Shape Optimisation for Creep Testing 2.0

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Abstract Nuclear fusion development is in the transition from conceptual to detailed design. This requires creep data for multiple materials over a wide range of temperatures and stresses. Traditional test programs will not be able to provide the required data in time. Materials Testing 2.0 (MT2) offers the potential to reduce the number of required tests and accelerate the collection of creep data. We describe current progress on designing MT2 tests for creep.

Possible Sessions
Materials Testing 2.0

Introduction
A step-change in the time-to-qualification of new materials is required if we are to meet the ambitious timeframes for fusion and next generation fission energy to meet net zero targets and global energy demand. Creep tests at high temperature can take 1,000s of hours, where each test corresponds to only a single stress and temperature in the design space. MT2 [1] offers a potential route to accelerate creep testing through complex specimen geometries that sample a wider region of the stress space in a single test.

Test Design Methodology
Material model identification quality offers a potential metric for discriminating between different candidate geometries. It is calculated as the Euclidean distance between known input model parameters and parameters from an optimisation routine using the chosen geometry, shown in Fig. 1. This approach does not include the effects of DIC filtering and noise but is a step towards such a 'full-simulation' approach.

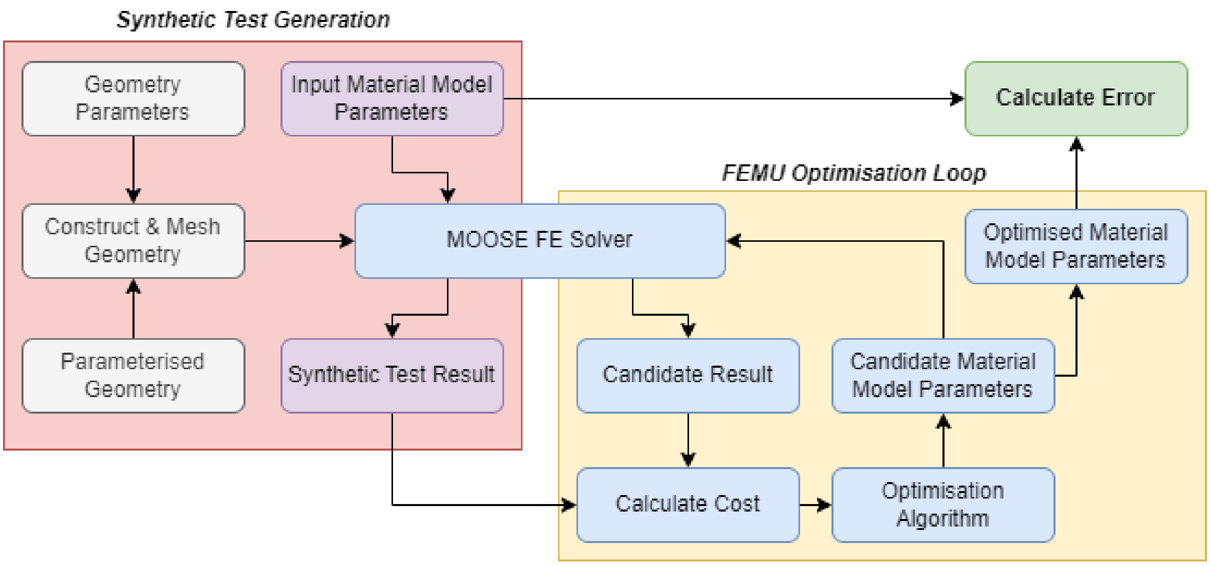

Figure 1: Methodology for calculating the error (identification quality) for a given set of geometry parameters and suitably parameterised geometry.

Running a full Finite Element Model Updating (FEMU) optimisation for each candidate geometry is computationally expensive. Parallelisation of solver runs was used to reduce the time taken for each optimisation. A grid search was used to sample the geometry parameter space, shown in Fig. 2. For each point in the grid a synthetic test result is generated then used as the target for the FEMU optimisation. Non-physical regions of the parameter space, either due to self-intersection or barrel-shapes were not considered. The geometry parameterisation used circular arcs to define the outer shape. This was chosen as it should be simpler to manufacture compared to spline-based approaches.

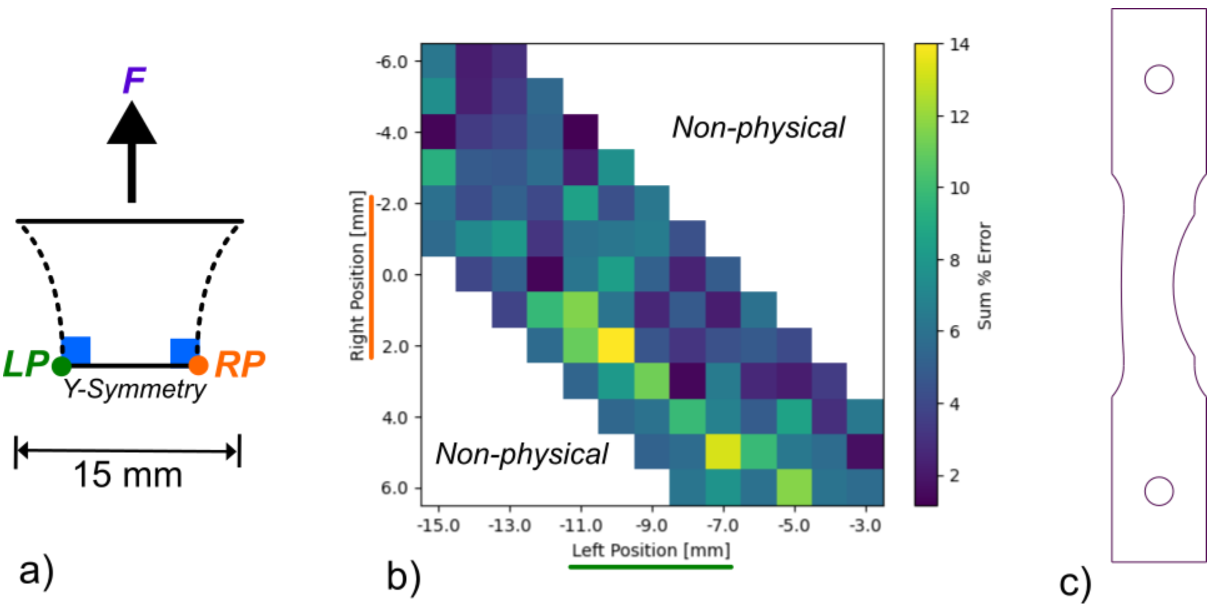

Figure 2: a) Geometry parameterisation scheme; left and right points can move and circular arcs are created through them, b) grid search of the parameter space showing % error on an material model optimisation using that geometry, c) an example of a geometry corresponding to (-8,3).

A unified viscoplastic model with Voce isotropic hardening and continuum damage was used. It has a total of 9 free parameters. This model form can describe primary, secondary and tertiary creep, necessary for modelling tests where these stages will all be represented on different parts of the specimen. 15 hour creep tests at a load of 1 kN were simulated using an input model calibrated to the behaviour of Oxygen-Free Copper at 300°C.

Results

The identification quality grid search has highlighted several candidate geometries that will be tested. Intuition based designs found in the literature [2] tend to be waisted. However, the identification quality metric suggests that bend-type designs may be better for accurately fitting constitutive models using the Materials Testing 2.0 approach.

Conclusions

An identification quality approach has been developed for selecting candidate creep testing 2.0 geometries. Contrary to intuition this approach suggests that geometries with a degree of bending are preferable.

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References

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