
UNIT 2.4 CARBON BRUSHES

OBJECTIVES

On completion of this unit, you should be able to understand:

- Brush material
- Brush angles
- Types of brushes
- Electrical characteristics of brushes
- Selection of brush grades
- Service performance of brushes
- Analysis of commutation problems
- Technical data of brushes
- Carbon brushes for BHEL machines

STRUCTURE

1. Introduction
2. Brush material
3. Brush angles
4. Types of brushes
5. Electrical characteristics
6. Selection of brush grades
7. Service performance
8. Analysis of commutation problems
9. Technical data
10. Carbon brushes for BHEL machines

1. INTRODUCTION

Brushes provide connection between rotating armatures and external circuitry, and play a major role in satisfactory commutation of DC machines.

During commutation, in the armature coil under short circuit by the brush, the current reverses from +I to -I. Since the change of current takes place in a very short period, an emf is induced in the armature coil undergoing commutation. Commutating poles are provided to nullify this emf by creating an equal and opposite voltage in the same coil. However due to design limitations/manufacturing tolerances, it is not possible to totally balance out the induced emf (known as reactance voltage), and therefore the residual voltage in the coil causes a circulation of current, which appears in the form of sparking under the brushes. As the process of commutation became more apparent, it was realised that a brush of comparatively higher resistance could materially assist the commutation.

In the early experimentally period, before 1880, when DC motors were under development, copper brushes, in the form of brush and not as a solid block, were used. It was from the early period that the term brush emanated, and is still continuing. Copper brushes used to cause high commutator wear, heavy sparking, and even welding into the commutator surface. These problems and the fact that higher resistance of the brush assists commutation, led to the use of the carbon as a brush material.

The other reason for using carbon for brushes on electrical machines is that the wear of the carbon brush and electrical erosion, considerably exceeds that of commutator resulting in higher commutator life.

Charles Van Depoele, one of the early traction pioneers in America, was the first to try brushes made of carbon on traction motors after successful trials in 1884.

2. BRUSH MATERIALS

Carbon is used for the brush in the following forms:

1. Natural Graphite
2. Hard Carbon
3. Electro-graphite Carbon
4. Metalized Carbons and Graphite

These grades of carbon are obtained by varying the combination of raw materials, and the processes followed for mixing them. The following chart shows the cycle used for production of non-metallic carbon brush material. flow sheet for the production of non-metallic brush material

A few examples of processes and material variants and their usual effect on the performance are given below:

Raw materials

Graphite - decrease friction

Copper, Silver - decrease contact drop

Pressing

Pressing at higher pressures reduce the porosity, give greater strength, increased brush life and narrower blackened results.

Graphitisation

Reduces the hardness, friction and specific resistance.

Impregnation

- Oils and waxes generally improve friction, stability and increase contact drop slightly.
- Resins strengthen brush material so that it becomes more resistant to breaking and chipping.
- PTFE reduces friction under humid conditions.
- Barium fluoride reduces friction and wear at very low humidity.

In view of the above an exceedingly complex multivariant relationship exists between the various aspects of performance requirements, specifications of raw materials and processing. Therefore, stability of a particular make and grade of brushes can only be established after extensive tests and trials.

For traction machines, the Electro-graphite grades are most suitably used. Technical data on some of the most commonly used brush grades for traction machines is given in annexure.

3. BRUSH ANGLES

Brushes are often defined by the methods of applying them to the commutator. They are three main classes:

1. Reaction
2. Trailing
3. Radial

(No. 1 & 2 are used only on non-reversing machines.)

Reaction Brushes

The brushes are said to be 'reaction' or 'leading' when the commutator is rotated against the angle of tilt i.e. the brushes are inclined in a leading direction. The angle between the centre line of the brush and the normal lines between 30 to 40 degrees.

Trailing Brushes

The brushes are said to be 'trailing' when the commutator is run in the same direction as the brushes are tilted. The tilt angle usually lies between 7 to 15 degrees.

Radial Brushes

Traction motors are invariably fitted with radial brushes i.e. their centre line is radial to the commutator, which permits operation under similar conditions for both direction of rotation.

4. BRUSH TYPES

Split Brushes

Commutator, howsoever well designed and manufactured, loses its trueness in the long run of service and high/low spots are often formed on its surface. The unavoidable commutator eccentricity gives rise to radial forces, which tend to break commutator to brush contact.

The split brush arrangements gives some freedom to each piece of carbon to move independently so that the commutator surface is closely followed and electrical contact is maintained. The biggest advantage is the resistance between leading and trailing edge of the split brush tends to reduce circulating currents.

Rubber-Top Brushes

Apart from damping the radial forces, the rubber-tops prevent passage of current through the brush holder springs. The springs thus do not get over heated and lose their tensions.

5. ELECTRICAL CHARACTERISTICS

(BRUSH TO COMMUTATOR CONTACT)

It is perhaps surprising that very little is known even today regarding brush to commutator phenomenon.

Microscopic study has revealed that area of the contact initially is only of the order of 1/4000th of brush area. As the machine is started, due to very high current density at these contact points, the carbon gets heated up and a gaseous layer is formed between the brush and commutator, which helps in current conduction. The commutator loses its fresh copper colour, and initial high brush wear (due to initial high friction and high current density), gradually comes down. The colour of the film on commutator becomes stable after some hours, or in some cases after several days of running, depending on the operating conditions. If no mechanical/electrical or thermal disturbances occur, brush tracks present a uniform polished colour, varying from dark chocolate to mild black.

During the course of service, the first indications of any commutation problem due to internal or external factors are often revealed from the condition of the commutator film. It is therefore extremely necessary to have adequate familiarity of the different types of the commutator films. This information is usually given in the brush literature. IEC specification No. 276 gives illustrations of some typical films. Part 4. of IS-3003, also includes some of such specifications.

6. SELECTION OF BRUSH GRADES

Brush grade selection involves considerable tests both on the test bed and under actual service conditions. It is sometimes found that brushes which are considered satisfactory on the test bed do not operate satisfactorily in service. In view of this, the proper grade can only be selected after suitable service trials and evaluation.

Indian Standard Specification IS-3003 covers dimensions, requirements and test procedures for carbon brushes.

Divergence in the physical properties and dimensions of carbon brushes can cause considerable trouble in service. Verification of the properties involves exhaustive testing, and since the carbon brushes are required to be procured rather frequently, it is not practicable to carry out such a large amount of tests on each lot purchased. It is extremely important, therefore, to restrict the brush procurement from established and well proven sources only, even if the prices may be higher. Also, whenever a new supply source or a new brush grade is considered, detailed tests/service trials should be carried out before approving the same for bulk use.

Some of the defects usually noticed on the carbon brushes are:

1. Dimensions not confirming to the drawing
2. Bowed/Curved and chipped carbons
3. Poor quality of pig tails, which results in their getting frayed/broken in service
4. Bad joints between pigtail and carbons, resulting in high unequal voltage drops across the same
5. Hair line, invisible cracks at pigtail to carbon joints
6. Physical properties not conforming to the grade

7. SERVICE PERFORMANCE

Howsoever good may be the design/manufacture of the machine, and the quality of the brushes, satisfactory performance cannot continue to be obtained without resorting to regular and proper maintenance of the brush-gear and commutator.

The importance of early detection of commutation troubles cannot be over emphasised. As such it is imperative that from the time the machines are commissioned, suitable statistical information should be collected on the basis of regular observations. Analysis of the data thus collected will help to avoid the possibility of any particular commutation problem assuming epidemic proportions.

Section II of BHEL's Workshop Manual covers the aspects which govern the satisfactory commutating performance of traction machines. In this section guidelines for operation, maintenance and trouble shooting are also covered.

8. ANALYSIS OF COMMUTATION PROBLEMS

The commutation problems are caused by several factors, some of which are enumerated here:

8.1 Carbon brushes

Poor quality of brushes, bad carbon to pigtail joints, wrong brush grades, mixing of grades on same machine, brushes too loose or tight in brush holders, improper bedding, brushes too thin or thick, brush angles not correct, etc.

8.2 Brush Gear

Brushes in incorrect positions, low or high spring tensions, unequal current sharing by brushes of the same arm, incorrect brush stagger, spring carrying current, excessive

vibrations due to poor/defective mounting of brush holders, high brush box to commutator clearance, unequal pressure on parts of split brush, brush holders prone to flashover damages, poor accessibility for maintenance, etc.

8.3 Commutator

Eccentricity, ovality, high and low bars, flats on commutator, ground mica, oily or dirty surface, bridging of mica grooves, rough surface, high commutator temperatures, inadequate stability due to poor seasoning, etc.

8.4 Machine Faults

Compole strength and gaps not correct, clogged ventilation ducts, poor ventilation, defective armature bearings, dynamic unbalance, wrong connections of compole or main field windings, armature or field winding faults, inadequate equalisation, commutating zone too narrow or unsymmetrical, poor commutation performance in general, saturated compoles, low field/armature ampere turns ratio, etc.

8.5 External Causes

Excessive vibrations due to defects in machine mounting or defective bogie designs or poor rail track, leakage from ventilation ducts, collapsed bellows, prolonged light load running, rapidly fluctuating or excessive loads, faults in control circuitry, mal-operation of line contactors, unequal load sharing by machines, excessive wheel slips or wheel locking, humid or corrosive atmosphere, towing of motors without lifting the brushes, oil/water/brake-shoe-dust coming with cooling air, high voltage transients, high ripple contents, poor maintenance, inadequate facilities in maintenance depots, etc.

Annexure-1

TECHNICAL DATA FOR CARBON BRUSHES

	EG0 (M)	EG236S (M)	EG14D (M)	EG225 (M)	EG59 (RE)	EG259 (M)	EG7097 (LC)	EG389 (LC)	EG6754 (LC)
Normal current density (Amp/cm ²)	10	11	9.5	11.0	11.5	8.5	10	10	10
Contact drop at normal current (Volts)	1.0	1.4	1.25	1.15	1.25	1.65	2.5	2.5	2.5
Specific resistance (ohm-cm)	1100	2200	4200	4100	5100	5800	4100	1700	4000
Apparent density	1.15	1.6	1.72	1.48	1.65	1.73	1.62	1.46	1.72 (gm/cm ²)
Coef. of friction	.11	.11	.11	.14	.15	.05	.15	.15	.15
% porosity (Apparent)		20	13.2	27.0		13			
Shore hardness (Scleroscope)	36	65	77	34	65	65	70	30	86
Compr. strength (Kg/cm ²)		410	840	230		750			
Transverse band strength (Kg/cm ²)	210	180	250	130	210	300	320	270	390
Shear strength (Kg/cm ²)		98	250	46		310			
Normal max. speed (M/sec)	20	50	45	50	50	50	50	45	45

Note: Most carbon materials are of a brittle granular structure, thus the physical properties can not be held within close tolerances. The figures quoted above therefore are typical values but considerable variability is to be expected between individual measurements.

Annexure-2

CARBON BRUSHES FOR BHEL TRACTION MACHINES

Sl.No.	Machine Type	Brush Grade	Size (TxWxL)	Drg. No.	Qty./M/c
1.	133AY / 133AX	EG14D Morgan	2(9.5X63.5X57)	D4775841	4
2.	253BW / 253AZ/ TM4601AZ/TM4603AZ	EG14D Morgan/ EG7097 Le Carbone	2(12.7X44.45X60)	D4775798	8
3.	TM4939AZ/165/165M	EG14D Morgan/ EG6754 Le Carbone	2(9.5X57.15X51)	D4775839	12
4.	AG15/AG2513	RE59 Ringsdroff	12.7X31.75X44.45	D4775293	8
5.	MG51 (GENERATOR)	RE59 Ringsdroff	12.5X31.75X43.2	D4775077	4
6.	MG51 (MOTOR)	EG225 Morgan	2(6.35X22.2X43.2)	D4775076	2
7.	TG10931/TG10919	EG225 Morgan EG389 Le Carbone	2(11.1X31.75X64)	D4775851	60
8.	EC9005/2	EGO Morgan	9.5X9.5X25	B4900350	4
9.	TM2701AZ	EG14D Morgan	16X64X65	D4775847	2
10.	TM3603AZ	EG14D Morgan	2(11X40X60)	D4776200	8

9, SUMMARY

In DC-DC and AC-DC diesel locomotives, a large number of DC machines have been used. Carbon brushes play an important role in these machines. Understanding the characteristics and its working helps the maintainers/users to run the machines trouble free. The brush material, brush rigging, types of brushes and electrical characteristics help the users in selecting proper grade for a particular application. The service performance is recorded and monitored in order to decide the proper selection of brush grade too.

Commutation in DC machines is a critical phenomenon. Proper analysis of commutation problem helps in minimizing the troubles. This unit also contains technical data of different carbon brushes, which are in use. A chart showing grades of brushes for specific application is given to help the reader .

11. SELF ASSESSMENT EXERCISE

1. Describe, How do you select a brush grade for an application.
2. Why is it necessary to monitor service performance of brush.
3. How do you analyse the commutation problem of a DC machine.
4. Why are the brushes placed at an angle in unidirectional machines.
5. Describe the process to obtain an Electro-graphite brush material.