Micro Magnetic Machines for Micro Turbomachinery

Personnel

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Sponsorship

ARO and DARPA

This project is part of the MIT Micro Gas Turbine Engine Project. The MIT Micro Gas Turbine Engine Project has the goal of using MEMS fabrication technologies to construct compact electric power generation systems from a gas turbine generator comprising a compressor, combustor, turbine and electric generator. Other systems under development include stand-alone motor/compressors and turbine/generators. The MIT Micro Gas Turbine Engine Project is highly interdisciplinary, involving students, staff and faculty from several academic departments and laboratories.

The first generation of motors and generators under development for the micro turbomachines mentioned above are electric as opposed to magnetic in nature. In contrast, this project seeks to develop alternative machines that are magnetic, specifically magnetic induction machines. These machines will be fabricated from electroplated cores and conductors using facilities at the Georgia Institute of Technology maintained by Professor Allen and his students, who are collaborators in this project. The main reason for pursuing magnetic induction machines, despite their increased fabrication complexity, is that they can operate with much wider air gaps thereby reducing windage losses. They also appear to be capable of providing a greater power and torque density than their electric counterparts, and the development of their associated power electronics appears to be less challenging.

To date, detailed models of the micro magnetic induction machine have been developed and used to design two-phase axial-gap planar motors having a 4-mm diameter. Based on these designs, fabrication flows which utilize the electroplating facility at the Georgia Institute of Technology have also been developed. Following these flows, first-generation non-laminated tethered motors, which serve as torque measurement devices have been fabricated and tested. Test results so far have demonstrated that the motors can be successfully run at their rated currents of 13 A peak per phase. This corresponds to a current density of 10^9 A/m^2, which is two to three order of magnitude higher than that achieved by conventional magnetic machines. With phase currents of 6 A peak, torques as high as 0.3 μNm have been measured, and this is as predicted by our models for non-laminated motors. Torques as high as 25-50 μNm are expected from laminated motors at rated current.

An expanded drawing of an electroplated tethered motor is shown in Figure 30. The upper half of the figure shows a copper conducting film deposited on a nickel-iron rotor suspended by epoxy or Kapton tethers. During operation, torque is measured through the bending of the tethers. The lower half of the figure shows the stator comprises a nickel-iron core and two copper windings that pass in quadrature through slots in the core; each winding occupies a separate layer. Figure 31 shows a micrograph of an experimental stator after the insulation has been etched away to reveal the top phase of the stator windings.

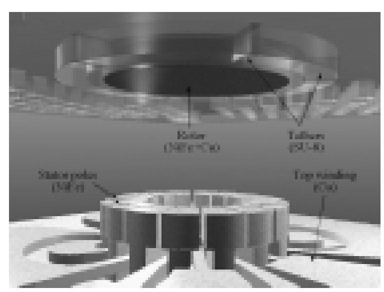

Fig. 30: An expanded view of a tethered micro magnetic induction motor showing the rotor above and the stator below.

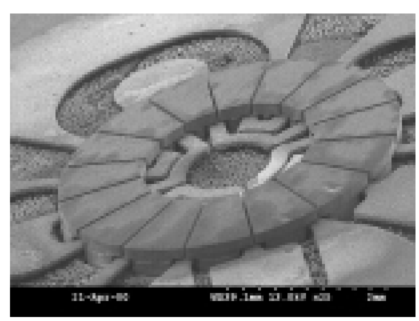

Fig. 31: A micrograph of an experimental stator after the insulation has been etched away to reveal the top phase of the stator windings. The outer radius of the stator core is 2 mm.