SynRM Rib optimal Design for High-Power Density

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Background

In this paper, we have studied the Open Rib Structure in design of Synchronous Reluctance Motor (SynRM). In the case of SynRM, mechanical stress is concentrated on the rib structure supporting the segment at high speed rotation, and the stiffness analysis results in the largest mechanical stress on the rib of q-axis. On the other hand, it was confirmed that relatively low mechanical stresses were distributed in the case of the d-axis rib. And we can find that increases the magnetic flux leakage and is an inappropriate design method for reducing the output power. In order to prevent this phenomenon, We have devised a structure that eliminates the bridges and ribs that reduce the output characteristics. 3D-printing technique was used to solve the stiffness problem caused by omitting the rib structure. The validity of this design was verified through fabrication and testing.

Objectives

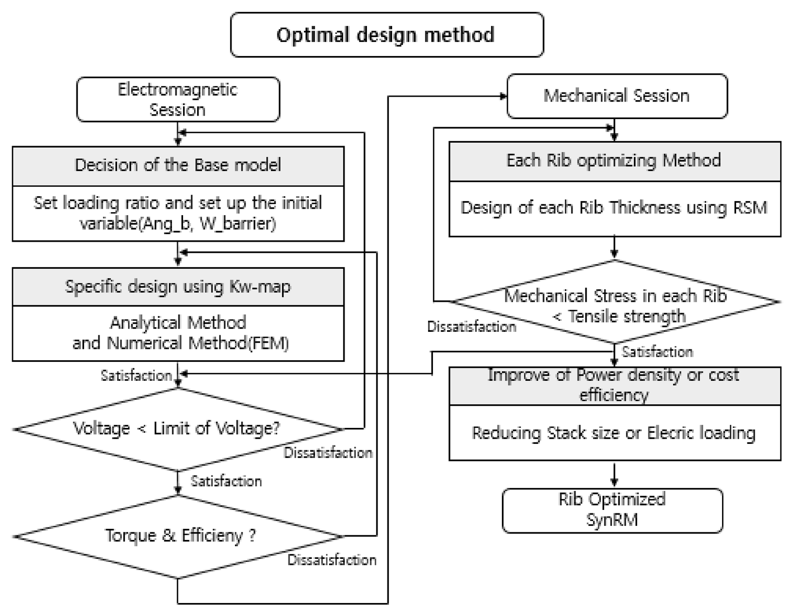
- ❖ To improve the output density of a synchronous reluctance motor, a design method of omitting the rib structure was devised.

Conclusion

- ❖ In this paper, the improvement of output characteristics of synchronous reluctance motor is studied.
- ❖ Magnetic Equivalent Circuit was used to analyze the factors affecting the output of the synchronous reluctance motor
- ❖ We have devised a method to improve characteristics by analyzing existing models.
- ❖ We have devised a structure that eliminates the bridges and ribs that reduce the output characteristics.
- ❖ 3D-printing technique was used to solve the stiffness problem caused by omitting the rib structure.
- ❖ The validity of this design was verified through fabrication and testing.

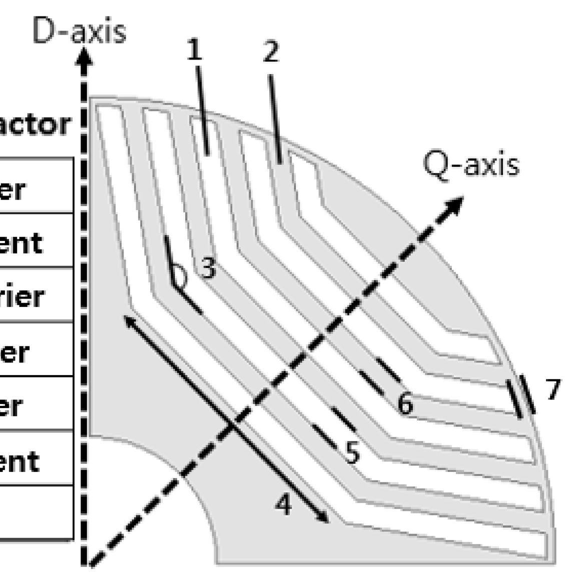
Introduction

Design Flowchart & Main Parameters of SynRM



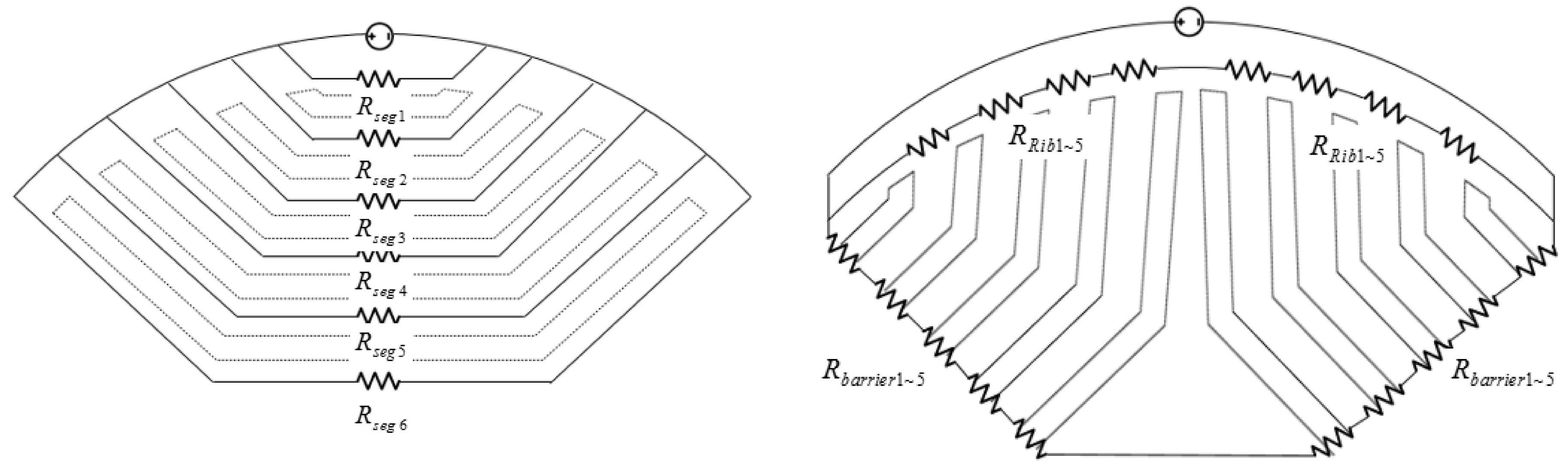
Main Design Factor

1.	N_Barrier
2.	N_Segment
3.	Ang_Barrier
4.	W_Barrier
5.	T_Barrier
6.	T_Segment
7.	T_Rib



- ❖ A flowchart for designing a synchronous reluctance motor was studied.
- ❖ Factors influencing the output were derived.

Magnetic Equivalent Circuit (a) D-axis, (b) Q-axis



- ❖ Magnetic Equivalent Circuit was used to analyze the factors affecting the output of the synchronous reluctance motor.

Equation of Synchronous Reluctance Motor

$$T_r = \frac{3}{2}\frac{P}{2}(L_d - L_q)i_d i_q \qquad PF = \left(\frac{L_d}{L_q} - 1\right) / \left(\frac{L_d}{L_q} + 1\right)$$

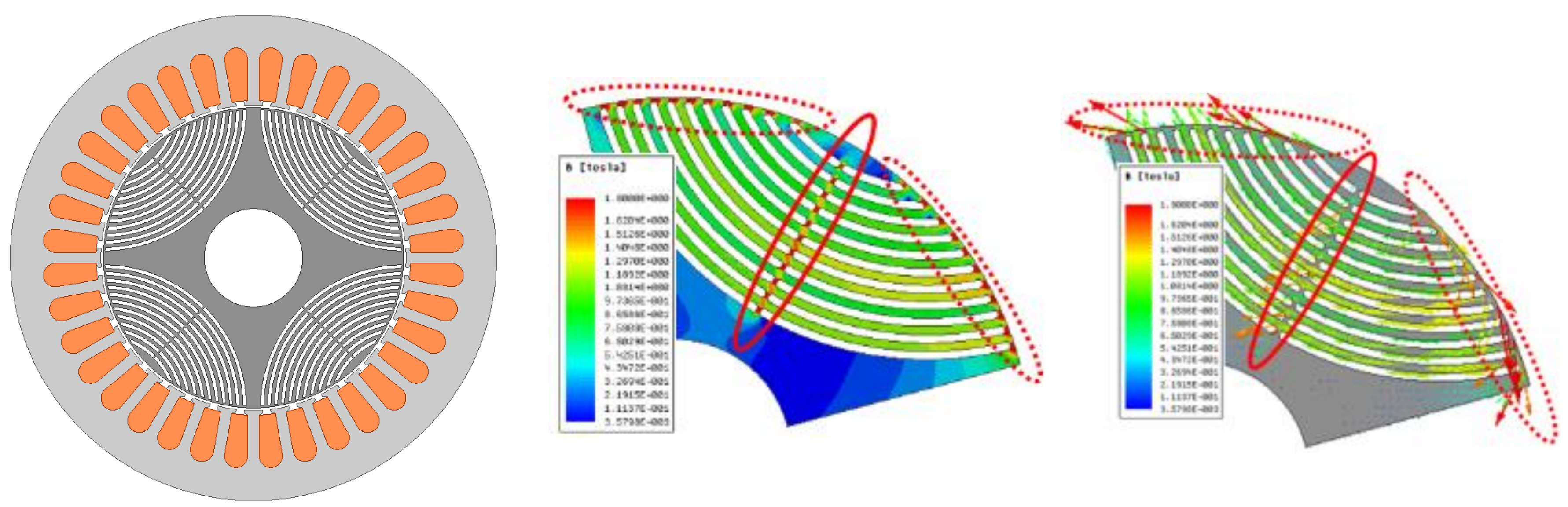
$$R_{seg1\sim5} = \frac{l_{seg1\sim5}}{\mu_{iron}\mu_o A_{seg1\sim5}} \qquad L_d = \frac{N^2}{R_{segment1\sim5}}$$

$$R_{barrier1\sim5} = \frac{l_{barrier1\sim5}}{\mu_{iron}\mu_o A_{barrier1\sim5}} \qquad L_q = \frac{N^2(R_{barrier1\sim5} + R_{rib1\sim5})}{2R_{barrier1\sim5}R_{rib1\sim5}}$$

$$R_{rib1\sim5} = \frac{l_{rib1\sim5}}{\mu_{iron}\mu_o A_{rib1\sim5}}$$

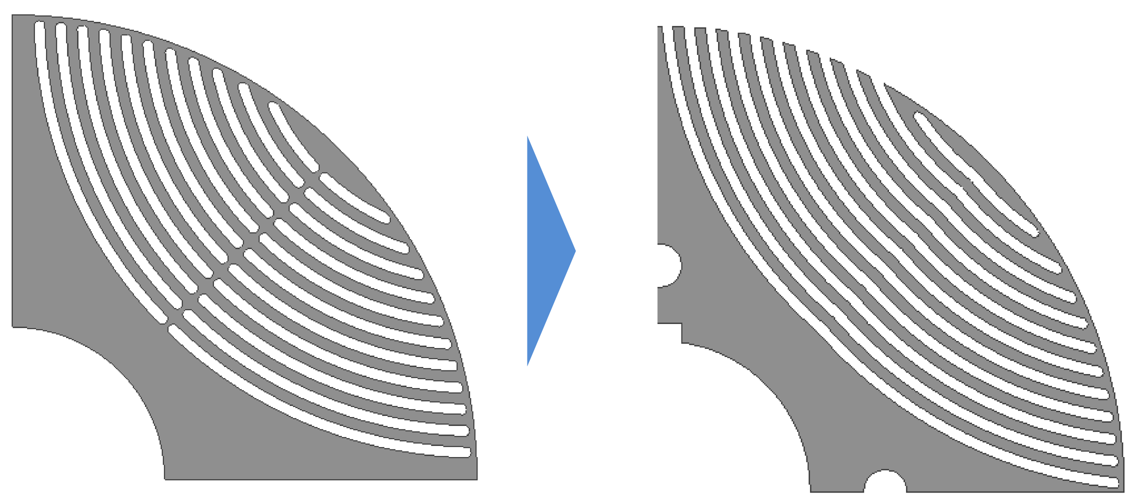
Design Process

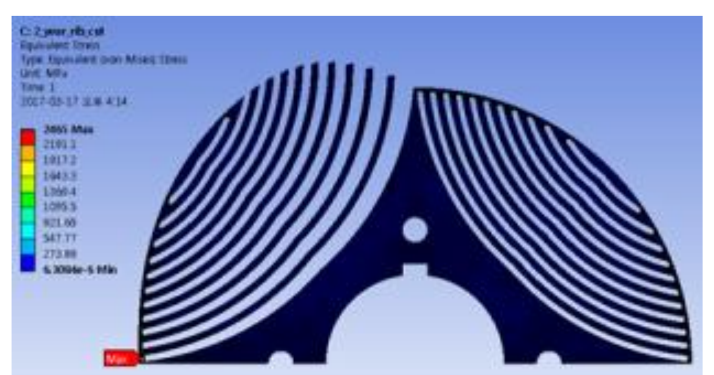
Characteristic of Existing Model



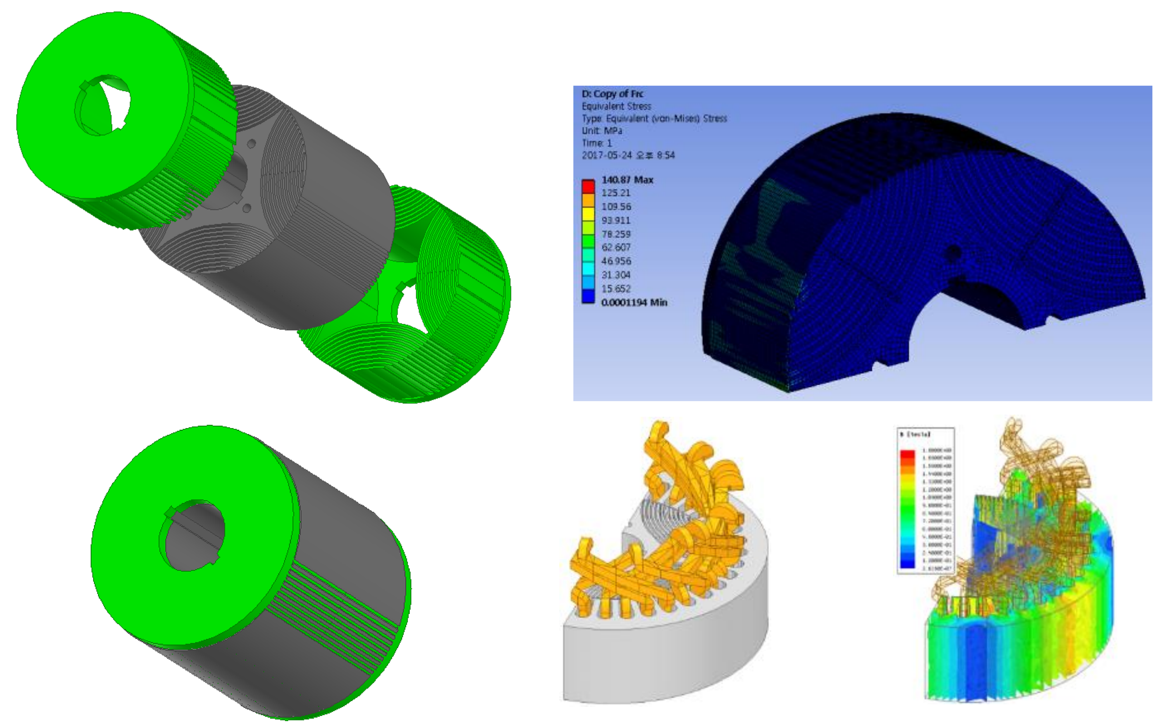
Model	Torque [Nm]	Speed [rpm]	Output Power [W]	Torque Ripple [%]	Core loss [W]	Copper loss [W]	Mechanical Loss [W]	Efficiency [%]	Power Factor	Induced Voltage [V_{peak}]	THD [%]
Existing Model	**3.3833**	1500	**531.48**	5.53	14.53	87.29	10	81.1	0.539	209.90	2.98

Process of optimal design process

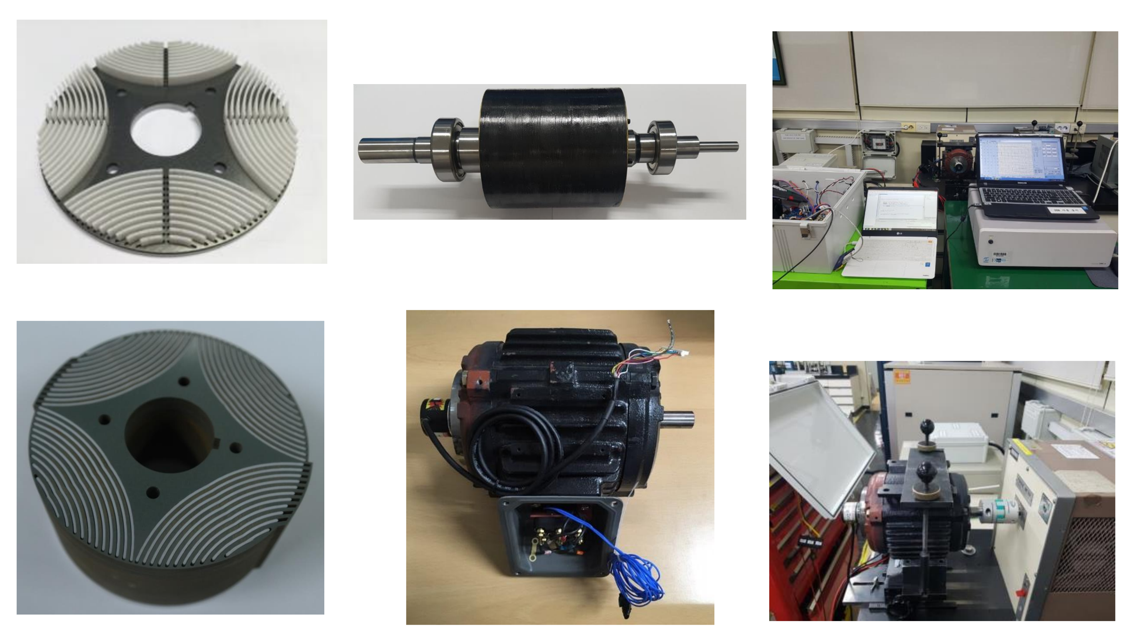




3D Printing Method and 3D Analysis



Manufacturing and Test



Model	Torque [Nm]	Speed [rpm]	Output Power [W]	Torque Ripple [%]	Core loss [W]	Copper loss [W]	Mechanical Loss [W]	Efficiency [%]	Power Factor	Induced Voltage [V_{peak}]	THD [%]
Existing Model	**3.3833**	1500	**531.48**	5.53	14.53	87.29	10	81.1	0.539	209.90	2.98
Open Rib Model	**3.6366**	1500	**571.23**	8.86	13.85	87.29	10	83.12	0.596	203.64	2.67