Mechanical Interaction Between the Insert and Outsert Coils of 100T Magnet System

Quyen Nguyen[1,2], Lynette Torrez [2,3], Doan Nguyen [2,3]

[1]The University of Texas at Austin, [2]National High Magnetic Field Laboratory, [3]Los Alamos National Laboratory

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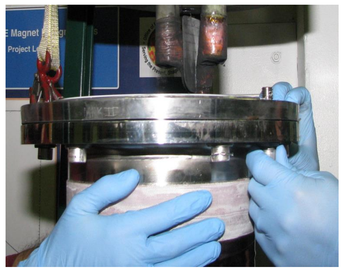
MOTIVATION

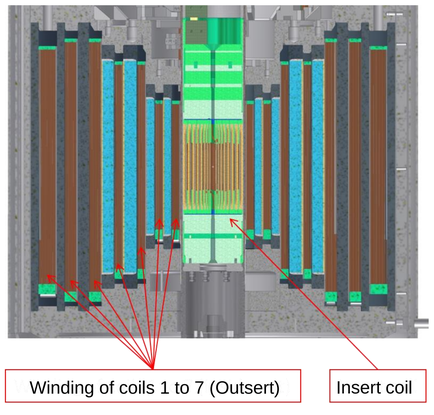
The 100T Magnet is a signature system, producing a non-destructive field up to 100.75T (world record) for ultra-high field research. A slight misalignment between the insert and outsert coil-sets will create a significant electromagnetic force between them. This project addresses the following questions:

- How do the forces acting on insert winding and metal structure depend on the misalignments and field amplitudes?
- Can we simulate the displacement of the insert to understand what we observed?
- How is the stress distributed over the insert stinger?

The stinger top flange was deformed due to high force on insert when there is a considerable misalignment

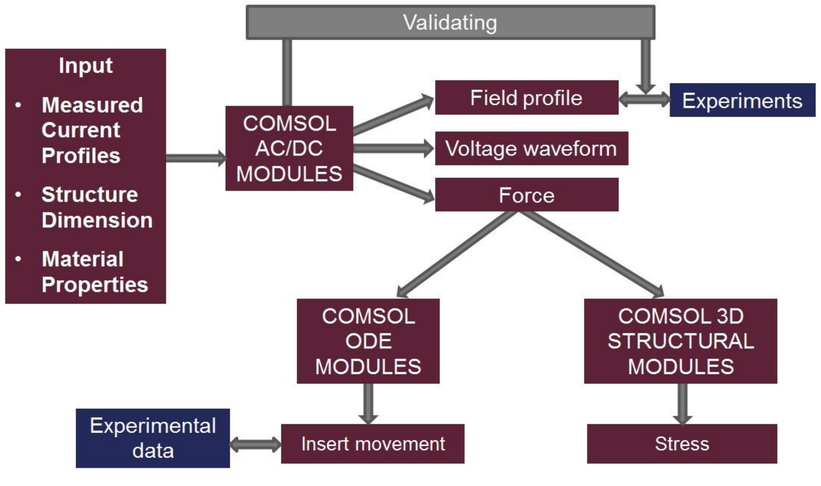


100 TESLA MAGNET

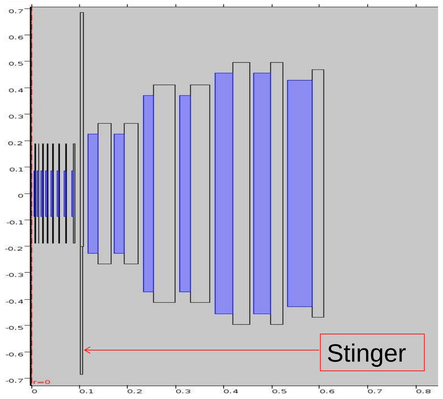


- 60T insert coil powered by a capacitor
- 40T outsert magnet powered by a 1.4 Gigawatt Generator
- Outsert magnet consists of 7 individual concentric coils

APPROACH



GEOMETRY AND MATERIALS



- The copper alloy for conductor windings
- MP35N reinforcement shell for winding layers of insert magnet
- S301 reinforcement shells for windings in outsert coils

FORCE ON THE INSERT

The operation is run at 39.5T background on the outsert and 15kV charge on the insert capacitor bank, or 95.5 T total field.

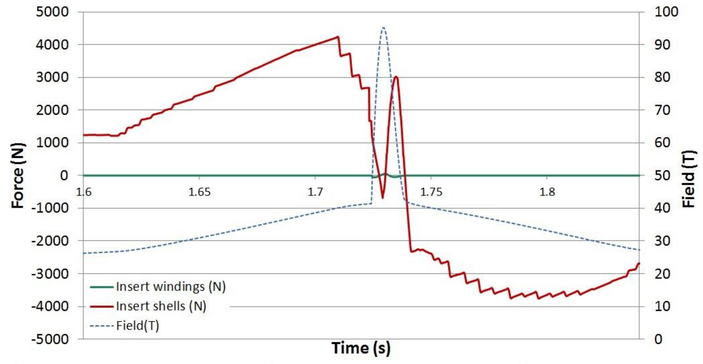


Figure 1: Force on the insert when the misalignment = 0 mm

- The force on the insert windings is 0 as expected.
- The force on the shells is as high as 4kN due to the fact that the stinger is not symmetric through the field center.

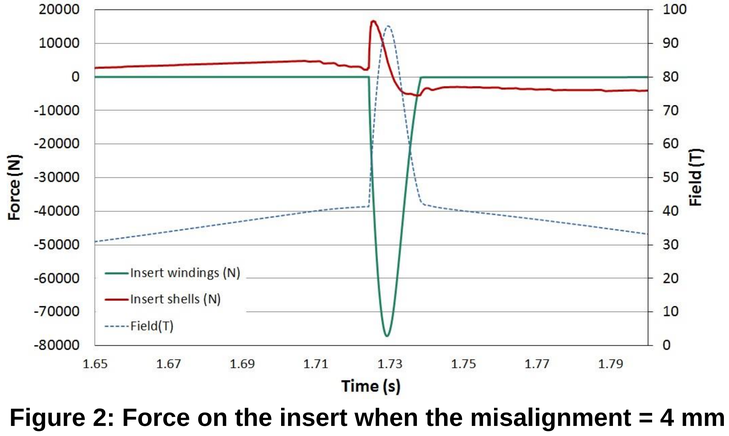


Figure 2: Force on the insert when the misalignment = 4 mm

- The force on the windings is high - up to 80,000N; graph has the same shape as insert field waveform.
- Force on shells also increases significantly since the eddy current position changes due to a higher misalignment.

MOVEMENT OF THE INSERT

$$Equation:\ F(t) - m\ddot{u} - ku - (\alpha m + \beta k)\dot{u} = 0$$

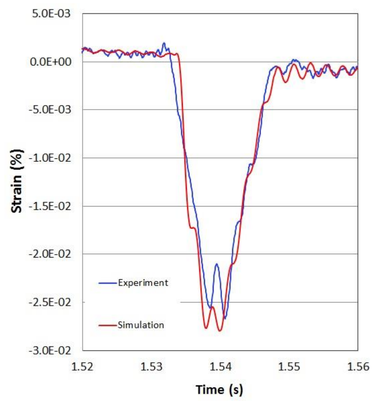


Figure 3: Strain at 33.5T background when MS = 6.5 mm

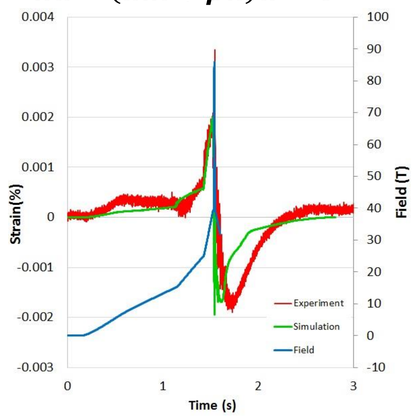


Figure 4: Strain at 39.5T background when MS = 0.2mm

- The simulation reproduced the experimental data well.
- The nodes for nature vibration were observed on both experimental and simulated data

STRESS ON THE STRUCTURE

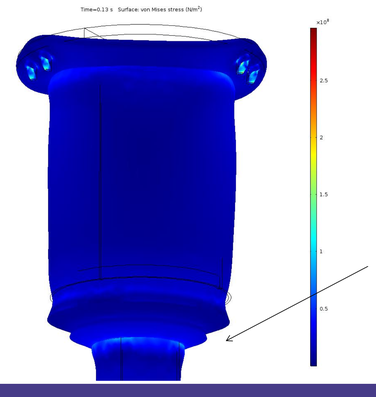
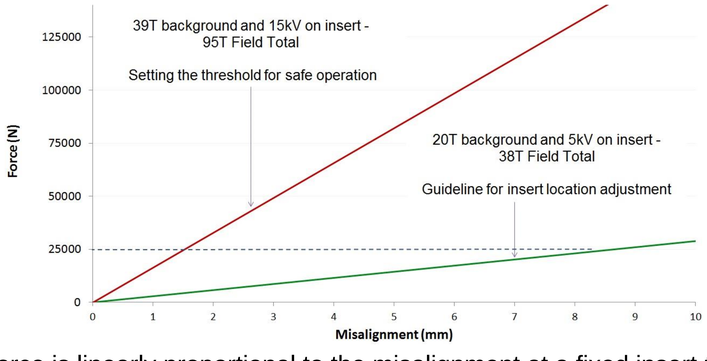


Figure 5: Deformation on the structure with upward force with 4 mm misalignment (MAGNIFIATION = 500)

Stress is highest – up to 250MPa - on the stinger neck. This may cause the structure to deform, as shown in Figure 5.

THRESHOLD FOR SAFE OPERATION

Figure 6: Force as a function of misalignment at various field



- Force is linearly proportional to the misalignment at a fixed insert field.
- Achievable and safe operation limit: 25kN or 0.012% strain or 1.25mm misalignment at 95T (15 kV)