Effect of Poles Embrace on Switched Reluctance Motor Design

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***Abstract*—Vehicle expansion and traffic congestion issues today become the causes on the growing of small electric vehicle such kick scooter and electric bicycles. Switched Reluctance Motor (SRM) has been choose as the right candidates to drive this small scale electric vehicle due to the advantages on simple construction and wide constant power region and effective torque speed characteristic.To build SRM, a proper design procedure must be performed to ensure an efficient performance of the motor. Commonly, to design this motor, only a few basic design consideration has been taken into accounts such, no of phases, stator pole arc, air gap thickness, and other SRM geometry. Thus, pole embrace effect has been investigated to know the effect on the design in order have a good performance of SRM. The test has been conducted using ANSYS FEA simulation by varying the stator and rotor pole embrace incrementally from 0.2 to 0.5. The pole embrace will be choose according to highest torque average and lowest torque ripple percentage. As the result, the chosen value for rotor pole embrace is 0.4 and 0.45 for stator pole embrace to design motor.**

***Keywords*— Electric Vehicle; Switched Reluctance Motor; Pole embrace; ANSYS FEA;**

I. INTRODUCTION

The Electric Vehicle (EV) hold a promising potential to deal with the problem of air pollution. But, due to the vehicle expansion and traffic congestion issues today, a small EV has growing attraction as a way out of transportation type. Currently, a small EV such as kick scooter or electric bicycles become more attractive. Even though these types of applications are always known for recreational activities and for short distance travel, it can only become a solution as a transportation mode once it has been modified. Besides, the lightweight built, environmentally friendly, and compact features can reduce the need of parking space and overcome the traffic jam problem [1].

A fully EV can constitute a zero emission vehicle. It use electric motor for propulsion and battery as storage device [2]. Rapid development in power electronic fields and powerful switching devices let another electric motor, SRM, to replace common electric motor in Electric vehicle development such Induction Motor, PMSM, DC motor as a traction system in EV. SRM has advantages such as simple construction due to its structure, wide constant power region at high speed, high fault tolerance, and effective torque–speed characteristics and robust construction. SRM offers several advantages to fulfill EV application development. In order to have an optimum design, its starts with the determination of motor dimensions or design geometry. The research need were fulfil by using several methods to define dimensions of SRM so a pre-exact figure can be obtained. Usually, to build a SRM, a proper design procedure must be performed in order to ensure efficient performance of the motor. Commonly, to design this motor, only a few basic design consideration has been taken into accounts such, no of phases, stator pole arc, air gap thickness, and other SRM geometry[3].

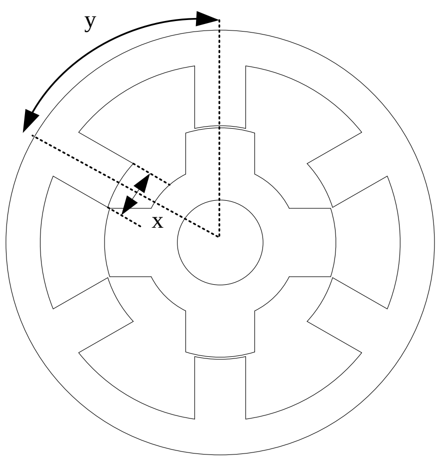


Fig. 1. Definition of stator pole arc to pole pitch of SRM

To have a good performance of SRM, one of the factor has to been taken is the pole embrace. Generally, embrace coefficient of SRM will influence the rotor and stator tooth width. Pole Embrace is defines as ratio of pole arc (x) to pole pitch (y) [4]as in Fig. 1. The changes in pole embrace will affect the output of motor in terms of torque ripple and average of torque. The importance of pole embrace is highlighted to meet the motor condition regarding on the starting capability, the minimum value of inductance during the misaligned condition of the diametrical poles, and while minimizing the switching frequency of phase winding.

In order to ensure the machine have a self-starting at any rotor positions, the selection of pole arcs need an attention. In this case, βs and βr must have a minimum angle of 30 degrees and βs+βr must be less than 90 degrees. Then, the feasible triangle can be used to determine both pole arcs. Fig.2 shows that the stroke angle of this motor is 30 degree. The range of stator pole arcs is from 30 to 45 degree. Meanwhile, rotor pole arc is from 30 to 60 degree. Pole embrace is defined as the ratio of pole arc to pole pitch. This value was not restricted to the design. It might be changed due to the fine tune process.

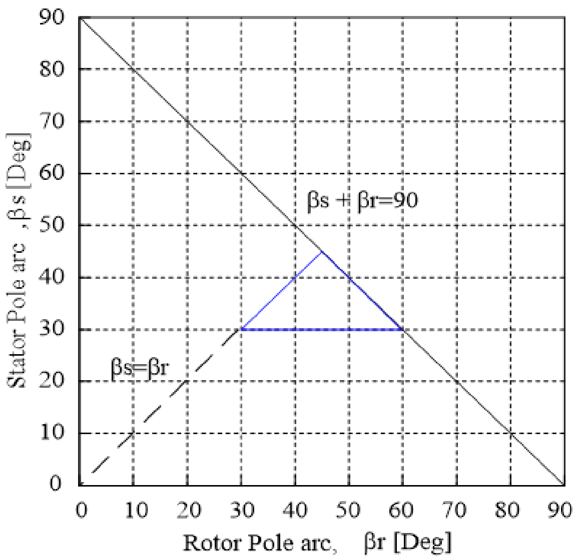


Fig.2. Feasible Triangle of 6/4 SRM

II. SIMULATION ANALYSIS

This section will explained on the simulation method to determine the effect of pole embraces variation. The pole embrace is defined as the ratio of the actual pole arc to the maximum pole angle. The maximum pole angle is 90 mechanical degrees for a four pole motor. If the actual pole arc is 45 mechanical degrees, the ratio is 0.5.To investigate the effect of pole embrace on Switched Reluctance Motor, ANSYS FEA is used to execute the task. The simulation runs with a few combination of pole embrace to achieve highlighted condition. In this study, the effect of pole embrace was investigated by varying the pole embrace step by step by changing the rotor and stator parametrically as in Table I .

TABLE I. ROTOR AND STATOR POLE EMBRACE VARIATION

Pole Embrace	
Rotor	Stator
0.2	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50
0.25	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50
0.3	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50
0.35	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50
0.4	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50
0.5	0.20
	0.25
	0.30
	0.35
	0.40
	0.45
	0.50

In FEA, pole embrace for both pole can vary from 0 to 1. But in this study, the value of stator pole embrace and rotor pole embrace is varied from 0.2 to 0.5 only. According to [5,6], experience designer chose to use 0.4 to 0.5 pole embrace as the ratio of rotor pole embrace while stator pole embrace is in the range of 0.3 to 0.45 value. Using FEA software, rotor pole embrace was set to constant value from 0.2 value while the stator pole embrace was varied from 0.2 to 0.5 value with step 0.05 value. The output of torque and torque ripple were measured and the best combination of stator and rotor pole embrace was used for further analysis.

III. Simulation Results

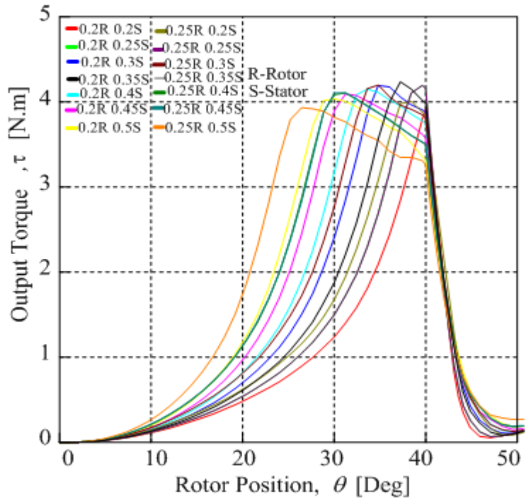
This section will present the result of effect on pole embrace on SRM modeling. The result shows effect on the output torque profile. The maximum torque, average torque and percentage of torque ripples had been measured to know which pole embrace combination gives the optimum output of SRM in term of torque production.

A few tests on pole embrace combinations had been executed. Fig. 3. Show the results on the effect of pole embrace at different combinations of pole embrace stator and rotor. Fig. 3(a) shows that the combinations of pole embrace for constant 0.2 rotor pole with variations of stator pole embrace start from 0.2 to 0.5.

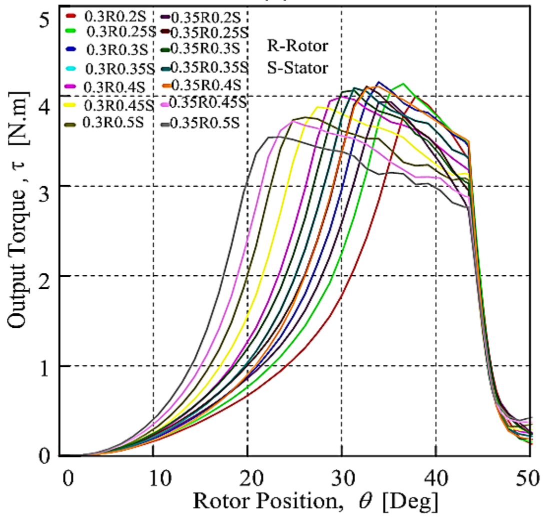
Findings show that combination of 0.2 value rotor pole and 0.5 stator pole produce high peak average torque at 1.91 N.m with maximum torque of 4.046 N.m, with 78.7 % torque ripple percentage. Meanwhile, for combination of stator and rotor pole at 0.2 value, the result shows that it produces average torque of 0.96 with 103.47% ripple torque percentage. For 0.25 value of rotor pole embrace, high average torque is at 0.4 and 0.5 stator pole with 72.7% ripple torque. Next, Fig. 3(b) shows that the highest average torque produced is from combination rotor pole 0.3 and 0.5 stator pole. It produces 62.2% torque ripple percentage. The lowest average torque produced is at 0.3 rotor pole embrace and 0.2 stator pole embrace with 1.49 N.m average torque.

Meanwhile, for 0.35 rotor pole embrace, stator pole embrace 0.5 value produced the lowest torque ripple percentage at 57.26% with 2.16 N.m average torque. The highest torque ripple is produced at combination 0.35 rotor pole and 0.2 stator pole at 81.4% ripple torque with 1.64N.m average torque.

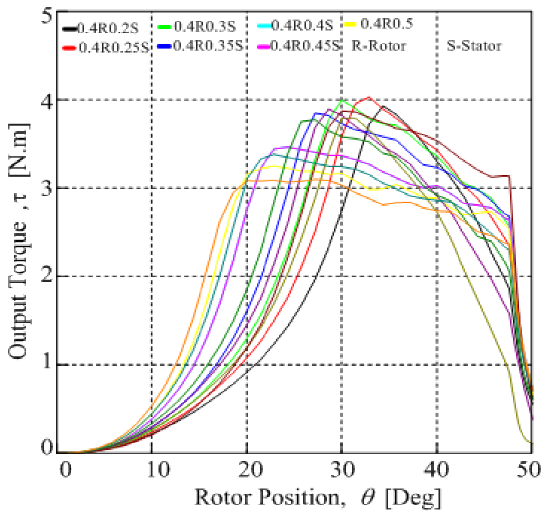
Fig. 3(c) shows that the highest torque average is produced at combination 0.4 rotor pole embrace and 0.5 stator pole embrace giving 2.17 N.m at 50.36% torque ripple. There are three combinations that stator pole embrace give almost the same value on peak average but different ripple percentage. The value is 0.35, 0.45, and 0.5 stator pole embrace. Next, for 0.45 rotor pole embrace, 0.5 stator pole value produced high average torque of 2.14 N.m with 40.7% torque ripple. Based on Fig. 3(d), combination 0.5 rotor pole embrace with 0.5 stator pole gives the lowest torque ripple at 37.16% with average torque of 1.9 N.m.



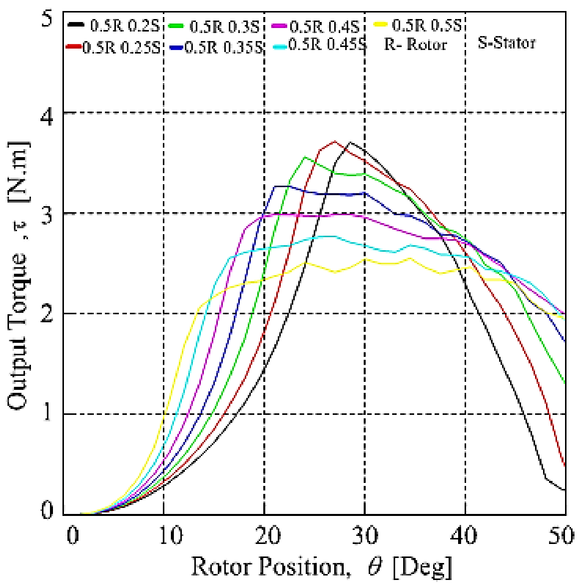
(a)



(b)



(c)



(d)

Fig.3. Effect of Pole embrace on Stator and Rotor Pole

IV. CONCLUSION

Based on the above findings, the trend to set up the rotor pole embrace shows that a larger stator pole slot can result in lowest torque ripple. The increasing of stator slot will result in lowest torque ripple. In order to have a high torque average, the stator slot must be set from 0.35 to 0.5 in range according to the simulation test. Other findings show that the increasing of stator pole embrace will produce width variation of torque profile and less torque ripple. This is due to the minimized factor of inductance value while misaligning condition for stator and rotor.For further analysis, the value of stator and rotor pole embrace was chosen in the range of 0.35 to 0.45. Meanwhile, rotor pole embrace was set from 0.4 to 0.5 stator pole embrace. This is because, the value for average torque is high and the torque ripple value is low. Thus, the chosen value for rotor pole embrace is 0.4 and 0.45 for stator pole embrace to design ,

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