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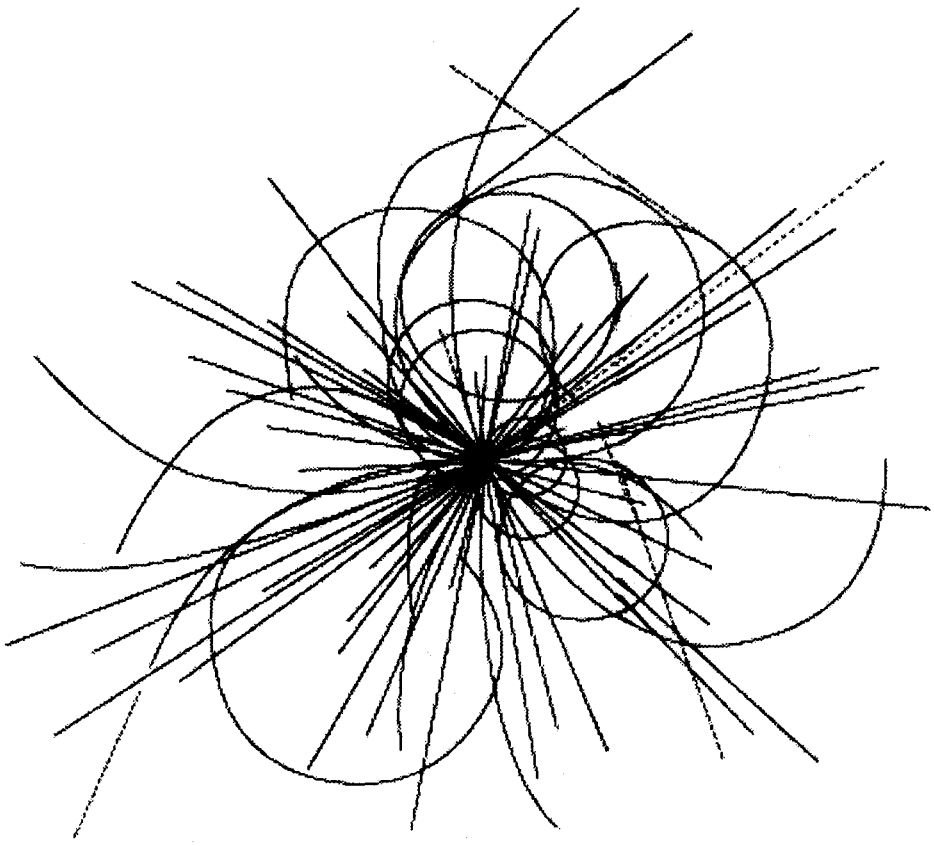

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SDC MUON BARREL TOROID 1/9.197 SCALE TEST MODEL AT SSC

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INTRODUCTION

The purpose of the scale model as shown in Figure 1 for the muon barrel toroid (MBT) is to discover any problems in the preliminary design[1] associated with the fabrication, assembly and installation.

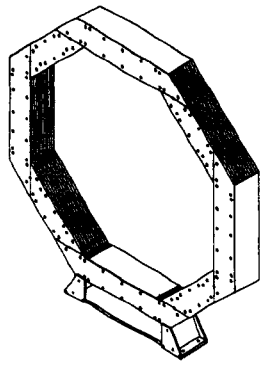

Figure 1. MBT test model ring assembly and support.

The information obtained from the model fabrication, assembly, installation, and testing processes will be used to evaluate the MBT preliminary design and to verify the finite element (FE) analysis. The final design of the MBT will take advantage of the experience gained from the test model to improve the design and engineering, fabrication methods, and assembly methods. The goals that are considered relevant to the test model include the following:

- Verify the in-plane and out-of-plane stiffness of the test model as predicted by the FE analysis.
- Verify the corner joint stiffness of the test model as predicted by the FE analysis.
- Verify the fabrication and assembly methods for the blocks, pins and keys on a small scale.
- Demonstrate the plate flattening scheme on a small scale.
- Insure that the preliminary design of the MBT can be assembled into the correct shape on a small scale.

A magnetic measurement will be performed to record the field density inside an air gap. The main goal is to find out the field distribution for the test model due to geometry variation. The field measurements will also provide the information to verify the magnetic property of the steel material as well as the impact on the field distribution due to material variation.

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DESCRIPTION OF TEST MODEL

Magnet Toroid

The test model has a scale of 1:9.197 compared to the full MBT. The octagonal ring consists of eight long blocks and four short blocks and represent 1/16 of the MBT. The details of design and dimensions for the test model are provided in Reference 2. Each long block consists of four 5/8" inside plates and two 3/4" outside plates. Each short block consists of ten 5/8" inside plates and two 3/4" outside plates. The long block uses 12 longitudinal bolts to hold the six plates together, while the short block uses eight longitudinal bolts to hold the twelve plates together. After assembly, the blocks are machined to final size. At either side of the block, there are six counterbore bolts for the long block, and twelve counterbore bolts for the short block. These corner bolts are used to connect the short and the long blocks into an octagonal ring.

There are two pins for each of the long and short blocks that are threaded to act as nuts for the corner bolts. There are two taper pins to be installed for each of the long and short blocks after the blocks are assembled together. These pins are intended to carry the shear when the blocks are being machined. There are two square keyways for each long and short block to help locate the blocks and carry the shear at the joint. There are four shear plates in the longitudinal direction for connecting the long blocks together. Since the scale model represents only one ring, the shear plates have much less impact than the shear plates for the full MBT.

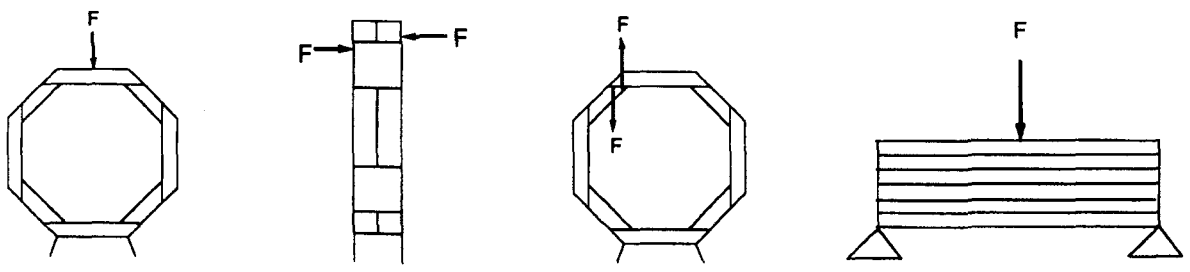
Mechanical Tests

(1) Vertical Deflection (x-y plane) – Measure the deflection in x and y at the top, middle and bottom sections of the ring, and the bolt load at the lower corner of the ring under various loads. This tests the stiffness of the ring in x-y plane (Figure 2).

(2) Lockwasher Deflection (y-z plane) – Measure deflections in z at the top portion of the ring and the bolt load at the lower corner when the load is applied in opposite directions above and below the upper block joint. This tests the lockwasher stiffness of the ring (Figure 3).

(3) Vertical Misalignment (x-y plane) – Measure forces in y at the upper corner to create a vertical gap between the two adjacent blocks. The bolts at one corner are removed to allow a vertical gap under a load. This tests the stiffness of the upper block joint and corresponding bolt loads (Figure 4).

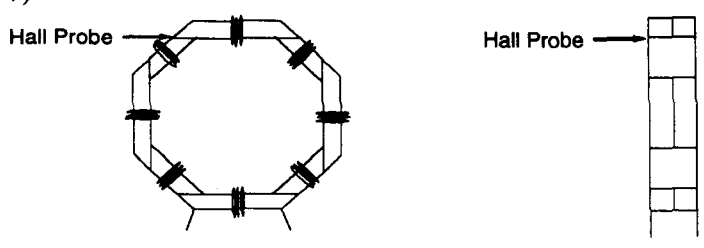
(4) Block Stiffness (x-y plane) – Measure deflections and relative displacement between laminated plates for a simply supported long block. This tests the stiffness of the laminated block (Figure 5).



Figures 2 – 5

Magnetic Tests

Magnetic Field (x-z planes) - Use a Gaussmeter and a transverse Hall probe to measure the magnetic field density in y inside the air gap (2 mm) between the adjacent blocks. The coils are placed in the center of each octane of the toroid. This tests the field uniformity and strength. (Figures 6 and 7)



Figures 6 – 7

TEST RESULTS

Mechanical Test Results

The comparison between the test model results and the FE analysis results is only applicable where the test model behavior is fairly linear because the FE models are constrained to behave linearly over the entire load range. The torque for all corner bolts is 90 in-lbs for the scale model and the FE models. The comparison is provided in Table 1. There is good agreement between the stiffness predicted by the FE model and the stiffness measured in the tests.

Table 1. Force/Displacement (kg/mm).

Case	Test Model	FEA	% Difference
1	13,500	13,700	+ 1.5
2	5.5	6.5	+ 18.0
3	356	288	– 19.0
4	3,496	4,130	+ 18.0

Magnetic Test Results

The magnetic field density measured in y for various points inside the air gap (in x-z plane) indicates the maximum field being 1.3 Tesla. The cross sectional area for the air gap is about 1.4 times the cross sectional area in the central region for the rest of the blocks. Since the filed lines are fairly perpendicular through the air gap and the total flux remains constant for each cross section, the magnetic field in the center region of the block is about 1.82 Tesla with the proper geometric correction. This measured value is in close agreement with the design value of 1.8 Tesla which is based on the permeability of the steel and the amp-turn design of the coils. (Figure 8)

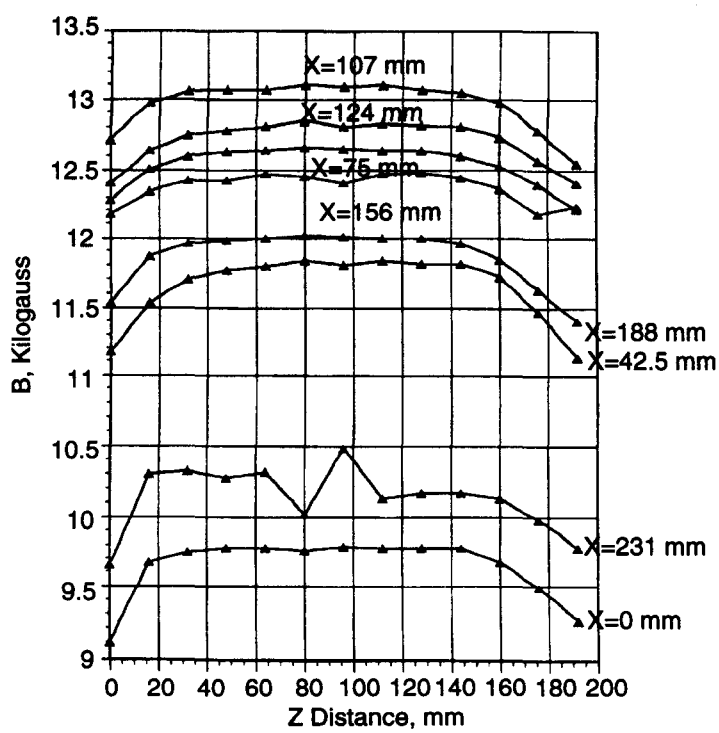


Figure 8. Magnet Field Distribution for Various X Distance inside the Air Gap (X=0 mm to X=231 mm).

CONCLUSION

The scale model does not indicate any difficulties in fabricating the parts, assembling the blocks, and installing the ring to meet the preliminary design of the MBT. All tolerances as required by the design can be achieved by the fabricator. The main deviation from the design is that all blocks except one used all-machined plates before the assembly.

The corner joints are tested within the safety limit for the M6 bolts. The corner joints remained under compression throughout the testing loads. There is no indication of failure under any testing case.

The comparison between the test results and FE results for case 1 are in good agreement as shown in Figure 9. An additional test case was performed to evaluate the corner joint stiffness for a tip-loaded cantilevered long block. The comparison between the test results and FE results is good and the FE model predicted higher (conservative) bolt loads when the external force gets higher (Figure 10). This provides the verification that the FE assumptions and modeling technique are sound and FE results are reliable in predicting the behavior of the full size structure.

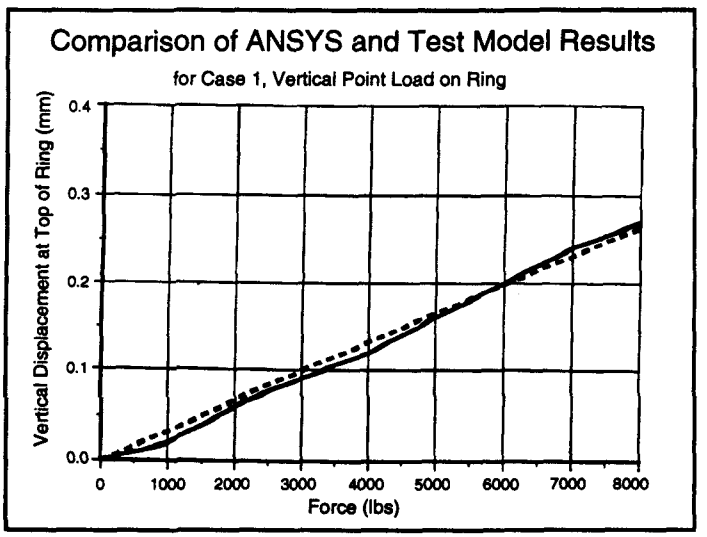


Figure 9. Comparison between test and FE results for case 1.

The magnetic distribution in the test model is quite uniform. The maximum field density of 1.3 Tesla is in agreement with the coil design and the magnetic property of the steel material used for the scale model. The impact from a material variation in one long block is found to be not as significant as predicted for the test model. The magnetic simulation for the scale model is not complete, but the preliminary results from computer simulation are in close agreement with the field measurement.

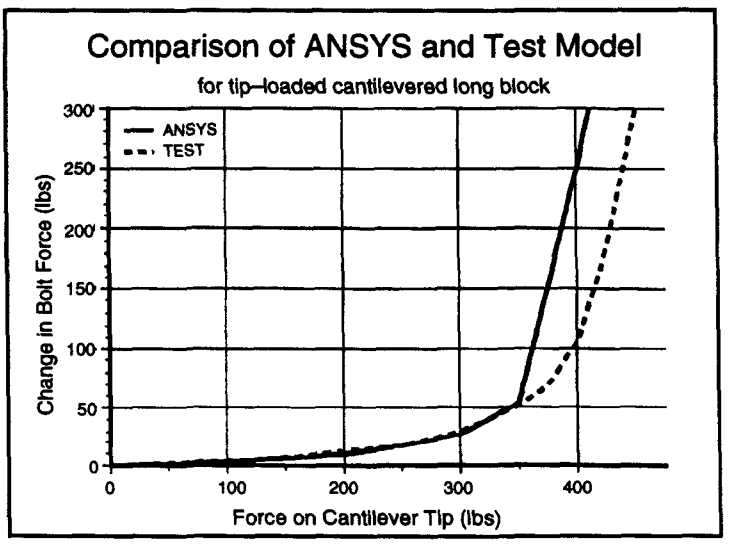


Figure 10. Comparison between test and FE results for tip-loaded case.

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