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PROGRESS ON SUPERCONDUCTING RF CAVITY DEVELOPMENT WITH UK INDUSTRY

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Abstract

As part of a STFC Industrial Programme Support (IPS) Scheme grant, Daresbury Laboratory and Shakespeare Engineering Ltd have been developing the capability to fabricate, process, and test a 9-cell, 1.3 GHz superconducting RF cavity. The objective of the programme of work is to achieve an accelerating gradient of greater than 20 MV/m at an unloaded quality factor of 1.0 x 10^{10} or better. Processes such as the high pressure rinsing and the buffer chemical polishing are being developed at Daresbury Laboratory and the manufacturing of the cavity half-cells and beam-pipes are being optimised by Shakespeare Engineering to enable this target to be achieved. These are discussed in this paper.

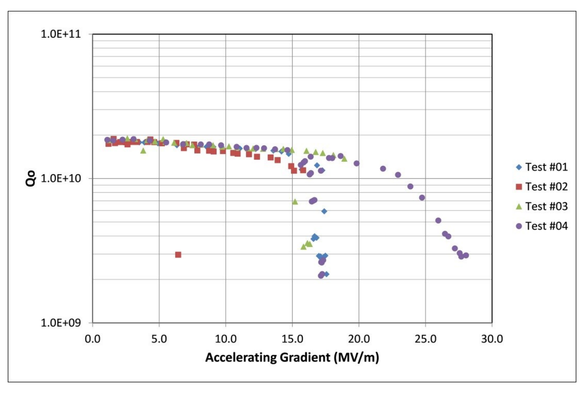
Introduction

The aim of the IPS project is to develop the capability of UK industry in the manufacturing of superconducting RF cavities.

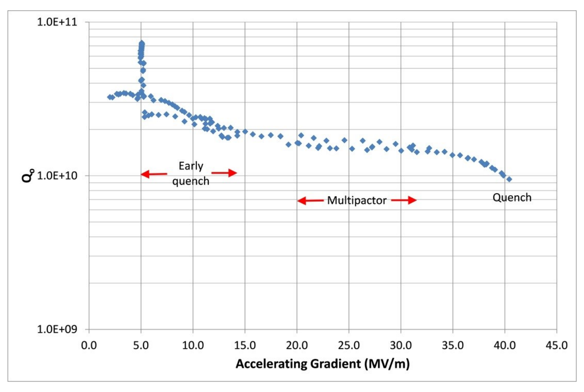
Deliverables:-

- Fabrication of 1.3 GHz of 9-cell niobium superconducting RF (SRF) cavity
- Target gradient of >20 MV/m with a Q_0 > 1x 10^{10} at 2K after BCP
- Target gradient of >30 MV/m with a Q_0 > 1x 10^{10} at 2K after EP and CBP
- Evaluation of processing techniques
- Expanded process capabilities
- Knowledge transfer – Documented processes and assured quality control

Single-Cell Achievements:-



PIPSS #01



PIPSS #03

Cavity Design

- Design of the 9-cell cavity is based on the Tesla cavity
  - No coupling ports
- Stepped equator and iris interfaces
  - Ease of parallelism of the equator planes
  - Repeatability of mating half-cells together
- Seamless beam-pipes

Fabrication

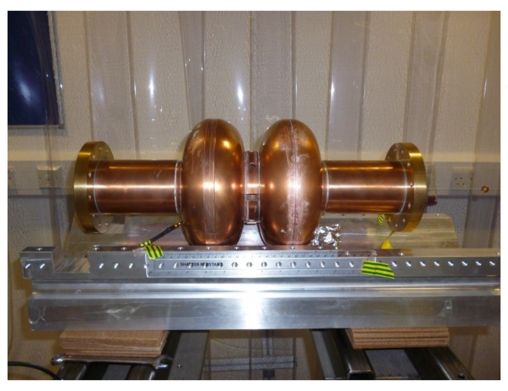
Beam-pipes:-

- Copper trials performed with 4 mm sheets
  - Minimises the risk of wall thinning
- Niobium beam-pipes successfully spun with minimal thinning of the wall thickness

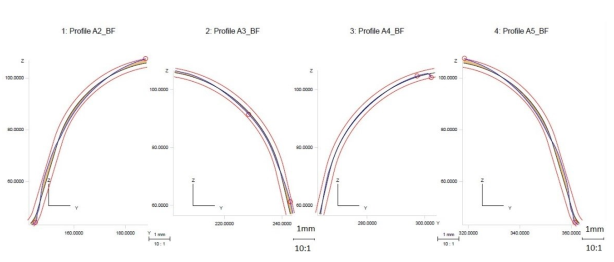
Niobium beam-pipe spinning and beam-pipes prior to machining

Cavity:-

- Deep-drawing tool dies have been manufactured from high carbon tool steel
- Trials have been performed with copper using a 60 tonne Müller press
  - Minimise the wall thickness variability
  - Reduce spring-back, to ensure equator roundness
- Trial 2-cell copper cavity fabricated
  - Excellent equator and iris interfacing of half-cells
  - Spring-back and thickness variability controlled
  - Within tolerances of ±0.2 mm
  - Consistency seen when comparing each of the end-cells and each of the mid-cells with each other
  - ✓ Profiles of dies verified

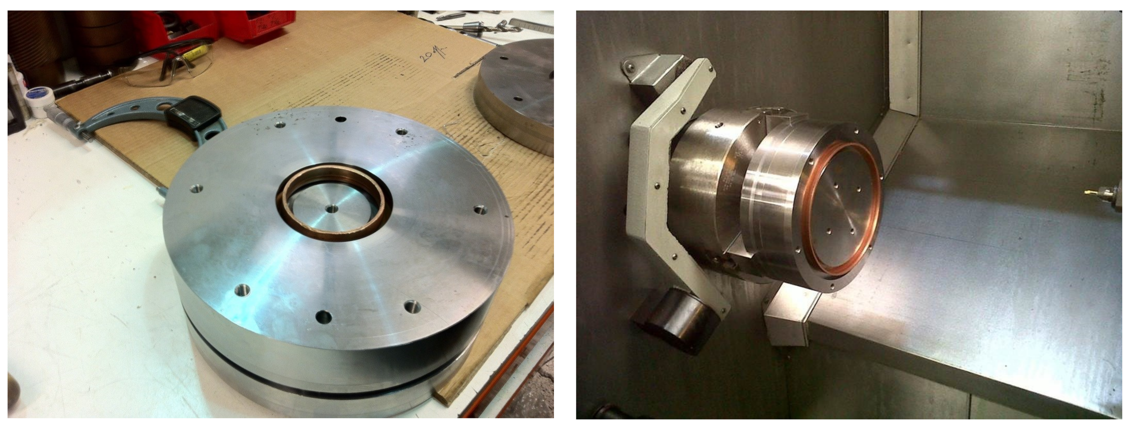


2-cell prototype copper cavity



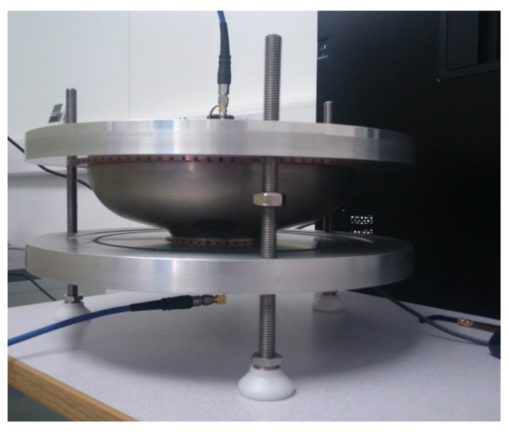
CMM measurements of 2-cell prototype copper cavity

- Niobium cell fabrication performed
  - Jigging has been specifically designed to ensure the half-cells/dumbbells repeatedly self-locate and the datum points in terms of the accuracy of the axial and linear features is maintained
- Frequency and CMM measurements performed on half-cells
  - Mainly within the 100 µm tolerance, with some deviation near the iris.
  - Consistent frequency measured for the various types of half-cells - within 5 MHz,
  - Could be explained by the deviation seen at the iris
- Half-cells are now ready for EB welding of the iris joints to form the dumbbells



Niobium half-cell cavity machining

Niobium half-cell



Frequency measurement of a half-cell

CMM measurements of niobium half-cell

Electron Beam Welding:-

- Electron beam welding trials have been performed at Bodycote PLC using a 150 kV 160 mA electron beam welder
  - Welding bay cleaned to improve welding pressure so as to meet the target pressure of 2 x 10^{-5} mbar
  - Welding parameters are being optimised with further trials continuing on both flat plate and beam-pipe samples
- Jigs have been designed and manufactured

Facilities

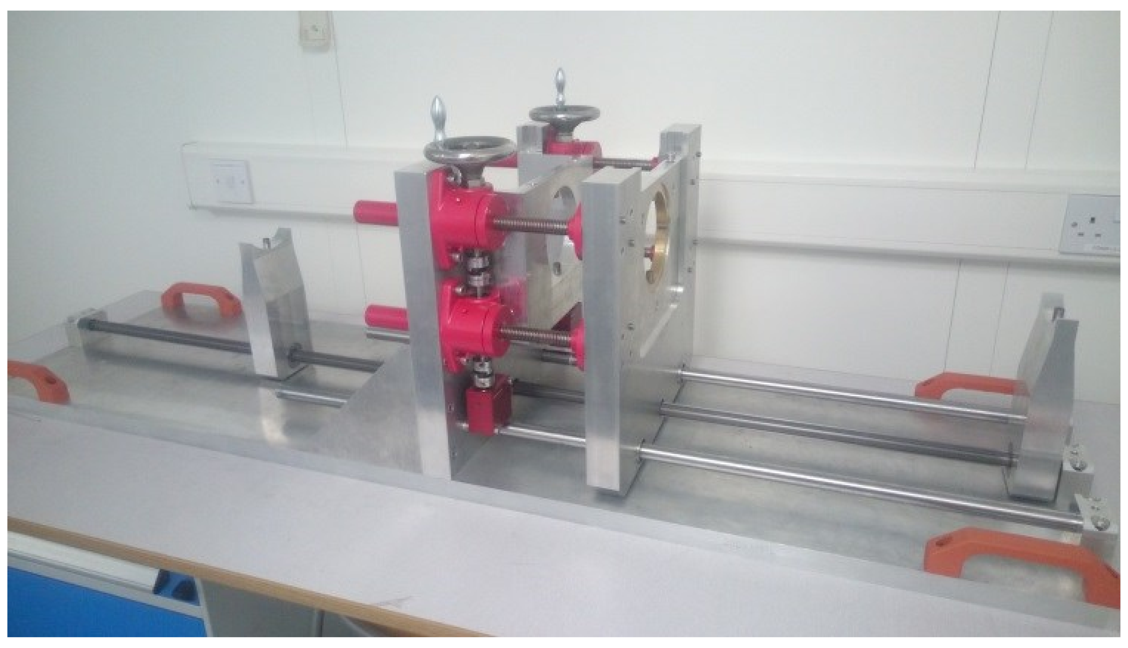
To enable the step from processing a single-cell cavity to that for a 9-cell cavity the facilities have been expanded to include a fully automated BCP etching facility and an automated HPR stand.

BCP Facility

HPR Facility

Mechanical Cavity Tuning:

- A manual mechanical cavity tuning fixture has been designed and built to provide a tuning range of 4.5 mm
  - A floating yoke is supported by 2 precision linear bearings
  - Cell tuning is achieved by adjusting the position of the floating yoke with respect to the fixed yoke
  - Split tuning plates slot into the yokes and clamp around the iris of the cavity
  - Tuner mechanism has inter-connecting actuators, ensuring equal and opposite rotation for even tuning
  - The positions of the cavity supports are adjustable to enable the tuning of the different cells.



Mechanical cavity tuning fixture

Summary and Future Plans

- As part of the initial MINI-IPS programme a gradient of 40MV/m at a Q_o of 1.0 x 10^{10} after EP and CBP has been achieved on a single-cell cavity
- Profile of pressing dies confirmed for the centre and end-cells with a prototype 2-cell copper cavity
- Niobium half-cells have been produced and characterised via frequency and CMM measurements.
- Spun niobium beam-pipes have been successfully fabricated with 4 mm niobium
- EB welding trials have been performed
- It is planned to progress the welding of the beam-pipes and half-cells in the near future

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