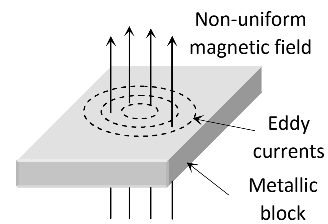
Application of EMI.

(1) Eddy current

When a changing magnetic flux is applied to a bulk piece of conducting material then circulating currents called eddy currents are induced in the material. Because the resistance of the bulk conductor is usually low, eddy currents often have large magnitudes and heat up the conductor.



These are circulating currents like eddies in water

Experimental concept given by Focault hence also named as "Focault current"

(i) Disadvantages of eddy currents

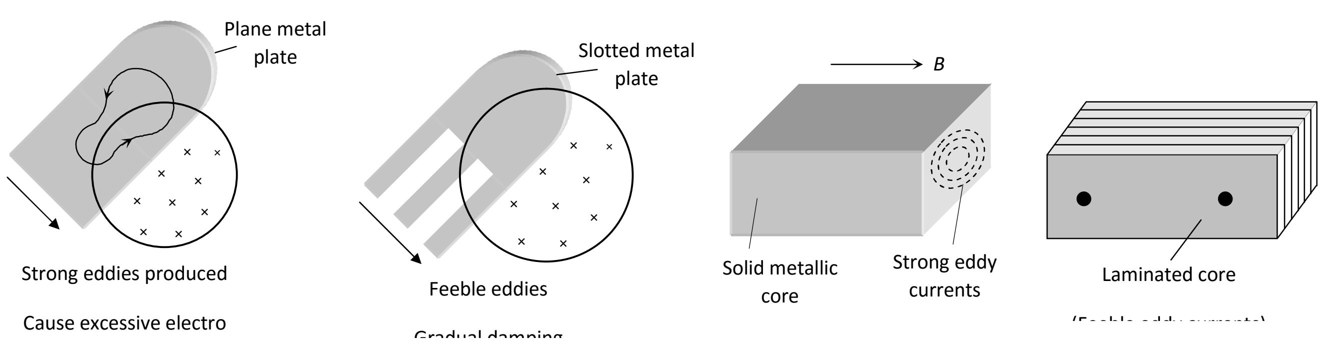
(a) The production of eddy currents in a metallic block leads to the loss of electric energy in the form of heat.

(b) The heat produced due to eddy currents breaks the insulation used in the electrical machine or appliance.

(c) Eddy currents may cause unwanted damping effect.

(ii) Minimisation of losses due to eddy currents

By Lamination, slotting processes the resistance path for circulation of eddy current increases, resulting in to weakening them and also reducing losses causes by them (slots and lamination intercept the conducting paths and decreases the magnitude of eddy currents and reduces possible paths of eddy currents)



(iii) Application of eddy currents: Though most of the times eddy currents are undesirable but they find some useful applications as enumerated below

(a) Dead-beat galvanometer: A dead beat galvanometer means one whose pointer comes to rest in the final equilibrium position immediately without any oscillation about the equilibrium position when a current is passed in its coil.

We know that the coil of a moving coil galvanometer is wound over a light aluminium frame. When the coil moves due to the torque produced by the current being measured, the aluminium frame also moves in the field. As a result the flux associated with the frame changes and eddy currents are induced in the frame. Eddy currents induced in aluminium frame as per Lenz's law always oppose the cause that produces them. Hence they damp the oscillation about the final steady position.

(b) Electric-brakes: When the train is running its wheel is moving in air and when the train is to be stopped by electric breaks the wheel is made to move in a field created by electromagnet. Eddy currents induced in the wheels due to the changing flux oppose the cause and stop the train.

(c) Induction furnace: Here a large amount of heat is to be generated so as to melt metal in it. To produce such a large amount of heat, a solid core of the furnace is taken (as against laminated core in situations where the heat produced is to be minimized).

(d) Speedometer: In the speedometer of an automobile, a magnet is geared to the main shaft of the vehicle and it rotates according to the speed of the vehicle. The magnet is mounted in an aluminium

cylinder with the help of hair springs. When the magnet rotates, it produces eddy currents in the drum and drags it through an angle, which indicates the speed of the vehicle on a calibrated scale.

(e) Diathermy: Eddy currents have been used for deep heat treatment called diathermy.

(f) Energy meter: In energy meters, the armature coil carries a metallic aluminium disc which rotates between the poles of a pair of permanent horse shoe magnets. As the armature rotates, the current induced in the disc tends to oppose the motion of the armature coil. Due to this braking effect, deflection is proportional to the energy consumed.

(2) dc motors

It is an electrical machine which converts electrical energy into mechanical energy.

(i) Principle: It is based on the fact that a current carrying coil placed in the magnetic field experiences a torque. This torque rotates the coil.

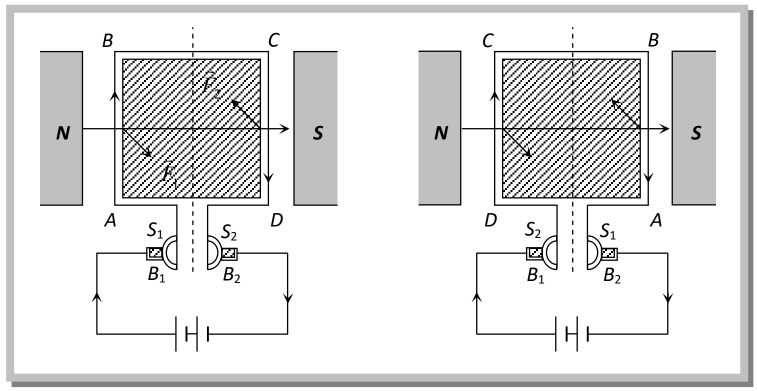
(ii) Construction: It consists of the following components figure.

ABCD = Armature coil

S1, S2 = split ring comutators

B1, B2 = Carbon brushes

N, S = Strong magnetic poles



(iii) Working: Force on any arm of the coil is given by $\vec{F} = i(\vec{l} \times \vec{B})$ in fig., force on AB will be perpendicular to plane of the paper and pointing inwards. Force on CD will be equal and opposite. So coil rotates in clockwise sense when viewed from top in fig. The current in AB reverses due to commutation keeping the force on AB and CD in such a direction that the coil continues to rotate in the same direction.

(iv) Back emf in motor: When the armature coil rotates in the magnetic field, an induced emf is set up in its windings. According to Lenz's law, this induced emf opposes the motion of the coil and its direction is opposite to the applied emf in the motor circuit. Hence the induced emf is known as back emf e = E – iR

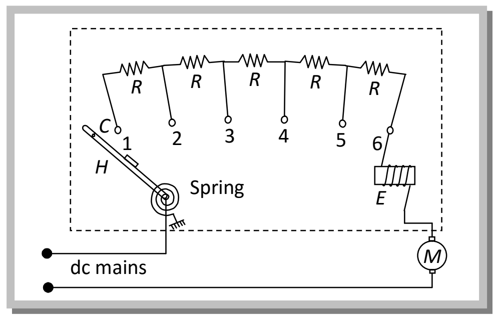
Value of back emf directly depends upon the angular velocity ω of armature and magnetic field B. But for constant magnetic field B, value of back emf e is given by $e \propto \omega$ or $e = k\omega$ ($e = NBA\omega \sin\omega t$)

Let e = Magnitude of induced emf, E = Magnitude of the supply voltage, R = Resistance of the armature coil, i = Current in the armature. According to Ohm's law $i = \frac{E + (-e)}{R} = \frac{E - e}{R}$ or $iR = E - e$

(v) Current in the motor : $i = \frac{E - e}{R} = \frac{E - k\omega}{R}$; When motor is just switched on i.e. $\omega = 0$ so e = 0

hence $i = \frac{E}{R} = \text{maximum}$ and at full speed, ω is maximum so back emf e is maximum and i is minimum. Thus, maximum current is drawn when the motor is just switched on which decreases when motor attains the speed.

Hence a starter is used for starting a dc motor safely. Its function is to introduce a suitable resistance in the circuit at the time of starting of the motor. This resistance decreases gradually and reduces to zero when the motor runs at full sped.



The value of starting resistance is maximum at time t = 0 and its value is controlled by spring and electromagnetic system and is made to zero when the motor attains its safe speed.

Note: Small motor tends to have higher resistance then the large ones and do not normally need a starter.

(vi) Mechanical power and Efficiency of dc motor: Power supplied to the motor, Pin = Ei

and the power dissipated in the form of heat = i2R

So remaining power = Ei – i2R. This power is known as the mechanical power developed in the motor.

Hence mechanical power, Pmech. = (E – iR) i = ei

Efficiency of dc motor $\eta = \frac{P_{mechanical}}{P_{\sup plied}} = \frac{P_{out}}{P_{in}} = \frac{e}{E} = \frac{\text{Back e.m.f.}}{\text{Supply voltage}}$

Note: η will be maximum if ei = maximum. which obtained when $\boldsymbol{e} = \frac{\boldsymbol{E}}{\mathbf{2}}$. So ηmax.= $\frac{E/2}{E} \times 100 = 50\%$

(vii) Uses of dc motors: They are used in electric locomotives, electric ears, rolling mills, electric cranes, electric lifts, dc drills, fans and blowers, centrifugal pumps and air compressors, etc.

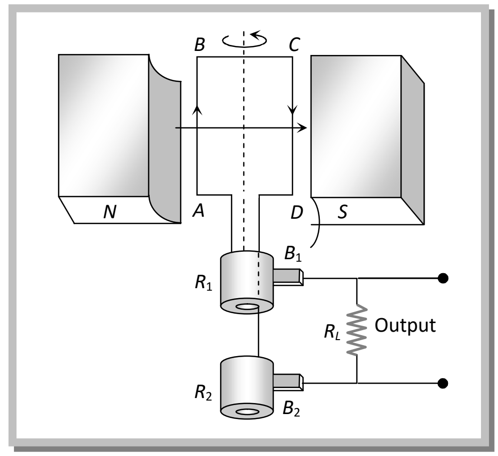
(3) ac generator/Alternator/Dynamo

An electrical machine used to convert mechanical energy into electrical energy is known as ac generator/alternator.

(i) Principle: It works on the principle of electromagnetic induction i.e., when a coil is rotated in uniform magnetic field, an induced emf is produced in it.

(ii) Construction: The main components of ac generator are

(a) Armature: Armature coil (ABCD) consists of large number of turns of insulated copper wire wound over a soft iron core.



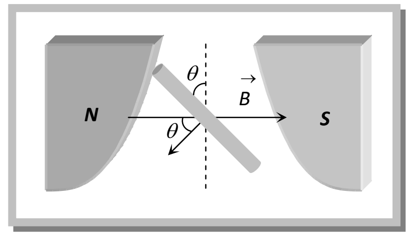
(b) Strong field magnet: A strong permanent magnet or an electromagnet whose poles (N and S) are cylindrical in shape in a field magnet. The armature coil rotates between the pole pieces of the field magnet. The uniform magnetic field provided by the field magnet is perpendicular to the axis of rotation of the coil.

(c) Slip rings: The two ends of the armature coil are connected to two brass slip rings R1 and R2. These rings rotate along with the armature coil.

(d) Brushes: Two carbon brushes (B1 and B2), are pressed against the slip rings. The brushes are fixed while slip rings rotate along with the armature. These brushes are connected to the load through which the output is obtained.

(iii) Working: When the armature coil ABCD rotates in the magnetic field provided by the strong field magnet, it cuts the magnetic lines of force. Thus the magnetic flux linked with the coil changes and hence induced emf is set up in the coil. The direction of the induced emf or the current in the coil is determined by the Fleming's right hand rule.

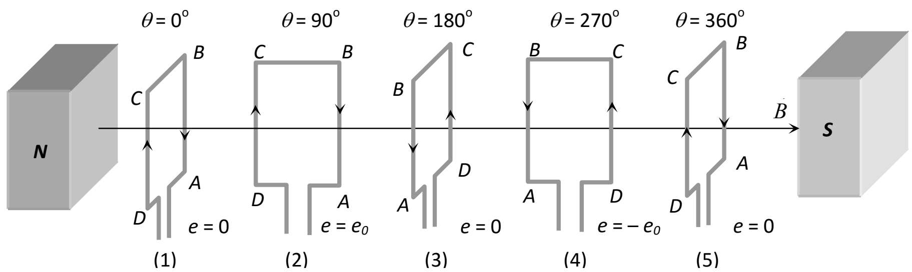
The current flows out through the brush B1 in one direction of half of the revolution and through the brush B2 in the next half revolution in the reverse direction. This process is repeated. Therefore, emf produced is of alternating nature.

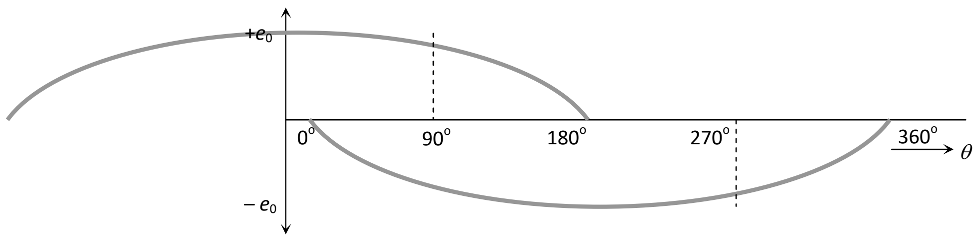


$$e = -\frac{Nd\phi}{dt} = NBA\,\omega \sin \omega t$$ = e0 sinωt where e0 = NBAω

$$i = \frac{e}{R} = \frac{e_0}{R} \sin \omega t = i_0 \sin \omega t$$

R → Resistance of the circuit





Note: Frequency of ac produced given by $[f_{AC}] = \frac{NP}{2}$, where P = Number of magnetic poles of field, N = Rotational frequency of armature coil in rps (rotations per seconds)

For (a) Simple generator P = 2 ⇒ fac = N (b) Multiple generator P > 2 ⇒ fac > N

To produce ac of given frequency, multiple generator is prove to be economical.

(4) DC generator

If the current produced by the generator is direct current, then the generator is called dc generator.

dc generator consists of

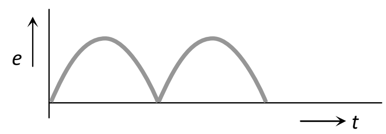
(i) Armature (coil)

(ii) Magnet

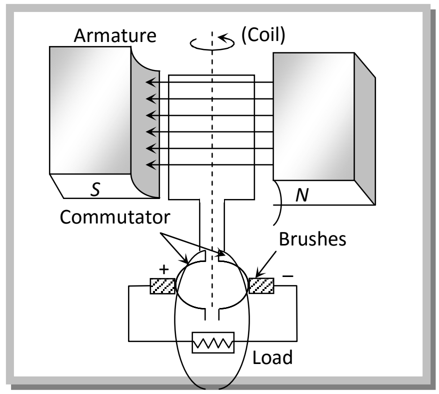
(iii) Commutator

(iv) Brushes

In dc generator commutator is used in place of slip rings. The commutator rotates along with the coil so that in every cycle when direction of 'e' reverses, the commutator also reverses or makes contact with the other brush so that in the external load the current remains in the some direction giving dc



(Output of a single loop dc generator for one cycle of rotation)



Note: Practical efficiencies of big generators are about 92% to 95%.

Concepts

DC motor is a highly versatile energy conversion device. It can meet the demand of loads requiring high starting torque, high accelerating and decelerating torque.

Constructionally there is no basic difference between a dc generator and a dc motor. Infect the same dc machine can be used interchangeably as a generator or as a motor.

All rating marked on dynamos and motors are for full loads. For example a 5 kW, 100 V, 1000 rpm dynamo delivers 5 kW electrical power at 100 V terminal voltage and it's speed of rotation at full load is 1000 rpm.