Amorphous Metal Ribbon (AMR) and Metal Amorphous Nanocomposite (MANC) Materials Enabled High Power Density Vehicle Motor Applications.

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Metal alloys with a frozen liquid (glassy) structure led to products called ***amorphous magnetic ribbons (AMRs)*** produced by ***planar flow casting***. In the late 1980's post-casting nanocrystallization steps were developed to produce magnetic ***metal amorphous nanocomposites (MANCs)*** with magnetic nanocrystals embedded in an amorphous magnetic matrix. Nanocrystals provide high magnetic inductions; and an exchange coupled amorphous phase provides high electrical resistivity. Applications of AMRs and MANCs in high speed motors, HSMs require low power losses at high-f to control T-rise. Power losses, are partitioned into losses with different f-dependences, including: (i) hysteretic, (ii) classical eddy current, and (iii) excess loss components. Hysteresis loss dominate at low- and eddy currents at high-f.

AMRs and MANCs have usable peak inductions comparable to Si-steels. Classical eddy current losses limit MANC switching. High resistivities allow high-frequency switching required for high power densities in HSMs. To minimize classical eddy current losses, small thickness and high resistivity are desired. Resistivity in MANCs is larger than Si-steels by 3-4x due to the amorphous matrix and increased further by alloying with ***virtual bound state (VBS) elements***.

Rare earth (RE) permanent magnet (PM) motors are ubiquitous but soft magnetic materials (**SMM**s) provide great potential for energy and cost savings and particular efficiencies in new motor topologies. Supply constraints on ***rare earth (RE) elements*** focusing attention on economical SMM alternatives in motors. Heavy REs, like Dy (a grain refiner in NdFeB permanent magnets) are the most critical REs. RE-lean or -free permanent magnets offer economic benefits and reduced scarcity for traction motors· ***Axial-flux permanent magnet motors (APFM)***, introduced in late 1970s-80s, offer efficiency improvements reducing rotor losses and higher power density. Axial-flux construction requires less core material and high torque-to-weight ratio. Since AFPM machines have thin magnets, they are smaller than radial flux counterparts making them attractive in space-limited applications.

I will describe a dual stator axial, Flux Switching with Permanent Magnet (FSWPM), motor built in a DOE AMO program. This 2.5 kW motor supports ~0.5 kW/kg specific power density proposed to be increased to >1.6 kW/kg in a 2^{nd} generation HSM. A motor test bed, operational at NCSU, has a 3-phase converter for drive current consists of a DC link capacitor and 6-pack SiC MOSFET modules. At 1200 V and 30 A maximum rating, the module can drive an our FSWPM HSMs. Materials developments for achieving higher power densities will be described,

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