Influence of soft magnetic material in a permanent magnet synchronous machine with a commercial induction machine stator

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This paper presents the efficiency optimization of a 6-pole induction motor (IM), converted into a 6-pole permanent magnet synchronous machine (PMSM). Firstly, the stator of the IM was kept unchanged and the rotor was converted into a permanent magnet (NdFeB magnets) rotor, resulting in higher average efficiency, similar to the line start machine in [1]. The rotor bars were removed, in contrast with [1]. Secondly, we investigated how much the efficiency can be increased by replacing the electrical steel in the stator by another material grade.

A numerical model is made of the resulting PMSM with 158 mm outer diameter, 36 stator slots, 1500 W nominal power and 1000 rpm nominal speed, and we consider a wide range of magnetic materials for the stator iron. The numerical approach is based on the finite element method (FEM), taking into account the rotor movement. Iron losses are computed according to the loss separation theory. Induction waveforms $B(t)$ were recorded in mesh points in the iron during the rotation of the machine. For each waveform, the hysteresis, classical and excess loss are computed using the time domain loss model. The parameters in this loss model are fitted based on hysteresis loop measurements on the stator of the machine. To measure these loops, an excitation and a measurement winding were added around the stator lamination stack.

The efficiency map of the original IM was measured in a test setup. The average efficiency in the speed range 500–1000 rpm and torque range $0.25T_{\text{nom}} - T_{\text{nom}}$ is 71.7% (max. 82.0%). Fig. 1 shows the computed efficiency maps of the converted machine with M800-50A material, and the same machine where the stator iron is replaced by M235-35A laminations with the same geometry. The average efficiency is 88.4% (max. 90.7% in range 100–1000 rpm and 4–15 Nm) and 91.1% (max. 94.9%) for the PMSM with original stator and with modified stator resp.

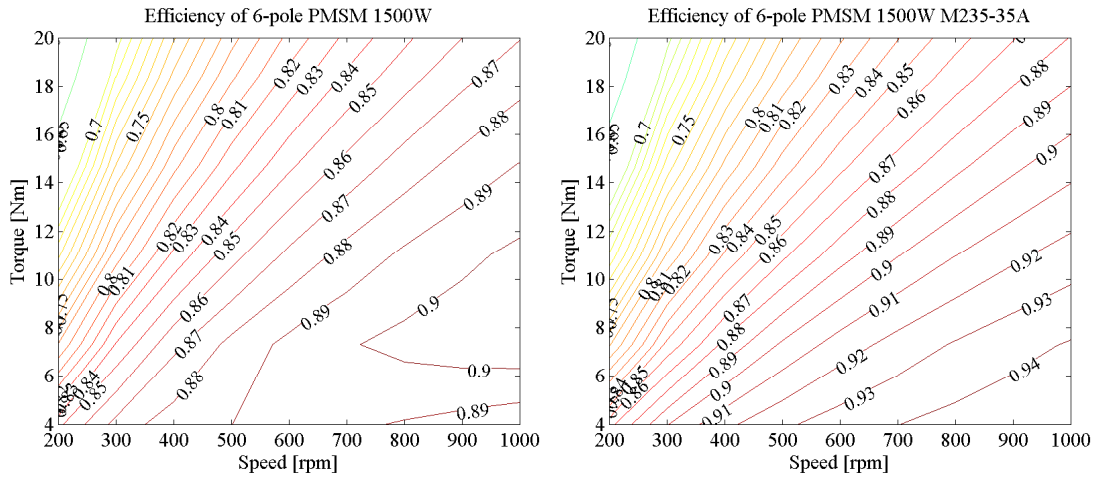

Figure 1: Efficiency map of a PMSM with (a) the original stator with M800-50A material; (b) the stator with M235-35A material.

[1] W. Fei., P. Luk, J. Ma, J. Shen, and G. Yang, IEEE Trans. Magn., **45** (2009),4724–4727.