difference between fixed and moving contacts is most probably caused by the presence of arcrunners at the fixed contacts. Thus the arc root not burning in only one place but moving along the whole contact. This points to a bigger role of evaporation in the moving contact erosion than in the case of fixed contacts.

4 CONCLUSION

It has been shown that for MCCBs the ratio of mass loss to $\int i\mathrm{d}t$ is the most suitable for the range of currents 6.5-10 kA. But before these ratios can be used for future development of switching devices, it needs to be discerned what their relationships to other circuit parameters and construction changes are.

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