Finite Element Analysis of Helical Spring Probe for Strain Dependence Measurements of Nb_3Sn

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Introduction

The strain dependence of critical current density in Nb_3Sn is a very important factor in superconducting magnet design. There are several devices used to apply a longitudinal strain to the conductor inside of a high magnetic field environment. A particularly useful device is the helical spring first used by Walters [1]. A project is now underway at the NHMFL for the design and installation of a helical spring strain test probe.

Results and Discussion

The helical spring device is a coiled spring with a special geometry intended to control the strain throughout the spring. The test conductor is soldered to the outside surface of the spring to hold it in place. By rotating one end of the spring with respect to the other, a longitudinal strain is applied to the conductor and the affect on critical current density can be measured.

An initial mechanical analysis of the helical spring was presented by Walters. However, it was noted by Walters and subsequent researchers that the prediction of the spring behavior provided by the simple analysis differed significantly from the actual performance. The practice has been to make the spring geometry according to the guidelines established by Walters and to determine the calibration afterwards by measurements made with the physical model. Other groups have performed Finite Element Analysis of the spring models in a more successful attempt to predict the spring behavior.

We are also using Finite Element Analysis to study the mechanical behavior of the spring. A number of scripts have been written in the ANSYS Finite Element Analysis program to model the induced rotation of the spring. After applying the appropriate constraints and displacements, we are then able to extract useful data relating the strain across the conductor to the applied angle of rotation and torque requirement. Fig. 1 shows a view of the results in ANSYS following an analysis. The use of scripts in the FEA modeling has allowed us to rapidly analyze a number of spring geometries and discrete angular rotations. Scripts have also been written to extract the important analysis data and compile it into a spreadsheet program where a graphical representation of the data can be displayed.

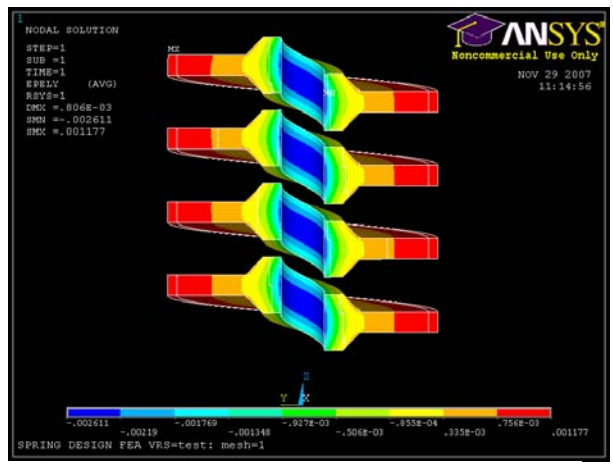

Figure 1.
Model view in ANSYS showing the longitudinal strain through a cross section of the spring.

In conjunction with the FEA, we have refined a still simple analytical analysis of the spring that may provide added insight into the difference between the analytical and FEA results.

Conclusions

The objectives of the continuing work are to (1) develop a FEA method and apply that analysis to a number of candidate spring geometries, and (2) compare aspects of the FEA with the extended analytical model for the spring. This work is the foundation for the design and implementation of the strain probe for use in the NHMFL facilities.

References

[1] Walters, C.R., *et al*., Cryogenics, **26**, 406-412 (1986).