OPTIMAL DESIGN METHODOLOGY BASED ON SENSITIVITY ANALYSIS FOR MARINE ELECTRIC PROPULSION SALIENT POLE SYNCHRONOUS MOTORS

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Abstract. In this paper the optimization procedure for a Salient Pole Synchronous Motor (SPSM) suitable for Marine Electric Propulsion Systems (MEPS) is presented involving preliminary and final design stages, respectively. The preliminary design is based on standard formulae while the final design implements sensitivity analysis investigation for several geometrical parameters by using finite element method.

Keywords: Marine electric propulsion systems, optimal design, salient pole synchronous motor, sensitivity analysis.

1. Introduction

In electrified ship's propulsion systems, synchronous motors can be considered as mature technological applications. In such applications low rotational speed salient pole synchronous motors connected to the propeller shaft directly are favored [1-4]. In this paper an optimization procedure based on sensitivity analysis investigation of several geometrical design parameters for a low rotational SPSM suitable for MEPS using finite element method is presented. The above mentioned design is accomplished by adopting a two step procedure for preliminary and final design stages, respectively, explained in the followings.

2. Preliminary Design Stage

Synchronous motor main dimensions are derived by using classical formulae. They are evaluated in order to fulfill the motor specifications such as nominal power, rotational speed, specific magnetic loading in the various parts, and electric loading in the windings. Additionally the temperature rise and the motor performance are equally approximately evaluated. The above mentioned main dimensions are then validated by using finite element analysis and the initial values obtained at the preliminary design stage are presented in Table 1.

TABLE 1: INITIAL AND FINAL VALUES OF THE MAIN DESIGN PARAMETERS

Parameter	Initial	Final	Dimension	Symbol	Initial	Final
Apparent Power (kVA)	1250	>>	Stator Internal diam (m)	*D int st*	2.65	2.05
Phases	3	>>	Air-gap length (m)	*Lgap*	0.009	0.0065
Nominal Voltage (V)	690 Y	>>	Active Part Length (m)	*L*	0.48	0.43
Nominal Current (A)	1045,9	>>	Teeth lip thickness (m)	h lip thick	0.004	0.003
Nominal Frequency (Hz)	35	>>	Stator slot height (m)	h slot stator	0.034	0.032
Nominal Speed (RPM)	140	>>	Rotor pole field height (m)	*h field*	0.175	0.149
Number of Poles	30	>>	Rotor pole width (m)	*b pole*	0.142	0.119
Maximum Torque (kNm)	71,6	104,2	Rotor pole shoe height (m)	*h pole shoe*	0.044	0.030
Efficiency n (%)	87,5	94,86	Pole arc / Pole pitch ratio	*Kf*	0.82	0.70
Total Harmonics Distortion (%)	13,3	2,33	Core Cutting Length (m)	-	49750	46162

3. Final Design Stage

Appropriate section of the motor geometry has been implemented in the solution domain in order to exploit the configuration symmetries corresponding to the different types of stator winding structures considered, as shown in Fig. 1. Analytical investigation of critical geometrical design parameters is accomplished leading to composite cost functions involving the following parameters extremum research: torque versus load angle and motor efficiency maximization, in conjunction with core cutting length, power losses and Total Harmonics Distortion (THD) minimization. The variations of the abovementioned quantities are shown in Figs. 2-4. The final values of the main design parameters derived by applying sensitivity analysis are given in Table 1.

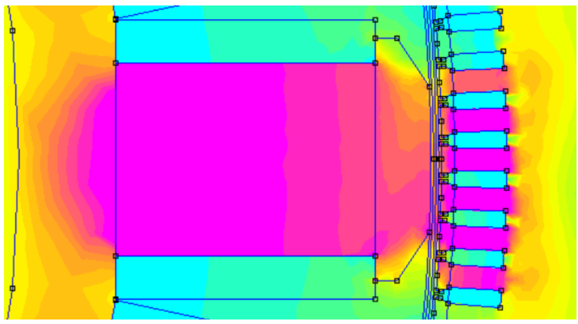

Fig. 1 Basic configuration of the proposed SPSM,

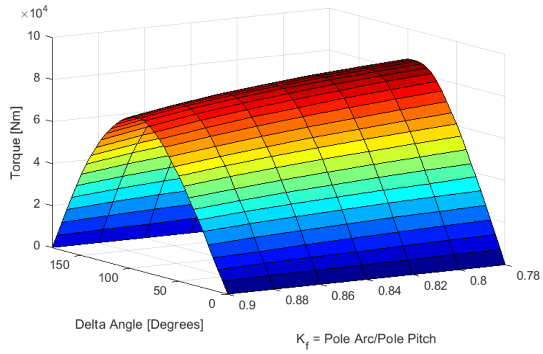

Fig. 2 Torque vs internal angle δ with K_f ratio variation.

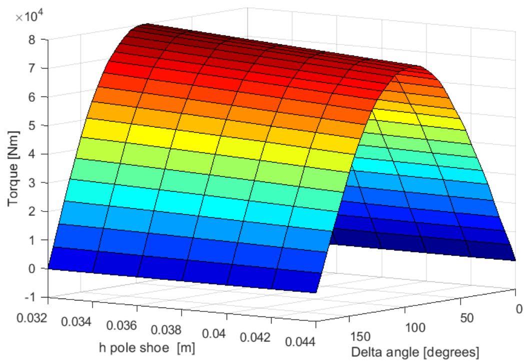

Fig. 3 Torque vs. internal angle δ with pole shoe height variation.

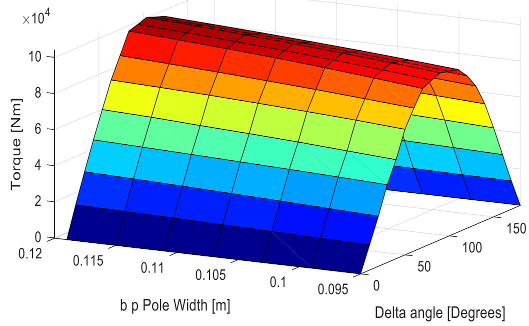

Fig. 4 Torque vs. internal angle δ with pole width variation.

Conclusion

By implementing the methodology proposed a substantial decrease of the rotor pole shoe height has been achieved with corresponding modification of the rotor pole width at the final design stage, through sensitivity analysis with respect to the initial values determined at the preliminary design stage. Moreover, this procedure resulted in a significant improvement of the developed torque and motor performance in conjunction with important reduction of the electromotive force THD.

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