HiPerDuCT Programme Grant

Final report: Friction Mechanisms

The proposed mechanism relies on the geometry shown in Figure 1. The structure is composed of jigsaw like pieces, each of which is made of bow-tie shaped elements which are connected by infill regions. Each coloured jigsaw block is a separate block that is only connected to other blocks by the interlocking jigsaw shape. When this configuration is subjected to tension in the longitudinal direction, the blocks start to slide against each other. This sliding causes friction forces in the interlocking structure. The role of the infill region is to introduce the transverse forces thereby increasing the frictional force in the wedges and so leading to higher overall longitudinal stresses in the structure.

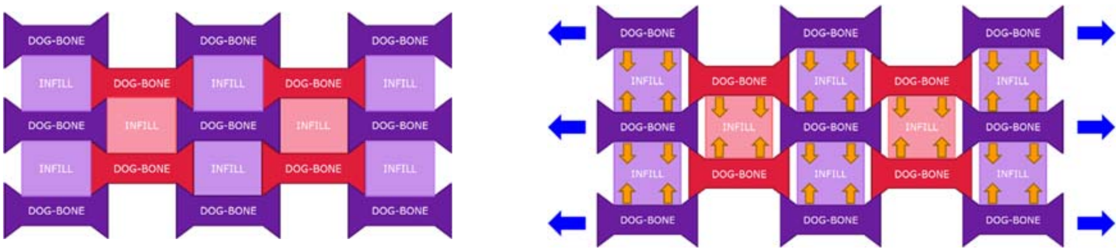

Figure 1: Geometry, a) unloaded specimen, b) loaded specimen

Ceramics

An investigation was performed on a model system made of MACOR, a brittle machinable glass ceramic (1). The initial modulus, strength and failure strain were, 67 GPa, 34.5 MPa and 5.15e-4, respectively. Finite element models indicate that pseudo-ductility with hardening behaviours can be obtained in ceramics by optimizing the interlocking structure of the jigsaw blocks.
Figure 2 shows that pseudo ductile behaviour with long plateaus can be obtained by changing the geometry. The failure strain of brittle ceramics can be increased significantly.

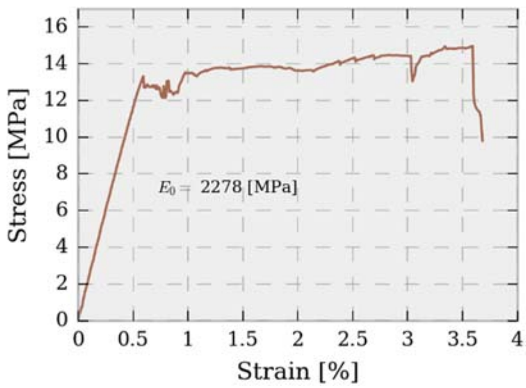

Figure 2: Pseudo-ductile behaviour achieved in interlocking ceramic structure

3D Printed materials

3D printed internally and externally constrained interlocking specimens were investigated (2) to test different configurations leading to pseudo-ductile behaviour.

Stress-strain plots for the configurations made of 3D printed materials are shown in Figure 3. It can be observed the specimens show an initial response which is approximately linear. The stiffness of the externally constrained specimen is higher because, for a given strain, the extension of the central part of the dog bone shape is small compared to the extension due to sliding of the inclined surfaces. The tangent stiffness for both curves starts to reduce (at a stress between 0.75 -0.9 MPa) and finally levels out at a maximum stress of around 1MPa.
At this point the sliding has started to localize at one position and beyond this, the stress drops gradually until complete separation of the interlocking shapes occurs at some position.

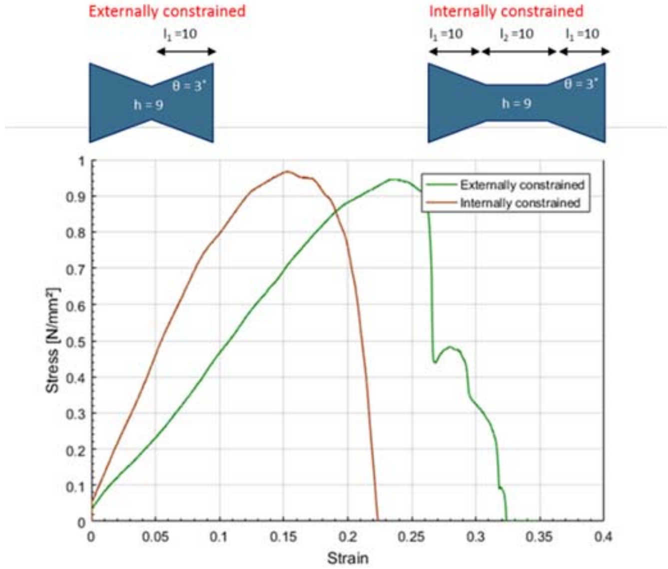

Figure 3: Mechanical response of 3D printed bow-tie structures

Composites

Composite specimens (2) show a non-linear behaviour. It can be seen that the specimen with no preload reaches a strength of 24 MPa at a strain of 18 %. However, the geometrically identical but preloaded specimen achieves 27 MPa at 15 % strain. Between approximately 3% strain and the curve peak, the curve of the preloaded specimen is shifted to higher stresses than the curve of the specimen without preload by a relatively constant value of about 5 MPa. The composite assembly fails prematurely due to localization of the deformations, but prior to failure the behaviour shows good agreement with the prediction.

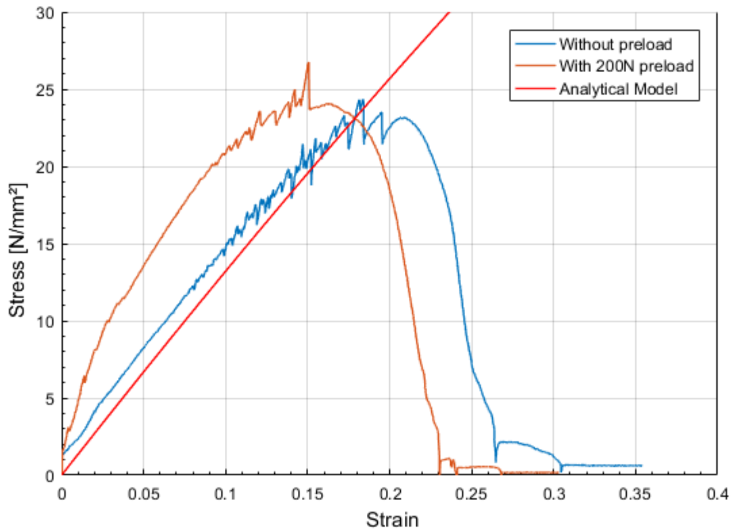

Figure 4: Mechanical response of composite bow-tie structure

References

1. Bacarreza O, Muñoz R, Robinson P, Shaffer MSP. Use of Friction Mechanism for Pseudo Ductility in Composites. ECCM17 - 17th European Conference on Composite Materials; 2016 26-30th June 2016; Munich, Germany.

2. Bacarreza O, Maidl S, Robinson P, Shaffer MSP. Exploring the use of friction to introduce ductility in composites. ICCM21 - 21st International Conference on Composite Materials; 2017 20-25th August 2017; Xi'an, China.