Effect of adhesive thickness on butt adhesive joints under torsional loads

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Introduction

Adhesive joints are increasingly being used in structural applications by several industries due to their improved mechanical performance when compared to classical mechanical fixing methods. In order to understand the mechanical performance of the adhesive joints it is required to determine the mechanical properties of the material used (e.g. adhesives and adherends). The loading modes more often used to characterize the structural adhesives are tensile and shear loads. In tension, the mechanical properties are obtained under a uniform and uniaxial state of stress. The strain to failure is highly dependent on the presence of defects such as voids and microcracks. During the tensile tests, the crack initiates next to a void and the specimen often fails there due to the high stress concentration. In shear, the presence of voids does not affect significantly the mechanical behaviour, as the remaining area is capable of sustaining further deformation and the stress distribution is in pure shear. The shear tests under torsion loading provide higher precision in strain to failure measurement than tensile tests because there is no stress concentration in the specimen [1].

A novel torsional testing machine was developed for determining the mechanical properties of structural adhesives. This machine ensures a perfect alignment of the specimens and avoids any spurious bending moments and any load of compression or tension during the test. The torsion machine was recently subject to a Provisional Portuguese Patent application (N. 109717 - 2016) due the innovative solutions it employs [2]. Different structural adhesives were selected and were characterized under shear loads in this novel torsion machine. For the torsional test machine, butt joints with solid adherends were used. The effect of adhesive thickness on the shear properties of the adhesive was evaluated.

A novel torsional testing machine

This invention consists of a machine specially designed to perform torsion tests on adhesive joints. This machine applies torsion loading to laboratory scale specimens for the determination of the shear stress-shear strain curve of these materials. The machine measures the torsion angle and torque applied, from which the shear stress-strain curve can be deduced.
A major feature of the machine is the alignment procedure of the specimen, which is done vertically with a counterweight that guarantees perfect alignment.

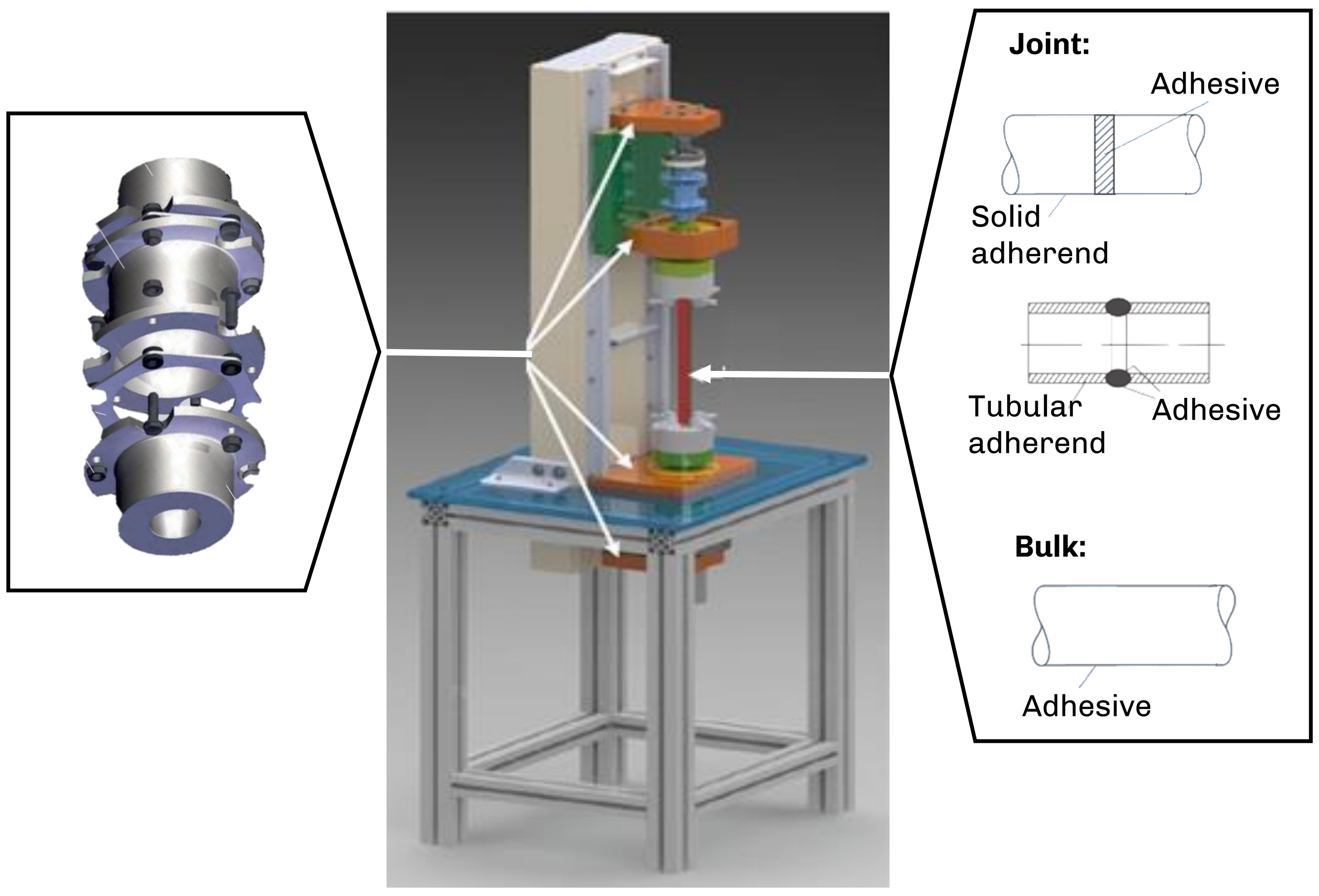

Figure 1 – Torsional testing machine.

Experimental details

Structural adhesives:

- Araldite AV 138 (Huntsman) – two-part brittle epoxy structural adhesive.
- Plexus MA 422 (ITW) – two-part ductile methacrylate structural adhesive.

Adherend:

- Low-strength steel - DIN St37 was used.

- Butt joints– according to ASTM D 2095 standard [3].

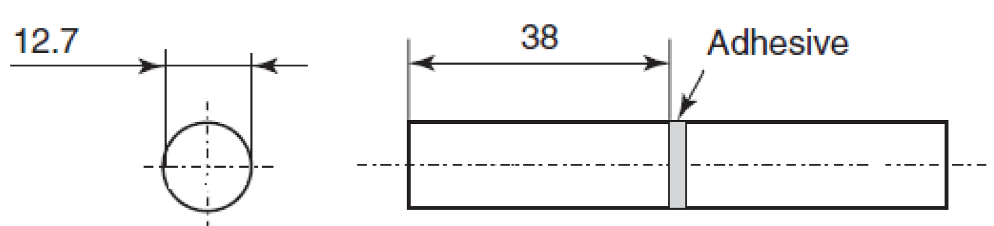

Figure 2 – Butt specimen geometry (dimensions in millimetres).

Numerical details

Software: ABAQUS (Dassault Systèmes Simulia Corp. Providence, RI, USA)

Element
Steel: An 8-node linear brick with reduced integration and hourglass control (C3D8R)
Adhesive layer: An 8-node linear three-dimensional cohesive element (COH3D8).

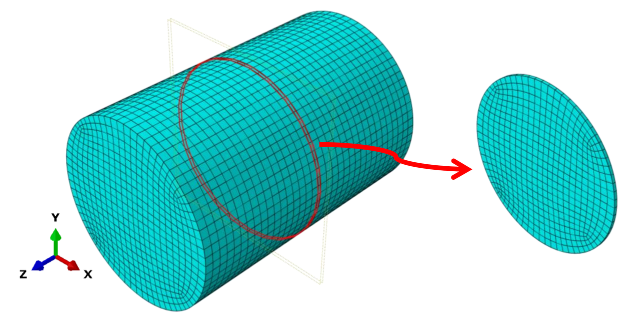

Figure 3 – Numerical model used.

Numerical results

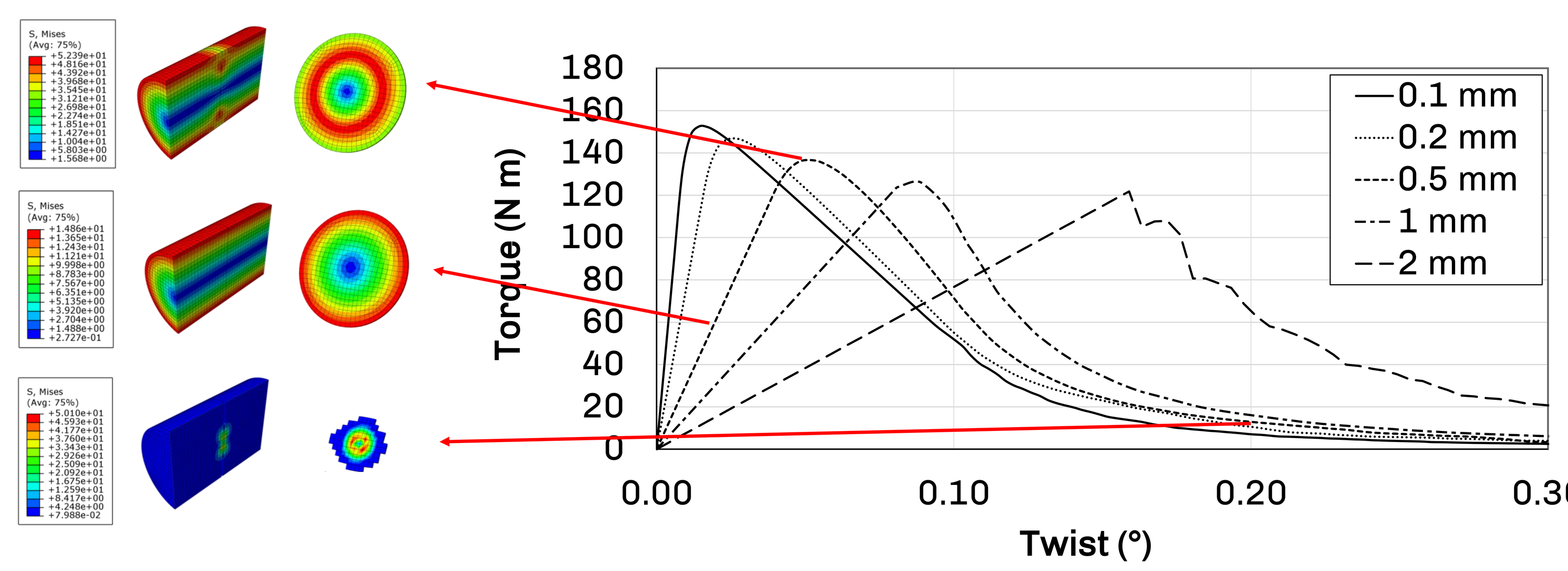

Figure 4 – Torque-twist curves for AV 138 adhesive as a function of adhesive thickness.

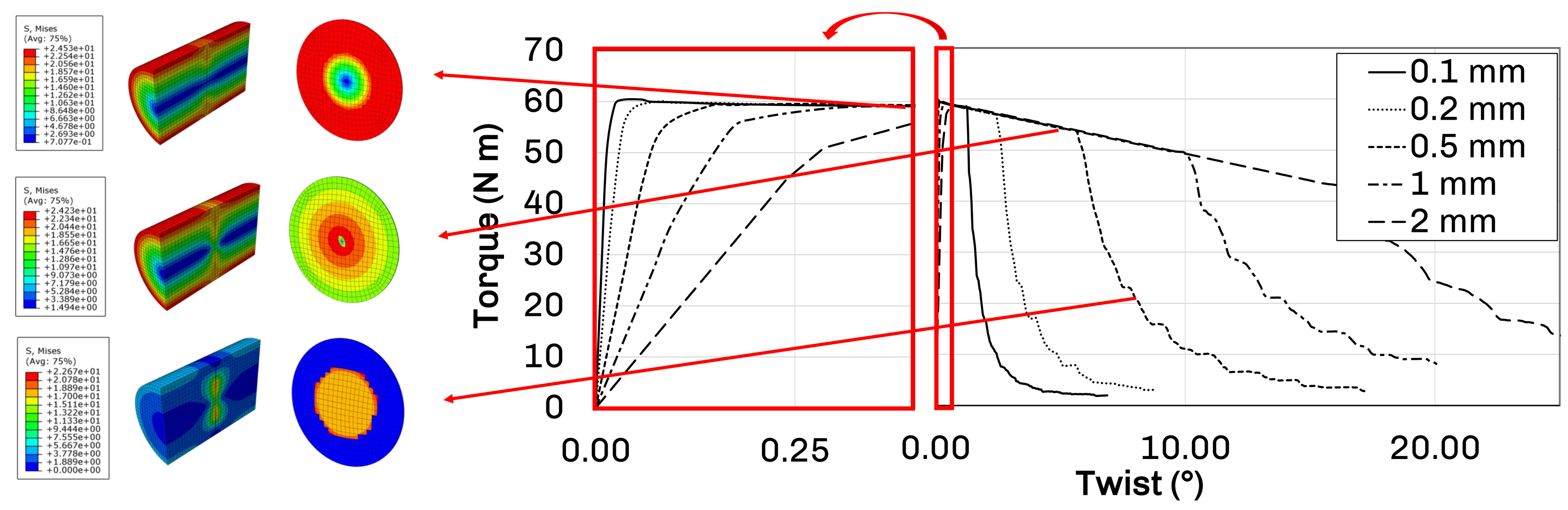

Figure 5 – Torque-twist curves for MA 422 adhesive as a function of adhesive thickness.

Conclusions

- The present torsion machine is able to perform a complete characterization of a structural adhesive via torsion loading.
- The determination of the strain to failure is properly characterized when used this novel torsion machine.
- The brittle adhesive becomes less stiff and the strength decrease with increase of adhesive thickness.
- The ductile adhesive becomes more flexible with increase of adhesive thickness (less stiff and strength, and more ductile).

References

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. Handbook of Adhesion Technology, (Springer-Verlag, Berlin, 2011).
[2] Dantas M.A., Carbas R.J.C., Lopes A.M., da Silva C.M., Marques E.A.S., da Silva L.F.M. (2021) Novel Torsion Machine to Test Adhesive Joints. In: Silva L., Adams R., Sato C., Dilger K. (eds) Industrial Applications of Adhesives. Lecture Notes in Mechanical Engineering. Springer, Singapore.
[3] L. F. M. da Silva, D.A. Dillard, B. Blackman, R.D. Adams. Testing Adhesive Joints: Best Practices, (Wiley-VCH Verlag GmbH & Co. KGaA, 2012).

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