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Studies on the Contact Characteristcs of Carbon Brushes and Commutation Theory

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Dc Machine is about the complex apparatus in the rotating machinery field, mainly because of the challenging problem of commutation. One of the reasons why a commutation phenomenon is difficult, is because there exists the complex contact characteristics between carbon brushes and a commutator, besides the complicated electromagnetic performances. During these 80 years, carbon brushes have been used in electrical machines. Altough many researches have been done in this same field, yet the knowledges about the contact phenomena of carbon brushes are not clear enough. On the other side, electrical machines are now often used at high altitudes, and the carbon brushes in these altitudes show some quite different phenomena from those on earth.

In this paper, first of all, the contact valtage between a carbon brush and a slipring was measured under several pressures, ranging from atomospheric pressure to vacuum, with the machine at rest as well as in running state, and the mechanism of the contact voltage was investigated using those obtained characteristics. After that, the sparkless zone of dc machine was thoroughly studied theoretically.

The contact resistance measured in stationary state was divided into the two parts, i.e., constriction resistance and film resistance. From the constriction resistatce, the true contact area of brushes was obtained, and from the film resistance, the effect of pressures was investigated. It was found that the true contact area of brushes consisted of three to ten spots with about $(4\sim5)\times10^{-3}$ cm radius, and the film resistence formed on the stationary slipring in dry air was increased proportional to the 0.4 th power of pressure.

Using those results the adequacy of a few representative theories about the mechanism of the contact voltage-current characteristics was investigated.

The contact voltage characteristics in running state were also measured in dry air and in saturated water vapor at the clean slipring, and in dry air at the slipring with oxide film from atmospheric pressure to vacuum. The experiments showed that the characteristics in dry air in running state were quite different from those in stationary state. Standing from these facts, the mechanism of the contact characteristcs has been made clear.

As the contact voltage-pressure characteristics in running state at a low pressure

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showed the contradiction to the generating conditions of the abnormal wear of the brush using in high altitude, the conditions of the abnormal wear have been investigated. For the generation of the abnormal wear in a low pressure, it was found that the surface of the commutator of the slipring had to be slightly rough besides the conditions which were already known. It was considered that the slight roughness of the surface was originated from the worse commutation in low pressure than that in atmospheric pressure. Such state of the commutation was confirmed experimentally at 200 mmHg to 400 mmHg pressure ranges, using the apparatus which showed the equivalent performance of commutation.

The above mentioned phenomena must be analysed by the commutation theory, but, at present, the commutation theory is not enough to explain the physical meaning of the commutation. Owing to this reason, the author expressed the differential equation of a commutation circuit, putting the voltage-current density characteristics of brush contact as the approximate bended curve. Solving this equation, the condition of the sparkless commutation were obtained. According to the results of the solution, the physical meaning of the sparkless zone has been made clear and it has also been found that the sparkless zone could be classified into the three types, i.e., the first; decided only by the contact voltage-current density curve, the second; by the contact voltage-current density curve and the linear commutation line, and the third; only by the linear commutation line. Moreover, the sparkless zone in the transient state of commutation circuit was obtained with the extension of the above equation. Finally, it has been made clear that the bad commtation in high altitude depended on the voltage current characteristics rather than the spark starting voltage of the contact, at low pressure and low humidity.