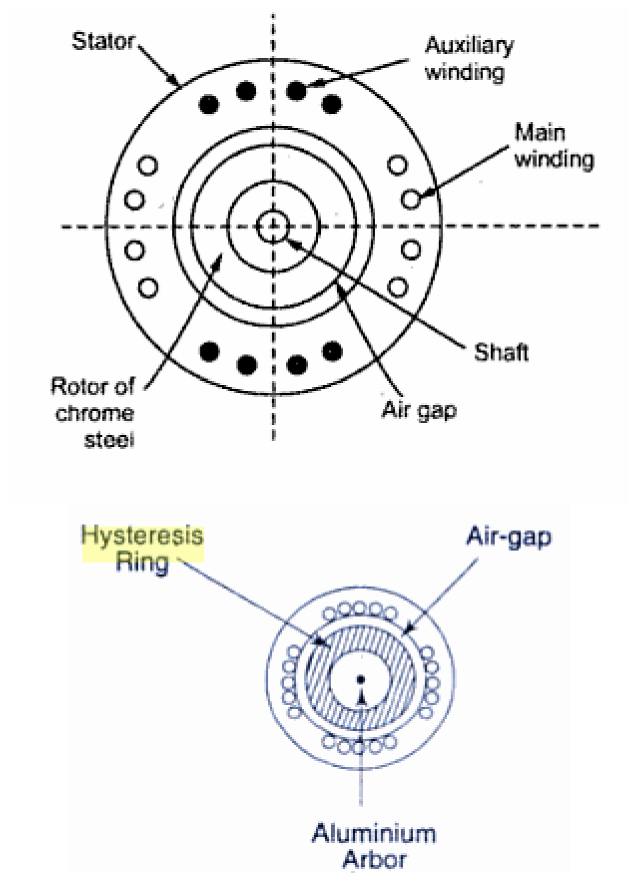
Hysteresis Motor

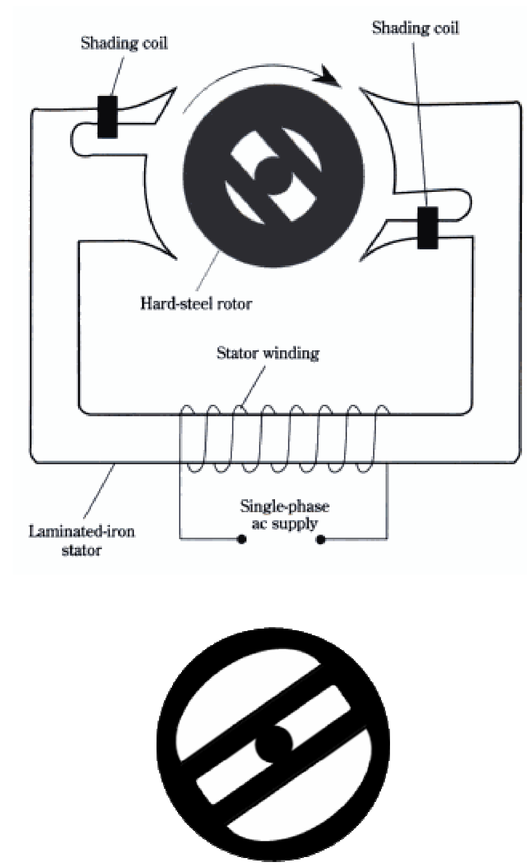
Defination: A hysteresis motor is a synchronous motor without salient (or projected) poles and without dc excitation which starts by virtue of the hysteresis losses induced in its hardened steel secondary member by the revolving filed of the primary and operates normally at synchronous speed and runs on hysteresis torque because of the retentivity of the secondary core.
It is a single-phase motor whose operation depends upon the hysteresis effect i.e., magnetization produced in a ferromagnetic material lags behind the magnetizing force.

Construction:

It consists of:
(i) **Stator:** A stator designed to produce a synchronously-revolving field from a single-phase supply.
The stator carries main and auxiliary windings (which is called split phase hysteresis motor) so as top produce rotating magnetic field as shown in Fig. 1 (a). The stator can also be shaded pole type (which is called shaded pole hysteresis motor) as shown in Fig. 1 (b).



(a)



(b)

Fig. 1 Different type of hysteresis motor

(ii) **Rotor:** The rotor of hysteresis motors are made with magnetic material of high hysteresis losses. i.e. whose hysteresis loop area is very large as shown in **Fig. 2**. The rotor does not carry any winding or teeth.

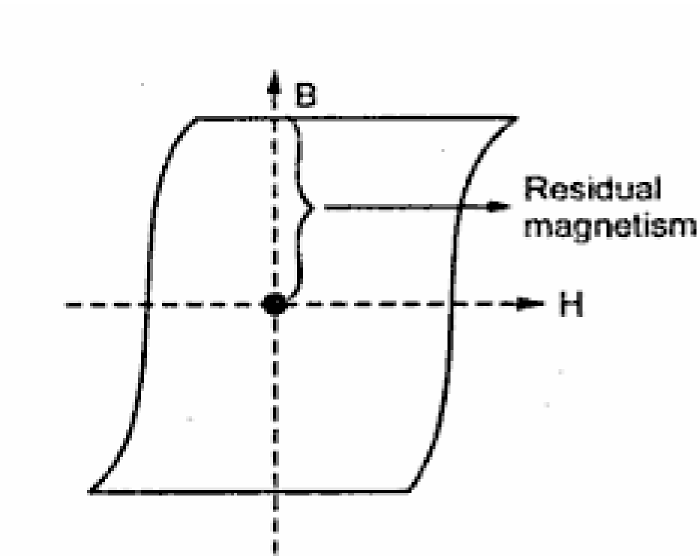


Fig. 2 Hysteresis loop for rotor material.

One type of rotor, invented by H. E. Warren and used in the Warren Telechron electric clock, is as shown in Fig. 1(b). It consists of two or more outer rings and crossbars, all made of specially selected heat-treated hard steel. Steel that has a very large hysteresis loop is chosen. When a rotating filed moves past the rotor, this hysteresis effect causes a torque to be developed and the motor starts to run. As synchronous speed is approached, the crossbars presents a low reluctance path to the flux thereby setting up permanent pole in the rotor and causing the motor to continue to rotate at synchronous speed. The Telechron motor has a shaded-pole stator as shown in Fig. 1(b).

Another type of rotor is smooth cylindrical type. Hysteresis rings of special magnetic material like chrome , cobalt steel or alnico or alloy are carried on supporting arbor made of a nonmagnetic material such as brass; the assembly is carried out on the shaft. The rotor is also design to obtain high resistivity to reduce eddy-current loss.

The hysteresis ring is affected by the rotational hysteresis causes by the stator windings and the direction of the magnetization of each element of the ring is different from that of the magnetic field or magnetic flux density. That is to say, the thicker the hysteresis ring becomes the larger the rotational hysteresis increases and to make matters worse, the output of the thicker ring motor becomes less than that of thin rotor motor.

Working Principle

When stator is energized, it produces rotating magnetic field. The main and auxiliary, both the windings must be supplied continuously at start as well as in running conditions so as to maintain the rotating magnetic field. The rotor, initially, starts to rotate due to eddy-current torque and hysteresis torque developed on the rotor. Once the speed is near about the synchronous, the stator pulls rotor into synchronism.

In such case, as relative motion between stator field and rotor field vanishes, so the torque due to eddy-currents vanisehes.

When the rotor is rotating in the synchronous speed, the stator revolving filed flux produces poles on the rotor as shown in **Fig. 3**. Due to the hysteresis effect, rotor pole axis lags behind the axis of rotating magnetic field. Due to this, rotor poles get attracted towards the moving stator poles. Thus rotor gets subjected to torque called hysteresis torque. This torque is constant at all speeds.

When the stator field moved forward, due to high residual magnetism (i.e. retentivity) the rotor pole strength remains maintained. So higher the retentivity, higher is the hysteresis torque. The hyteresis torque is independent of the rotor speed.

The high retentivity ensures the continuous magnetic locking between stator and rotor. Due to principle of magnetic locking, the motor either rotates at synchronous speed or not at all. Only hysteresis torque is present which keeps rotor running at synchronous speed.

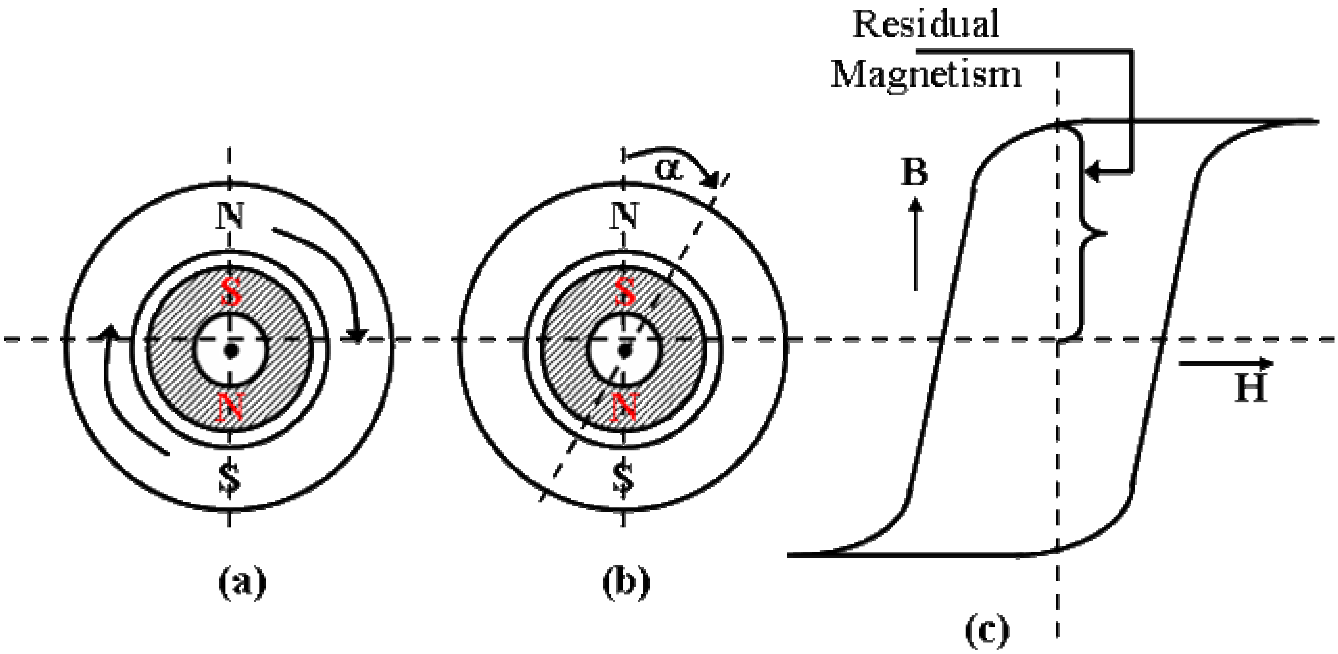


Fig. 3 (a) Stator poles induce poles in the rotor, (b) Torque developed on the rotor due to residual magnetism of the rotor, (c) Hysteresis loop of the rotor material.

Mathematical Analysis

Initially, the electromagnetic torque is developed by a hysteresis motor by virtue of the eddy-current loss and the hysteresis loss. The eddy-current loss can be given by:

$$Pe = K_e B^2 f_2^2 \tag{1}$$

Where, K_e is a constant, f_2 is frequency of eddy-current, and B is flux density.
In terms of slip s, the rotor frequency f_2 is related to the stator supply frequency f by

$$f_2 = sf \tag{2}$$

Thus (1) and (2) yield:

$$P_e = K_e B^2 s^2 f^2 \tag{3}$$

The torque due to eddy current is given by:

$$T_e = \frac{P_e}{s\omega_s} = \frac{K_e B^2 s^2 f^2}{s\omega_s} = K_1 s \tag{4}$$

Where, $\omega_s = 2\pi N_s = \dfrac{2\pi \times 120 f}{P}$ and $K_1 = \dfrac{K_e B^2 f^2}{\omega_s}$

So, $T_e \infty s$ all other parameters are constant.

It is clear from Eq. (4) that when the rotor rotates at synchronous speed, the slip becomes zero and torque due to eddy current component vanishes. It only helps to start.

The hysteresis-loss is given by:

$$P_h = K_h B^{1.6} f_2 = K_h B^{1.6} sf \tag{5}$$

Where, K_h is an another constant.
The corresponding torque is given by:

$$T_e = \frac{P_h}{s\omega_s} = \frac{K_h B^{1.6} sf}{s\omega_s} = K_2 = \text{constant} \tag{6}$$

It is clear from Eq. (6) that the hysteresis component is constant at all the rotor speed.

Hysteresis losses are produced in the rotor of a hysteresis motor is proportional to the area of hysteresis loop. These losses are dissipated as heat in the rotor.

Let us assume that the hysteresis loss per revolution is E_h joules and that the field rotates at N_s revolution per minute. The energy dissipated in the rotor per minute is

$$W = N_s E_h \tag{7}$$

The corresponding power (dissipated as heat) is:

$$P_h = \frac{W}{t} = \frac{N_s E_h}{60} \tag{8}$$

However, the power dissipated in the rotor can only come from the mechanical power used to drive the rotor. This power is given by

$$P_h = \frac{2\pi N_s}{60} T_h \tag{9}$$

Thus (8) and (9) yield:

$$\frac{2\pi N_s}{60} T_h = \frac{N_s E_h}{60}$$

Whence $T_h = \dfrac{E_h}{2\pi}$ (10)

Where, T_h is torque exerted on the rotor [N-m] and Eh is hysteresis energy dissipated in rotor [J]

Problem: A small 60 Hz hysteresis motor possesses 32 poles. In making one complete turn with respect to the revolution field, the hysteresis loss in the rotor amount to 0.8 J. Calculate (i) the hysteresis torque, (ii) the maximum power output before the motor stall, (iii) the rotor losses when the motor is stalled, and (iv) the rotor losses when the motor runs at synchronous speed.

Solution:

(i) The hysteresis torque is: $T_h = \dfrac{E_h}{2\pi} = \dfrac{0.8}{2\times 3.14} = 0.127 \quad N-m$

(ii) The synchronous speed is: $N_s = \dfrac{120f}{P} = \dfrac{120\times 60}{32} = 225 \ rpm$

The power is: $P_h = \dfrac{2\pi N_s}{60} T_h = \dfrac{2\times 3.14\times 225}{60} \times 0.127 T_h = 3\,W \ or \ (3/746) \ hp$

(iii) When the moyor stalls, the rotating field moves at 225 rpm w.r.t. the rotor. The energy loss per minute is therefore, $W = N_s E_h = 250\times 0.8 = 180 \ \ J$

The power dissipated in the rotor is: $P_h = \dfrac{W}{t} = \dfrac{180}{60} = 3\,W$

(iv) There is no energy loss in the rotor when the motor runs at synchronous speed because the magnetic domains no longer reverse.

Torque-Speed Characteristics

The starting and running torque is almost equal in this type of motor. As stator carries mainly the two-windings its direction can be reversed interchanging the terminals of either main winding or auxiliary winding. The torque-speed characteristics is as shown in **Fig. 4**.

As seen from the characteristics torque at start is almost same throughout the operation of the motor.

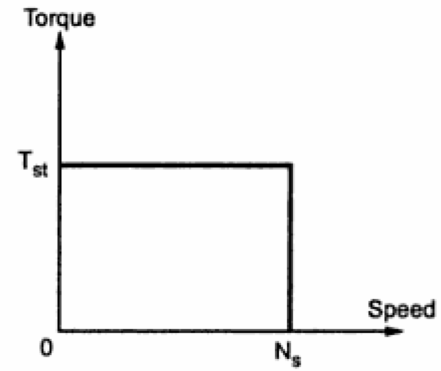


Fig. 4 Torque-speed characteristics of hysteresis motor

Advantages:

The advantages of hysteresis motor are:

1. As rotor has no teeth, no winding, there are no mechanical vibrations.
2. Due to absence of vibrations, the operation is quiet and noiseless.
3. Suitability to accelerate inertia loads.
4. Possibility of multispeed operation by employing gear train.

Disadvantages

The disadvantages of hysteresis motor are:

1. The output is about one-quarter that of an induction motor of the same dimension.
2. Low efficiency
3. Low power factor
4. Low torque
5. Available in very small sizes

Applications

Due to noiseless operation it is used in sound recording instruments, sound producing equipments, high quality record players, electric clocks, teleprinters, timing devices et.