UK Atomic Energy Authority

LMD KoM June 2021

Design Activity, Planned and Future Tasks at CCFE

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EUROfusion

Research Councils UK Energy For a Low Carbon Future

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Introduction

1. Overview on activities from FP8 that were completed in 2020
2. Update on activities from FP8 that were completed in 2021 or that are still ongoing in 2021
3. Plans for 2021
4. Outlook for 2022 (and beyond?).

FP8 2020 Summary

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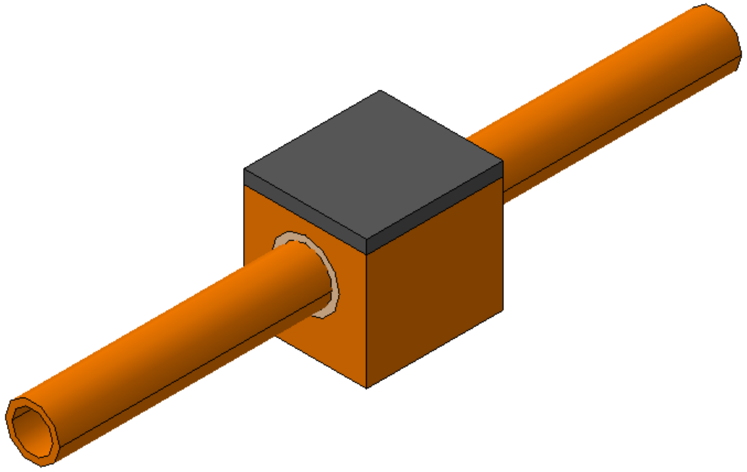
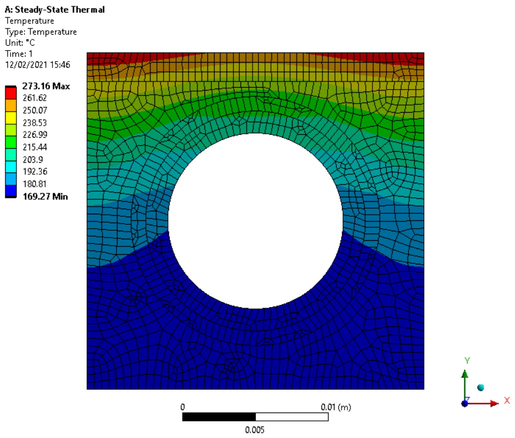
Mock-up Design for HHF Testing

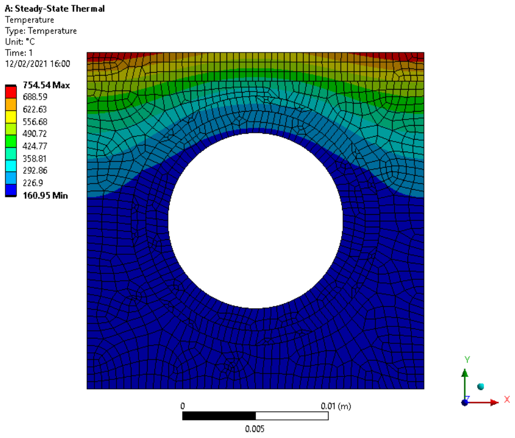


- Uses standard mono-block interlayer design
- Width 23mm
- Heights adjusted to suit test parameters
- CPS pre-saturated with Sn
- AM or Hiped W CPS
- W coating on CuCrZr heat sink block

Coolant
Pressure: 20 Bar
Flow Rate: 1.05 m/s [7.125 l/m]
Bulk Temperature: 160 deg C
Heat Flux
Steady State: 1.5 MW.m^{-2}



Coolant
Pressure: 20 Bar
Flow Rate: 14.0 m/s [95.0 l/m]
Bulk Temperature: 160 deg C
Heat Flux
Steady State: 10.0 MW.m^{-2}

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Surface of width 0.023m and length 0.1m gives an area of: 0.0023 m^2
Particle flux at average surface temperature of 680.4degC: 1.9825606068660288e-13 m^-2.s^-1
The particle flux leaving the surface is 4.5598893957918 66e-16/s.
The LM mass flux leaving the surface is 8.988572054824197e-41 kg/s.
For a test length of 300s, the estimated Sn mass lost through evaporation is 2.696571616447259e-38kg
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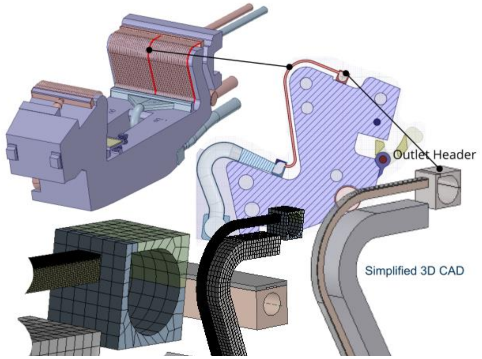
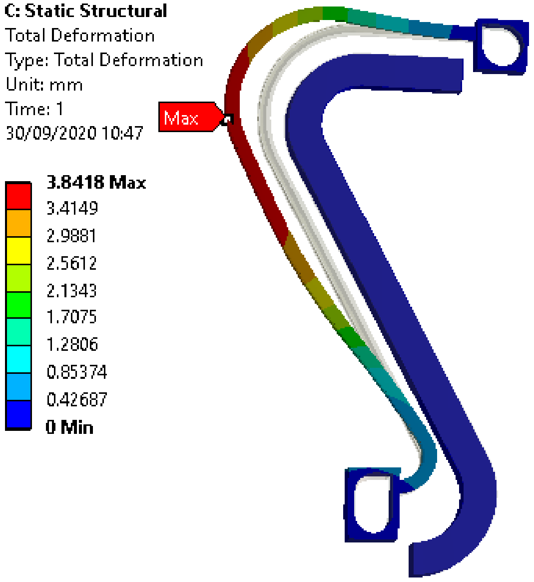
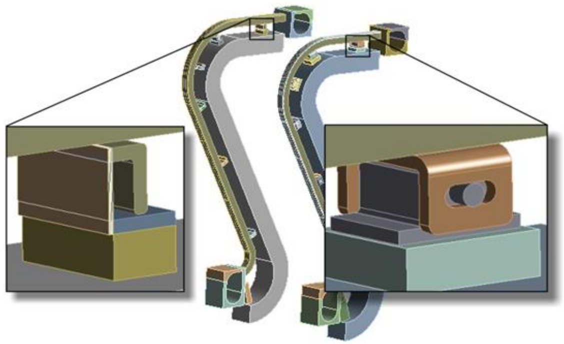
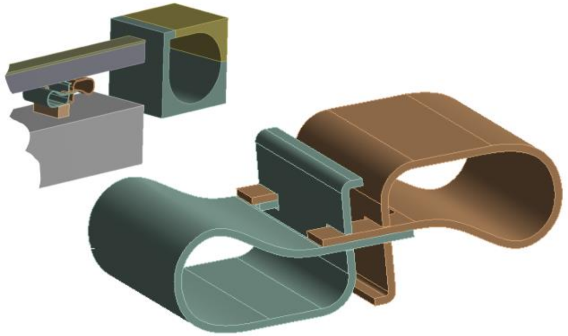
FP8 2020 Summary

Coupling of the LM PFC module to the DEMO cassette

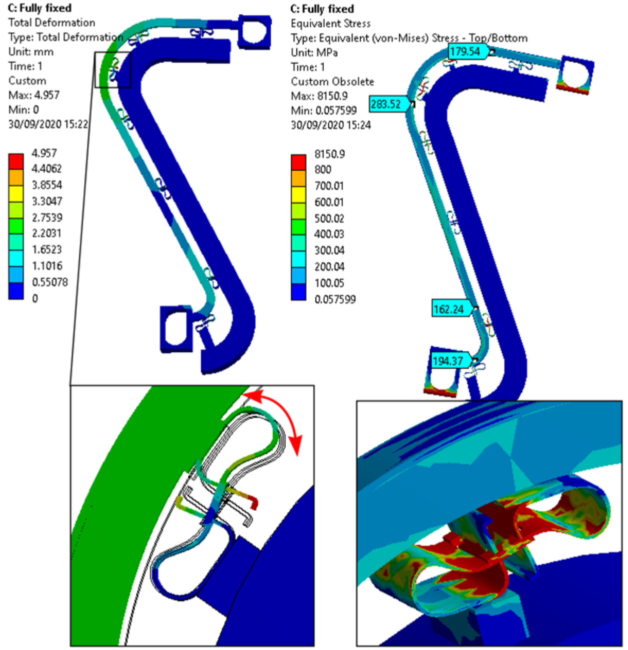








- ‘Spring Steel’ structure
- Lateral displacement limited by slot depth
- Compressive displacement controlled by vertical legs



- Lower reaction loads compared to base-line design
- Stresses throughout PFC lower than slider and strain based concepts

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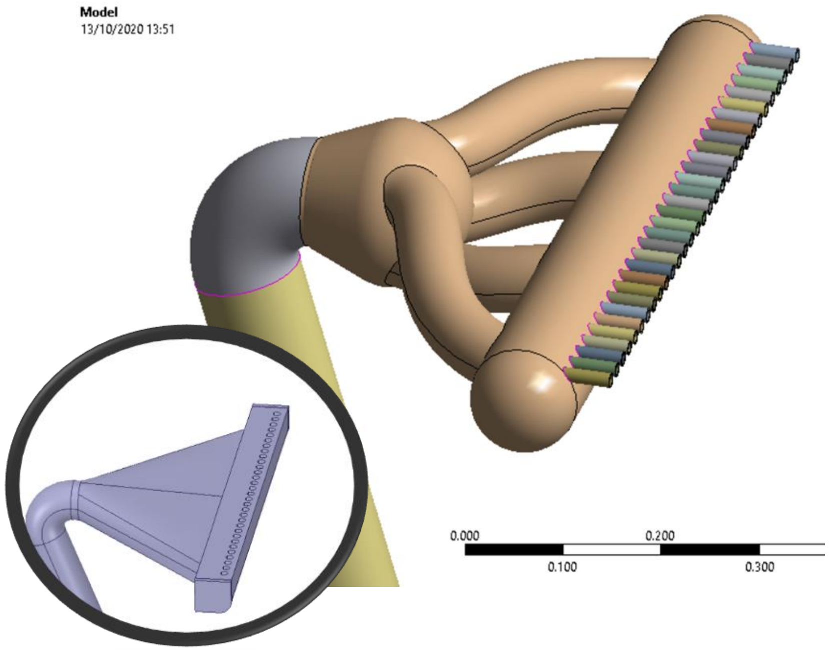
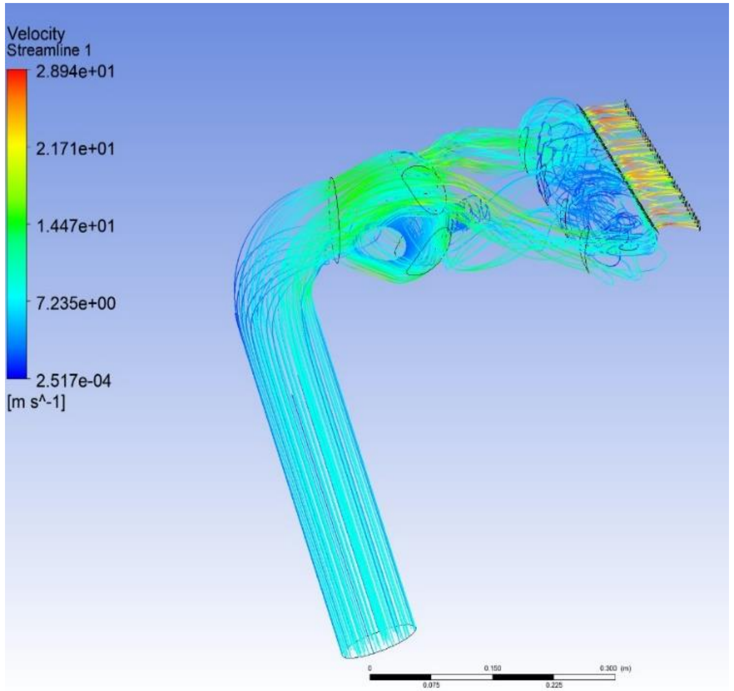
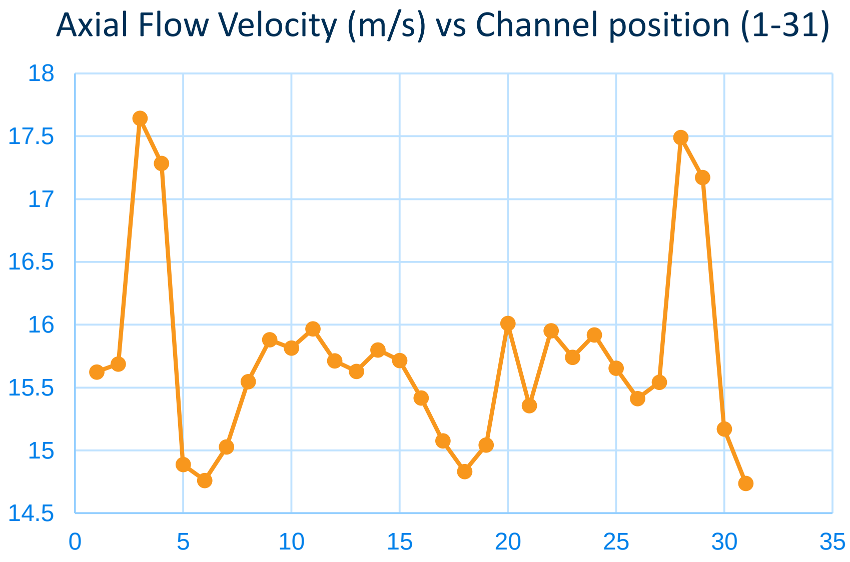
FP8 2020 Summary

Identification of PFC cooling circuit components requiring upgrade for operation at PWR conditions







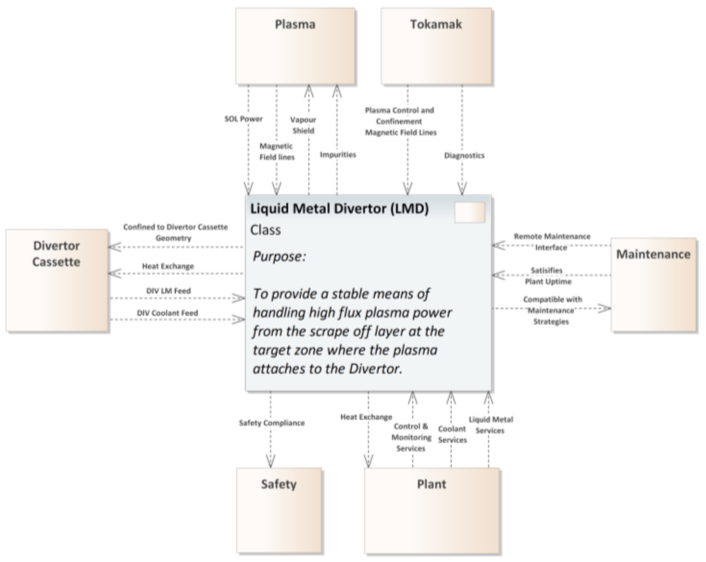
- CFD analysis was performed using similar techniques carried out for the analysis of the baseline design

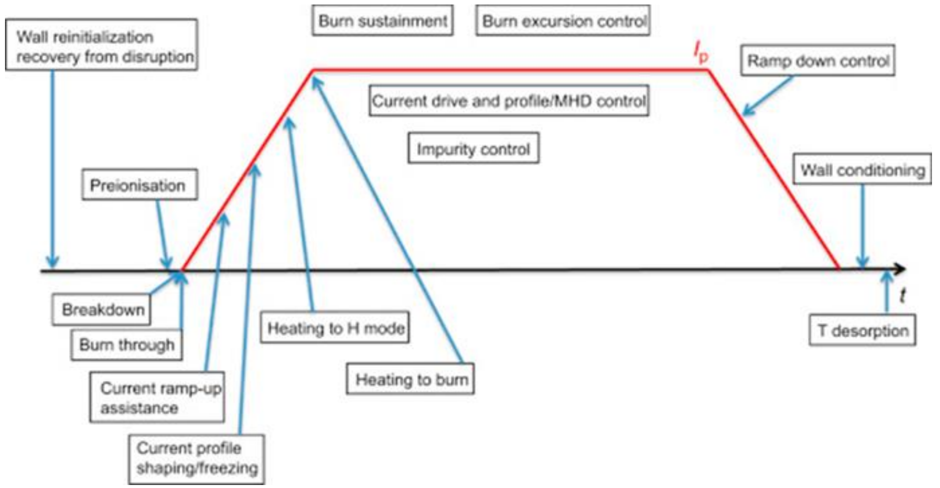
- Axial velocity varies by +/- 8% from mean
- Symmetric about the central PFC pipes
- Velocity profile across PFC outlets influenced by diffuser inlets

FP8 2020 Summary

Systems Engineering

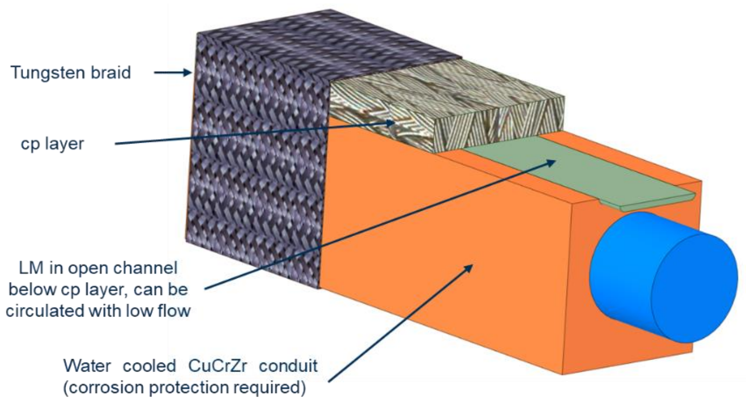
- Conducted a functional break down of the LMD system and target for the plasma operation use case.
  - Used the functional break down to investigate potential LMD components that satisfy such functions in a component function matrix.
- Conducted an internal LMD system interface definition and types using the functional break down and component links.
- Conducted a preliminary FEMCA evaluation of the LMD system and the LM target.
  - Looked at potential failure modes and the impact on DEMO's plasma operations.



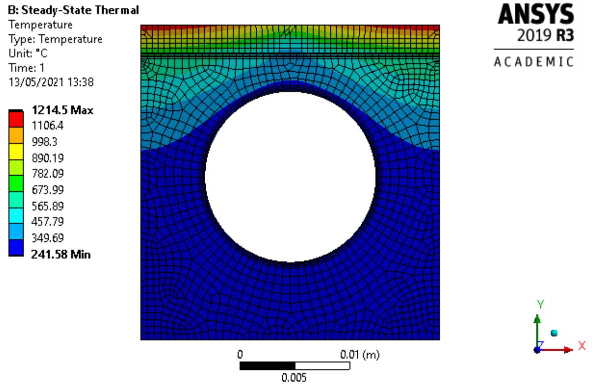


FP8 Tasks in 2021 Overview

Parametric Optimization

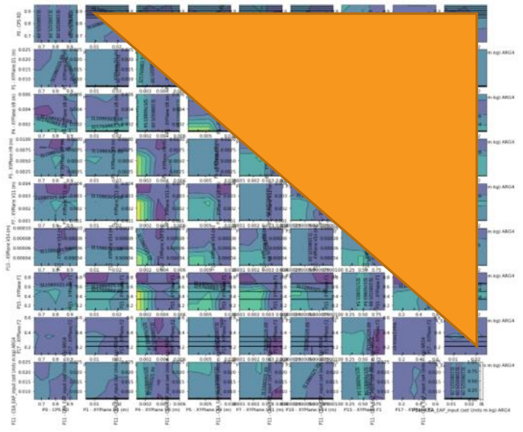


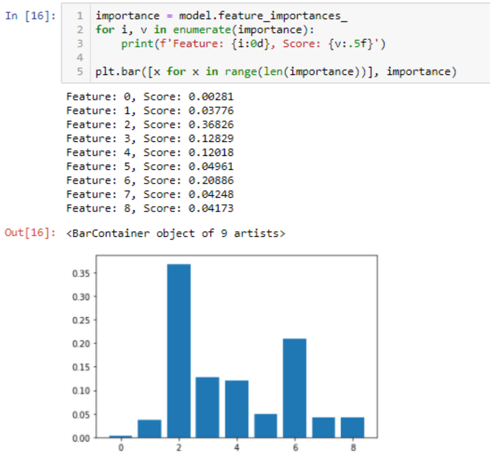
Target Design and Optimisation



- Optimisation of water cooled, Sn target design
- Use flowing Sn supply as ‘thermal brake’ to manage CHF
- Limit Sn velocity <0.01m/s to avoid MHD pumping losses

Reduced Order Modelling using ML

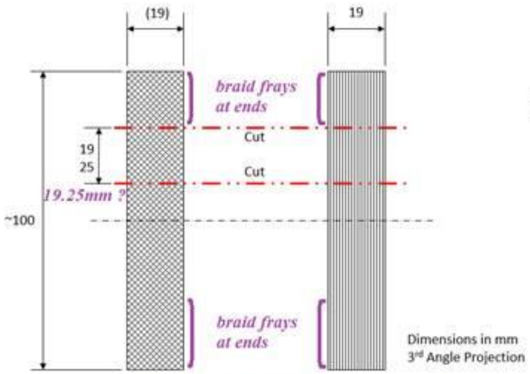


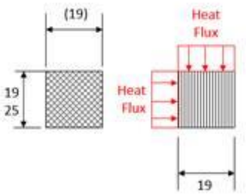


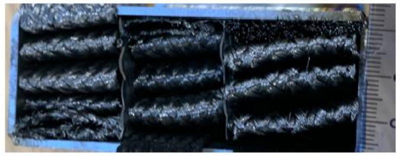
- Save on expensive CPU time (money/time)
- Create Reduced Order Models for easy collaboration and integrations with other codes
- Can be set-up and calibrated to run with digital twins
- Optimise design quickly – determine a design confidence
- Find feature sensitivity – increase/decrease as required

FP8 Tasks in 2021 Overview

CPS Development







- Pitches 80, 100 and 150 suitable for HIPing
- Higher Pitches too loose

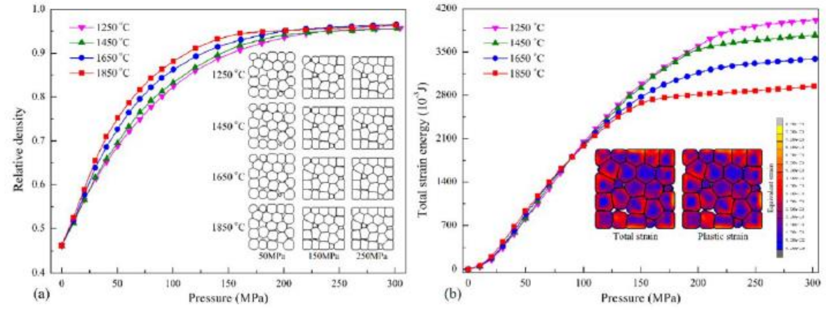


Fig. 2. (a) Evolution of relative density ρ with pressure P for the HIPing of tungsten powders at different temperatures; (b) Evolution of total strain energy with HIPing pressure P at different temperatures.

- Single HIP run
- 4 x Canisters with 3 Braid Pitch Samples
  - 1: Atmospheric pressure
  - 2: Full Outgassing
  - 3: Partial Outgassing
  - 4: Open Canister
- Significant distortion on outgassed canisters
- HIP parameters determined from literature

FP8 Tasks in 2021 Overview

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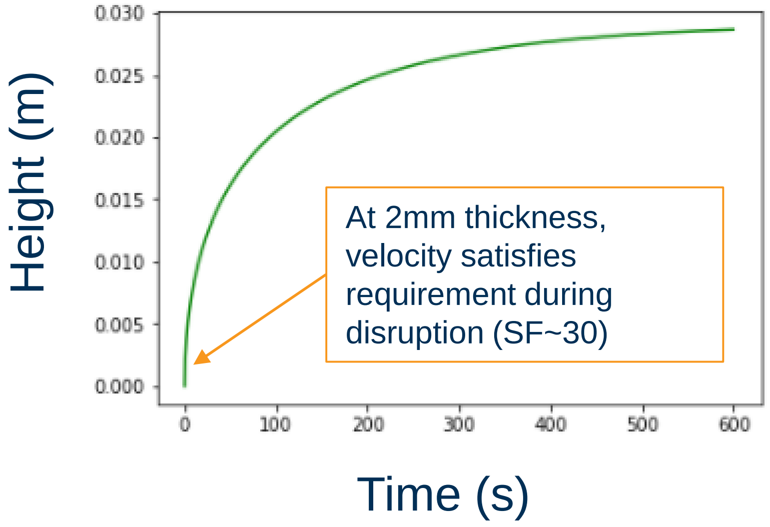
CPS Development

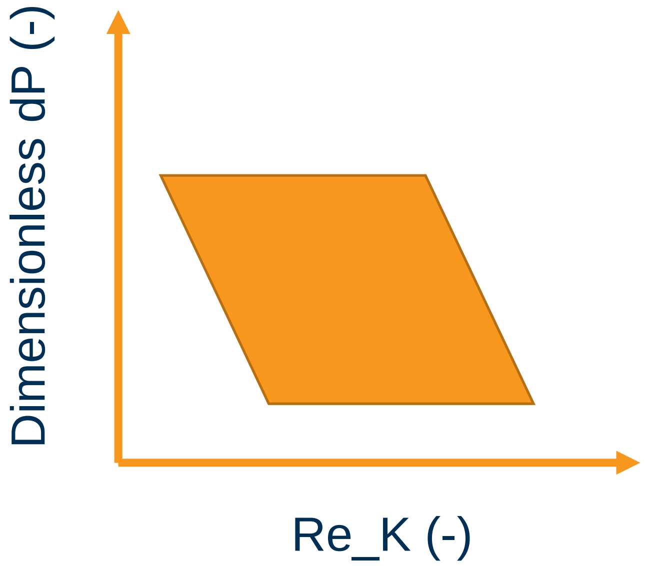
Fluid Velocity through CPS



Capillary Performance given by: $\frac{K}{r_{eff}}$

Where: K: Permeability
reff: Effective Pore Radius

- Graph shows e=0.3, r_pore=100um
- Capillary model modified to include inertial and frictional effects
- Desirable to keep Re_K < 0.95 (~v=0.07m/s)
- Kozeny-Carmen Correlation to predict permeability from porosity – most data is for compact particle beds
- Assumes cos(Θ)=1 – wetting different for different CPS
- MHD to be included by dimensionless gradients



- Define parameter limits
- Find CPS operating space
- Select porosity and pore size
- Feedback into models

<u>Increasing K and decreasing reff are key to maximising liquid propagation</u>

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2021 Planned Work

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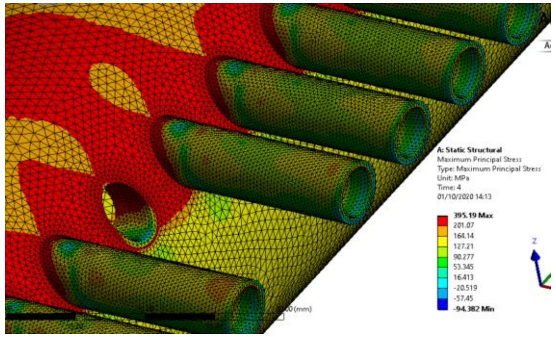
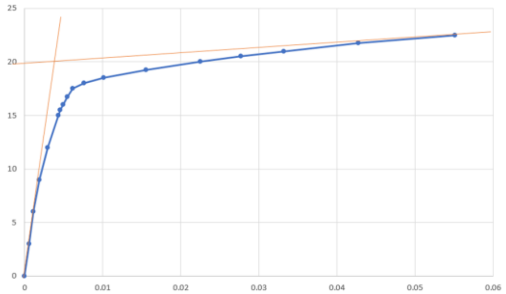
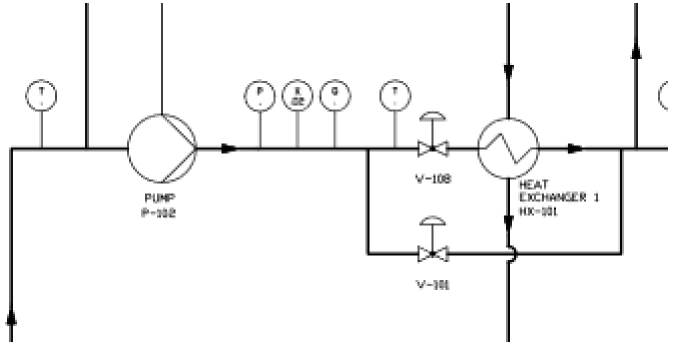
High Pressure Coolant Integration



- Identification of upgraded components
- PFC Performance at PWR conditions
- Assess material limits to MCC-RMx
- Identify hardware strategies



Sn Loop Design



- Systems functional requirements definition/diagram (SRD)
- Create functional description of Sn loop with initial scoping calculations
- Preparation of the Process Flow Diagram
- Produce the Piping and Instrumentation Diagram (P&ID)

Demo Optimization

- Space constraints exploration study
- Compatibility with RM strategy – options
  - Static, piped system
  - Dynamic, mobile system
- Target concept integration(s)
- Plant level interfaces to the LMD system and the impact on DEMO's plasma operations

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2021 Planned Work

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Systems Engineering

- Identify plant level interface types such as the TFV interface and impact on plant operations
- Identify a higher plasma function that acts as the driver for lower level LMD system functions – with the intent to use this study with last years functional break down study to produce LMD functional requirements in the following years.
- To have ConOps of the mobile LM servicing model for DEMO's pulsed plasma operation, with a comparison to the static system and impact on plant availability.
- Investigate the mobile use case beyond DEMO as an operation given that commercial feasibility is dependent on continuous tokamak systems.

CPS Testing

- HHF testing of HIPed braided W samples

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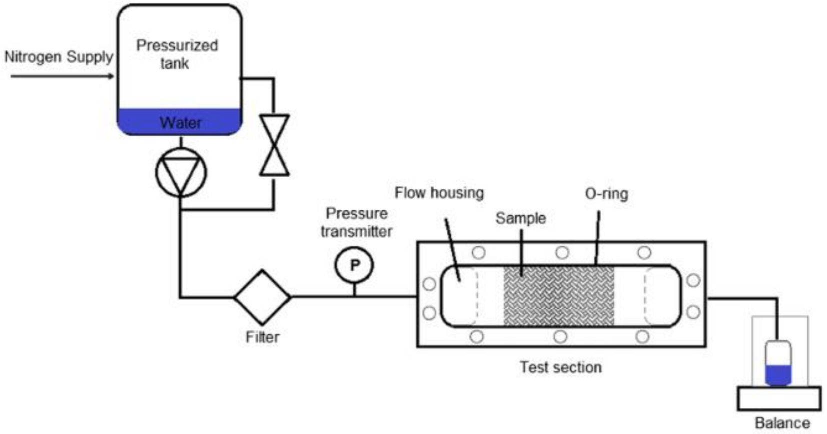
Outlook for Post 2021

- Continued Sn Loop analysis – component validation/testing – supplier engagement
- CPS Development – CPS permeability/flow modelling/testing/validation
- Pre-filled Sn concept – dynamically refilled in-between pulses
- Neutronics study – LMD targets – reduced shielding – impact on cassette
- Mock-up testing
- ROM code coupling and model parameterisation/optimisation (Python, OptiSLang, Twin Builder)



Questions?

Thanks for listening!