An Investigation on Stator Copper Loss by Using Different Stator Slot Size

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***Abstract*—The input power to an induction motor is in the form of three phase electric voltages and currents. The first losses encountered in the machine are I2R losses in the stator winding. The stator copper loss occurs when the stator windings is energized. This can be reducing by increasing the stator slot size. This paper present the investigation on the stator copper loss effect between two different stator slot size which is 6mm and 8mm using 2D Finite Element Analysis (2D-FEA), model of 0.5hp induction motor.**

***Index Terms*—Induction motor, stator slot, copper loss.**

I. Introduction

Induction machine is the most used of all electric motors. It is generally easy to build and cheaper than corresponding dc or synchronous motors. The induction motors is rugged and require little maintenance [1]. The ac induction consists of stationary member, called the stator and the rotating member, called the rotor.

An induction motor can be basically described as a rotating transformer. The input power to an induction motor P_{in} is in the form of three phase electric voltages and currents. The first losses encountered in the machine are I^2R losses in the stator windings (*the stator copper loss* P_{SCL}). Then some amount of power is lost as hysteresis and eddy currents in the stator (P_{core}). The *air-gap power* P_{AG} is the power transferred to the rotor of the machine across the air gap between the stator and rotor. After the power is transferred to the rotor, some of it is lost as I^2R losses (*the rotor copper loss* P_{RCL}), and the rest is converted from electrical to mechanical form (P_{conv}). Finally, friction and windage losses $P_{F\&W}$ and stray losses P_{misc} are subtracted. The remaining power is the output of the motor P_{out} [2].

AC power is used to energize the stator windings. The stator copper loss is occurs when the stator windings are energized. However small, it will cause power losses. This is due to heat generated or I^2R heat losses resulting from the current flowing in the windings. The value of the winding resistance will increase with temperature and this will depend on the current loading and the effectiveness of the overall cooling of the machine [3]. In this paper, the effect of different stator slot size on the stator copper loss is presented.

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II. The Design Specification

Table I shows the stator slot specification of the induction motor.

TABLE I: Design Specification of Induction Motor

Motor parameter	Value
Horse power	0.5
Phase [Φ]	3
Pole	4
Frequency [Hz]	50
Electrical steel material thickness [mm]	0.35
Outer diameter of stator[mm]	180
Inner diameter of stator[mm]	68
Stator slot width A [mm]	6
Stator slot width B [mm]	8
Number of Stator slot	24

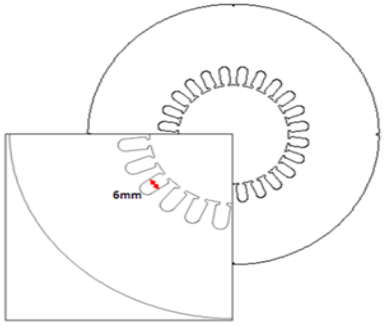

Fig. 1. Stator slot width 6mm

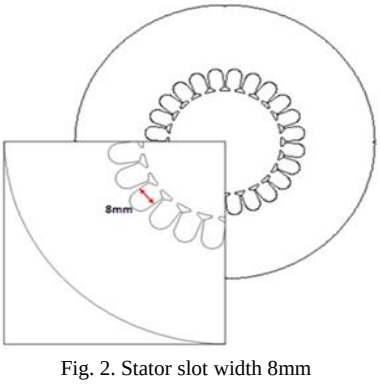

Fig. 2. Stator slot width 8mm

This parameter is important as it is used to simulate the FEM software. From this, the result is obtain and used to calculate the stator copper loss of the two stator slot design. The stator teeth are design with parallel sides to avoid localized saturation within the teeth [4].

III. The Analysis Method

After the motor design specification from Table I is inserted into the FEM software data, it is simulated by using

AC analysis solver for two different stator slot size which is 6mm and 8mm design base as shows in Fig. 1 and Figure 2. Based on simulation, results from two different stator slot size are analyzed and its properties differences are stated. In this simulation, copper conductivity is used and the model of copper is 5.77e7sm^{-1}and the number of turns for coil windings is 60.

IV. Finite Element Analysis Results and Discussion

Finite- element analysis (FEA) is used to examine the stator copper loss between two stator models. The proportion of copper loss to total loss is greater than iron loss in induction motors. The result obtained from the FEA, Table 2 shows the nameplate while Fig. 3 and 4 shows the parameter of the 0.5HP induction motor equivalent circuit of two different stator slot size.

TABLE II: 0.5HP Induction Motor Nameplate for Both Stator Slot Size

Stator slot size	6mm	8mm
Phase	3	3
Frequency	50	50
Voltage	415	415
RPM	1425	1425
Current	1.5382	1.6915
Efficiency	75.43	77.65

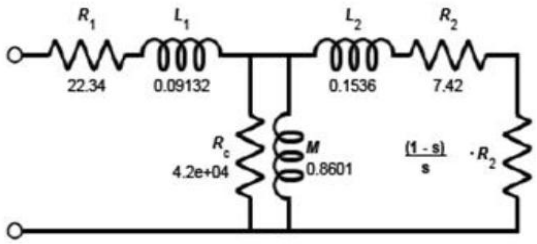

Fig. 3. 0.5Hp induction motor parameter (equivalent circuit) for stator slot size 6mm

From Table II, the stator slot size of 8mm is more efficient than stator slot size of 6mm. The equivalent circuit in Fig. 3 and Fig. 4 shows that the value of R_1 for 8mm stator slot size which is 17.0338Ω is lower than value of R_1 for 6mm stator slot size which is 22.3365Ω. From this value, the stator copper loss can be determine by using formula $P_{SCL} = 3I_1^2R_1$

For stator slot 6mm,

$$P_{SCL} = 3I_1^2R \quad (1)$$
$$= 3(1.5382)^2(22.3365)$$
$$= 158.55watts$$

For stator slot 8mm,

$$P_{SCL} = 3I_1^2R_1 \quad (2)$$
$$= 3(1.69149)^2(17.0338)$$
$$= 146.21watts$$

The calculation shows that at speed 1425 rpm, the design with stator slot of 8mm shows less stator copper loss compare to stator slot measurement of 6mm, same as shows in Fig. 5 and Fig. 6. Stator copper loss of stator slot 8mm is 146.2watts and the stator copper loss of stator slot 6mm is 158.5watts as shows in Fig. 7. This is due to the increase of the stator slot size will decrease the resistance of the stator coil, thus the stator copper loss is reduced [5].

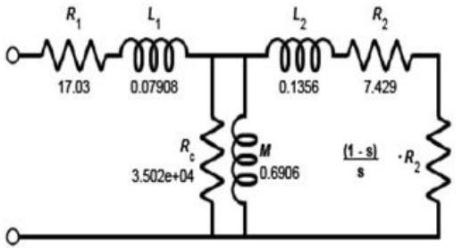

Fig. 4. 0.5Hp induction motor parameter (equivalent circuit) for stator slot size 8mm

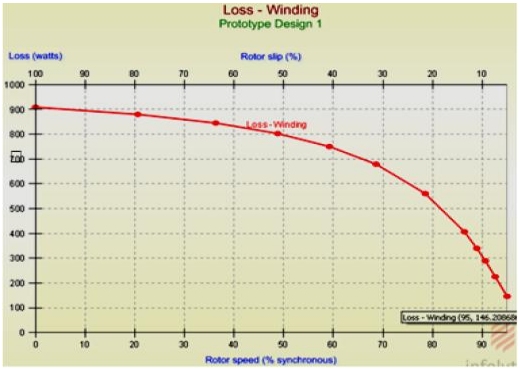

Fig. 5. Graph of stator copper loss for stator slot width 8mm

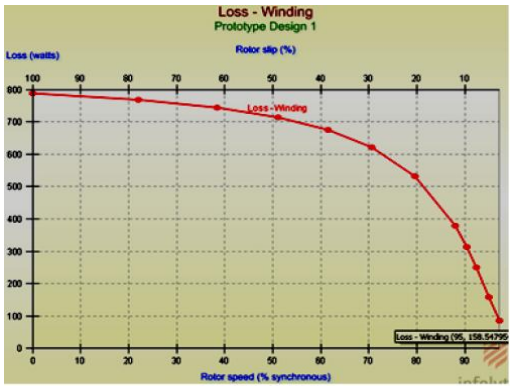

Fig. 6. Graph of stator copper loss for stator slot width 6mm

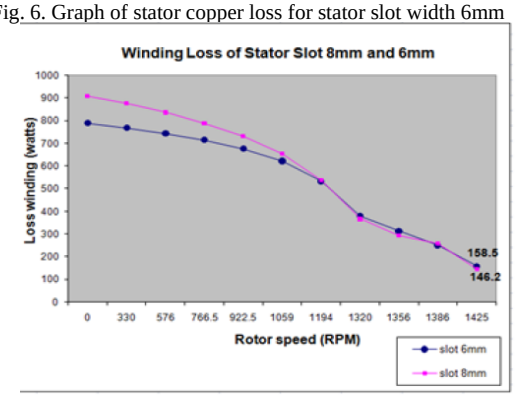

Fig. 7. Graph of stator copper loss for stator slot width 8mm and 6mm

V. Conclusion

The effect of different stator slot size on the stator copper loss using 2D-FEA was proposed. We may conclude from the results that the stator copper loss is reduced by increasing the stator slot area. By increasing the stator slot area from 6mm to 8mm, 7.78% of stator copper loss can be

reduced. This can save several amount of energy that was consumed by the induction motor.

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