The Use of Quadrature Axis Flux Barriers in Linear Synchronous Machines

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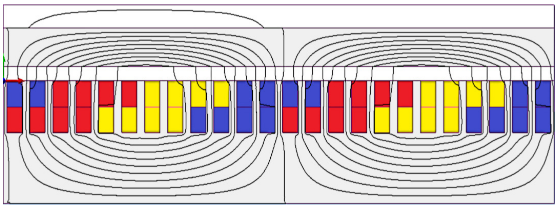
I. Introduction

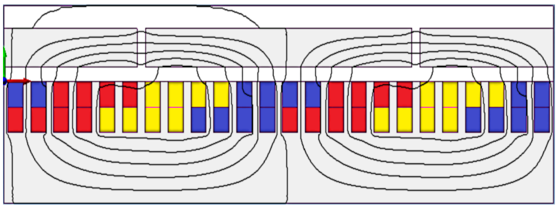
The use of quadrature axis flux barriers has been introduced in two previous papers (1)(2). In the first of these the geometry was tubular, in the second the machine had linear planar form. Finite Element analysis was used in each paper to examine only a few cases. This paper aims to develop a simple analytical tool for the linear planar case so that the machine performance can be assessed over a wide parameter range.

II. Action of the Barriers

The barriers are positioned in the quadrature axis as may be seen from the diagrams of Figures 1 and 2. Figure 1 shows the effect on the magnet flux density and it can be seen that the barrier produces only a minor change. In contrast the barrier produces a large change in the armature flux as may be observed from Figure 2. The reduction of armature flux has a beneficial effect in two performance areas. First the synchronous reactance is reduced leading to a better power factor and secondly the demagnetising effect on the magnets by the armature flux is reduced.



a - No Flux Barrier



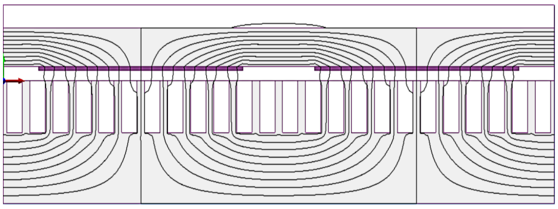
b - With Flux barrier

Fig. 1. Armature field with and without the quadrature axis flux barrier

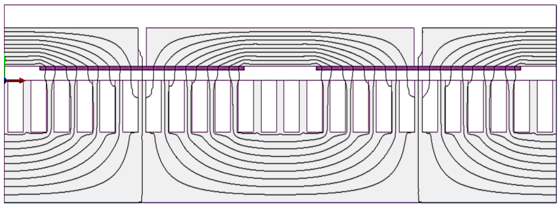
III Analysis

In order to assess the effects of the barriers on the machine performance the conventional performance equations have been adapted so that they take into account the barriers. This yields the expected reduction of the armature flux with a consequent increase of power factor and a reduction of the demagnetizing effect of the armature. Figure 3 shows a study of a machine with a pole pitch of 270 mm, magnet thickness of 3mm and clearance of 8mm, for a set of quadrature flux barrier gap widths. It can be seen that as the core gap increases the armature flux density is reduced which reduces the de-magnetising effect on the magnets. The power factor as expected improves with increased core gap. The tangential force is reduced slightly due to the small pole area reduction.

Results from 2D finite element analysis at zero core gap and 8mm core gap are plotted on Figure 3 as single points and it will be seen that the agreement is satisfactory.



a - No Flux Barrier



b - With Flux Barrier

Fig. 2. Permanent magnet field with and without the quad axis flux barrier

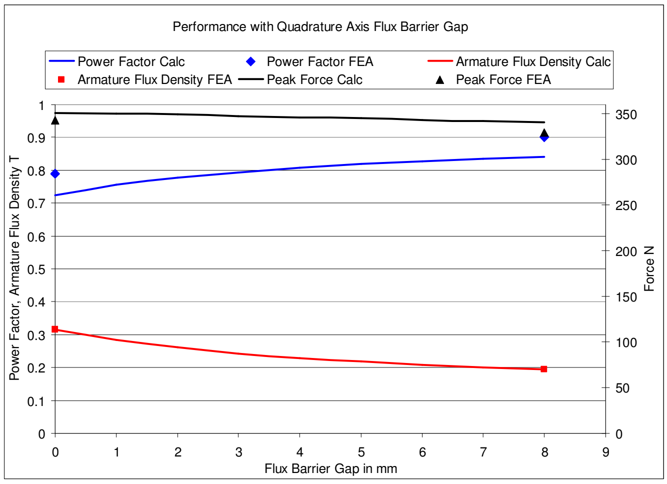


Fig.3. Results from simple theory and Finite Element Analysis

IV Conclusions

Satisfactory results for machines with quadrature axis gaps can be obtained from simple analysis. Reduced armature flux can be obtained using the gap. This results in reduced magnet demagnetization together with improved power factor.

IV References

[1]. Cox, T.; Proverbs, J.; Eastham, J. F. "*Linear synchronous machine performance improvement with flux barriers*" 6th IET International Conference on Power Electronics, Machines and Drives (PEMD 2012).

[2] Benarous, M.; Eastham, J.F. "*Over-load capacity of tubular permanent magnet linear motors*" IEEE International Electric Machines and Drives Conference, (IEMDC 2009).