THE DIRECT CURRENT MOTOR.*

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Dynamo electric machines belong to the class of machines which are called reversible. This does not mean that they can be run backwards, but that the transformation of energy which goes on in the machine is reversible.

If we apply mechanical energy to a dynamo so as to make it rotate, it will generate a current of electricity. This current we can send to a distance through conductors, let it enter a machine, another dynamo, and this machine will start to rotate and convert the current or electrical energy supplied to it into mechanical work—the motion of visible masses of matter. In this accomplishment we started out with mechanical energy, and come back to it far from its first application. Electricity in the transformation has only been a link, a means of transmitting the power. Motion is necessary to produce the current, and the dynamo or motor is merely a device for transforming what is called energy from one form to another.

A motor is therefore the same machine as a dynamo, or a dynamo to which a current is supplied. Therefore, in studying the inner working of a motor, we must deal with exactly the same principles that we find at work in dynamos. The main parts which are to be considered in a dynamo are the field magnets and the armature. The field magnets, which produce the magnetic field, are usually stationary; the armature, the part in which the currents are induced, revolves.

A commutator is also required, either to carry the current generated in the conductors of the armature to the line, as in a dynamo, or to conduct the current from the line to the conductors of the armature, in the case of a motor.

If a conductor forming a loop is moved across a magnetic field, a current will flow in this conductor; this current will be generated as long as the motion lasts, and the moment that it stops the current will vanish; also, if a conductor carrying a current is placed in a magnetic field in a plane at right angles to the magnetic lines, it experiences a force urging it to move in that plane. The motion will last as long as the current is flowing in the conductor and as the conductor is still in the field. Motion is therefore necessary to produce the electric current, and the electric current will in turn produce motion.

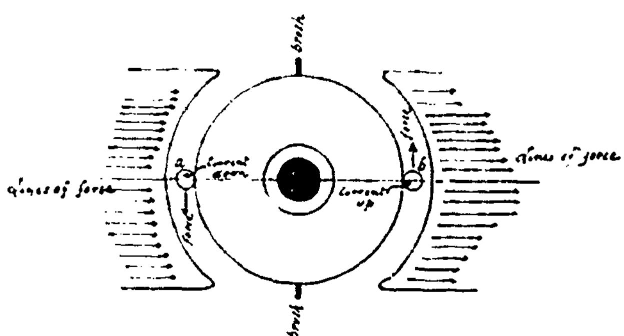

Fig. 1.

The armature, as found in dynamos, is simply a collection of loops of wire so arranged that each conductor in its rotation between the field magnets is carried past these field magnets, and current is generated in these conductors. In a motor, the conductors carrying current and placed in a magnetic field are subjected to a force which, as will be presently explained, produces a rotation of the armature.

Fig. 1 shows a section of an armature and pole pieces of a dynamo. This section is in a plane at right angles to the shaft; a and b are two conductors forming a part of the same loop, the currents in these being in opposite directions. It will be found that conductor (a) will be subjected to a force acting downwards, while the force on (b) will be upwards, the effect of these two forces, as will readily be seen, being to turn the armature about its axis. If any number of conductors are arranged on the surface of this armature, the forces acting on these conductors will be all downwards on one side of the brush plane and upwards on the other side. These forces, acting on the conductors at a certain distance from the axis of the shaft, results in a twist, so that the shaft will be turned. If we were to rotate by hand the armature of a small dynamo, we would find that as long as the dynamo is not made to generate any current, the resistance to turning the armature would be very small. As a matter of fact, this resistance is that simply due to the friction of the shaft in its bearings, and the friction due to the pressure of the brushes on the commutator. But if we should now close the circuit of the dynamo so that the machine will generate a current, the force that we shall have to exert to keep the machine rotating is many times greater, for since the conductors are now carrying current, the force which we find acting between magnetic fields and conductors carrying current is acting against the imparted motion of the dynamo.

In a motor this force is the one which causes the machine to rotate, and is therefore acting in the direction of rotation.

It seems puzzling to the mind of the unacquainted observer how it is that so much force has to be exerted to drive a dynamo under load; the armature revolves between the polar pieces quite freely, the mechanical friction can absorb but very little power, then what becomes of the surplus power which is mechanically imparted to the machine. The answer is, that there is a force which the magnetic field exerts on the conductors of the armature since they now carry current; this force or drag opposes the rotation, the larger the current in the armature the greater this drag and the more the power which is required to keep the machine revolving.

In a motor this drag is the driving force, and is the one which produces the rotation.

THE STARTING OF ELECTRIC MOTORS.

In starting an electric motor from a stand-still, it will be found necessary to introduce a resistance in the armature circuit of the motor, this resistance to govern the current and reduce it to any desired flow. At starting, or when the motor is running slowly, the current has to go through a resistance box called starting box, and then through the conductors of the armature; the field coils are either connected directly to the line as in shunt-wound motors, or in series with the starting box and armature as in series-wound motors. The current strength is therefore given by the ratio of the electro-motive force of the line and the total resistance introduced in the circuit. In order to speed up the motor, the resistance of the starting box is gradually taken out, until the motor is placed directly on the line and is then running at its rated speed.

Without this resistance at the start, the current that would go through the motor would probably be excessive and prove injurious to the insulation of the armature; besides it would not be doing useful work, for useful work is only done when the armature revolves. The current at start should be large enough to start the rotation, but not large enough to injure the motor.

If the resistance in circuit is now cut out gradually the motor will speed up, and it will be found that the faster the motor runs the weaker the current becomes. This is due to a generating action taking place in the motor itself on account of its speed, in fact the motor by its rotation is now working as a dynamo on its own account and tends to generate a current in the circuit in the opposite direction to that which is driving it. As the production of current is due to an electro-motive force, this generating action taking place in the motor will be found to be due to an electro-motive force acting as soon as the machine is rotating. This electro-motive force, which is called a counter electro-motive force, varies with the speed, that is, increases or decreases with the speed. The current now does not depend on the electrical resistance of the circuit alone, but is checked by this electro-motive force of reaction which is working against the electro-motive force of the line. Therefore, whereas in a generator there is only one electro-motive force acting, in a motor there must always be two as soon as the machine is developing work, that is, as soon as the machine is rotating.

The electrical energy supplied to a motor is measured by the product of the voltage on the line into the current flowing; this product is expressed in watts, and if divided by 746, will give the electrical horse power delivered to the motor. This energy, usually called the electrical input, is, however, not wholly converted into useful work, and only a portion of this (happily a large one) will be available on the shaft.

The energy supplied is expended in two ways, in heating the circuit and in doing work. The expenditure of energy in the form of heat is the product of the resistance of the circuit into the square of the current. This product is expressed in watts, and may be termed heat watts. This amount of power is lost and simply heats up the machine; to reduce this loss will be to make the resistance of the armature as small as possible. The difference between the total watts supplied to the motor and the heat watts may be called the mechanical watts, that is, it is this part of the total energy which will be transformed in the machine from

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