Efficiency Improvement of Tapered Pole Amorphous Magnetic Material Machine

This brochure provides the summary of the results which aims to demonstrates further efficiency improvements of the machine introduced in

N. Ertugrul, R. Hasegawa, W. L. Soong, J. Gayler, S. Kloeden, and S. Kahourzade, "A Novel Tapered Rotating Electrical Machine Topology Utilizing Cut Amorphous Magnetic Material", IEEE Transactions on Magnetics, Vol. 51, No. 7, 2015.

Table I. Specifications and dimensions of the baseline machine.

DIMENSIONS	
Outer/inner diameters	110 mm/ 45 mm
Axial length	30 mm
Air gap	0.5 mm
STATOR SPECIFICATIONS	
Number of slots	12
Slot depth	17 mm
Winding turns per phase	96
Winding type	Double-layer, concentrated
Measured phase resistance	0.21 Ω
Material	Metglas 2605SA1 AMM
ROTOR	
Number of poles	10
Permanent magnet	Bonded NdFeB
Magnet remnant flux density	0.71 T
Magnet thickness	6 mm
Rotor yoke	Steel 4140

Fig. 2 shows the tapered-field AMM stator core. To create the core, the Metglas 2605 SA1 AMM ribbons were wound to a tapered shape then annealed and impregnated to improve the material properties and insulate the surface of the tape wound core, respectively. Finally, the slots were cut using a custom built jig and abrasive waterjet technology. After insertion of windings the core was coated with an epoxy resin to protect against delamination. Fig. 2 also shows the base line rotor with segmented bonded flat-shape PMs.

Fig. 4a compares the open circuit losses of the machine using the baseline rotor yoke (blue) and the designed one (red). The FE results shows the losses of the new rotor reduce in average 35% from 1000 rpm to 7000 rpm where the average measured loss was only improved by 15% within the speed range. This is due to the slight increment of the measured mechanical loss due to 16% weight increase in the new rotor structure. The combined open circuit losses (FE calculated and measured mechanical loss) were in good agreement with the measured loss.

Fig. 4b shows both the measured and the FE efficiencies using the baseline and the modified rotor configurations. The results demonstrates an efficiency improvement of 3.5% at 2kW output as under load the effect of rotor loss was more dominant than mechanical loss.

Fig.4c compares the measured and the FE results of the electrical and non-electrical loss components of the rotor configurations. It was concluded from these results that at 2kW load, the measured non-electrical loss of the new rotor reduced by 45%.

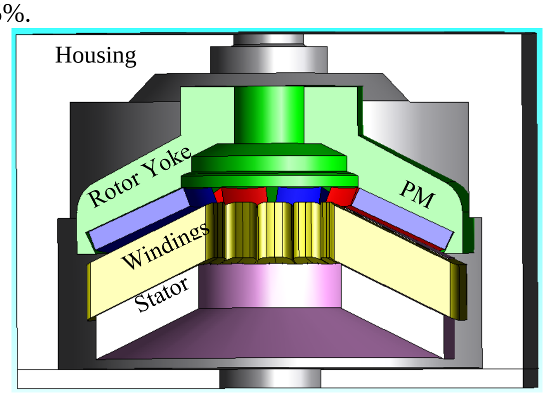

Figure 1. Cross section of the machine used in FE model.

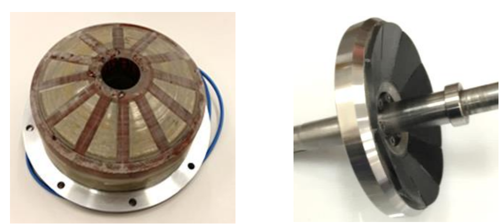

Figure 2. Prototype tapered AMM stator with windings and the rotor

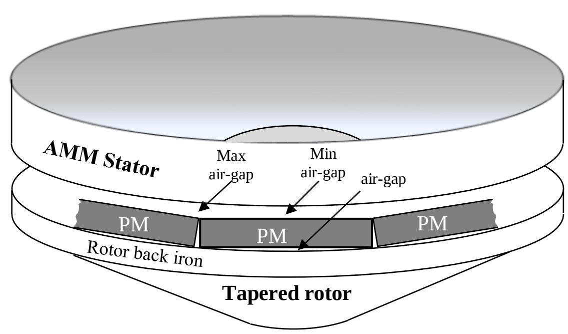

Figure 3. Air gap structure of the prototyped machine.

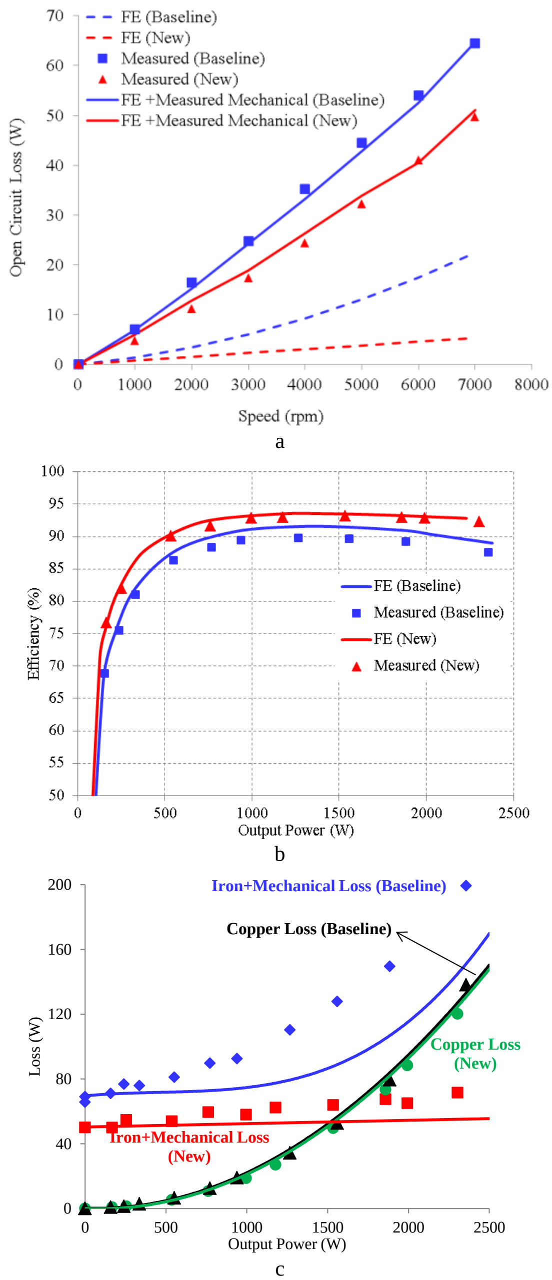

Figure 4. Comparison of the baseline and improved rotor configurations, a) Open circuit losses, b) Efficiency charactersitics, and c) Loss components.

This new 12-slot 10-pole tapered field PM machine with a 25° taper angle operating at the speed of 7000 rpm can offer 93.5%. It is believed that further efficiency improvement is possible (up to 96%) in the final production level.