

# Switched Reluctance Motor Design and Optimization

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**Abstract:** In the field of electric vehicle engineering, Switched Reluctance Motors (SRMs) are progressively drawing the attention of developers for their streamlined structural design, superior torque output, economical cost-benefit, and excellent energy efficiency ratios. This paper takes a four-phase 8/6-pole switched reluctance motor as an example, with a rated power of 7.5Kw and a rated speed of 1500r/min. According to the basic design requirements of the SRM, the SRM parameter design flow is designed, and a Matlab calculation program is written for the preliminary calculation of the SRM parameters, and the detailed design of its motor structural parameters is carried out. After that, the stator and rotor pole arc coefficients of the SRM are parametrically analyzed using Maxwell2D tool according to the design experience, and the optimal stator and rotor pole arc coefficients are selected. The simulation results show that the design optimization scheme can effectively reduce the SRM torque pulsation.

**Keywords:** Switched reluctance motor, Torque pulsation suppression, Polar arc coefficient.

## 1. Introduction

Under the rapid development of electric vehicles, switched reluctance motors (SRMs) have been rapidly developed with their excellent performance<sup>[1]</sup>, and it is of great significance to study the problem of excessive torque pulsation so that they can be applied to electric vehicles.

The structural parameters of the motor have a very important influence on the torque pulsation, and the optimally selected structural parameters can greatly reduce the torque fluctuation<sup>[2]</sup>. Reasonable selection of air gap magnetic density, so as to reduce noise at the same time to better balance the performance of the drive motor. and at the same time better balance the performance of the drive motor<sup>[3]</sup>.

This paper addresses the problem of excessive torque pulsation in SRMs, and carries out research on torque pulsation from the optimization of motor structural parameters.

## 2. Basic Requirements for SRM Motor Design

The basic requirements for the design of the SRM motor selected for this drive system are shown in Table 1.

Table 1. Three Scheme comparing

Parameters	Numerical
Rated power	7.5kW
Rated voltage	280V
Rated RPM	1500r/min
Efficiency	88%
Speed range	200-2000r/min

## 3. Design of Structural Parameters

### 3.1. Design principles for structural parameters

In the design of switched reluctance motors, the core length, Rotor Outer Diameter and stator Outer Diameter are critical

dimensions that have a direct impact on the motor's operating performance and manufacturing process. In the design, the slenderness ratio of the motor is considered first.

$$\lambda = \frac{l}{D_r} \quad (1)$$

If the slenderness ratio of the motor is too large, the motor becomes slender and increases in length, which reduces the length of the end of the armature windings in proportion to the overall windings, thus helping to save copper; and due to the thinning of the core, its interference with the end field is reduced, which optimizes the prediction of magnetization curves from the two-dimensional model; in addition, the rotational inertia of this type of motor is relatively low which is favorable for starting and regulating speed. However, if the dimensions are small, the motor will appear thicker and shorter, and its characteristics will be the opposite. Based on practical experience with medium to large AC motors, this parameter should normally be set between 0.5 and 3.0.

In the early stages of electromagnetic design, it is common to set the current waveform at the rated operating point of the motor as a square wave and use the equivalent square wave current to determine the main dimensions. The basic arithmetic can be found in

$$D_r^2 l_\delta = \frac{6.1}{AB} \cdot \frac{k_i}{k_m} \cdot \frac{P_{em}}{n_N} \quad (2)$$

$k_i$  is the peak winding current coefficient, which is generally taken as 0.48 ~ 0.51

$k_m$  is the square wave current coefficient, generally taken as 0.62 ~ 0.81

$l_\delta$  is the calculated length of the armature, which generally has  $l_\delta = 1.05 l$

$P_{em}$  is the electromagnetic power as shown in equation (3).

$$P_{em} = \frac{1 + \eta_N}{2\eta_N} P_N \quad (3)$$

The ratio between the stator and rotor diameters of switched reluctance motors depends on the number of stator and rotor poles and the operating requirements of the motor.

$$\frac{D_r}{D_{so}} = 0.4 \sim 0.7 \quad (4)$$

In addition to the main dimensions, the stator and rotor pole arcs and need to meet the following conditions: in the design, the general use of the pole arc coefficient for analytical studies.

$$\begin{cases} \min(\beta_s, \beta_r) \geq \frac{2\pi}{qN_r} \\ \beta_s + \beta_r \leq \frac{2\pi}{N_r} \end{cases} \quad (5)$$

The shaft diameter of the motor is to be satisfied while ensuring mechanical strength:

$$D_i = (0.4 \sim 0.5) D_r \quad (6)$$

After preliminary determination of the structural dimensions, the number of series turns per phase of the motor windings can be estimated by the following formula:

$$N_{ph} = \frac{3.04 N_r U_N \theta_c}{n_N B D_r l_\delta} \quad (7)$$

### 3.2. SRM Parameter Determination

Because the basic need of design is to have some experience to choose the parameters, and the torque and efficiency of the motor are closely related to its structure and control parameters. Therefore, in order to obtain better torque and efficiency characteristics of switched reluctance motor, we can refer to Fig. 1 for the design.

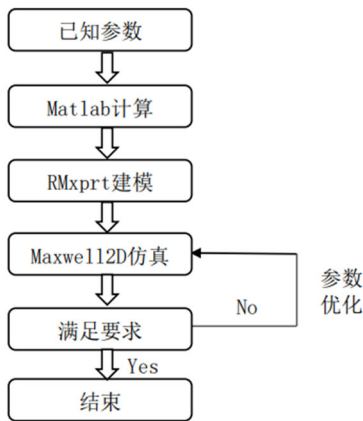


Figure 1. Parameter Design Flowchart

According to the motor design requirements in Table 1 in Matlab to write the parameter calculation program as shown in Figure 2. editing area for the Matlab calculation program, in the command window to execute the program after the calculation in the work area can be obtained directly from the motor parameters as shown in Table 2.

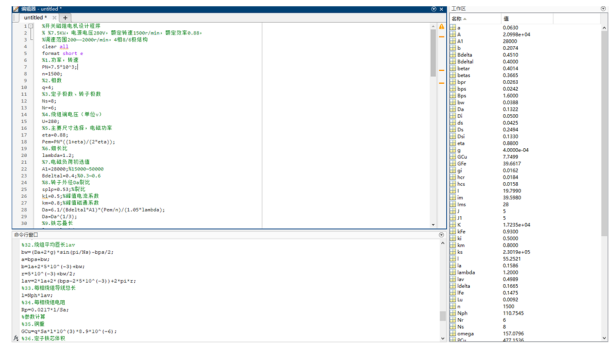


Figure 2. Matlab calculation process diagram

According to the above obtained motor parameters according to the structural parameters in the RMxpirt module on the motor stator, rotor size and coil and other parameters to set up the motor two-dimensional model as shown in Figure 3. in RMxpirt on the motor simulation calculations to get the efficiency of the motor for 90%, to meet the design requirements. The model created in RMxpirt is imported into Maxwell 2D to create a model as shown in Fig. 4.

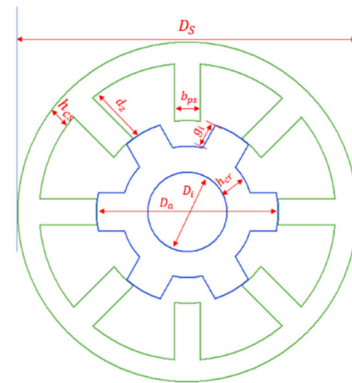


Figure 3. Switched Reluctance Motor 2D Model

According to the design experience of a large number of scholars, the torque pulsation is greatly influenced by the outer diameter of the rotor and the stator and rotor pole arc coefficients. Therefore, the stator and rotor arc coefficients of the motor are parameterized for joint simulation and analysis.

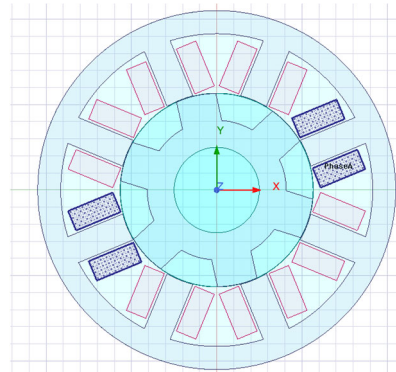
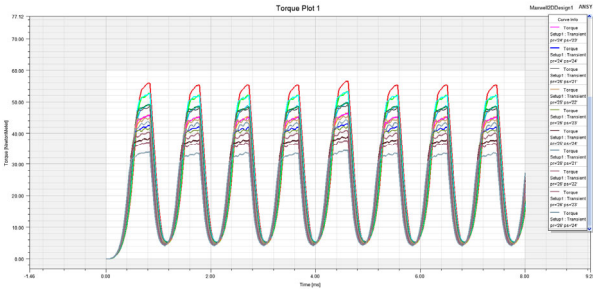


Figure 4. Switched Reluctance Motor 2D Model

The stator and rotor arc coefficients are set as variables, the default value is 4, and the step size is 1 for simulation analysis, so as to select the optimal stator and rotor arc coefficients. The comparison of SRM torque variation with stator and rotor arc coefficients is shown in Fig. 5.



**Figure 5.** Comparison of SRM stator and rotor pole-arc coefficient optimized torques

According to the primary design objective of this simulation experiment is to reduce the motor torque pulsation, so under the condition of ensuring that the motor output torque meets the design requirements, priority is given to selecting the parameter values with smaller torque pulsation. The main structural parameters of the final SRM are shown in Table 2.

**Table 2.** Switched Reluctance Motor Structure Parameter

Parameters	Numerical
Stator outer diameter ( $D_s$ /mm)	210
Stator yoke height ( $h_{sy}$ /mm)	13.8
Stator pole coefficient	0.419
Rotor outer diameter ( $D_r$ /mm)	113
Rotor yoke height ( $h_{ry}$ /mm)	15.8
Rotor Arc Coefficient	0.454
Shaft diameter ( $D_i$ /mm)	50

#### 4. Simulation Results Analysis

Define average torque

$$T_{av} = \frac{T_{max} + T_{min}}{2} \quad (8)$$

In order to quantify the degree of torque pulsation, a torque pulsation coefficient is introduced.

$$K = \frac{T_{max} + T_{min}}{T_{av}} \quad (9)$$

As shown in Table 3, the average torque and torque fluctuation values before and after the modification of SRM can be learned that after optimization, the new average torque reaches 18.12, which stays above 95% of the original value, while the torque pulsation coefficient is reduced to 87.11% of the pre-optimization value.

**Table 3.** Table of changes in average torque and torque pulsation before and after SRM optimization

	Torque pulsation factor	Average torque (N·m)
pre-optimization	19.02	1.63
post-optimization	18.12	1.42

#### 5. Conclusion

Based on the design requirements, the preliminary parameters of the SRM were obtained by writing a parameter calculation program in Matlab according to the design principles of the motor, followed by importing the structural parameters of the SRM in RMxpert and performing simulation calculations. The results show that the efficiency of the motor is 90%, which basically meets the design requirements. After that, we optimized the stator and rotor pole arc coefficients of the motor in Maxwell 2D.

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