1.4 HYBRID STEPPER MOTOR

The word Hybrid means combination or mixture. The Hybrid Stepper Motor is a combination of the features of the Variable Reluctance Stepper Motor and Permanent Magnet Stepper Motor. In the center of the rotor, an axial permanent magnet is provided. It is magnetized to produce a pair of poles as North (N) and South (S)

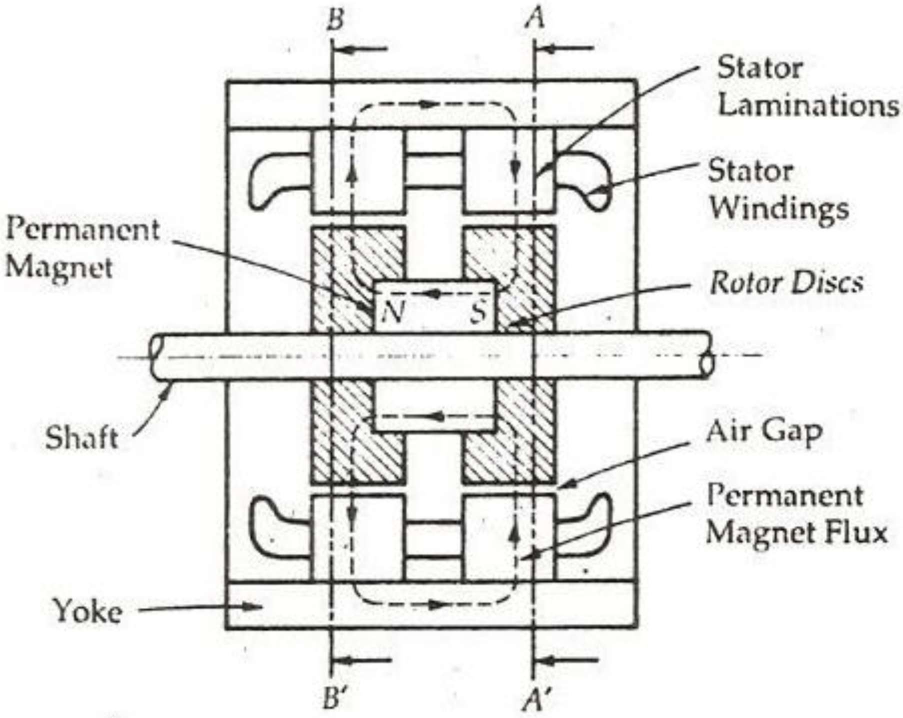

Figure 1.4.1 Hybrid stepping motor

[Source: "special electric machines" by R.srinivasan page:2.26]

At both the end of the axial magnet the end caps are provided, which contains an equal number of teeth which are magnetized by the magnet. The figure of the cross section of the two end caps of the rotor is shown below.

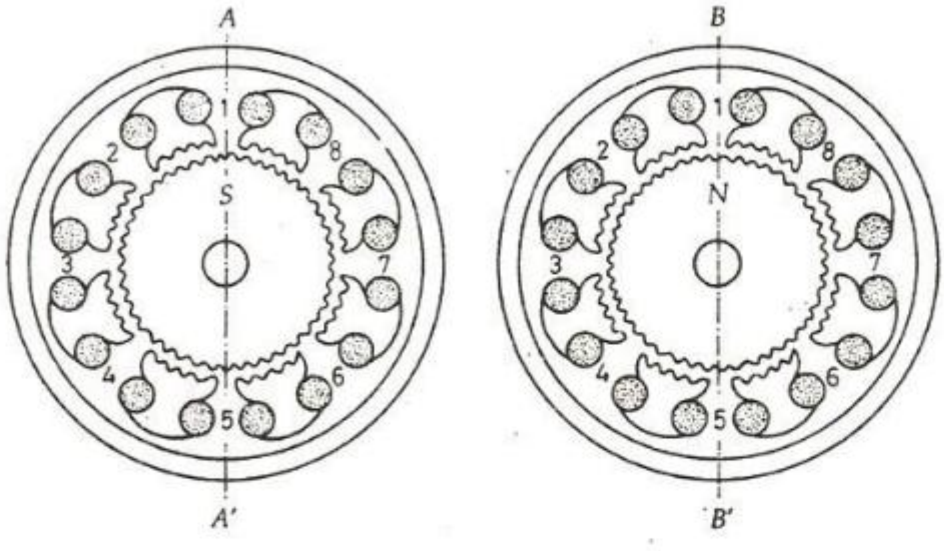

Figure 1.4.2 Hybrid stepping motor

[Source: "special electric machines" by R,srinivasan page:2.26]

The rotor teeth are perfectly aligned with the stator teeth. The teeth of the two end caps are displaced from each other by half of the pole pitch. As the magnet is axially magnetized, all the teeth on the left and right end cap acquire polarity as south and North Pole respectively.

The coils on poles 1, 3, 5 and 7 are connected in series to form phase A. Similarly, the coils on the poles 2, 4, 6 and 8 are connected in series to form phase B.

When Phase is excited by supplying a positive current, the stator poles 1 and 5 becomes South poles and stator pole 3 and 7 becomes north poles.

Now, when the Phase A is de-energized, and phase B is excited, the rotor will turn by a full step angle of 1.8^{o} in the anticlockwise direction. The phase A is now energized negatively; the rotor moves further by 1.8^{o} in the same anti-clockwise direction. Further rotation of the rotor requires phase B to be excited negatively.

Thus, to produce anticlockwise motion of the rotor the phases are energized in the following sequence +A, +B, -A, -B, +B, +A…….. For the clockwise rotation, the sequence is +A, -B, +B, +A……..

One of the main advantages of the Hybrid stepper motor is that, if the excitation of the motor is removed the rotor continues to remain locked in the same position as before the removal of the excitation. This is because of the Detent Torque produced by the permanent magnet.

Advantages of Hybrid Stepper Motor

The advantages of the Hybrid Stepper Motor are as follows:-

- The length of the step is smaller.
- It has greater torque.
- Provides Detent Torque with the de-energized windings.
- Higher efficiency at lower speed.
- Lower stepping rate.

Disadvantages of Hybrid Stepper Motor

- Higher inertia.
- The weight of the motor is more because of the presence of the rotor magnet.
- If the magnetic strength is varied, the performance of the motor is affected.
- The cost of the Hybrid motor is more as compared to the Variable Reluctance Motor.

1.5 THEORY OF TORQUE PREDICTION

According to Faradays laws of electromagnetic induction

Flux linkages $\lambda = N\upsilon$

$\lambda = Li$

Varying the current ‗i‘ of an electromagnet (i.e) equivalent of varying the mmf

Varying the reluctance $L = \frac{\tilde{N}}{S}$

By varying reluctance

mmf = Nυ

Reluctance = $\frac{1}{A\mu}$

Flux = $\frac{Ni}{S}$

Flux linkages $\lambda = \frac{N.Ni}{S} = \frac{N^2}{S}$

Inductance $L = \frac{\text{flux linkages}}{\text{Ampere}}$

$$L = \frac{N^2 i}{Si}$$

$$L = \frac{N^2}{S}$$

If the reluctance of magnetic circuit can be varied, inductance L and the flux linkages λ can also be varied.

Consider a magnetic circuit as shown in fig. 1.5.1

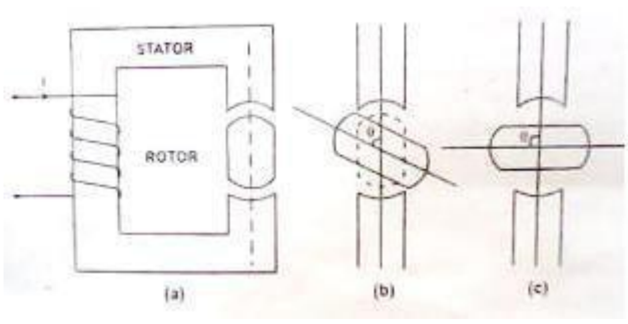

Figure 1.5.1 Magnetic circuit

[Source: "special electric machines" by Srinivasan page:2.41]

The stator consists magnetic core with two pole arrangement. Stator core carries a coil. Rotor is also made up of ferrous material. The motor core is similar to a salient pole machine. Let the angle between the axis of stator pole and rotor pole be θ. let the angular displacement be illustrated using fig. 1.5.1 (a, b and c).

Case 1: θ = 0

As shown in fig. 2.29 (a) the air gap between the stator and rotor is very very small. Thereby the reluctance of the magnetic path is least. Due to minimum reluctance, the inductance of the circuit is minimum. Let it be L_{max}

Case 2 : θ = $\mathbf{45^0}$

As shown in fig. 2.29(b) in this only a portion of rotor poles cover the stator poles. Therefore reluctance of the magnetic path is more than that of case 1.due to which the inductance becomes less than L_{max}

Case 3: θ = $\mathbf{90^0}$

As shown in fig. 2.29(c) the air gap between the stator poles has maximum value. Thereby reluctance has a value yielding minimum inductance. Let it be L_{min}.

Variation in inductance with respect to the angle between the stator and rotor poles is shown in fig. 2.30.

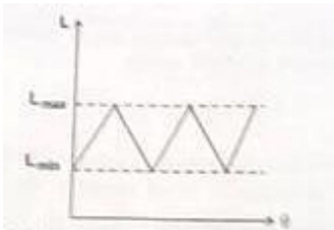

Figure 1.5.2 Magnetic circuit

[Source: "special electric machines" by Srinivasan page:2.41]

Derivation for reluctance torque

As per faradays law of electromagnetic induction an emf induced in an electric circuit when there exists a change in flux linkages.

emf induced e = - $\frac{\partial y}{\partial t}$

Where λ = NΦ or λ = Li

Therefore e = - $\frac{d}{dt}$ [Li]

$$= - L\frac{\partial i}{\partial t} - i\frac{\partial L}{\partial t}$$

$$= - L\frac{\partial i}{\partial t} - i\frac{\partial L}{\partial \theta} \times \frac{\partial \theta}{\partial t}$$

$$= - L\frac{\partial i}{\partial t} - i\,\omega\frac{\partial L}{\partial \theta}$$

Magnitude of e = $L\frac{di}{dt} + \omega\, i\frac{\partial L}{\partial \theta}$

If the direction of current I is opposite to that of e, then the electric power is transferred from the source to the inductor. On the other hand, if the direction of current I is same as that of e, then the source gets the electrical power from the inductor.

On the basis of magnetic circuit/field theory it is known that the stored energy in a magnetic field.

$$We = \frac{1}{2} Li2$$

The rate of change of energy transfer due to variation in stored energy or power due to variation in stored energy.

$$\frac{dWe}{dt} = \frac{1}{2} L.\ 2i\frac{\partial i}{\partial t} + = \frac{1}{2} i2 \frac{\partial L}{\partial t}$$

Mechanical power developed/consumed = power received from the electrical source – power due to change in stored energy in the inductor

Power received from the electrical source = ei

$$\therefore ei = i L\frac{di}{dt} + \omega^{;2} \frac{\partial L}{\partial \theta}$$

Power due to change in stored energy

$$= Li\frac{di}{dt} + \frac{1}{2}\omega i^2 \frac{\partial L}{\partial \theta}$$

Mechanical power developed

$$= i L\frac{di}{dt} + \omega i^2 \frac{\partial L}{\partial \theta} + Li\frac{di}{dt} + \frac{1}{2}\omega i^2 \frac{\partial L}{\partial \theta}$$

Mechanical power developed

$$Pm = \frac{1}{2}\omega i2\frac{\partial L}{\partial \theta}$$

$$Pm = \frac{2\pi NT}{60}$$

Pm = ωT

Where $\omega = \frac{2\pi N}{60}$

Therefore reluctance torque $T = \frac{P_m}{\omega}$

Reluctance torque $T = \frac{1}{2} i^2 \frac{\partial L}{\partial \theta}$

Note:

* Torque corresponds to monitoring when $\frac{\partial L}{\partial \theta}$ is +ve.

* Torque corresponds to generating when $\frac{\partial L}{\partial \theta}$ is -ve.

* Torque is proportional to i2 : Therefore it does not depend upon the direction of the current.