Low Loss Design of a Flux-Modulated Motor Considering Air-Gap Harmonics

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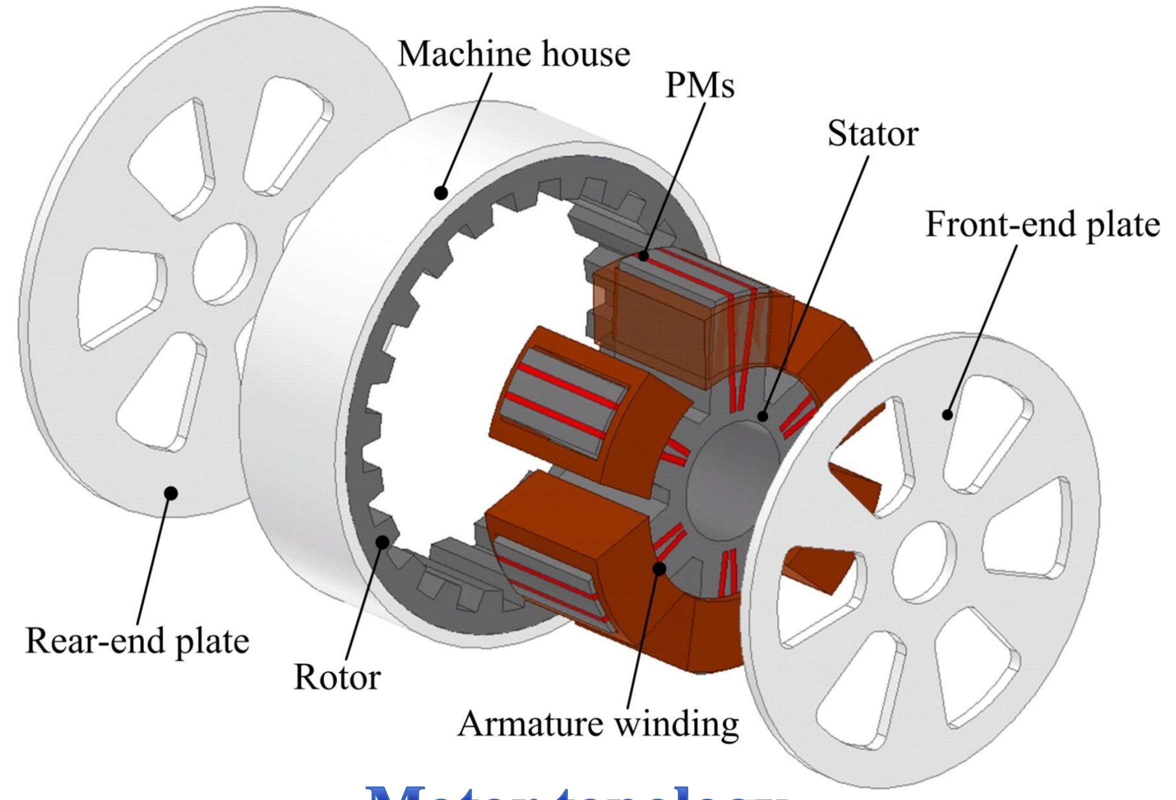
Abstract

Since the permanent magnet (PM) loss has a great influence on the temperature rise of the motor and the irreversible demagnetization, the reduction of the PM loss is significant for the performance of PM motors. In this paper, a new method based on adjustable ratio magnetic motive force (MMF) is proposed to realize the reduction of the PM loss of a flux-modulated permanent magnet (FMPM) machine with PMs on the stator. By analytical method, it can be concluded that the air-gap harmonics are greatly affected by MMF. Thus, the air-gap harmonics can be reduced by adjusting the MMF, which contributes to the decreasing of the PM loss. By the proposed method, the rated on-load PM loss of the investigated motor is reduced by 36.2% while the output torque almost keeps unchanged.

Conclusion

In this paper, an adjustable ratio MMF is proposed to reduce MMF harmonics, and then reduce flux density harmonics and PM loss. The principle of this method has been explained by using 2-D MMF model, and the great impact of the proportion of MMF on harmonics is highlighted by analytical method. The impact factor of PM loss (ξ) is introduced and the adjustable ratio MMF and low PM loss design can be realized by optimizing parameter ξ. Furthermore, parameter ξ also affects other performances, so the machine is optimized taking PM loss, output torque and cogging torque into account. The optimal machine has much lower PM loss and P_t under different rotational speed and input current. Running at rated condition, PM loss and P_t are reduced by 36.2% and 23.7% respectively with output torque declining by 3.1%. This paper provides a new method for low loss design from the perspective of harmonic reduction.

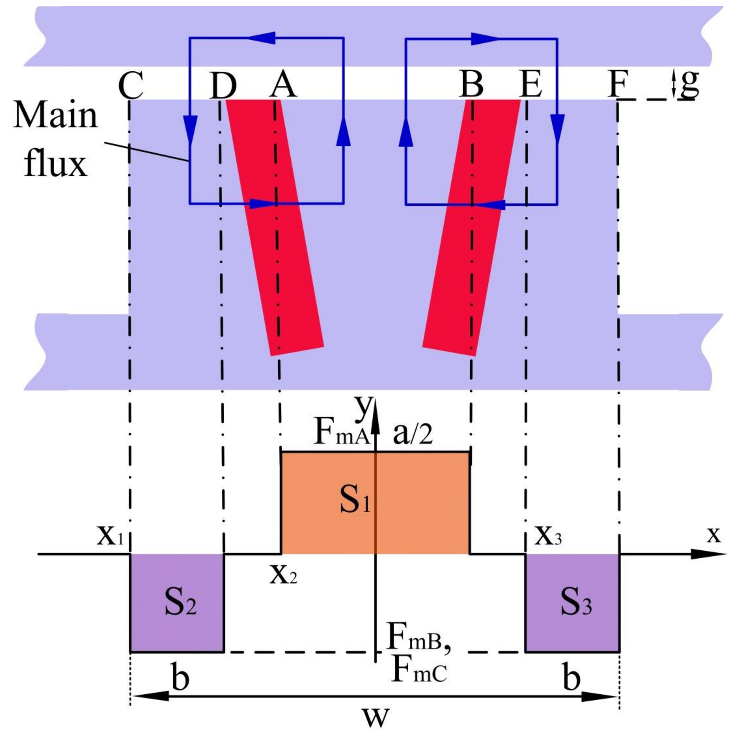
Motor structure



Motor topology

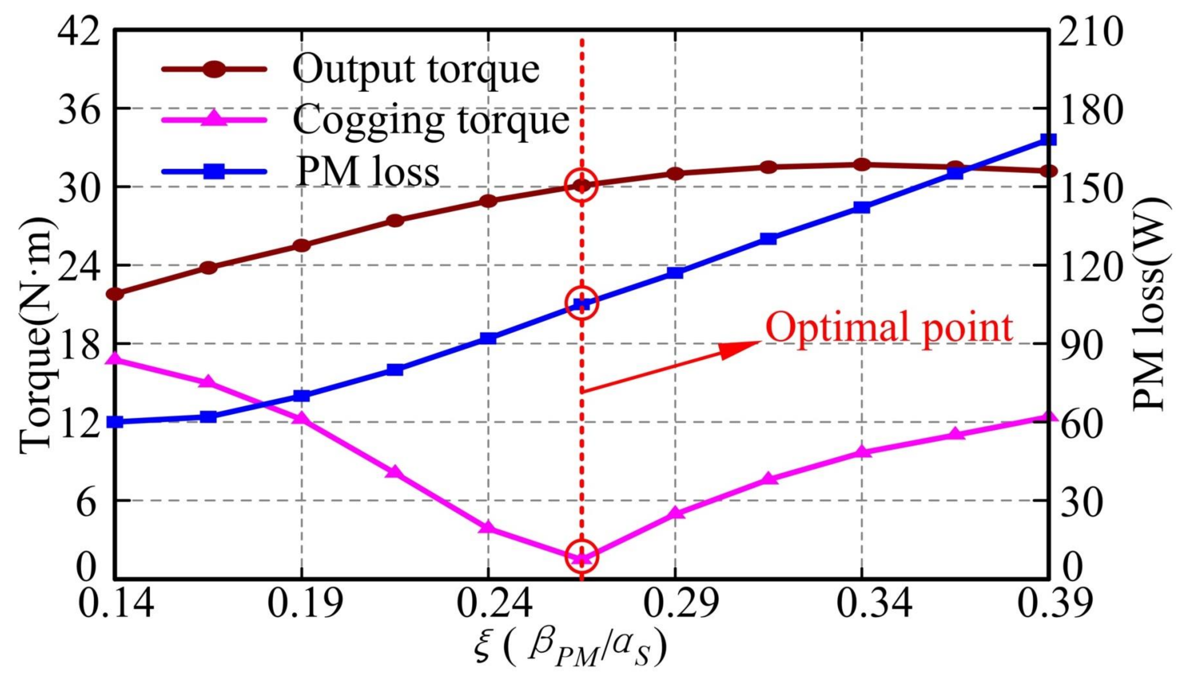
A V-shape out-rotor flux modulated permanent magnet motor is investigated in this paper.

Design principle and improvement



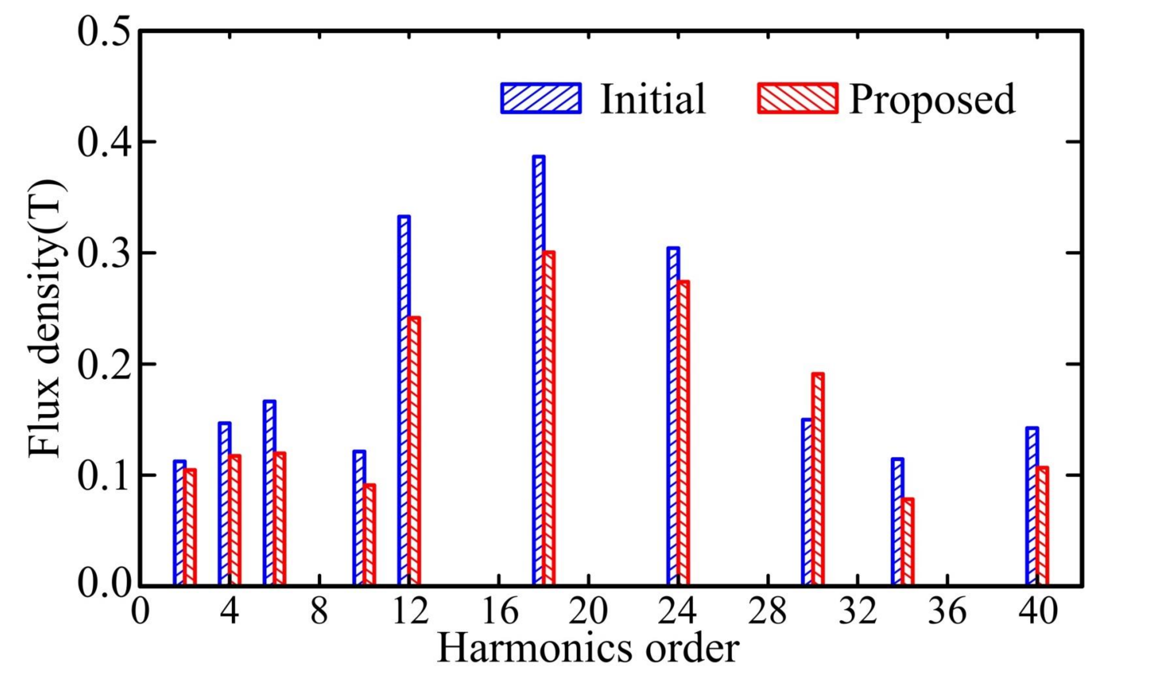
Distribution of magnetic field

According to the law of continuity of magnetic flux, it can be drawn that S_1=S_2+S_3 and S_2=S_3, which is the basis of analysis.



Impact of ζ on motor

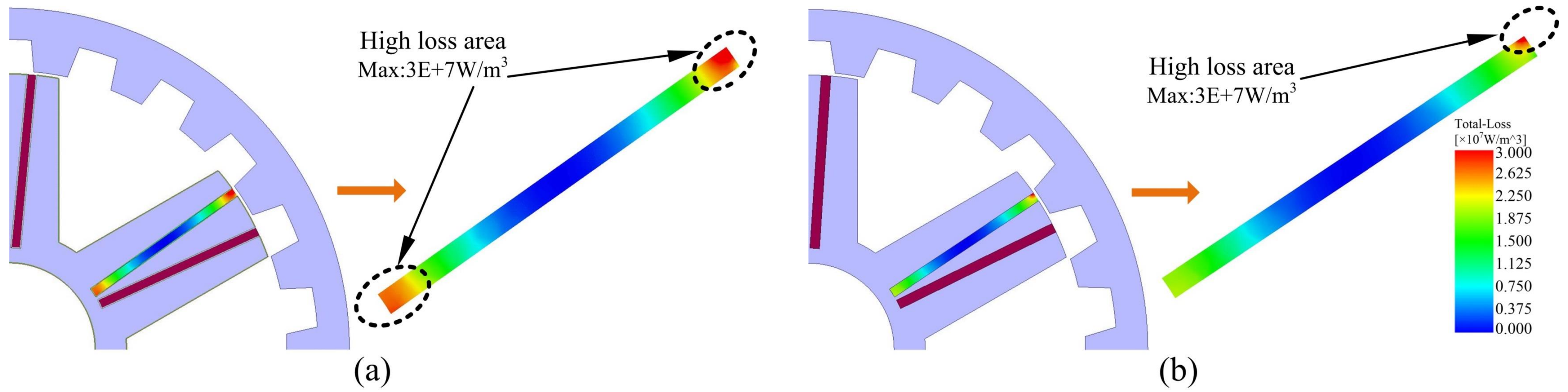
ζ is the key parameter of this method. The motor is improved taking PM loss, cogging torque and output torque into consideration



Comparison of flux density harmonics

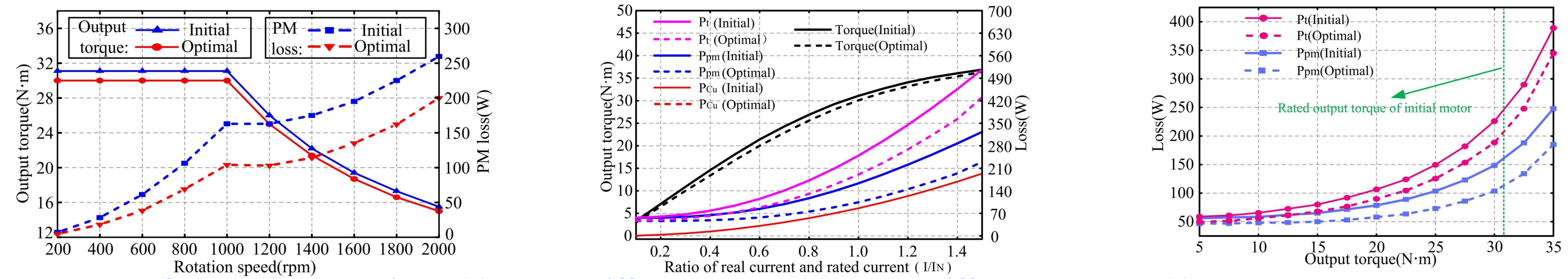
By optimizing ζ, the air-gap flux density harmonics are reduced effectively, which indicates the rationality of this method.

Results



Comparison of PM loss distribution. (a) Initial (b)Optimal

The high PM loss area of the optimal motor is almost eliminated completely, and low PM loss design is achieved.



Performance comparison. (a) Under different speed. (b) Under different current. (c) Under same torque

The performances of two motors are compared in detail. Fig. (a) and Fig. (b) indicate that under different rotation speed and input current, PM loss is reduced greatly while the output torque almost keeps unchanged. Fig. (3) shows that when the same torque is obtained, PM loss is still much lower.