High Velocity Forming of Superconducting Structures with Bulk Nb and Cu Substrate

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Presented by: Jean-François Croteau (ESR 9), 12 April 2018

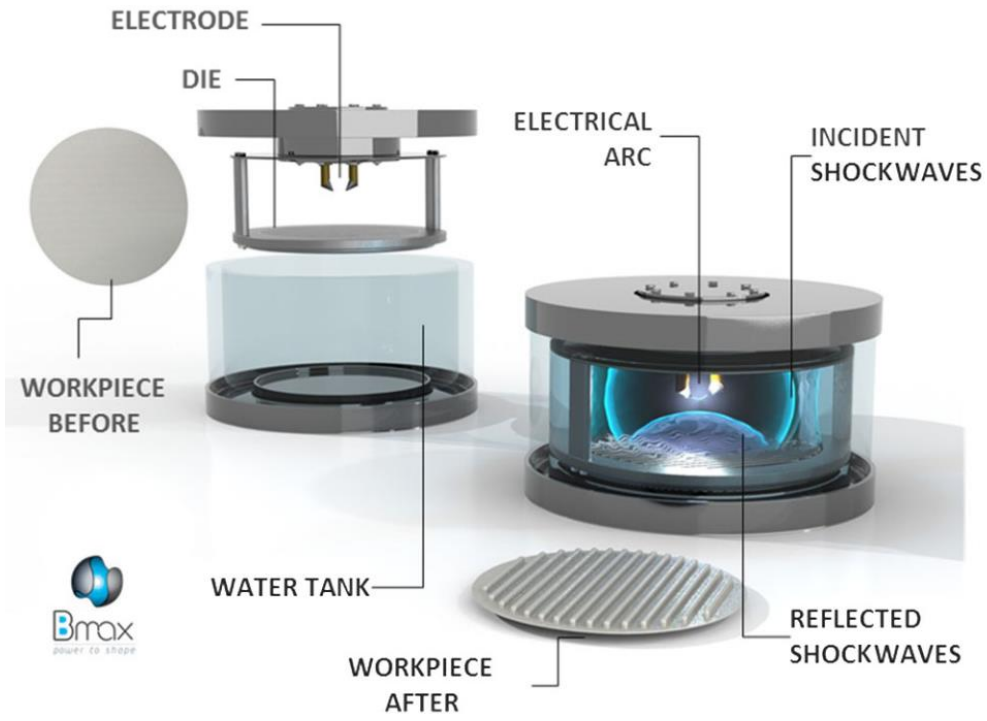
EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879

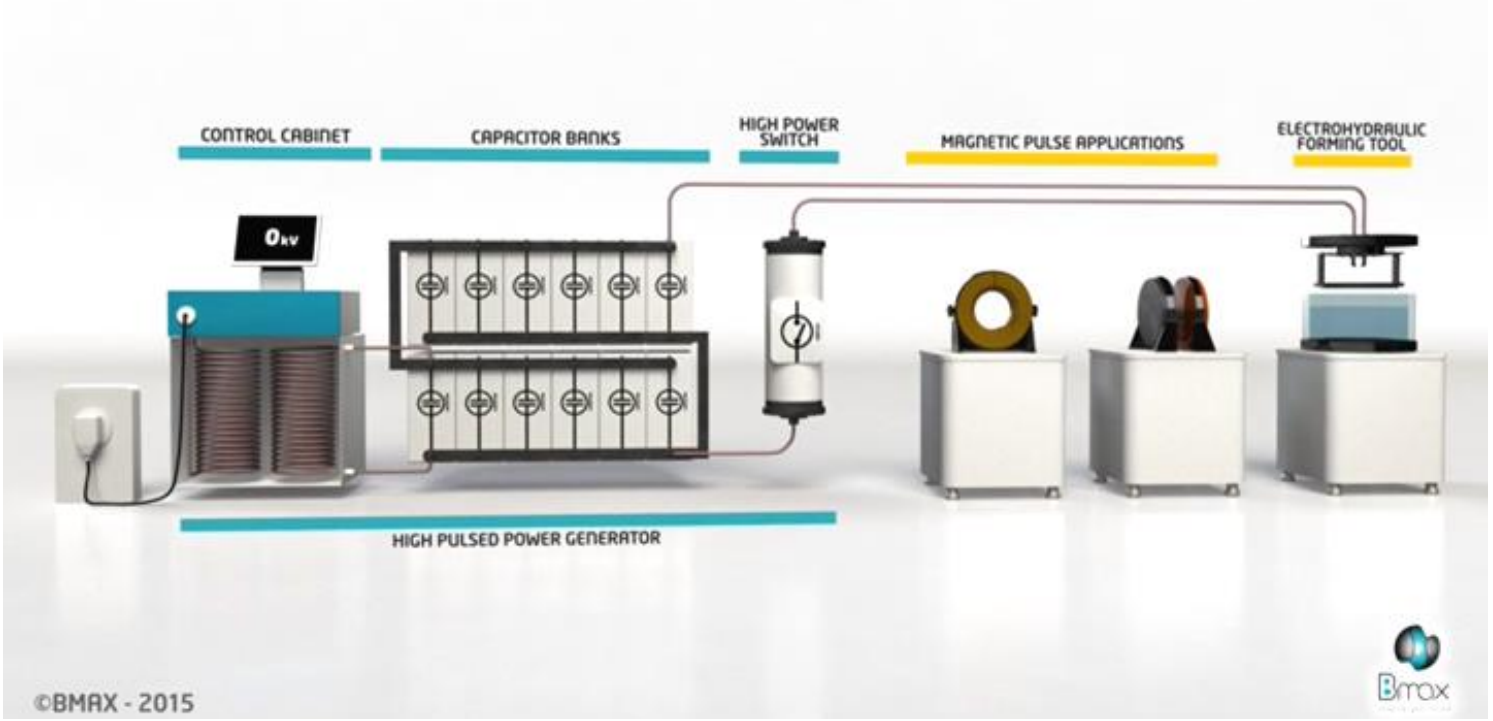
Project Objectives

- Mechanical characterization of copper and niobium at high strain-rates
- Design of compensation die for the fabrication of niobium half-cells
- Fabrication of half-cells with large grain niobium sheets
- Microstructural studies of cavities formed by different processes
- Investigation of the feasibility of forming seamless cavities

Electrohydraulic Forming

- High strain-rate deformation of metal by a shock wave inside a water tank
- Shock wave is generated using a high voltage discharge of capacitors



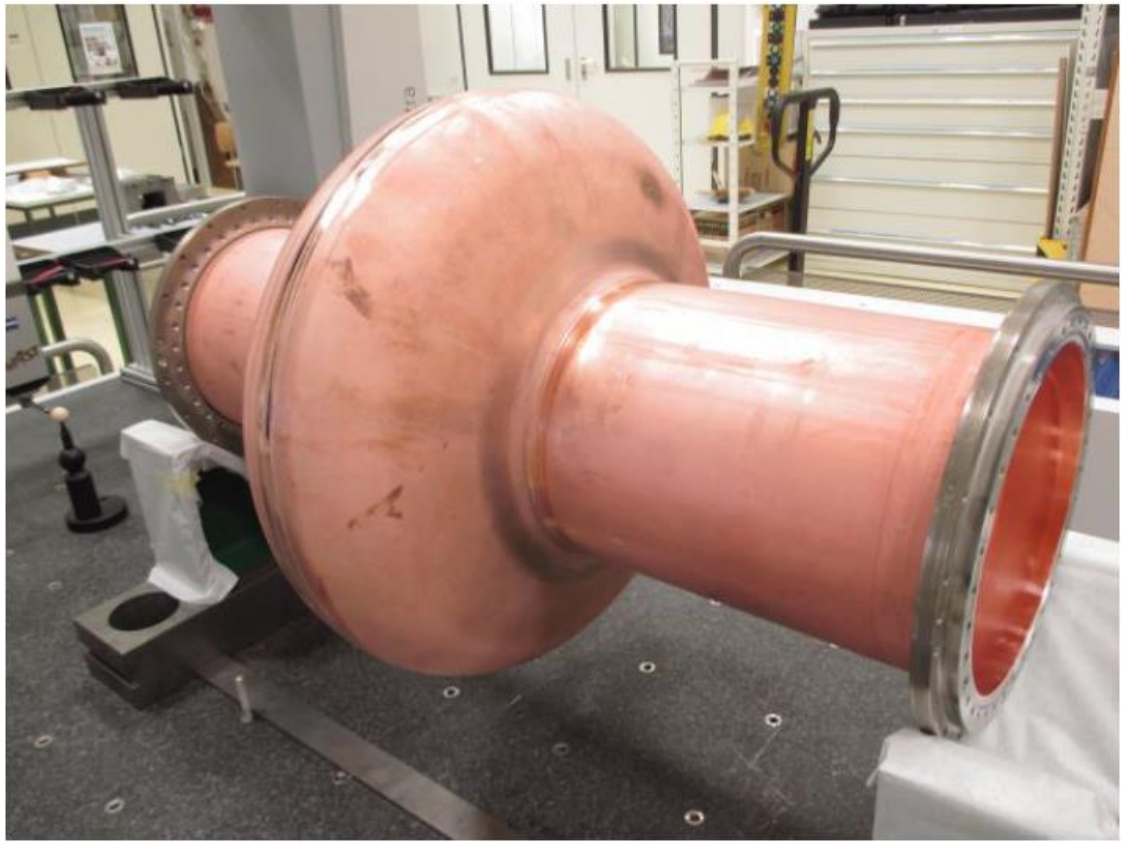


Electrohydraulic Forming

Currently used with CERN
to produce half-cells

Advantages

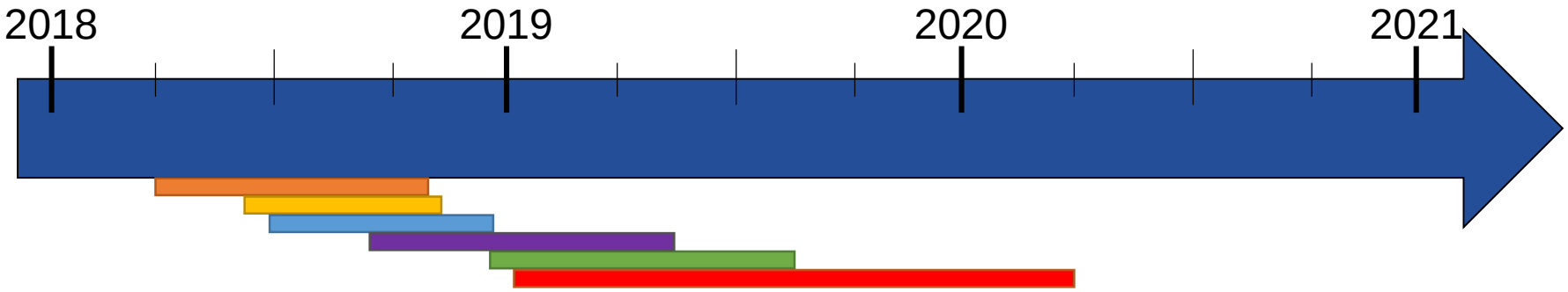
- High shape accuracy
- High reproducibility
- Thin affected layer on surface
- No foreign particles embedded
- No intermediate heat treatment stages required



400 MHz cavity from EHF half-cells welded at CERN

Project Timeline

EASITrain Project kick-off Mid-term Expected completion



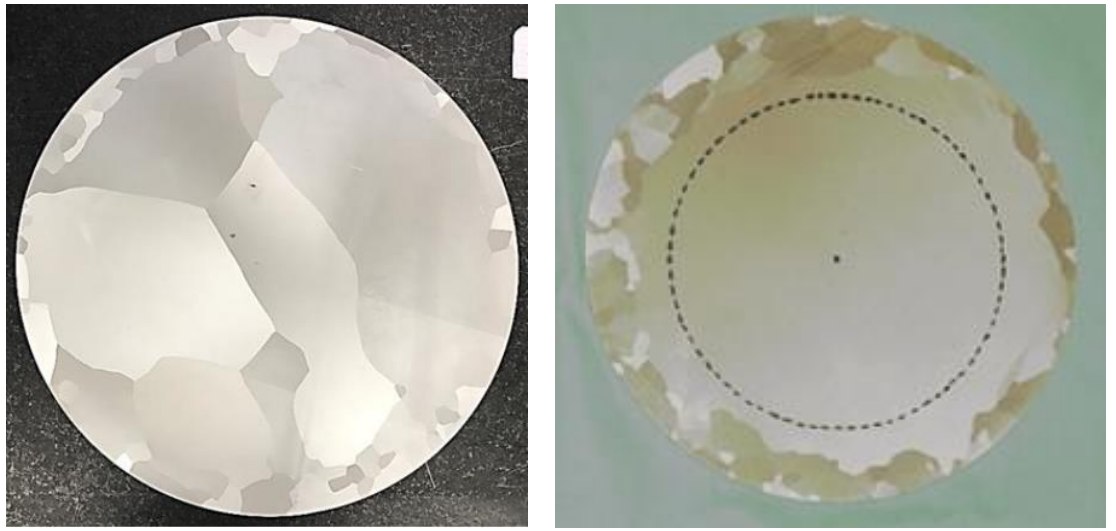
Phases

1. Constitutive laws at high strain-rate
2. Determination of forming limit diagram
3. Compensation die for 800 MHz half-cells
4. Characterization of mechanical properties after forming
5. Large grain Nb half-cells
6. Investigate feasibility of seamless cavities

Material Characterization at High Strain Rates

- Constitutive model for OFE Cu and Nb
- Theoretical modelling of forming limit diagram with ENSTA Bretagne validated with experimental data
- Split-Hopkinson bar tests in compression and tension
- Adaptation of in-house testing device for large grain Nb

Strain rate	**Method**
$< 1\ \mathrm{s}^{-1}$	Tensile test
$10^2 - 10^4\ \mathrm{s}^{-1}$	Split-Hopkinson

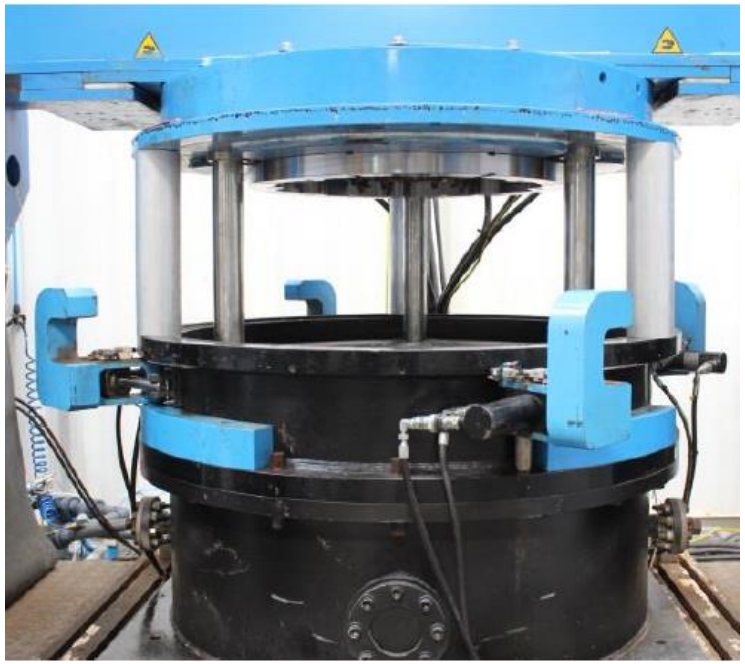


Large grain niobium sheets [1]

[1] P. Kneisel, et al., “Development of Large Grain/Single Crystal Niobium Cavity Technology at Jefferson Lab,” 2007, vol. 927, pp. 84–97.eet

Design of Compensation Die

- Compensation die for fabrication of Nb half-cells that fit within prescribed tolerances for 800 MHz cavities
- New die to fit in the current die-splitter used for 400 MHz Cu half-cells



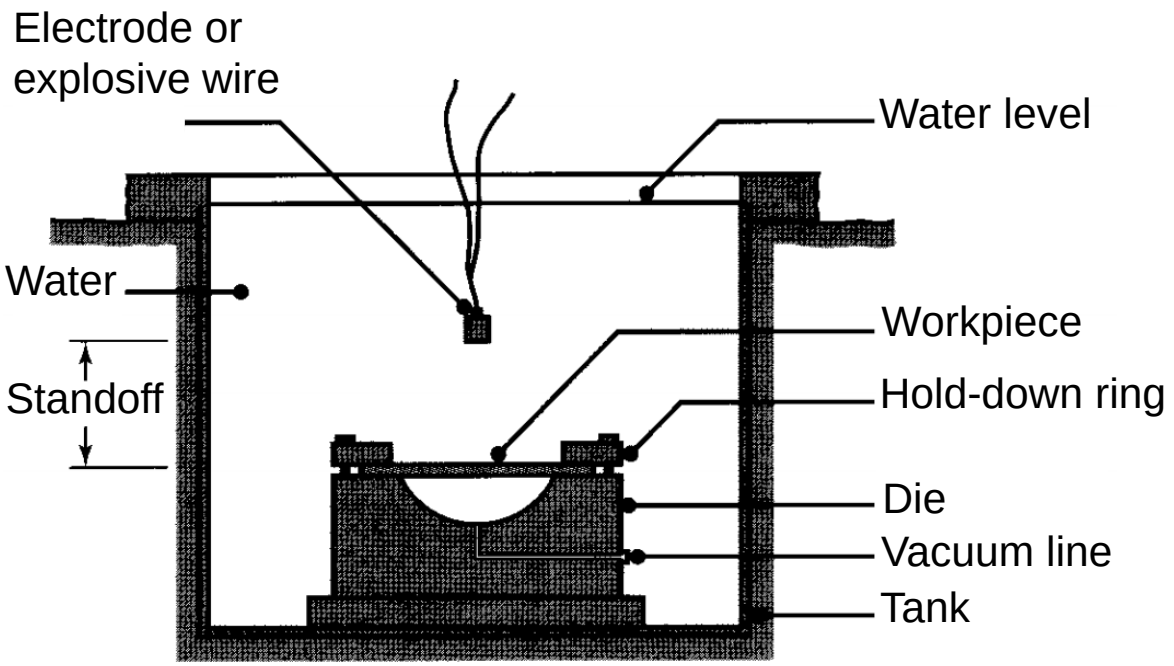
Old die-splitter

Current die-splitter

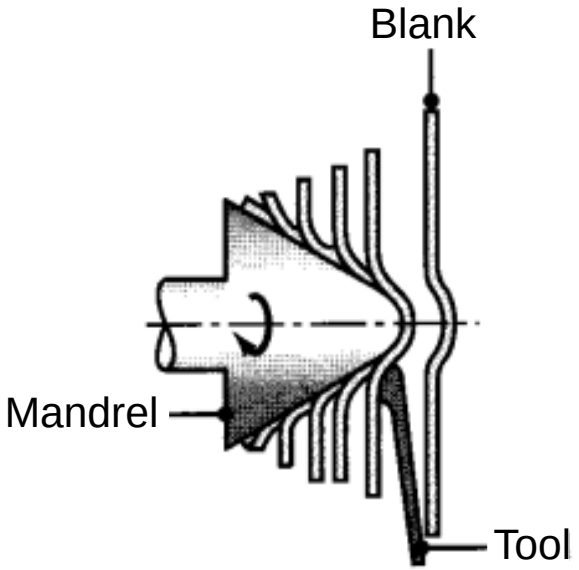
Future compensation die

Comparison of Microstructures

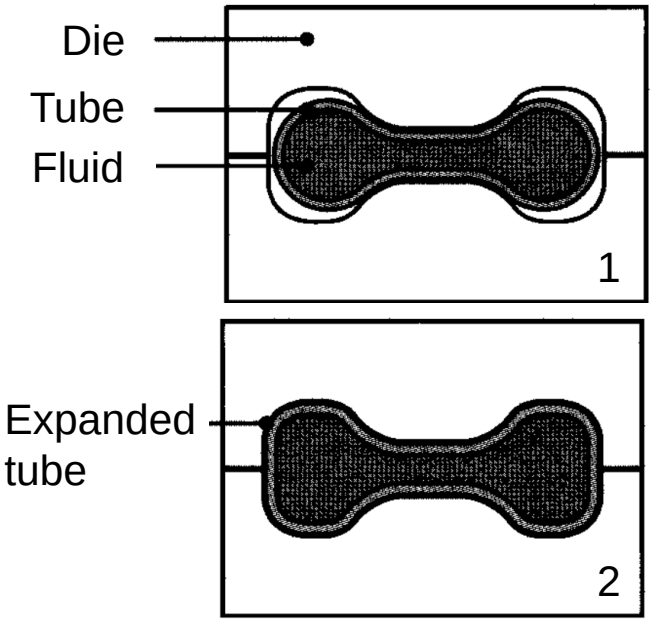
- High vs low strain rate deformation techniques
- Microstructural and mechanical characterizations (hardness, dislocation densities, deformation mechanisms, recrystallization, RRR)



Electro-hydro forming



Spinning



Hydroforming

Figures: S. Kalpakjian and S. R. Schmid, Manufacturing engineering and technology, Seventh edition. Upper Saddle River, NJ: Pearson, 2014.

Investigation of Seamless Cavities

- Defects at weld have negative effects on the heat transfer properties and for the formation of superconducting thin films
- Significant reduction of production costs and time
- Investigate the feasibility of the fabrication of seamless cavities

6 GHz seamless cavity produced with EHF

Challenges and Risks

- Receiving Cu and Nb sheets
- Experimental results of large grain Nb half-cells
- Procurement of Cu and/or Nb tubes for seamless cavities
- Split-Hopkinson tension tests
- Modification of in-house setup for large grain Nb characterization at high strain-rates

Project Status

- Project started on March 1st 2018
- Currently cutting Cu samples for secondment at ENSTA Bretagne to test mechanical properties of OFE Cu at low and high strain rates
- Design of 800 MHz Nb compensation die
- Literature review, trainings on finite element modelling and more at I-Cube Research

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