The Carbon Brush and How it Relates to Commutation

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A good deal has been said and written on the subject of commutation and the factors that affect performance of DC motors and generators. The carbon brush is scrutinized most critically because excessive sparking is frequently blamed on the brush applied. True enough, a change in brush grade and design can often clear up faulty performance caused by adverse operating conditions. For example, contaminants such as sulphur or ammonia that cause excessive filming can be tolerated by use of a brush grade which is less filming or has some cleaning action.

Temperature, low humidity or altitude conditions can be met by applying brush materials that have been especially treated to meet these ambient situations.

Brush current densities that affect the friction characteristics and vibration can often be dealt with by a change in brush design. The split brush with a pad, the Multiflex, the Red Top, or even the Bias Multiflex brush is quite commonly used.

The fact is that in most cases there is a brush to meet adverse operating conditions enabling you to get acceptable commutating results. The difficulty lies in applying the brush grade or design that will perform well over the widest range of conditions. You might say a brush for all seasons.

We feel the greatest concern is with brushes applied on high voltage DC motors and generators. Therefore, these thoughts will be concentrated on the electro-graphitic category of brush grades though we do have need for carbon graphite and metal graphite materials for other applications

Having some idea of the makeup and process of developing electrographitic brush materials may be helpful in understanding the complexity in determining the best material for an application. Also, why is it that one brush performs well in one motor or generator but not in another though seemingly identical operations.

In electrographitic grades the basic materials used are lampblack, calcined petroleum coke and natural and artificial graphite with coal tar pitch as binder. Molded into plate form at pressures to 3,000 lbs. per square inch the plate is put into gas baked furnaces and brought up to temperatures as high as 1000° C per hour. This is done slowly to prevent voids or laminations in the material. The plate is then placed in an electric graphitizing furnace bringing the temperature close to 3000° C. Figure 1 illustrates the time cycle involved.

The material characteristics are varied by the percentage of lampblack, by the difference in molding pressures, by the speed of bake and by the extent of graphitizing. Carbon and graphite are chemically the same material. However, they differ in their structural atomic arrangement: carbon is essentially amorphous while graphite is definitely crystalline. Most carbon is converted to graphite by heating above 2200° C, at which temperature the crystals form. Carbon is high resistant and graphite very low resistant-both electrically and thermally. Lampblack is a carbon material but it does not graphitize easily. The more lampblack used the higher the resistance. The resistance of the brush material then

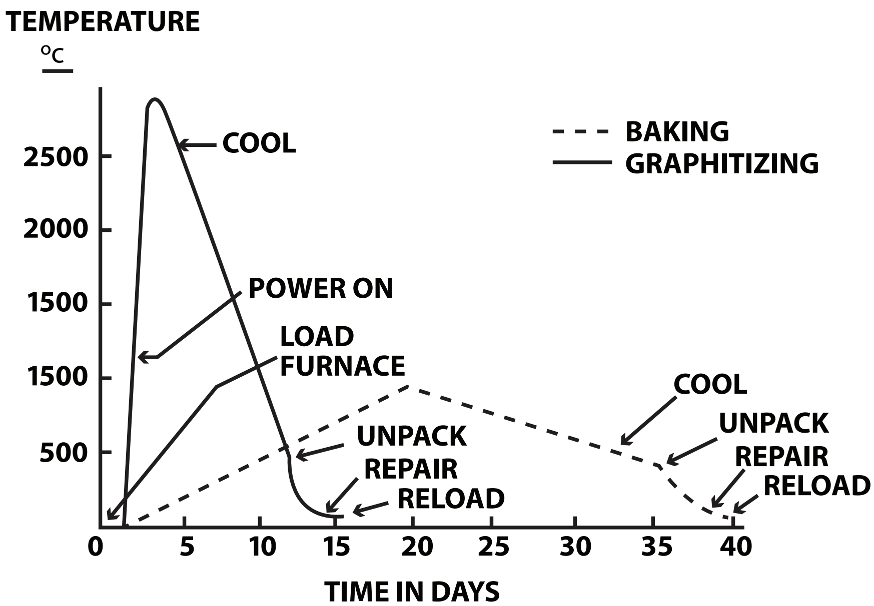

Fig. 1

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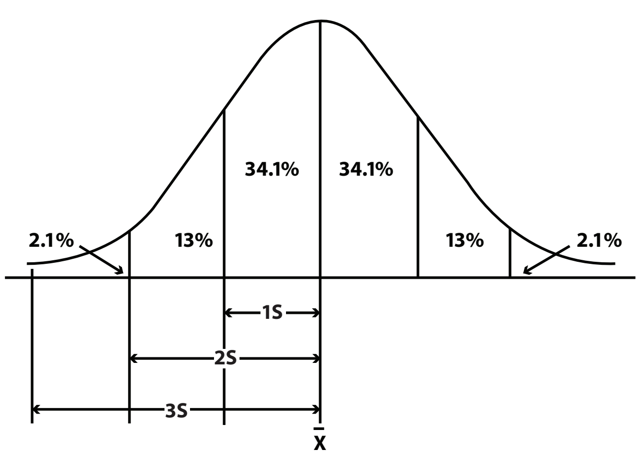
is controlled largely by the percentage of lampblack. Higher resistance offers better commutating characteristics, but there is then less binder used and the structural strength of the material is lower.

From a relatively few carbon plate developments there are several grades offered by modifying the grade with additives to give additional strength and to reduce friction characteristics. This is done by impregnating many kinds of oil and phenolic resin into brush materials.

The result is the availability of perhaps hundreds of grades of brush materials with a wide range of characteristics to be applied to hundreds of operating conditions. The characteristics of some grades do overlap and the necessary manufacturing tolerances may result in performance differences with a given grade. See Figure 2 of the Standard Deviation. The production control is quite precise, but nevertheless the applying of brushes is still considered more an art than a science.

Fig. 2

STANDARD DEVIATION CURVE



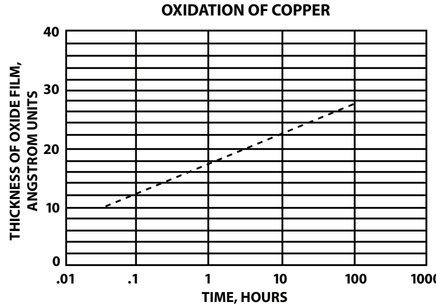
We believe carbon companies offer materials with a high standard of quality control, but at best there are many factors that influence commutation and to identify which is causing the problem is in itself a problem.

There are some general areas of concern with respect to commutation and we shall try to give helpful suggestions to assure acceptable performance.

Firstly, let us consider the commutator surface. A brush would wear as chalk on a slate board if the commutator did not have a copper oxide film. This oxide film forms very rapidly in air. It is measured in Angstroms and Figure 3 illustrates the rate of filming of copper. Additional copper oxide is formed when the motor or generator is operating and the brushes are carrying current.

Fig. 3

OXIDATION OF COPPER



As a brush is held against a revolving Commutator only about 10% of the apparent brush face is making mechanical contact. This contact surface is known as the Hertz area which moves continuously over every surface of the face of the brush. The electrical conducting area is found within the Hertz area. This represents only about .1% of the Hertz area though there may be as many as twenty separate simultaneous conducting areas within this mechanical contact surface. At these highly conductive spots the process of current flow or funneling through a non-conductive oxide film phenomena of brush behavior is governed by the voltage or contact drop when two surfaces are forced together. Therefore the contact drop of the brush material and the spring tension applied are important considerations to achieve acceptable commutation. That is to conduct current without a visible arcing.

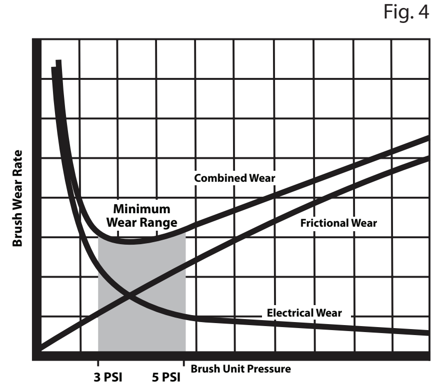
Bear in mind also that during current flow there is necessarily always some transfer of copper from the contact surface. The copper transferred to the face of the brush should then vaporize and with the moisture in air form a copper oxide film on the Commutator surface. This film is very low in friction and assures good brush life.

The maintaining of a good film is sometimes difficult because of the several factors affecting this film. Frequently threading conditions are caused by hardened copper particles acting as small cutting tools. When there is excessive transfer of copper to the face of the brush the copper deposit becomes work hardened and cuts into the commutator surface. This excessive transfer of copper often is the result of light load conditions; though an abrasive brush material or a contaminated atmosphere will also cause commutator threading.

Another problem of excessive copper transfer to the brush is found in copper drag. The particles of copper from the face of the brush are most often deposited on the trailing edge of the commutator bars. Chamfering of commutator bars will help to prevent the damaging result of copper drag but may not eliminate it. Light spring tension and brush bounce can cause copper drag, but some brush materials have a tendency to drag copper more than others.

We have made mention of the importance of spring tension and illustrate in Figure 4 the dramatic effect of brush wear from improper tension.

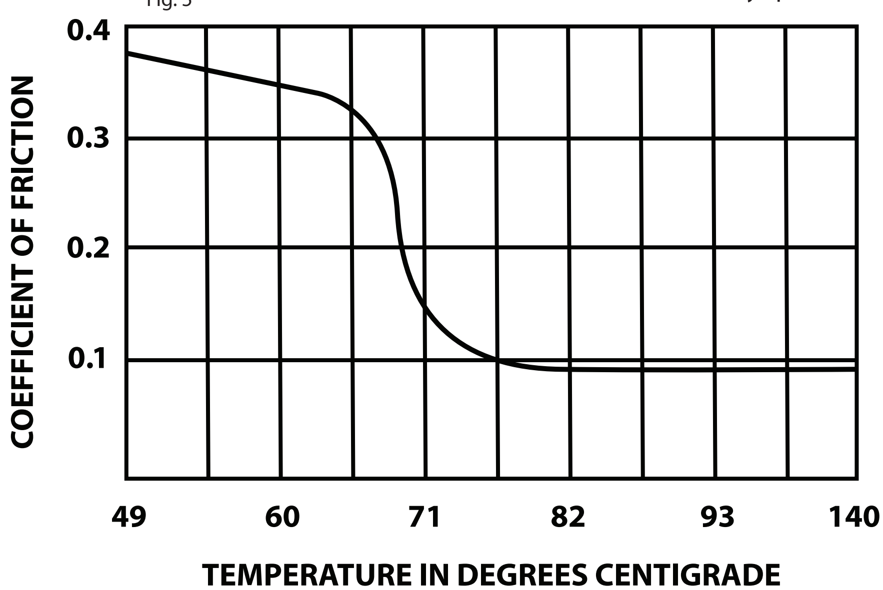
Fig. 4



Increase in brush friction will result in the removal of the Commutator film and cause rapid brush wear. Light current density causes high friction and most often the brush will carry overloads easier than light loads over an extended period of time. The reason being that your friction is lowest when brush temperature is between 75° - 140° C. Figure 5 shows the curve and points up where high friction conditions will remove the copper oxide film.

Cold weather and very low humidity conditions – moisture less than 2 grams per cubic foot air – could result in brushes eroding away in a matter of a few hours.

Fig. 5



Another common commutator condition is that of bar marking. It is usually found in a pattern around the entire surface of the commutator. This is related to the winding configuration in the armature and the number of conductors per slot. Generally this is not serious unless the commutator bars become burnt or etched. A change in brush design with improved commutating characteristics usually corrects this condition.

There are other factors that influence commutation, such as improper brush holder adjustment. That is, brushes are out of neutral or not evenly spaced.

It is also important to keep the mica between the commutator bars cut down. Being a laminated material a layer can work its way to the commutator surface and these fins of mica will act just like a knife edge. The brushes will bounce and cause burning of the commutator surface. Mica fins and too light a spring tension are found to be the most common fault of brush performance. Also uneven spring tension will provoke selective action.

There could be improper interpole adjustment, a short in the windings, or a worn bearing causing the brush to bounce. All result in poor brush performance, but these conditions should be corrected by qualified maintenance personnel and not by brush change.

To give the brush a chance, the commutator surface should be kept true and on high speed units vibration should not be more than four mils.

In summary, the most important factor is to keep the brush on the commutator and properly seated before carrying heavy current loads. We strongly suggest the brush should be concaved to fit the radius of the commutator. Also avoid operation where load conditions are too light, and remove brushes if necessary to increase current density.

We recommend operation above 60 amperes per square inch of brush. Current densities of less than 40 amperes per square inch could lead to brush and commutator problems.

Generally, the brush is capable of doing far more than it is given credit. We suggest you put it to work!

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