



ME – PhD Thesis Colloquium



Design and performance of a plunger type DC solenoid valve fabricated using annealed soft magnetic AISI 430 steel for aerospace application

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ABSTRACT

Solenoid valves are extensively used in the aerospace sector mainly for their compact design, repeatable and reliable performance, fast response and simple yet robust design. Normally, the reluctance offered by the air gap presumed to be the largest was expected to play a comparatively important role in the dynamic performance of a solenoid valve irrespective of the choice of materials. Hence, historically not much attention was being paid to the selection of materials for this end use. However, it transpires from this work that annealing of AISI 430 steel, which is better known for its structural properties rather than its magnetic properties, can lead to an increase of 24 % in the load carrying capacity of the solenoid actuator under study. It also turns out that usage of material with higher saturation flux density can enhance the speed of opening response by almost 70 %. Hence, proper material selection holds the key in the operation of these devices.

Since the start transient performance is perhaps the most important event associated with the health of a solenoid valve, the performance of the valve has been modeled around it. This is proposed as a health monitoring tool and a correlation with temporal coil current evolution with other physical parameters like plunger stroke, velocity and electromagnetic force of attraction has been established. A robust analytical multi-physics model has been built taking the non-linearities of material magnetic performance into consideration. Improvements attributable due to annealing AISI 430 steel, which forms the core magnetic material for this application, has been studied. The temperature range of 840 to 1160°C at 100°C intervals, has been completely characterized for microstructural aspects using SEM, XRD, EBSD, micro-hardness and optical microscopy. Key microstructural aspects which determine magnetic parameters like saturation flux density, coercivity, remanence and relative permeability, have been identified. It is seen that the temperature range of 840 to 850°C is best suited for the envisaged end use in a plunger type DC solenoid valve. Up to 15% improvement in saturation flux density could be obtained due to annealing treatment. Coil mutual inductance, magnetically-induced friction, energy conversion efficiency in DC solenoids and effect of plunger angle in attenuation of pressure surges associated with sudden valve opening and closing are the other aspects examined.

ABOUT THE SPEAKER

Subrata Chakrabarti did his ME in Mechanical engineering from IISc during 2009-11. He is from LPSC, ISRO. He has pursued his doctoral research under Prof Aloke Kumar and Prof Balaram Sahoo. He has been associated with the design and development of various types of solenoid valves used in ISRO's satellites and launch vehicles.

