FABRICATION OF SUPERCONDUCTING CAVITIES FOR THE RF SEPARATED KAON BEAM

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Abstract

Superconducting cavities for the RF Separated Kaon Beam Project are formed by joining multiple niobium half-cells by means of electron-beam welding. In the deflection mode the fields are a maximum in the iris, and hence this area is critical. Strict mechanical and electrical tolerances are imposed, especially in the iris region. A fabrication process has been developed that minimizes deviations from the nominal design shape. This maximizes the opportunity to achieve design frequency and field flatness in the final cavities.

HALF-CELLS

Several multi-cell cavities have been fabricated at Fermilab using half-cells deep-drawn from 1.6 mm thick niobium blanks. Recently a decision was made to form half-cells from 2.2 mm thick niobium blanks for the purpose of improving the structural rigidity of the final cavities. Two approaches are under investigation. Half-cells are formed at Fermilab (FNAL) by deep-drawing, while Advanced Energy Systems (AES) has been contracted to produce half-cells using a hydroforming process. In both approaches the half-cells are coined at the iris to achieve the required curvature. Critical factors that are required to be controlled in the forming process are: (1) Half-cell length and the shape of the inner (RF) surface, (2) Circumferential uniformity of individual half-cells, and (3) Repeatability of inner surface shape from half-cell to half-cell.

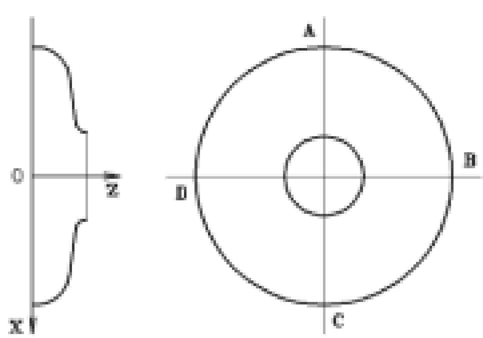

Figure 1: Half-cell geometry

From each batch of half-cells several are selected for inspection. Using a coordinate measuring machine (CMM), the inner surface of each selected half-cell is profiled along axial planes at 0 (A), 90 (B), 180 (C), and 270 (D) degrees, as shown in Figure 1. The CMM data is directed to a computer code that compensates for the radius of the CMM probe.

A second computer code is used to calculate the deviation from design shape as a function of axial displacement, z, for each selected half-cell. Deviation from design shape is defined as the distance from the actual surface to the design surface as measured along the normal to the actual surface. The parameters of interest are shown in Figure 2. Results for typical FNAL and AES half-cells are shown in Figure 3 and Figure 4 respectively.

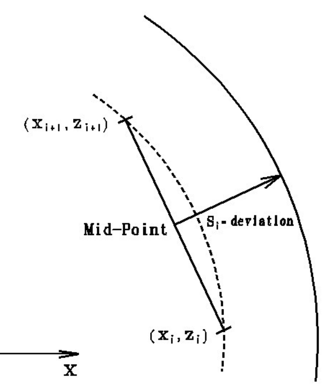

Figure 2: Deviation of measured surface (dashed line) from design surface (solid line)

The mean deviation magnitude for AES half-cells is ~26 microns [0.001”], while that for FNAL half-cells is ~64 microns [0.0025”]. Both approaches show more significant error in the iris region.

To check circumferential uniformity the deviation from design shape as a function of axial displacement from all four sets of compensated CMM data for individual half-cells can be compared. Repeatability is verified by observing the deviation from design shape for compensated CMM measurement data from a statistically significant number of half-cells.

DUMBBELLS

Dumbbells are formed by electron-beam welding half-cells together at the iris. The half-cells are held in a welding fixture that is designed to insure that their equatorial planes are as close to parallel as possible after welding, while still allowing freedom for weld shrinkage in the axial direction. A near full-penetration, external weld pass is followed by an overlapped, internal weld pass. The welding fixture is shown in Figure 5.

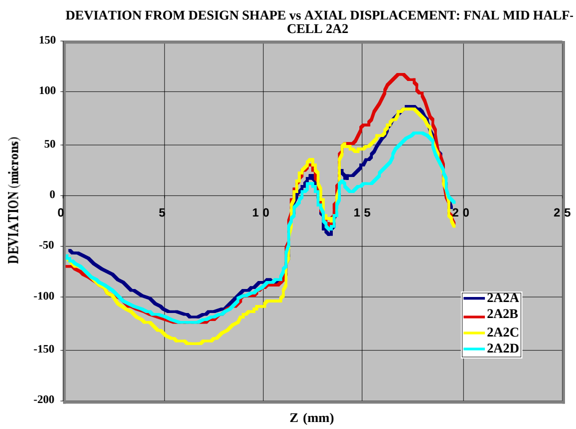

Figure 3: Half-cell deep-drawn and coined (FNAL)

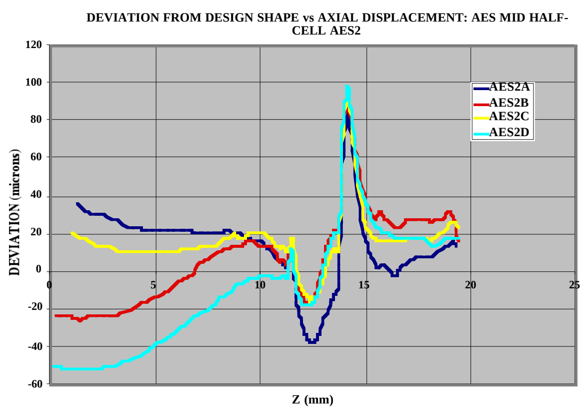

Figure 4: Half-cell hydroformed and coined (AES)

The inner surface of each dumbbell is inspected as previously using the CMM. Critical factors to be anticipated or controlled are: (1) Shrinkage at the iris, (2) Tilting of the equatorial planes, and (3) Loss of circumferential symmetry at the iris due to welding distortion. Iris shrinkage is predicted statistically from previous welds. Tilt is somewhat influenced by the design of the welding fixture, but also appears dependent on material thickness (dumbbells formed from thicker niobium appear to exhibit less tilt). Tests are underway to improve circumferential symmetry at the iris by determining the optimum electron-beam welding current profile.

Compensated measurement data compared to design shape for a dumbbell welded from FNAL mid half-cells are plotted in Figure 6.

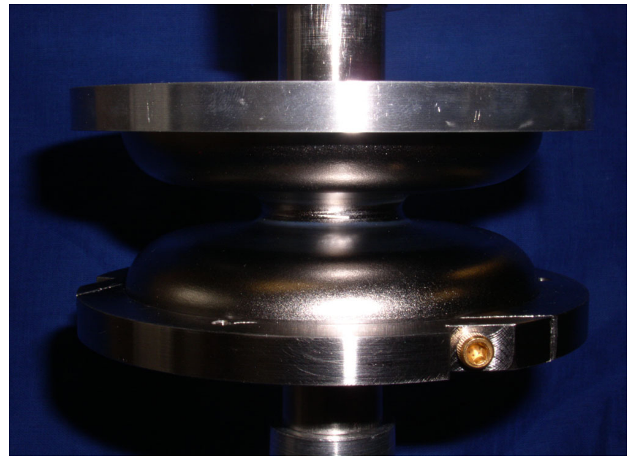

Figure 5 (a): Half-cells set up for external weld pass

Figure 5 (b): Half-cells set up for internal weld pass

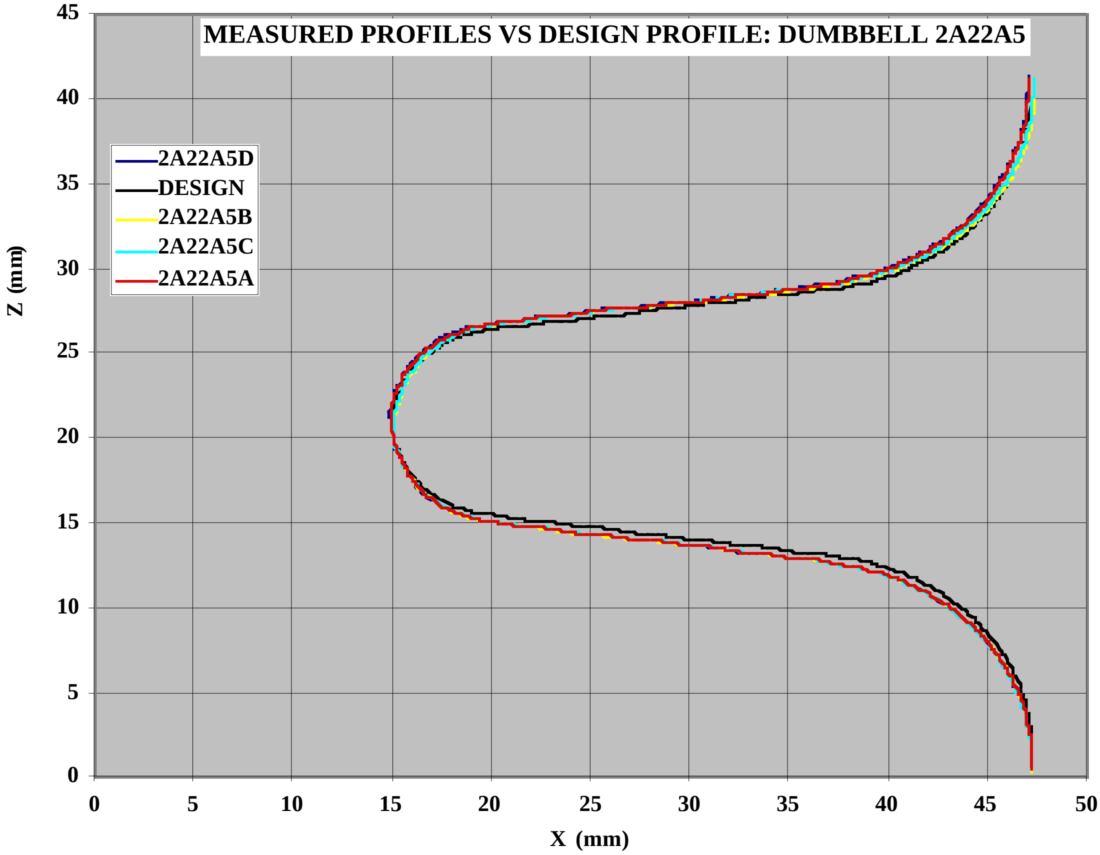

Figure 6: Measured profiles compared to design profile

CONCLUSIONS

A small sample of 2.2 mm niobium half-cells for the 3.9 GHz Kaon Separator have been formed and measured. The hydroformed half-cells conform to the design shape more closely than the deep-drawn half-cells. Circumferential uniformity and half-cell to half-cell repeatability appear approximately similar, although deviation from the design shape in the iris region is still a concern.

Dumbbells formed from 2.2 mm half-cells exhibit less tilt and significantly less tendency to deform asymmetrically in the iris region as a result of electron-beam welding than those formed from 1.6 mm half-cells.

ACKNOWLEDGMENTS

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