



DOCTORAL THESIS IN
STOCKHOLM, SWEDEN 2003

A Low-Leakage Linear Transverse-Flux Ma- chine for a Free-Pis- ton Generator

WAQAS ARSHAD

*Academic Dissertation which, with due permission of the KTH Royal
Institute of Technology, is submitted for public defence for the on
Wednesday the 11th June 2003, at 12:00 a.m. in*

Abstract

The presented work is about a new low-leakage linear transverse-flux electrical machine. The machine is dimensioned for a free-piston generator. The intended application is in series-hybrid vehicles. The free-piston generator is an integration of a free-piston combustion engine with a linear electrical machine. It provides benefits in efficiency, emissions and multi-fuel capabilities, to name a few. These combustion benefits are only possible if the total mover mass is kept quite low (e.g. 4 kg for a 50 kW unit). The limited mover mass and competitiveness demands result in a very stringent set of specifications for the electrical machine.

Most existing electrical machine topologies are preliminarily investigated. Of these only a transverse-flux machine (TFM) is found to be promising. Even for the case of the TFM, a factor 2 improvement in the performance indices of the existing TFMs is required. Different surface-mounted TFMs are investigated for improvement. It is found that the analytically acceptable solutions fail during the three-dimensional finite-element analysis (3D-FEM). These designs suffer from a very significant pole-to-pole armature leakage flux in the stator. Similar design improvements for the buried-magnets TFMs are also investigated. Fortunately, in this case a promising design is derived. This design exhibits low leakage and is verified with FEM analysis. A down-scaled one-phase 1.7 kW proof-of-concept TFM of this design is dimensioned. It is analysed thoroughly, both analytically as well as by 3D-FEM computations. It is found that for this particular prototype the design suffered from saturation. It is shown how this design can be modified to yield the desired force with the allowed mover mass. The efficiency is found to be only slightly lower than the demands but a poor power factor is noted.

The prototype is built. Unfortunately, all the desired measurements could not be carried out. This is because the built-machine suffered with two major manufacturing defects. The magnets are found to be demagnetised to about 50% of their manufactured value. It is also found that the translator poles on the average are 7% longer (in the axial direction) than the stator poles. Low values of no-load induced voltage and force are thus measured. The correlation between the manufacturing defects and the measurements is established. Due to insufficient measurement data, this relationship is mainly of an indicative nature only. A more correct picture requires construction of a new prototype. Still, the results do point towards a near fulfillment of the objectives. Other addressed topics include, an investigation into a separate free-piston generator project with reduced specifications, application of the presented work to renewable energy sources like wind- and wave-energy and a brief introduction to the free-piston application aspects.

Keywords: Free-Piston Generators, Linear Machines, Transverse-Flux Machines, Hybrid Vehicles, Electrical Machines Design.

Keywords

Free-piston generators, linear machines, transverse-flux machines, hybrid vehicles, electrical machines design