Shaded-Pole Motor [1, Ch-9 and 2, Ch-22]

For applications requiring small power ratings, 1/20 hp or less, the shaded-pole induction motor is probably most widely used today.

**Shaded-Pole Motor:** A shaded-pole motor may be defined as a single-phase induction motor provided with an auxiliary short-circuited winding or winding displaced in magnetic position from the main winding.

In usual form of construction, salient poles are used, and the auxiliary short-circuited winding consists of a single turn placed around a portion of the main pole. This coil is known as shading coil because it causes the flux in that portion of the pole surrounded by it to lag behind the flux in the rest of the pole.

**Essential Parts of a Shaded-Pole Motor [1, p. 176]:**

Fig. 9-1 gives a schematic representation of a simple shaded-pole motor. There is but a single winding which is connected to the line, a second winding permanently short-circuited upon itself, and a squirrel cage rotor.

This short-circuited winding is displaced from the main winding by an angle which can never be as much as 90 electrical degrees.

It has to be shifted from the axis of the main winding by a definite amount in order to set up a component field along an axis in space different from that of the main winding; furthermore, this shift has to be less that 90° so that a voltage can be induced in the short-circuited winding by transformer action of the main winding.

**Working Principle of a shaded pole motor[2, p. 516]:**

When a single phase ac power is applied to the stator winding, a magnetic field is created. The winding of shaded pole delays the creation of magnetic field in the portion of the stator poles. This produces a magnetic field in the shaded portion that is approximately 90° apart from the magnetic field produced in the main portion of the pole. That means two fluxes are obtained which are displaced both in time and space. The net effect of these two fluxes is moved across the pole from the unshaded portion to the shaded portion. Thus a rotating field is obtained which is always moved from the unshaded portion to the shaded portion.

The net rotating flux cut the rotor conductor thus an emf is induced in the rotor and current flows through the conductor. Thus the force is developed to the conductor of rotor and rotor start to rotate.
How a rotating field is produced in a shaded pole motor?

The shaded-pole motor is actually split-phase type as shown in Fig. 22.24.

When alternating current is applied to the field winding, there is a change of flux in the core. This change of flux causes an induced voltage in the shading coil, and this induced voltage causes a shading-coil current in such a direction as to oppose the core flux.

Since an induced current always flows in such a direction as to oppose the change in flux which induces it, the current in the shading coil delays the build up of the shading flux. The flux in the shaded part of the pole thus lags the flux in the main (unshaded) part of the pole.

Fig. 22.25 Flux in Shaded-pole motor, main-field current increasing

Fig. 22.26 Flux in Shaded-pole motor, main-field current at maximum.

Fig. 22.27 Flux in Shaded-pole motor, main-field current decreasing.
At the same time, the main flux and the shaded-pole flux are obviously displaced in space, although by less than 90°.

To obtain the rotating field, it is necessary only that there be two component fields, displaced both in time and in space. Since there are both a time and a space displacement between two fields, the conditions for setting up a rotating field are present, no matter how imperfectly. Torque is thus developed in the squirrel-cage rotor.

The movement of flux around the stator may be more clearly illustrated in the following explanation and diagrams. Only one salient pole is shown, while the shading coil is given two turns to simplify the discussion that follows:

1. If the line current is rising during its first quarter cycle, as shown in Fig. 22.25(b), the current caused by induced voltage in the shading coil opposes the setting up the flux. This current is shown in Fig. 22.25(a). The opposing magnetomotive force (mmf) of the shaded coil therefore causes most of the flux to be concentrated in the main, unshaded portion of the pole.

2. When the line current has reached its maximum positive value, as shown in Fig. 22.26(b), the flux too is at its maximum value, but now there is no change in the flux. Hence there is no current in the shading coil, and the flux is uniformly distributed across the entire pole, including the shaded portion. Essentially the field axis has shifted toward the shaded part of the pole.

3. When the line current is decreasing, the current in the shading coil must be in a direction to maintain the flux, i.e. oppose the decrease, and must therefore now reverse, as shown in Fig. 22.27(a). The concentrates the flux in the shaded-pole portion while it gets weaker in the main part of the pole. The field has thus shifted even further toward the shaded portion.

4. Finally, when the main-field current reverses, the current in the shading coil maintains some flux in that portion of the pole, although the polarity of the reminder of the pole has already reversed. This is shown in Fig. 22.28. At some time after this instant, the mmf of the main field and that of the shading acting on the shaded-pole piece will be exactly equal and opposite, resulting in zero flux through the shaded pole. The flux cycle will then repeat itself for the next half-cycle of the line current, starting first in the opposite direction.

Examine of Figs. 22.25 to 22.28 shows that the flux moves across the pole from the unshaded portion to the shaded portion, giving the effect of a rotating field. The net effect of time and space displacement is to produce a shifting flux in the air gap which shifts always toward the shading coil. Therefore, the direction of rotation of a shaded-pole motor is always from the unshaded to the shaded portion of the pole.

In the simple motor seen in the previous figures, the direction of rotation is fixed by physical construction. The motor must always rotate in the same direction as the field motion, or from the...
unshaded to the shaded portion of the poles. In most cases, therefore, the shaded poles motor cannot be reversed.

**Why the shaded pole motor is noisier than the other single phase induction motor?**

The field of the shaded-pole motor is not constant in magnitude but shifts from one side of the pole to the other. Because the shaded-pole motor does not create a truly revolving field, the torque is not uniform but varies from instant to instant. Thus this type of motor tends to make the motor noisier than it would be for a conventional split-phase or capacitor-type single phase induction motor of the same size.

**Reversible Motors**

9-11 Use of Two Motors in Tandem

Since the ordinary shaded-pole motor is inherently unidirectional, because the shading coil, reversibility poses a problem. Some manufacturers solve this problem by using two motors, one for each direction of rotation. Both rotors are mounted on the shaft, and one stator or the other is energized, depending upon the direction of the rotation desired. One such motor is illustrated if Fig. 9-17.

![Fig. 9-1 Shaded-Pole Induction Motor](image1)

9-12 Use of Two Wound Shading Coils per Pole

Fig. 9-18 shows schematically how a shaded-pole motor can be reversed if it is provided with two shading coils per pole.

![Fig. 9-18 A reversible shaded-pole motor with two auxiliary windings.](image2)

![Fig. 22.29 Reversing Shaded-Pole Motor.](image3)
One each salient pole of these motors, there are two shaded segments and hence two shading coils. The shading coils that are one pole pitch apart are connected in series, and a single-pole double-throw (SPDT) switch short-circuits either set of coils to change the direction of rotation. The circuit is shown in Fig. 22.29, with the switch in clockwise-rotation position. This places coils 1 and 3 actively in the circuit, being shorted by reversing switch. Coils 2 and 4 remain in series with each other, but are on open circuit and so are inactive.

The main field flux is shown increasing vertically downward, and the arrow on the shaded coils show the current in them. It thus seen that the shading coils must be connected in such a manner as not to have their induced voltages in opposition, or there may not be any current in them, and hence no flux lag.

**Advantages of shaded-pole motors:**

(i) Rugged construction
(ii) There are no brushes, no commutator, no capacitor, no moving switch, no governor, no slip-rings.
(iii) Cheaper in cost
(iv) Small in size
(v) Requires little maintenance
(vi) Its stalling locked-current is only slightly higher than its normal rated current so that it can remain stalled for short periods without harm.

**Disadvantages of shaded-pole motors:**

(i) Very low starting torque
(ii) Low efficiency due to the presence of harmonics in the winding current particularly third harmonics.
(iii) Low power factor

**Applications:**

Shaded-pole motors have many applications, among which are fans, blowers, heaters, vending machines, hair dryer, slide and moving projectors, advertising displays, rotisseries etc..

**Characteristics of a Shaded-Pole Motor**

The torque versus speed characteristic curve of a shaded pole motor is shown in the following figure. It is seen from the figure that the speed of a shaded pole motor can be control by varying the applied voltage.
Remember:
# The shaded pole motor is only a very small fractional horsepower motor.
# The direction of rotation is from unshaded to the shaded portion of the pole face.
# The field of the shaded-pole motor is not constant in magnitude but shifts (rotates) from one side of the pole to the other.

Problem: A 6 W, 115 V, 60 Hz, 2 poles shaded-pole induction motor operates at 2900 rpm when the input power is 21 W. Calculate (i) the full-load efficiency, and (ii) the slip.

Solution:
\[
\eta = \frac{P_o}{P_i} \times 100\% = \frac{6}{21} \times 100\% = 28.6\%
\]
\[
N_s = \frac{120f}{P} = \frac{120 \times 60}{2} = 3600 \text{ rps}
\]
\[
s = \frac{N_s - N_r}{N_s} = \frac{3600 - 2900}{3600} = 0.194 \text{ or } 19.4\%
\]

Possible Questions:
1. Define the shaded-pole motor.
2. What are the essential parts of a shaded-pole motor?
3. Define shading-coil of a shaded-pole motor.
4. Briefly describe the working principle of a shaded-pole motor.
5. How a rotating field is produced in a shaded pole motor?
6. Why the shaded pole motor is noisier than the other single phase induction motor?
7. What are the method to reverse the rotation of a shaded pole motor?
8. Briefly describe any one method to obtain the reverse operation of a shaded-pole motor.
9. List the advantages of a shaded-pole motor.
10. List the disadvantages of shaded-pole motor.
11. List the applications of shaded-pole motor.

References