

TAXFLOW ANALYSIS OF THE STRUCTURE OF THE COMMUTATOR

Muradova Alevtina Aleksandrovna, PhD, Dotcent

Bozorov Abdusalim Tillaboyevich

Annotation

A **commutator** is a rotary electrical switch in certain types of electric motors and electrical generators that periodically reverses the current direction between the rotor and the external circuit. It consists of a cylinder composed of multiple metal contact segments on the rotating armature of the machine. Two or more electrical contacts called "brushes" made of a soft conductive material like carbon press against the commutator, making sliding contact with successive segments of the commutator as it rotates. The windings (coils of wire) on the armature are connected to the commutator segments.

Commutators are used in direct current (DC) machines: dynamos (DC generators) and many DC motors as well as universal motors. In a motor the commutator applies electric current to the windings. By reversing the current direction in the rotating windings each half turn, a steady rotating force (torque) is produced. In a generator the commutator picks off the current generated in the windings, reversing the direction of the current with each half turn, serving as a mechanical rectifier to convert the alternating current from the windings to unidirectional direct current in the external load circuit.

A spring is typically used with the brush, to maintain constant contact with the commutator. As the brush and commutator wear down, the spring steadily pushes the brush downwards towards the commutator. Eventually the brush wears small and thin enough that steady contact is no longer possible or it is no longer securely held in the brush holder, and so the brush must be replaced.

It is common for a flexible power cable to be directly attached to the brush, because current flowing through the support spring would cause heating, which may lead to a loss of metal temper and a loss of the spring tension.

When a commutated motor or generator uses more power than a single brush is capable of conducting, an assembly of several brush holders is mounted in parallel across the surface of the very large commutator. This parallel holder distributes current evenly across all the brushes, and permits a careful operator to remove a bad brush and replace it with a new one, even as the machine continues to spin fully powered and under load.

High power, high current commutated equipment is now uncommon, due to the less complex design of alternating current generators that permits a low current, high voltage spinning field coil to energize high current fixed-position stator coils. This permits the use of very small singular brushes in the [alternator](#) design. In this instance, the rotating contacts are continuous rings, called [slip rings](#), and no switching happens.

Modern devices using carbon brushes usually have a maintenance-free design that requires no adjustment throughout the life of the device, using a fixed-position brush holder slot and a combined brush-spring-cable assembly that fits into the slot. The worn brush is pulled out and a new brush inserted.

The different brush types make contact with the commutator in different ways. Because copper brushes have the same hardness as the commutator segments, the rotor cannot be spun backwards against the ends of copper brushes without the copper digging into the segments and causing severe damage. Consequently, strip/laminate copper brushes only make tangential contact with the commutator, while copper mesh and wire brushes use an inclined contact angle touching their edge across the segments of a commutator that can spin in only one direction.

The softness of carbon brushes permits direct radial end-contact with the commutator without damage to the segments, permitting easy reversal of rotor direction, without the need to reorient the brush holders for operation in the opposite direction. Although never reversed, common appliance motors that use wound rotors, commutators and brushes have radial-contact brushes. In the case of a reaction-type carbon brush holder, carbon brushes may be reversely inclined with the commutator so that the commutator tends to push against the carbon for firm contact.

A commutator consists of a set of contact bars fixed to the rotating shaft of a machine, and connected to the armature windings. As the shaft rotates, the commutator reverses the flow of current in a winding. For a single armature winding, when the shaft has made one-half complete turn, the winding is now connected so that current flows through it in the opposite of the initial direction. In a motor, the armature current causes the fixed magnetic field to exert a rotational force, or a torque, on the winding to make it turn. In a generator, the mechanical torque applied to the shaft maintains the motion of the armature winding through the stationary magnetic field, inducing a current in the winding. In both the motor and generator case, the commutator periodically reverses the direction of current flow through the winding so that current flow in the circuit external to the machine continues in only one direction.

Practical commutators have at least three contact segments, to prevent a "dead" spot where two brushes simultaneously bridge only two commutator segments. Brushes are made wider than the insulated gap, to ensure that brushes are always in contact with an armature coil. For commutators with at least three segments, although the rotor can potentially stop in a position where two commutator segments touch one brush, this only de-energizes one of the rotor arms while the others will still function correctly. With the remaining rotor arms, a motor can produce sufficient torque to begin spinning the rotor, and a generator can provide useful power to an external circuit.

A commutator consists of a set of copper segments, fixed around the part of the circumference of the rotating machine, or the rotor, and a set of spring-loaded brushes fixed to the stationary frame of the machine. Two or more fixed brushes connect to the external circuit, either a source of current for a motor or a load for a generator.

Commutator segments are connected to the coils of the armature, with the number of coils (and commutator segments) depending on the speed and voltage of the machine. Large motors may have hundreds of segments. Each conducting segment of the commutator is insulated from adjacent segments. Mica was used on early machines and is still used on large machines. Many other insulating materials are used to insulate smaller machines; plastics allow quick manufacture of an insulator, for example. The segments are held onto the shaft using a dovetail shape on the edges or underside of each segment. Insulating wedges around the perimeter of each segment are pressed so that the commutator maintains its mechanical stability throughout its normal operating range.

In small appliance and tool motors the segments are typically crimped permanently in place and cannot be removed. When the motor fails it is discarded and replaced. On large industrial machines (say, from several kilowatts to thousands of kilowatts in rating) it is economical to replace individual damaged segments, and so the end-wedge can be unscrewed and individual segments removed and replaced. Replacing the copper and mica segments is commonly referred to as "refilling". Refillable dovetailed commutators are the most common construction of larger industrial type commutators, but refillable commutators may also be constructed using external bands made of fiberglass (glass banded construction) or forged steel rings (external steel shrink ring type construction and internal steel shrink ring type construction). Disposable, molded type commutators commonly found in smaller DC motors are becoming increasingly more common in larger electric motors. Molded type commutators are not repairable and must be replaced if damaged. In addition to the commonly used heat, torque, and tonnage methods of seasoning commutators, some high-performance commutator applications require a more expensive, specific "spin seasoning" process or over-speed spin-testing to guarantee stability of the individual segments and prevent premature wear of the carbon brushes. Such requirements are common with traction, military, aerospace, nuclear, mining, and high-speed applications where premature failure can lead to serious negative consequences.

Friction between the segments and the brushes eventually causes wear to both surfaces. Carbon brushes, being made of a softer material, wear faster and may be designed to be replaced easily without dismantling the machine. Older copper brushes caused more wear to the commutator, causing deep grooving and notching of the surface over time. The commutator on small motors (say, less than a kilowatt rating) is not designed to be repaired through the life of the device. On large industrial equipment, the commutator may be re-surfaced with abrasives, or the rotor may be removed from the frame, mounted in a large metal lathe, and the commutator resurfaced by cutting it down to a smaller diameter. The largest of equipment can include a lathe turning attachment directly over the commutator.

Early machines used brushes made from strands of copper wire to contact the surface of the commutator. However, these hard metal brushes tended to scratch and groove the smooth commutator segments, eventually requiring resurfacing of the commutator. As the copper brushes wore away, the dust and pieces of the brush could wedge between commutator segments, shorting them and reducing the efficiency of the device. Fine copper wire mesh or gauze provided better surface contact with less segment wear, but gauze brushes were more expensive than strip or wire copper brushes.

Modern rotating machines with commutators almost exclusively use carbon brushes, which may have copper powder mixed in to improve conductivity. Metallic copper brushes can be found in toy or very small motors, such as the one illustrated above, and some motors which only operate very intermittently, such as automotive starter motors.

Motors and generators suffer from a phenomenon known as 'armature reaction', one of the effects of which is to change the position at which the current reversal through the windings should ideally take place as the loading varies. Early machines had the brushes mounted on a ring that was provided with a handle. During operation, it was necessary to adjust the position of the brush ring to adjust the commutation to minimize the sparking at the brushes. This process was known as 'rocking the brushes'.

Various developments took place to automate the process of adjusting the commutation and minimizing the sparking at the brushes. One of these was the development of 'high resistance brushes', or brushes made from a mixture of copper powder and carbon.^[3] Although described as high resistance brushes, the resistance of such a brush was of the order of milliohms, the exact value dependent on the size and function of the machine. Also, the high resistance brush was not constructed like a brush but in the form of a carbon block with a curved face to match the shape of the commutator.

The high resistance or carbon brush is made large enough that it is significantly wider than the insulating segment that it spans (and on large machines may often span two insulating segments). The result of this is that as the commutator segment passes from under the brush, the current passing to it ramps down more smoothly than had been the case with pure copper brushes where the contact broke suddenly. Similarly, the segment coming into contact with the brush has a similar ramping up of the current. Thus, although the current passing through the brush was more or less constant, the instantaneous current passing to the two commutator segments was proportional to the relative area in contact with the brush.

The introduction of the carbon brush had convenient side effects. Carbon brushes tend to wear more evenly than copper brushes, and the soft carbon causes far less damage to the commutator segments. There is less sparking with carbon as compared to copper, and as the carbon wears away, the higher resistance of carbon results in fewer problems from the dust collecting on the commutator segments.

The ratio of copper to carbon can be changed for a particular purpose. Brushes with higher copper content perform better with very low voltages and high current, while brushes with a higher carbon content are better for high voltage and low current. High copper content brushes typically carry 150 to 200 amperes per square inch of contact surface, while higher carbon content only carries 40 to 70 amperes per square inch. The higher resistance of carbon also results in a greater voltage drop of 0.8 to 1.0 volts per contact, or 1.6 to 2.0 volts across the commutator.

Reference

1. Sodirjonov, M. M. "Some Thoughts on The Evolution of Approaches to The Concept of Human Capital." *The American Journal of Social Science and Education Innovations* 2.08 (2020): 144-150.
2. Sodirjonov M. M. *ETHNOSOCIOLOGICAL FACTORS OF SOCIAL TRANSFORMATION IN MODERN UZBEKISTAN //ACTUAL ISSUES OF FORMATION AND DEVELOPMENT OF SCIENTIFIC SPACE*. - 2020. - PP. 27-34.
3. Mahamadinovich S. M. The essence of social capital consequences and their influences to the modern society //Bulletin of Science and Education. – 2020. – №. 2-2 (80).
4. Sodirjonov M. M. Some Thoughts on The Evolution of Approaches to The Concept of Human Capital //The American Journal of Social Science and Education Innovations. - 2020. - Vol. 2. - No. 08. - Pp. 144-150.