RFD Crab Cavity Manufacturing

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RFD Crab Cavity Prototypes

Manufacturing of **2x Jacketed Cavities**

- See R. Calaga talk (16th Oct.)
- See T. Capelli talk (18th Oct.)

- RFD-SPS cavity fabrication started at CERN, cryostating to be performed at UK and the conceptual design in an advanced stage
- RFD-HL-LHC dressed cavities in-kind contribution from US-AUP with CD1 approval
- RFD-HL-LHC cryostating is approved to be an in-kind from Canada-TRIUMF
Rationale behind RFD prototype cut out:

- Favor high-added-value operations (EB welding, trimming)
- Shaping of easiest subcomponents
- Make use of DQW know-how and (tooling!)
- Optimize raw material cost VS. Process (Memento: 2x cavities)
Cavity Build Up

Ports:

Manufacturing Phases

Cap:

Manufacturing Phases
Cavity Build Up

Manufacturing Phases
Cavity Build Up

Manufacturing Phases
RFD Cavity Manufacturing: Strategy

- **Extremities:** same procedure (and tools) as per DQW
- Initial tests in annealed Cu OFE, then Niobium
- **Material:**
  - Stainless Steels, Bronze (CuSn12), EN 1.2343, …
  - Highly attentive to Niobium and NbTi condition @ reception

Niobium:
- Alumina inclusions
- Automatic inspection on samples of incoming material

NbTi:
- Niobium inclusions, not detected during supplier NDT

Experience is directly translated onto ongoing discussions with suppliers and into current updates of corresponding CERN specifications: (# 3300, # 3301, # 4055)
Manufacturing: Machining Strategy

How to handle unconventional shapes?

...theoretical-shape clamping...

- More indulgent on shaping and machining
- Advanced tools needed down to last weld

...VS. free-state (stress-free) clamping...

- Forming: must yield best shape possible (→ coining!)
- Machining: no easy referencing.. must go hand in hand with metrology
- Welding: no last minute surprises
Manufacturing: Welding Strategy

**Butt welds** (no key/slotted configuration):
- Easy check for alignment and defects
- Easy RF trimming
- Multi-axis milling

**If RF surface visible:**
4mm weld, smoothing on RF side.

**If RF surface not visible:** thickness reduction for critical welds (→ lower energy input, less risky,..)

**Backing Ring** when remachining feasible

Corner-Pole smoothing
Finite Element Simulations

Why?
• Compare different manufacturing choices & steer strategy
• identify forming defects & highly stressed regions
• predict on the final thickness distribution

What?
Shaping of: Pole, Main Body, H-HOM waveguide, End Cap, Corner

Working on Springback modelling and ongoing material characterizations:
• Anysotropy
• Niobium Frictional behaviour

r values curves for each direction and their averages
Waveguides

Deep drawing + coining of half-boxes
No extrusion of extremity interface

- Less forming steps
- High forming ratios and stretching in correspondance of extremity interface
- Easier machining (only thickness & height for EBW)

- Challenging EBW due to sudden EB direction changes:
  - RF side 100% accessible for smoothing & eventual repairs
Waveguides: H-HOM Status

Good global shape tolerances achieved
Tool modification ongoing for improvement on:
• shape nonconformity due to springback
• thickness reduction @ angles

0.6mm thck. Red.

0.7mm

±0.1mm

0.3mm

±0.1mm
Shaping:
- Bending + Extrusion + Coining

Machining
- multi-axial thickness reduction on both int & ext edges

Rigid component (6.35 mm thickness)
- calibration after forming
- Stiffer during machining
- Shaping defects propagate to CNC machining

Universal tool for all machining steps
Metrology (after shaping and coining):

- RF perimeter @ weld: **smaller in avg. 0.2mm** (per radius)
- Shape error peaks due to **thinning of material during extrusion**

Machining + re-coining should grant 0.1mm enlargement (per radius)
Local calibration for remaining nonconformities

**Profile @ weld with Pole**

- Part’s final edges

0.7mm

0.65mm
Shaping: standard process via press bend

Multi-axis machining for interface with corner

Status: ready for shaping of cavity parts
…With respect to DQW Bowl..
Shaping/machining/welding **strategy is in all similar**

Large **displacements** of sheet (friction)
RF surface open to the world
More **radical rates of strain** on the piece
No scratches on RF surface

Shape inside specified tolerances, apart from local peak at rounding (can be corrected)

Shape at weld interface to further improve once final milling performed
RFD Manufacturing: Sub-deliverables

Deliverable #1:
- Main body ready for deliverable #3 (tuner + stiffener welding)
- End Cap ready for welding with Deliverable #2

Deliverable #2:
- Waveguides: ready for welding onto Deliverable #1
- Remaining extremities ready for welding with Deliverable #1

Deliverable #3:
Welding of major subassemblies onto 2x cavities. Where provided subassemblies carry reduced Shaping-remachining interactions
R&D phase to be finalized in Q4 2018

After Manufacturing Plan: welding tests, qualifications and prototypes production

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Conclusions

• **DQW experience** instrumental for RFD manufacturing strategy
• **Interactions with Nb/NbTi material supplier**: small delay for missing Niobium, but instrumental for future series orders

• Feasibility check for initial processes to be finalized in upcoming weeks.
• Shaping **strategy** for all critical components **validated**.
• **First Niobium pieces** in sight.

• **Next:**
  - Launch production of extremities
  - Weld tests & qualifications
Thanks!