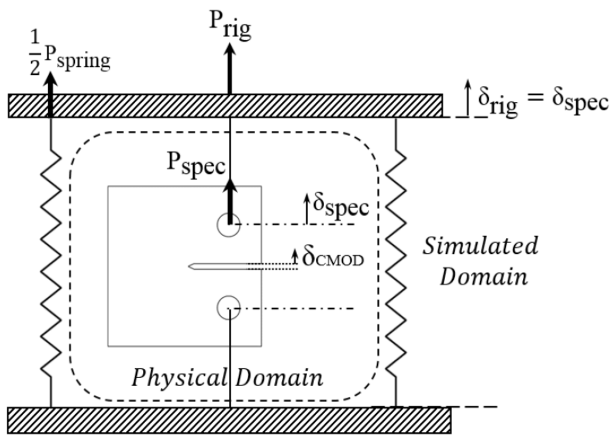
Experimental development and validation of a simulated three bar rig for finite compliance materials testing

University of BRISTOL

J. Hutchings, E. McLaughlin, R. Moore and C. E. Seow

Three bar model

The three bar model is a method of performing finite compliance loading in mechanical testing. Finite compliance loading introduces phenomena such as elastic follow-up and relaxation of residual stress. Previously these have been modelled mathematically and tested using a physical three bar rig. In this project a feedback control algorithm was developed to simulate three bar model forces on a physical C(T) specimen.



Finite compliance

Finite compliance loading is the loading condition between fixed-load and fixed-displacement loading. Finite compliance is implemented in the three bar model through the ratio of stiffness between the outer and inner bars.

Elastic follow-up

Elastic follow-up governs the rate at which load is shed from a substructure to the surrounding material. The amount of elastic follow-up can considerably alter the loading capabilities of a structure. For this reason it is important to have a comprehensive understanding of the concept and its implications.

Project Aims:

- Create a feedback controller modelling a three bar rig, simulating finite compliance loading in the linear-elastic and elastic-plastic region.
- Decouple crack growth from plasticity, using partial unloads.
- Examine the effects of elastic follow-up on load distribution and residual stress.
- Implement and validate the simulated models using a LabVIEW programme interfaced with a tensile test machine.

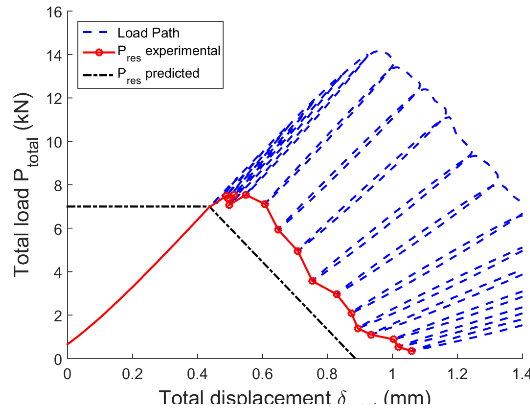
Results

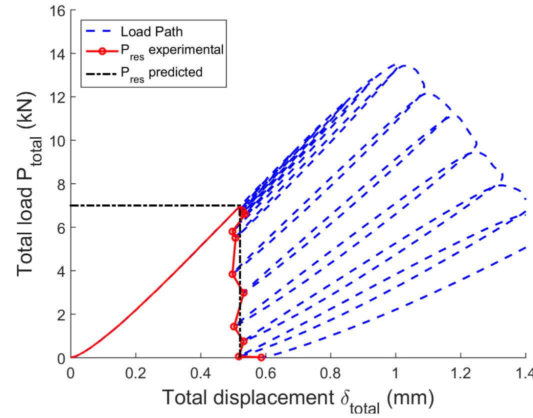
The results from testing in the elastic-plastic (right) show good agreement with the theory presented in the report. In each loading condition, fixed-load, fixed-displacement and finite compliance loading, a residual stress of 8 kN was placed on the specimen. The residual stress then relaxes at varying rates depending on the loading condition.

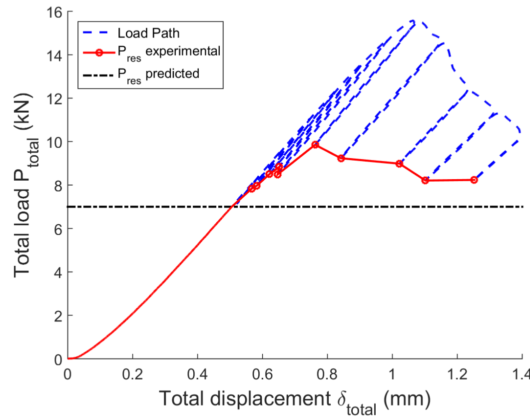
In fixed-displacement control, the amount of elastic follow-up in the structure is very high. This results in the residual stress being shed to the surrounding structure as plasticity takes place. The experimental data (black dashed line) shows good agreement with the ideal behaviour.

In fixed-load control, the amount of elastic follow-up in the structure is very low. Hence, the surrounding structure bears none of the residual stress as plasticity occurs. The behaviour of the experimental data strays from the ideal model. This is due to complications in the measurement of specimen stiffness during testing.

In finite compliance loading, the experimental behaviour also deviates slightly from the predicted data. This is again due to difficulties measuring specimen stiffness. However, both the fixed-load and finite compliance experimental data show the correct trend.







Discussion and conclusions

Through properly accounting for machine dynamics in the algorithm and effectively reading correct specimen stiffness values, experimental results which were in good agreement with the theory were achieved. These results characterised the effects of finite compliance loading on load shedding in the linear-elastic and elastic plastic region. The effects of elastic follow-up on load shedding and relaxation of residual stress indicate that is it imperative that these phenomena must be considered during structural design. This exemplifies the fact that feedback control loops are good way of simulating mechanical testing of complex structures and should be viewed as a viable replacement for intricate testing rigs.