

Carbon brushes for fractional and subfractional horsepower motors

Electrical influences on the carbon brush run

Carbon brushes used in universal motors or permanent-magnet direct current motors are subjected to substantial electrical stress, since almost always commutation assistance is waived due to economic reasons. Therefore the following references should be considered when designing a motor.

Neutral zone and commutation conditions

Asymmetries, which are caused by the exciting coils, have their full effect on the carbon brush load. In order to obtain optimal lifetime for the carbon brush, it is necessary to provide a commutator connecting angle on the rotor, which accommodates the operating conditions of the motor.

The required connecting angle has to be determined from case to case and has to be newly appointed each time, since the cut of the sheet metal and the electrical utilization vary. Since universal motors are operated frequently at different load conditions, only a compromise is possible in regards to the connecting angle.

Motors for reversible operation are an exception, in which no commutator connecting angle is possible. Increased commutator sparking and reduced brush lifetime needs there-

fore to be anticipated for such motors. In reversible motors the ends of the rotor coils are connected to the commutator in such a way, as if there was no field distortion during the operation. Despite the resulting unfavorable position of the brush - in relation to the neutral zone of the operation - it is possible to achieve adequate service life for the brush, if the correct brush material is chosen.

Transformer segment voltage

The transformer segment voltage adds with its active current an additional load to the electrical load of the carbon brush. This voltage reaches maximum value with interconnected commutators when the corresponding coil commutates. The transformer segment voltage is induced inductively into the rotor coil through the exciting field of the universal motor, which is driven by alternating current. It is therefore recommended, cost permitting, to have as many segments and rotor coils as possible. Recent experience has shown, that even with segment voltage levels of 10-12 volt, in special cases even higher levels, satisfactory service life times of the carbon brushes could be attained, if the correct carbon brushes have been chosen.

Field tapping and/or electronic speed control

The oldest method of speed control is field tapping. But in certain circuits this creates disadvantages for the carbon brush run.

In order to achieve 2 or 3 motor speeds, several circuits exist, which are based partially on multi-level tapping of one end of the field coil.

Tapping only one end of the field coil causes a great difference in the wear of the two carbon brushes of a motor assembly. This is due to field unbalances between the two commutation zones. In extreme cases the difference in the wear of the two carbon brushes can amount up to one power of ten.

This can be prevented by experimenting to determine the best possible material for the carbon brushes and/or by possibly using two different materials (mixed components).

Similar difficulties are to be expected when diodes, thyristors, or triac circuits are used. Depending on the type of the circuit, a great difference in the wear of the two assembled carbon brushes occurs here as well. The so-called one-way circuits with diodes and thyristors are particularly critical. A solution in such cases is the

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use of carbon brushes with a high resistivity or of carbon brushes with certain cleaning properties. But it is sometimes necessary to use different brushes in an assembly, whereby it should be determined through experiments, with which brush materials the motor should be equipped.

Electrical resistance, specific load capacity of the carbon material and drop in contact voltage

The resistivity of the carbon brushes can be varied from 0.01 to more than 3000 $\mu\Omega\text{m}$. The lowest value of 0.01 $\mu\Omega\text{m}$ is achieved by using materials with a high metal content, whereby values of more than 3000 $\mu\Omega\text{m}$ can be achieved with carbon-graphite materials. When using resin bonded graphite materials, a resistivity value of up to 8000 $\mu\Omega\text{m}$ is possible.

The voltage drop from carbon brush to commutator is high, when compared to the voltage drop within the carbon brush body itself. This is due to the usually small number of contact points between the carbon brush and the commutator. The reduced number of contact points causes a reduction of the carbon brush cross section, which results in an increase of the resistance. This is known as constriction resistance. An additional reason for the voltage drop is copper oxide, which forms on the surface of the commutator. It is possible to reduce both the loss caused by the longitudinal resistance of the carbon brush itself as well as the loss at the transition points by choosing the correct carbon brush material and by tailoring the carbon brush to the specific requirements.

It is usually necessary to use materials with a metal content for fractional and subfractional horsepower motors with voltages smaller than 36 volt. These carbon brush materials have both a lower resistance of the brush itself as well as lower transition losses at the contact point of the carbon brush running surface and the commutator than brush materials without metal content.

Carbon brush materials with a high material resistance are generally used for motors with terminal voltages of more than 42 volts. These are essentially carbon brushes made from carbon and sometimes resin-bonded graphite, if the commutator insulation is flush. If the commutator insulation is undercut, the carbon brushes are usually made from carbon graphite, resin-bonded graphite and sometimes electro-graphite. The last mentioned are used only rarely in today's motors with low weight per horsepower due to the low resistance of the brushes. The carbon graphite materials are characterized by the hereby possible high resistances, which reduce the short-circuit currents. If resistance and specific load of the carbon body are coordinated accordingly, the transition losses remain within justifiable limits as well. Since these carbon brushes also exhibit a certain cleaning ability, the roughening of the commutator surface, caused by commutator sparking, is kept within a normal range. This guarantees a longer life of the carbon brush. On the other hand the carbon brushes must not be too abrasive, so that the wear on the commutator remains minimal. It is therefore necessary to optimize the corresponding carbon brush material for each motor design by making trial runs.

Various limits for the specific electrical loads apply for the carbon brush materials used in fractional and subfractional horsepower motors. The values for the maximum electrical load for the individual materials and applications can be found in brochure 13.21. However, these values should be considered only as recommended values, since the contact conditions in the holder as well as the cooling conditions have a significant influence. A somewhat lower electrical load should be intended in the case of electronically regulated motors or thyristor-fed and/or triac-fed motors, since with these kind of motors the average value of the current, which is used to determine the cross section of the brush, may exhibit every 10 to 20 milliseconds short-term peak loads of up to 500%. This in turn causes, due to the rapid field changes, high induction voltages in the rotor, which results in ongoing brief overloads in the contact surface of the carbon brush.

Generally speaking, too large specific electrical loads of the carbon brush destroy the patina on the commutator and increase the commutator abrasion.

It is likewise harmful if the specific electrical load is too low, since it causes increased and varying friction. Therefore a specific load of between 5 and 10 A/cm² should be the intended ideal value for motors with 220 - 240 V. For Motors up to 120 V the ideal value of the specific electrical load should be smaller than 20 A/cm².

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