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Electric Motor / Energy and Power

Calculation of shaded-pole motor losses and efficiency at full load in 6 steps

By Edvard Csanyi  | Jan, 17th 2018 | 5 comments | Translate| Save to PDF

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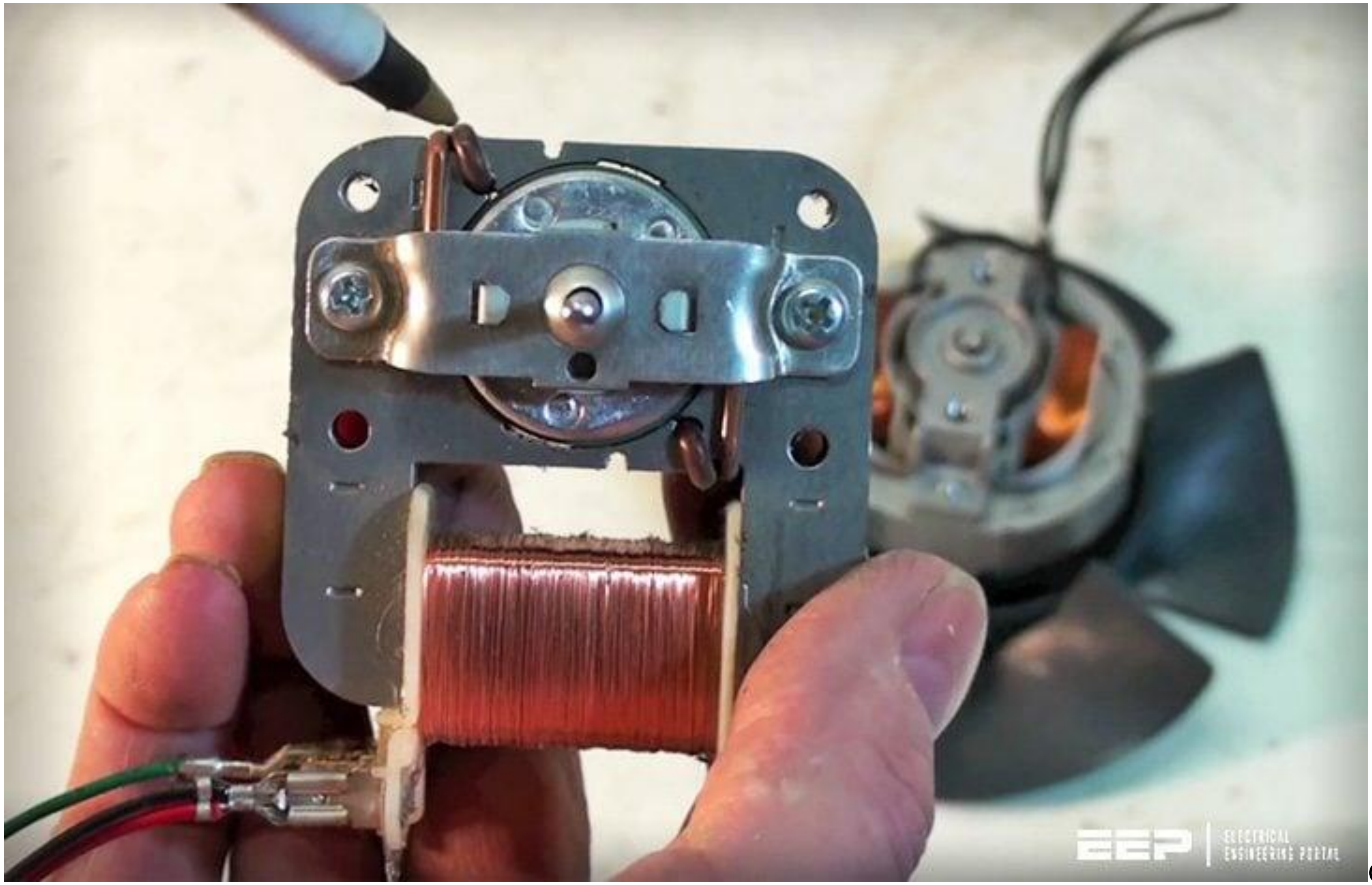
The basics of shaded-pole motors

First, let's say few words about shaded-pole motors, and then dive into calculation procedure. A shaded pole motor is the simplest form of a single phase motor and is very low in cost.



Calculation of shaded-pole motor losses and efficiency at full load in 6 steps (photo credit: grayfurnaceman via Youtube)

It develops a rotating field **by delaying the build up of magnetic flux through part of the pole structure**. The shaded portion of the pole is isolated from the rest of the pole by a copper conductor that forms a single turn around it.
The magnetic flux in the unshaded portion increases with the current through its winding. Magnetic flux increases in the shaded portion.

However, it is delayed by the current induced in the copper field.

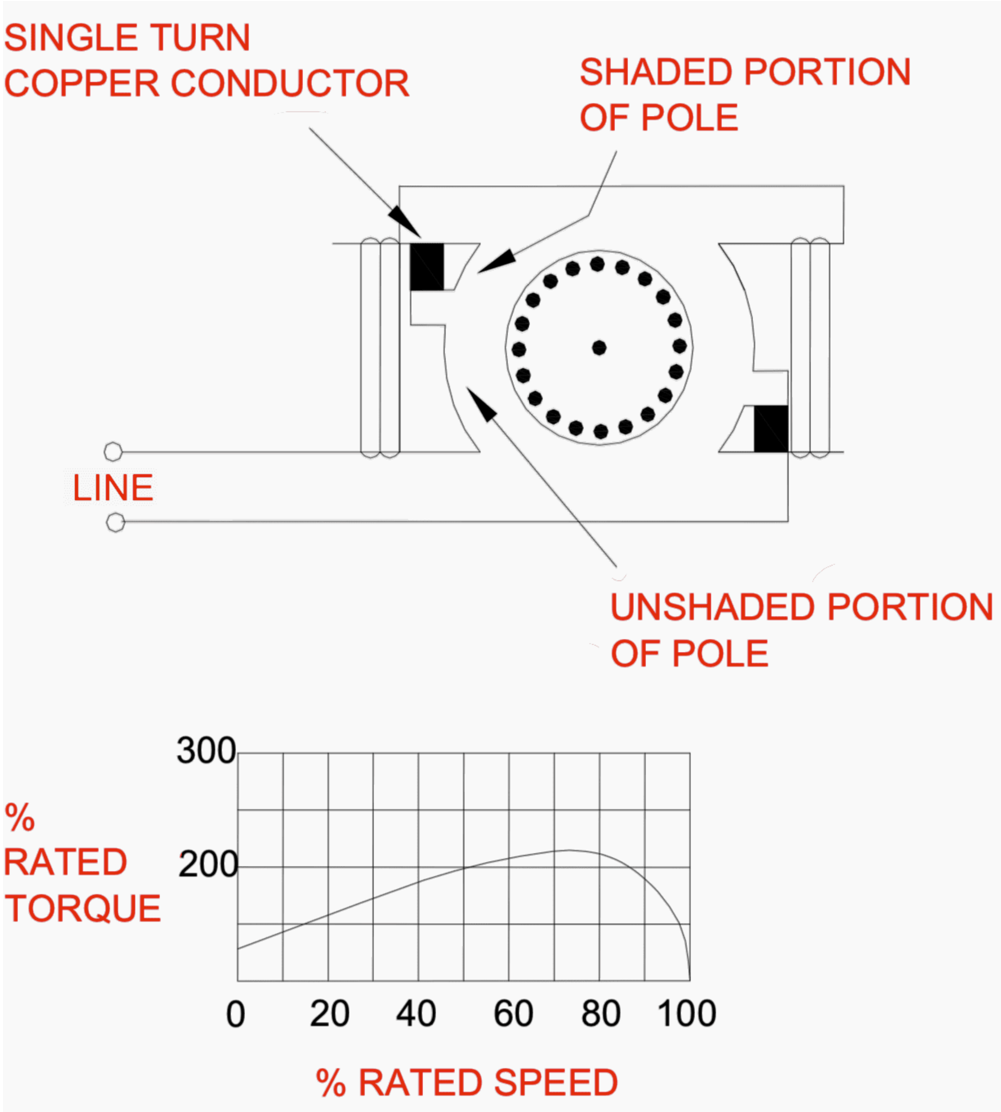


Figure 1 – Basic construction of shaded-pole motor

The magnetic field sweeps across the pole face from the unshaded portion to the shaded portion, developing a torque in the squirrel cage.

To maximize torque, the rotor is made with relatively high resistance.

Shaded pole motors are used **where low torque is acceptable (such as fans)** and are usually **less than 1/4 HP**. Due to their very low efficiency, shaded pole motors should only be used in applications where the motor is either very small or operates for very short periods of time (e.g. shower fan motor).

Calculation Procedure

A four-pole shaded-pole motor (Figure 2) has the following data associated with it:

- Nominal voltage 120 V,
- Full-load delivered power of 2.5 mhp (millihorsepower),
- Frequency 60 Hz,
- 350-mA full-load curent,
- 12-W full-load power input,
- 1525 r/min full-load speed,
- 1760 r/min no-load speed,
- 6.6 W no-load power input,
- 235 mA no-load current, and
- Stator resistance measured with DC of 30.

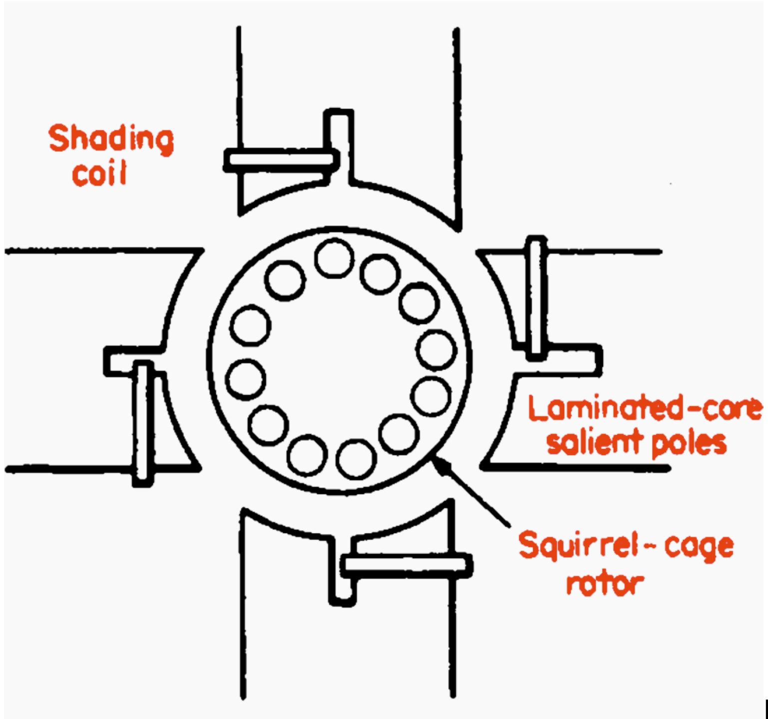


Figure 2 – Four-pole, shaded-pole motor with a squirrel-cage rotor

Calculate the losses and efficiency at full load.

Step #1 – Calculate the Rotational Losses

From the no-load conditions, consider that the rotational losses of friction and windage are equal to the power input less the stator-copper loss. The stator resistance, measured with dc, was found to be **30 Ω**.

This is not the same as the effective AC value of resistance, which is influenced by nonuniform distribution of current over the cross section of the conductors (skin effect). **The increase of resistance to ac as compared with dc may vary from 10 to 30 percent**, the lower values being for small or stranded conductors and the higher values for large, solid conductors.

Assume a value of 15 percent for this problem. The rotational losses P_{fw} equal:

P_{fw} = $P_{NL} – I_{NL}^2(R_{dc})$ = 6.6 W – (235 × 10^{-3} A)^2(30 Ω)(1.15) = 6.6 W – 1.905 W = **4.69 W**
(**R_{dc}** is dc-to-ac resistance-correction factor)

Step #2 – Calculate Stator-Copper Loss at Full Load

At full load the stator-copper loss P_{scu} is:
P_{scu} = $I_{FL}^2(R_{dc})$(350 ×10^{-3} A)2(30 Ω)(1.15) = **4.23 W**

Step #3 – Calculate the Slip

The synchronous speed for a four-pole machine is obtained from the relation **n = 120 f/p**, where **f** frequency in Hz and **p** the number of poles.
Thus, **n = (120)(60)/4 = 1800 r/min**.
Since the actual speed is 1525 r/min at full load, the slip speed is **1800 – 1525 = 275 r/min**, and the slip is **(275 r/min)/(1800 r/min) = 0.153 or 15.3 percent**.

Step #4 – Calculate Rotor-Copper Loss at Full Load

In induction machines, the rotor-copper loss is equal to the power transferred across the air gap multiplied by the slip. The power transferred across the air gap equals the input power minus the stator-copper loss. Thus, at full load:

P_{rcu} = (12 W – 4.23 W) (0.153) = **1.2 W**

Step #5 – Summarize the Full-Load Losses

Stator-copper loss	4.23 W

Rotor-copper loss	1.2 W
Friction and windage loss	4.69 W
Total losses	**10.12 W**

Step #6 – Calculate the Efficiency

The motor delivers **2.5 mhp**. The input is **12 W** or (12 W)(1 hp/746 W) = **16.1 mhp**.
Therefore, the efficiency is:
η = (output)(100 percent) / input = (2.5 mhp)(100 percent) / 16.1 mhp = **15.5 percent**
Alternatively, the developed mechanical power is equal to the power transferred across the air gap multiplied by:
(1 – s), or (12 W – 4.23 W)(1 – 0.153) = **6.58 W**.
From this must be subtracted the friction and windage losses:
6.58 – W 4.69 W = 1.89 W, or (1.89 W)(1 hp/746 W) = **2 .53 mhp**.
The efficiency is:
η = (input – losses)(100 percent) / input = (12 W – 10.12 W)(100 percent)/12 W
η = 15.7 percent.

References:

- Electric Motors – Energy Efficiency Reference Guide by CEA Technologies Inc.
- Handbook Of Electric Power Calculations by H. Wayne Beaty

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https://youtu.be/wHhhj8IHq5c?si=j8nZ30EWRlaJp61z

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