Materials Testing 2.0 for Creep

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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 programmes 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. A demonstration of the geometry optimisation and testing is presented for Oxygen-Free High Conductivity (OFHC) copper at room temperature.

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 100s or 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 heterogeneous specimens that sample a wider region of the stress space in a single test.

Test Design

A key challenge for the MT2 approach is how to design a test. Waisted creep specimens have already been demonstrated [2], [3], but with no clear rationale behind the chosen geometry. In this work a shape optimisation routine was developed, using the geometry parameterisation shown in Fig. 1. The geometries were generated using Gmsh and the models run using the open-source finite element solver MOOSE. The material behaviour was approximated with a power-law creep model. The NSGA-II genetic algorithm was used to optimise on two objectives: maximising the range of stresses and minimising the plasticity generated upon initial loading. These two objectives are opposing, and the algorithm generates a set of pareto optimal solutions. The parameter set with the lowest initial plasticity was chosen to test.

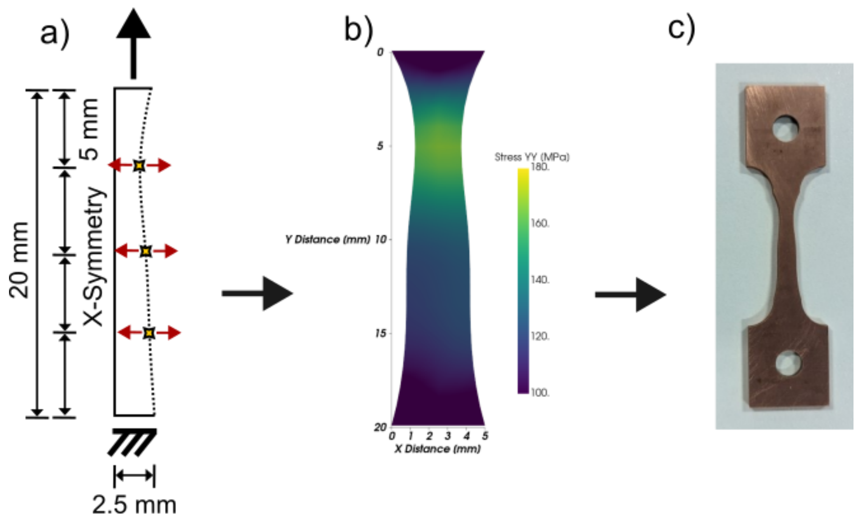

Figure 1: a) Geometry parameterisation scheme, a spline is constructed through the 3 points which are free to move in the X direction at fixed Y position, b) elastic stress for the optimised geometry, c) actual specimen produced from OFHC copper.

The chosen specimen design was produced from Oxygen-Free High Conductivity (OFHC) Copper. This was chosen as it should creep at room temperature, whilst still being relevant to fusion as a heat-sink interlayer in some divertor designs.

Results

Initial results from the testing are shown in Fig. 2. Even at room temperature there is a clear increase in the accumulated creep strain with increasing stress, as expected. The low levels of creep strain mean that there is significant noise and uncertainty associated with the data. Further work is required to improve the quality of captured images and investigate the DIC processing parameters to reduce noise.

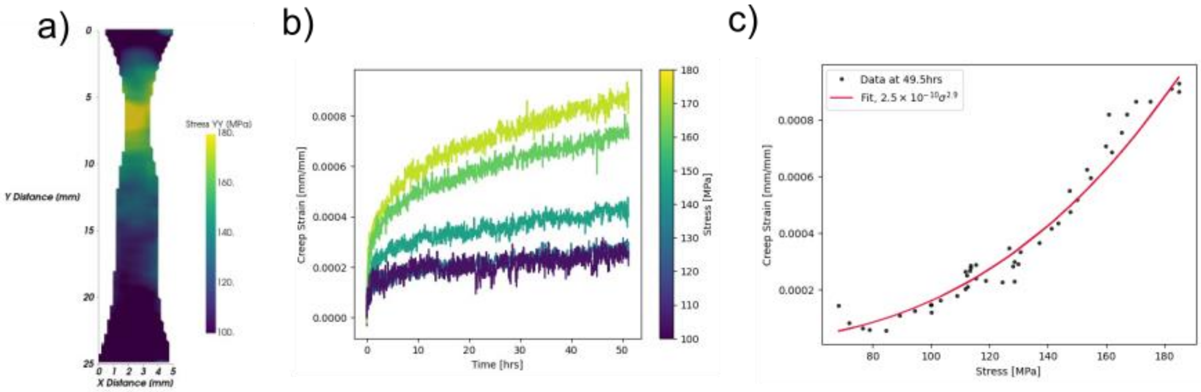

Figure 2: a) Stresses after elastic loading, calculated assuming isotropic elastic elasticity with $E = 121.8\text{GPa}, \upsilon = 0.31$, b) creep strain over time at various stress levels on the specimen, c) elastic stress vs accumulated creep stress after 49.5 hrs.

Conclusions

A shape optimisation routine has been demonstrated for designing MT2 creep tests in OFHC copper at room temperature. Initial results show promise but are susceptible to noise. The next steps are to use the data from an MT2 specimen to identify the parameters of an appropriate material model.

Acknowledgements

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References

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