COMSOL® Analysis-Led Design Of Prototype Coil Program For Bi-2212 Coils

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INTRODUCTION: Superconducting magnets have temperature, field, and strain limits. In order to generate fields above 24 T, a new class of materials – high temperature superconductors (HTS) are being explored. FEM modeling has proven pivotal in a subscale coil program for $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212). The focus of this poster revolves around the strain limits for this conductor and the role of COMSOL® Multiphysics in designing experimental coils.

Figure 1. Bi-2212, from wire to test coil

COMPUTATIONAL METHODS:
Three modules are used in 2D axisymmetric models for this work:

- The magnetic fields (*mf*) module computes for the fields generated from both insert and outsert magnets. For the inserts, individual wires are given an external current density.
- The heat transfer (*ht*) module handles the temperature excursion from room temp to the cryogenic operating temperature of 4 K, which is coupled to the structural mechanics for thermal stresses.
- The solid mechanics (*solid*) computes the resultant stress of the energized coils. The Lorentz stress is the primary source stress, and each material is given empirically determined mechanical properties.

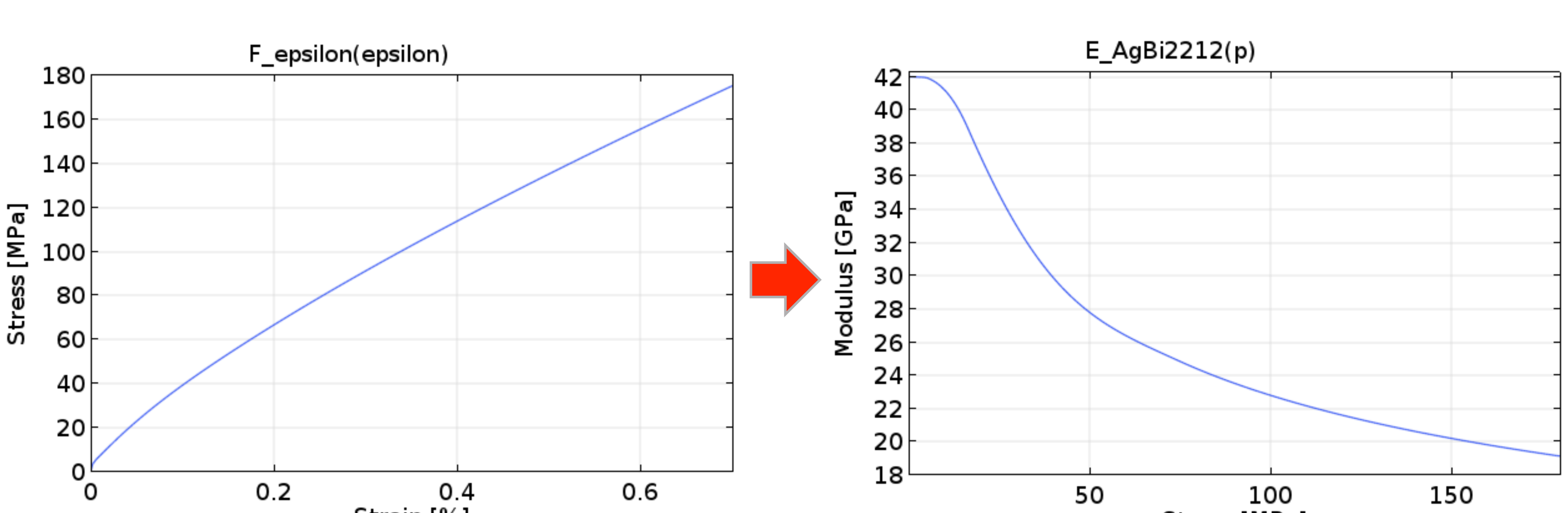


Figure 2. Experimental materials characterization (stress-strain curve) data converted to stress-dependent modulus.

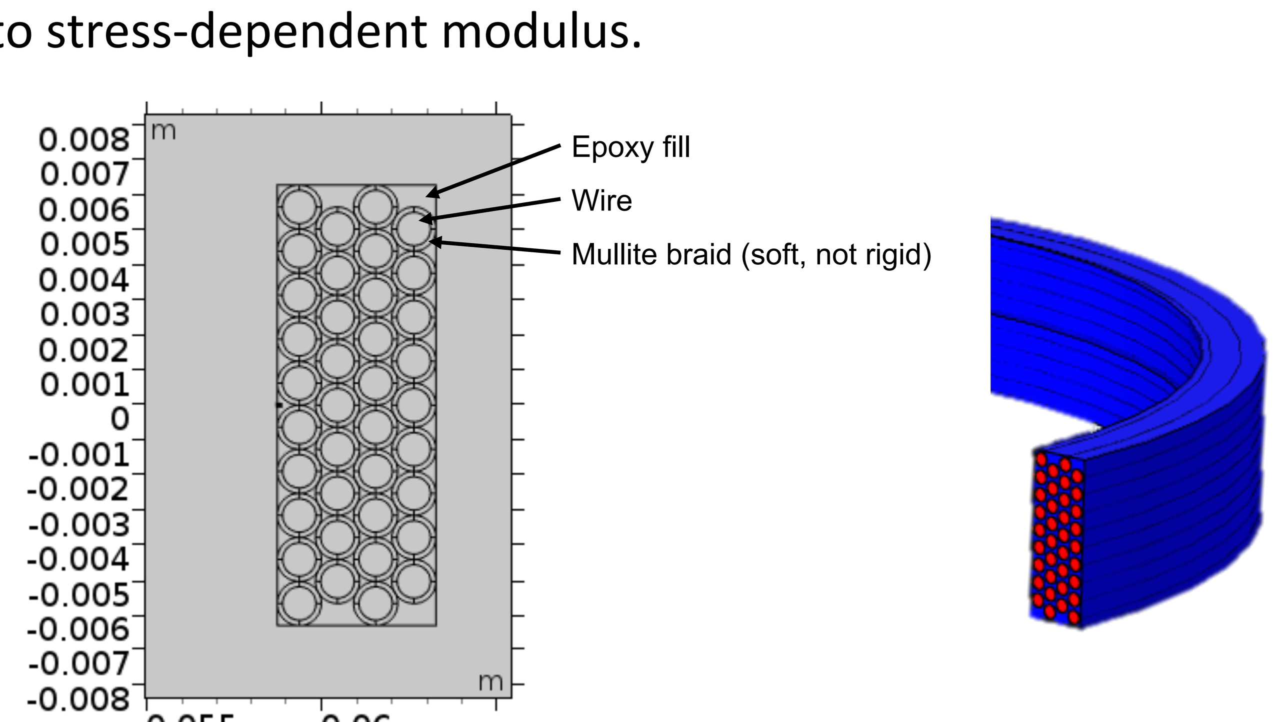


Figure 3. 2D axisymmetric geometry of test coil

RESULTS: Presented is a set of results for the first of a series of 'Riky' test coils. The coil is not reinforced and was intended to validate the modeling by comparing numerical results with experimental results of a coil fabricated to similar dimensions.

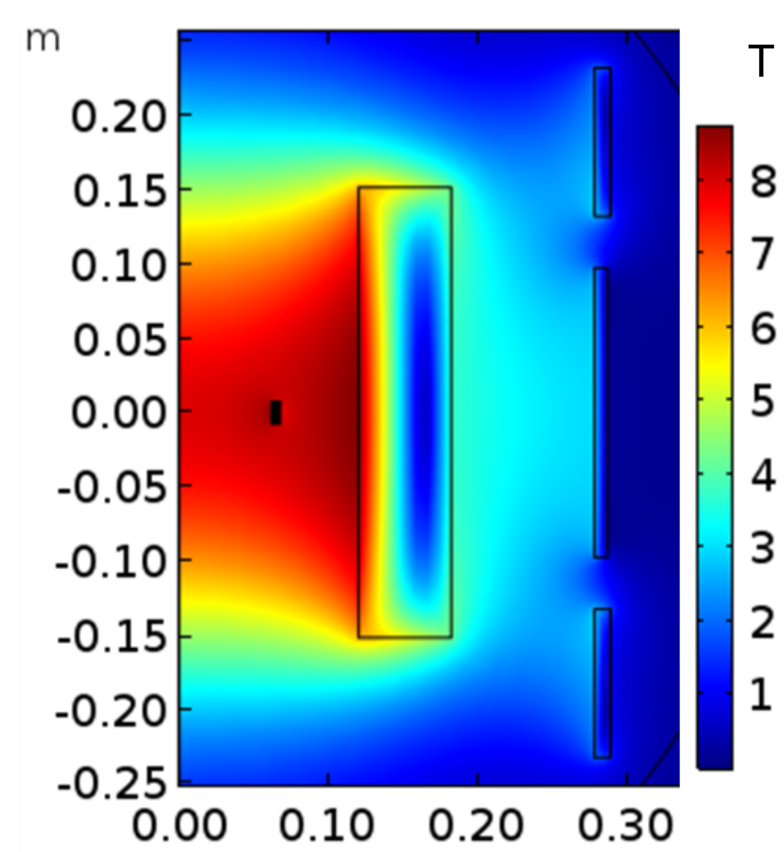


Figure 4. Total field generated of magnet system (from Fig. 1)

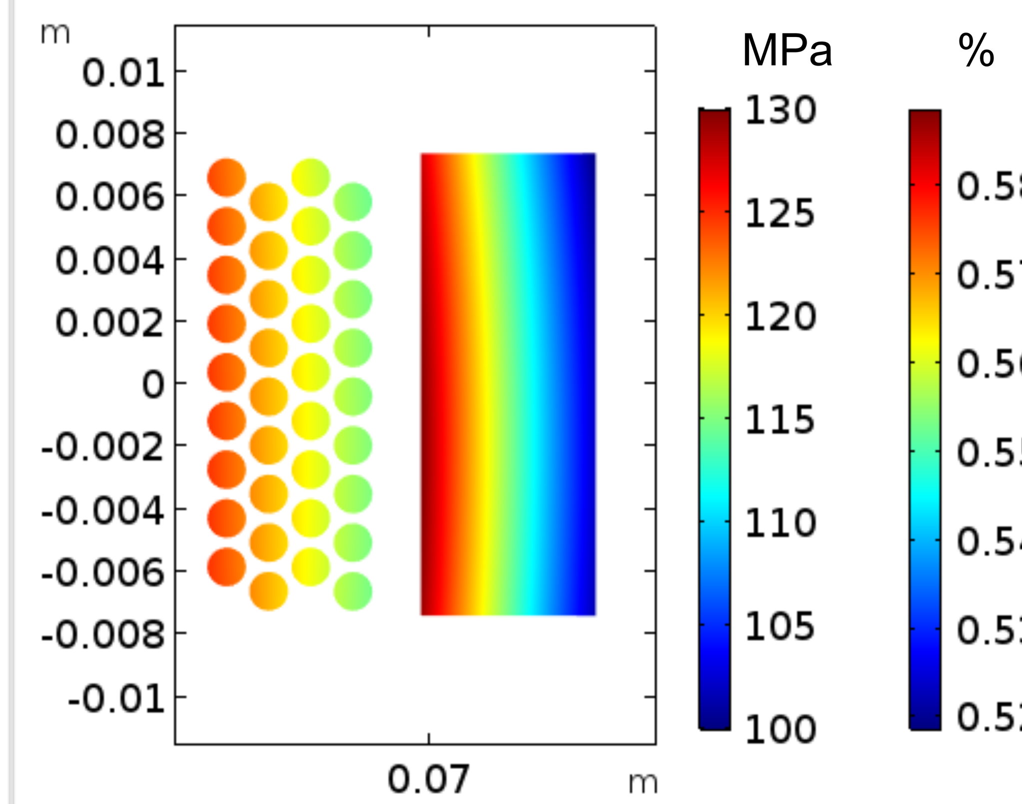
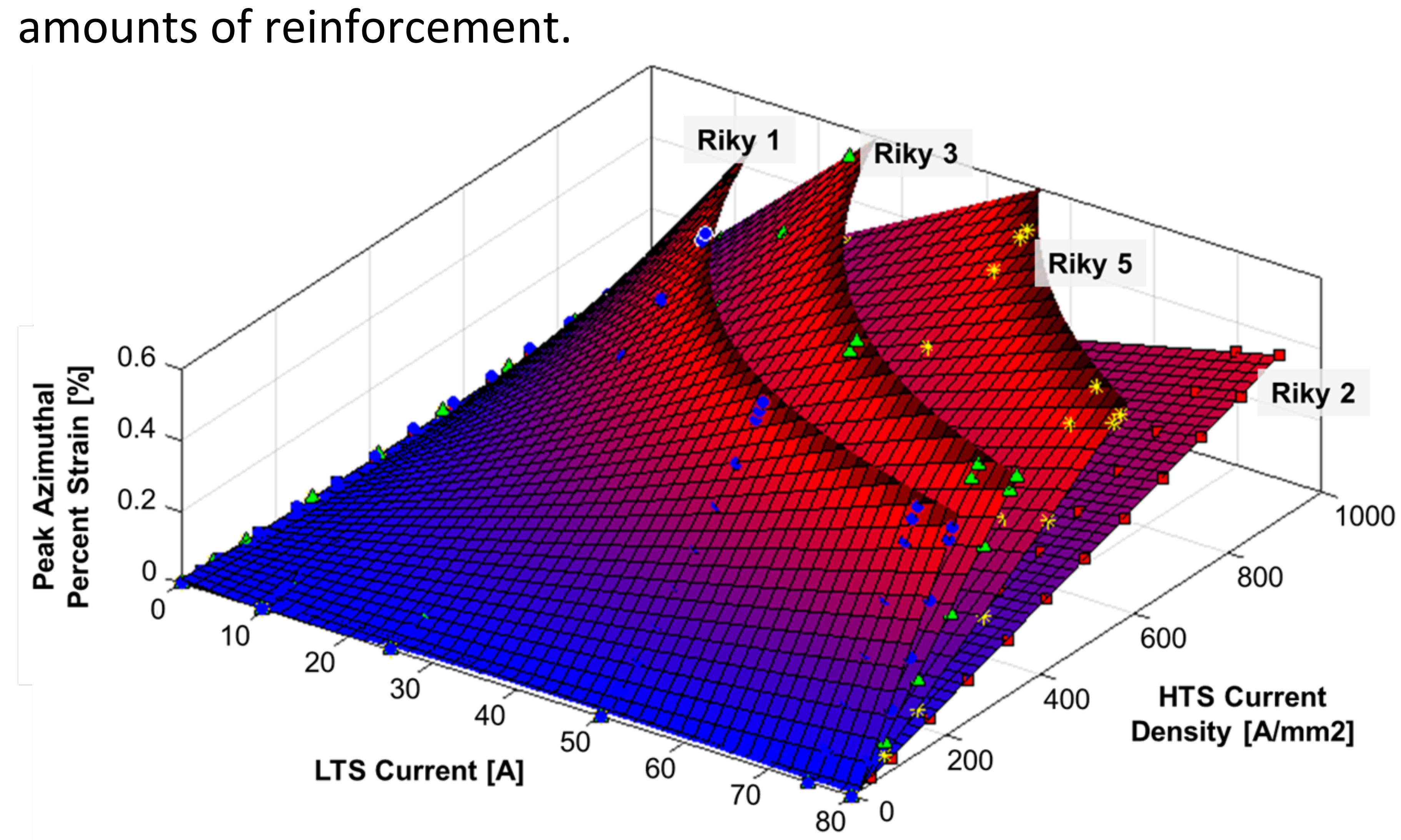


Figure 5. Focusing in on the insert only, azimuthal stress (left) and strain (right)

The performance of this test coil, nested within an 8 T outsert magnet, was predicted to reach 360 A before reaching the 0.6 % critical strain. By varying the field of the outsert magnet and the test coil operating current, a predicted operative envelope can be generated and used as a guide for the experimental test. Below, is a comparison of four of these 'Riky' test coils with varying amounts of reinforcement.



CONCLUSIONS: The efficacy of our reinforcement scheme shows excellent stress management, and thus strain mitigation.

The experimental validation of each of these coils was very good. Riky-2 was reinforced beyond our experimental capability to drive the coil to failure. The design of Riky-3 was driven by the modeling effort; it needed to fail due to strain within our experimental capabilities. Riky-3 failed within 1 % of the predicted value. A second quantitative test is currently being worked on; the goal is to reach 0.6 % but at a slightly higher current.

ACKNOWLEDGEMENTS:
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