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Study on the Novel Design Process of Working Bar of Double cage Induction Motor

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Abstract

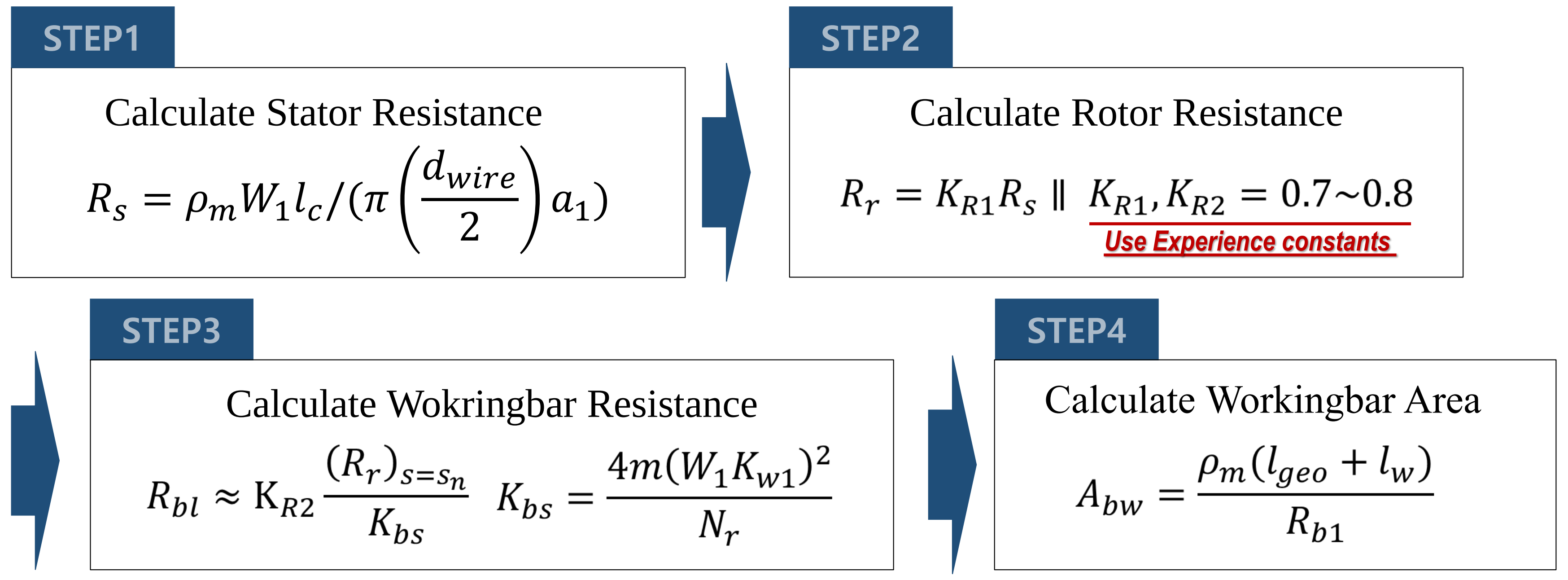
The induction motor is the most commonly used energy-consuming facility, which has great improvement effect in high-efficiency design. Double cage type rotor is designed for design of an orientation motor that satisfies high efficiency and high starting torque. Since the existing double cage rotor design is calculated using the efficiency constant, errors in the characteristic analysis result will result in results lower than the actual efficiency. In this paper, a new design process of working bar of double cage motor for high efficiency design is proposed. Finally, it was compared with existing design methods through the Magnetic Equivalent Circuit, and the process was validated through performance tests of the Finite Element Analysis results and start-up products.

1. Introduction

It is implementing policies such as the minimum efficiency system that mandates reduction of greenhouse gas emissions worldwide and requires the use of high-efficiency devices to use energy resources reasonably. In particular, regulations on industrial motors, which are widely used in industries and households, are being tightened, and demand and research for high efficiency designs is increasing. Double cage type induction motor among the induction motor satisfies high starting torque and high efficiency characteristics. In most cases, working bar design of double cage rotors uses an experience constant. However, this applies to high voltage and high capacity induction motors (100kW or higher), and errors occur in the low and medium capacities of the induction motors, resulting in lower-than-real efficiency results in the analysis results.

In this study, the optimal design process of double cage rotor working bar satisfying high efficiency and high starting torque was proposed by model of 15kw type double cage induction motor used in pump system.

2. Conventional Rotor Design



STEP1

Calculate Stator Resistance

$$R_s = \rho_m W_1 l_c / \left(\pi \left(\frac{d_{wire}}{2}\right) a_1\right)$$

STEP2

Calculate Rotor Resistance

$$R_r = K_{R1} R_s \parallel K_{R1}, K_{R2} = 0.7\sim0.8$$

Use Experience constants

STEP3

Calculate Wokringbar Resistance

$$R_{bl} \approx \mathrm{K}_{R2} \frac{(R_r)_{s=s_n}}{K_{bs}} \quad K_{bs} = \frac{4m(W_1 K_{w1})^2}{N_r}$$

STEP4

Calculate Workingbar Area

$$A_{bw} = \frac{\rho_m (l_{geo} + l_w)}{R_{b1}}$$

<Fig. 1> Double cage Induction Motor Working Bar Design using Experience Constant

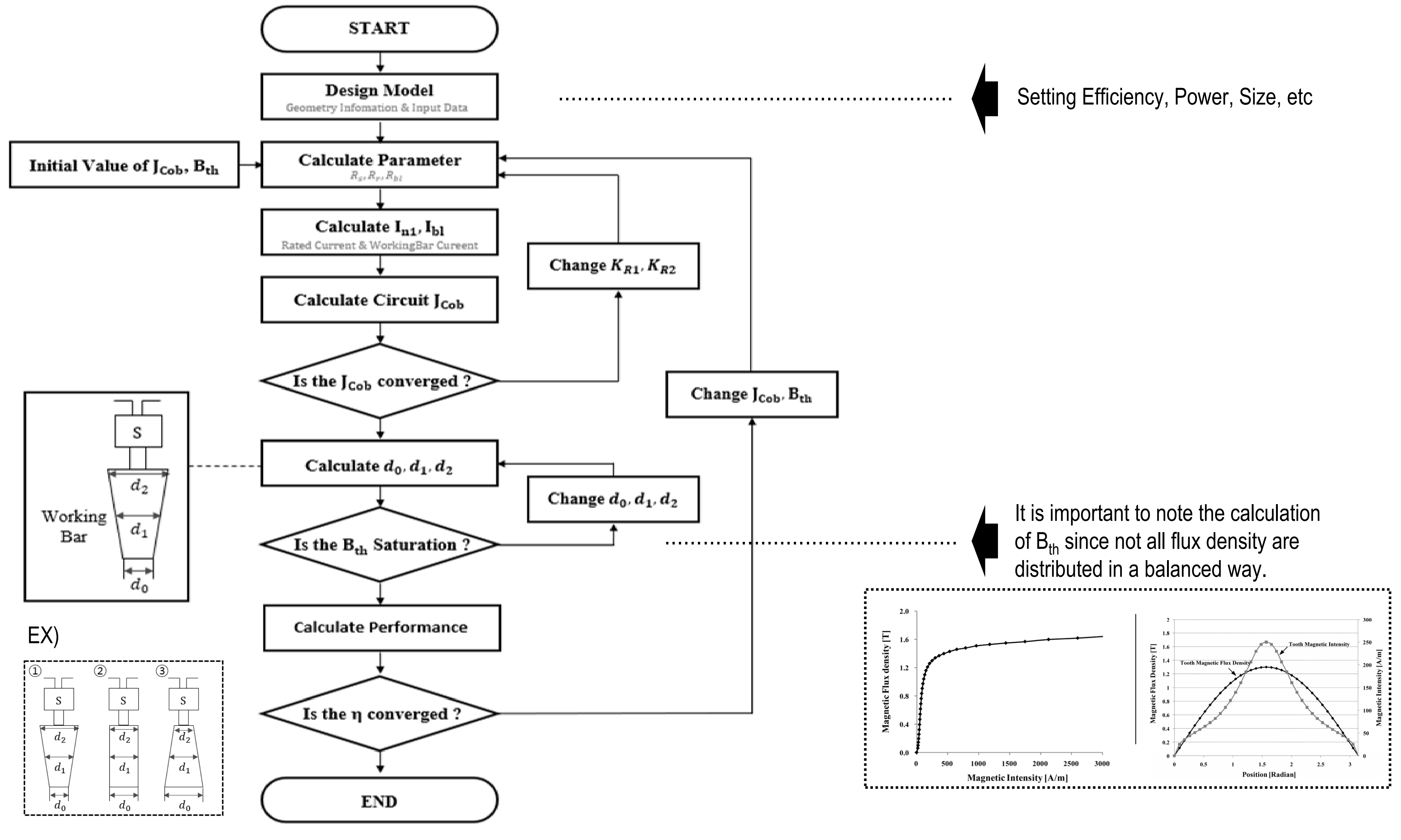
Experience constants are often used in the design of the working bar of double-cage bars, but this applies to high-voltage and high-capacity induction motors (more than 100 KW), making it difficult to predict accurate performance due to errors in low-capacity induction motors.

Sym	Description	Sym	Description	Sym	Description
R_s	Stator resistance	ρ_m	Resistivity of the material	W_1	Number of serial turns
l_c	Length of the coil	d_{wire}	Diameter of the coil	a_1	Number of parallel circuits
R_r	Rotor resistance	K_{R1}	Rotor resistance / Stator resistance	K_{R2}	Working bar resistance / Rotor resistance
R_{b1}	Working bar resistance	m	Number of phase	K_{w1}	Winding factor
N_r	Number of rotor slot	A_{bw}	Workring bar Area	l_{geo}	Stacking length
l_w	Working bar endring length	R_{b1}	Working bar resistance		

3. High Efficient Double Cage Induction Motor Working Bar Design Process

Remark!

- ► *Regression of K_{R1} and K_{R2} rather than existing experience constants to obtain optimal values for the target*
- ► *Determining the shape of the working bar to generate the target performance by parametering the shape of the working bar*
- ► *If the final design motor does not meet the target efficiency, re-design after resetting the rotor current density (J_{cob}), rotor teeth flux density (B_{th})*

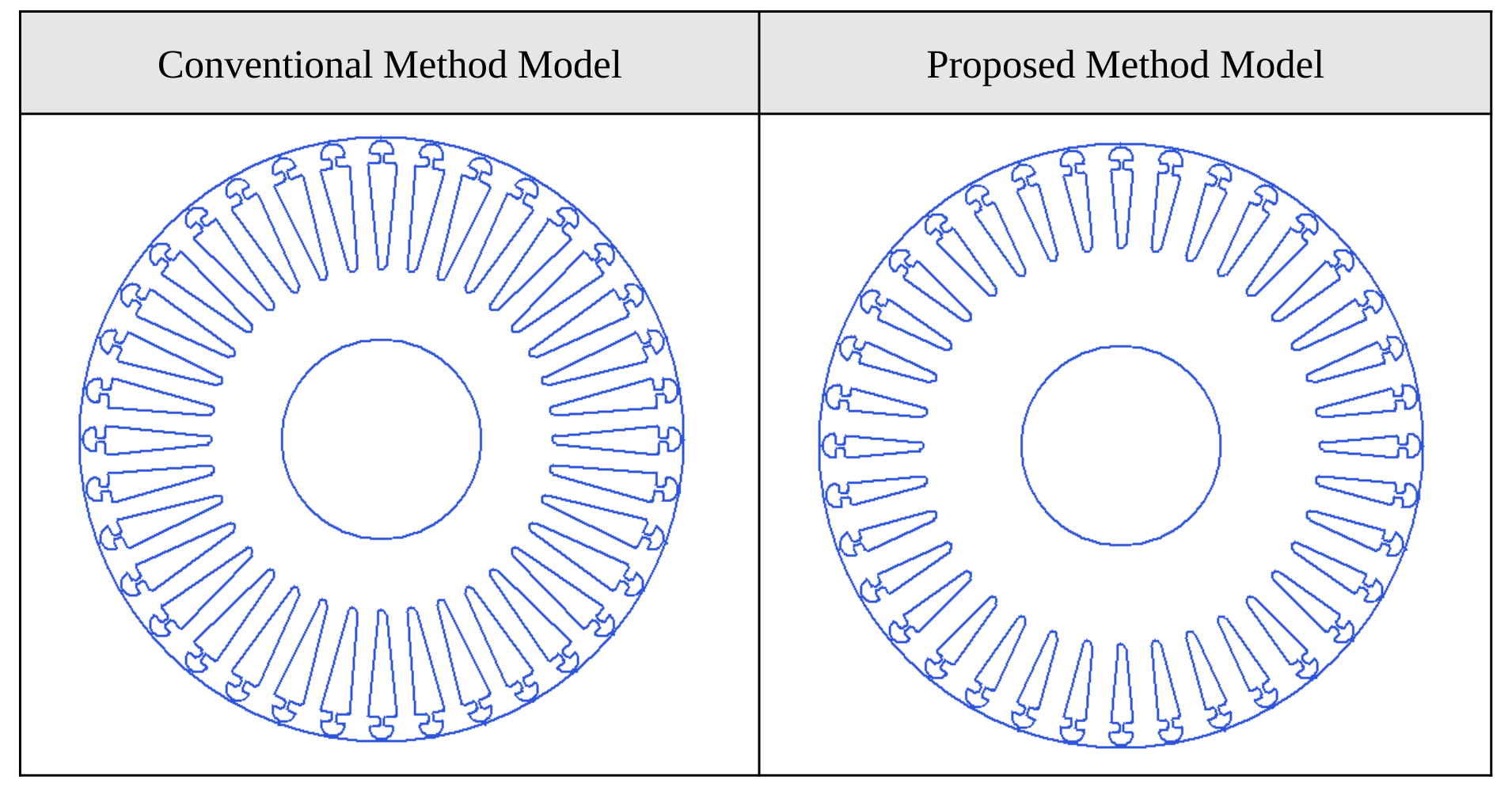


Setting Efficiency, Power, Size, etc

It is important to note the calculation of B_{th} since not all flux density are distributed in a balanced way.

<Fig.2> Performance Calculation Process of Double cage Induction Motor

4. Magnetic Equivalent Circuit(MEC) Analysis Result

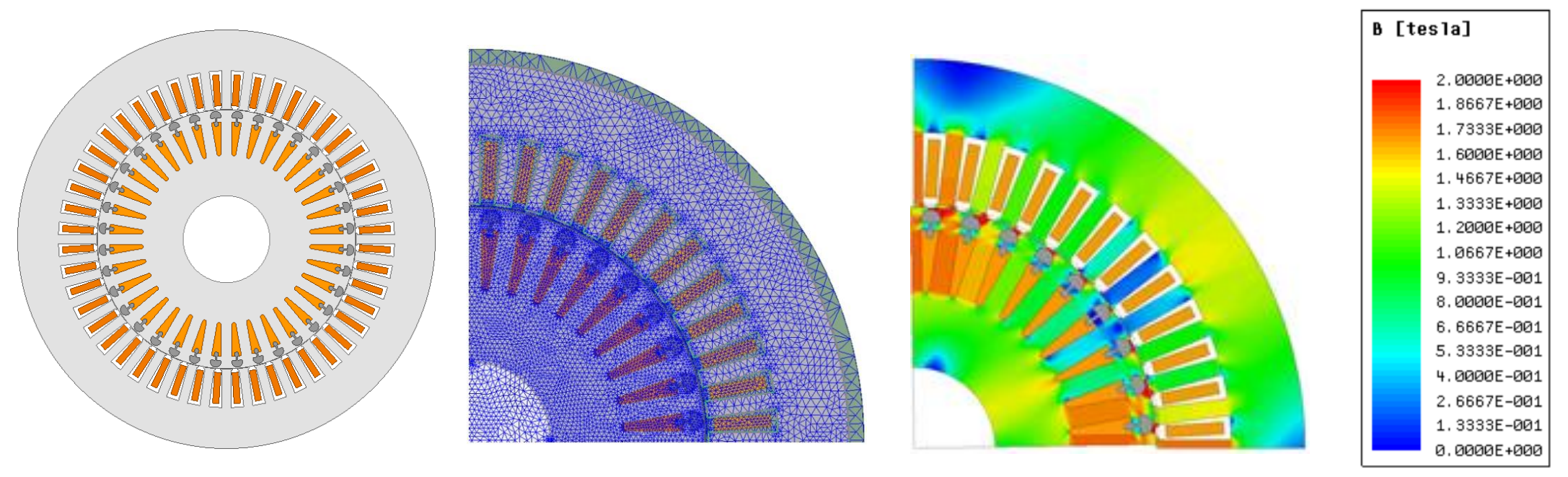


<Fig. 3> Comparison of Double cage Rotor Shape by Design Method

<Table. 1> Motor Specification and MEC Result Comparison

Parameter		Conventional Model	Proposed Model
Phase		3	
Power		15kW	
Material	Stator / Rotor	50PN470	
	Starting Bar	Aluminum	
	Working Bar / Coil	Copper	
Winding	Series Turns per phase	160	
	Winding Layers	1	
	Parallel Branches	1	
Pole		4	
Slot(Stator / Rotor)		48 / 36	
Rated Speed (rpm)		1762.09	1760.38
Torque @Rated Speed (T)		79.83	79.95
Current @Rated Speed (A_{rms})		43.57	26.73
Output Power (W)		14730.1	14739.1
Efficiency (%)		88.57	91.51

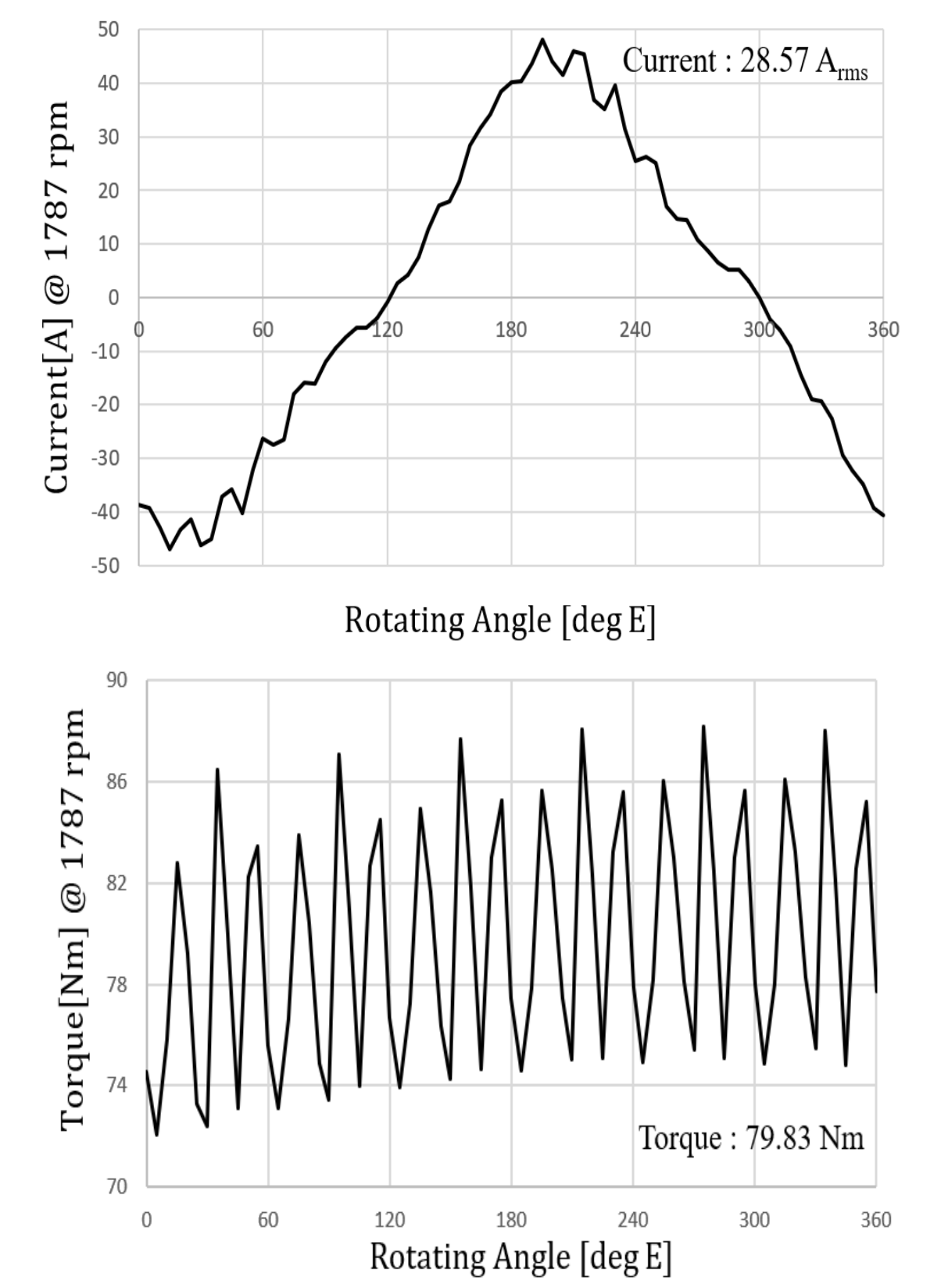
5. Finite Element Method(FEM) Analysis Result



<Fig. 4> Proposed Method Model, Mesh Operation, Magnetic Flux Density

<Table. 2> Compare MEC and FEM result

Parameter	MEC	FEM
Rated Speed (rpm)	1760.38	1784.62
Torque @Rated Speed (T)	79.95	79.83
Current @Rated Speed (A_{rms})	26.73	28.57
Output Power (W)	14739.1	14919.6
Efficiency (%)	91.51	92.21

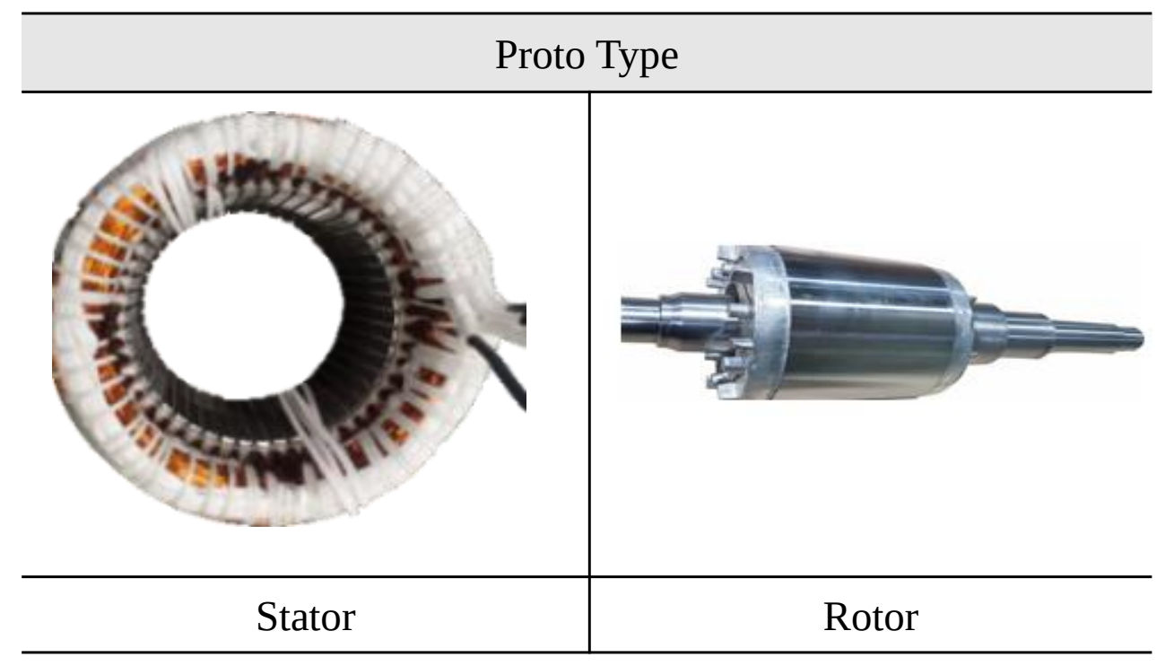


<Fig. 5> Proposed Method Model Current, Torque

7. Performance Test

<Table. 3> Compare FEM and Test Result

Parameter	FEM	Prototype
Rated Speed (rpm)	1784.62	1777.31
Torque @Rated Speed (T)	79.83	80.95
Current @Rated Speed (A_{rms})	28.57	31.46
Output Power (W)	14919.6	15066.6
Efficiency (%)	92.21	91.71



<Fig. 6> Test Production Motor

9. Conclusion

In this paper, an optimal design process for a rotor of a double cage induction motor pursuing high efficiency was proposed. An iterative calculation method was used to calculate the current density and the rotor teeth density of the rotor. The validity of the equivalent circuit analysis method proposed in this paper is verified by comparing the FEM analysis result and the dynamo test measurement result through the prototype production. The rotor optimum design method of the proposed double cage induction motor is predicted to be helpful in the optimum design of the high efficiency induction motor because it can predict the characteristics analysis result of the more accurate motor in advance.

10. Reference

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