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Impact in Adhesive Joints for the Automotive Industry at Low and High Temperatures

R.A. Mata[1], G.M.S.O. Viana[2], M.B.S.F.P. da Costa[2], L.F.M. da Silva[1], M.D. Banea[1], R.J.C. Carbas[2]

[1]Department of Mechanical Engineering, Faculty of Engineering, University of Porto, Portugal

[2]Institute of Mechanical Engineering (IDMEC), Faculty of Engineering, University of Porto, Portugal

Abstract

In recent years there has been an increasing interest in the automotive industry in applying adhesive bonding in structural components of vehicles. When adhesive joints are used in this area, some factors such as impact loading and temperature variation have a decisive role. Under these conditions, the joint must provide enough strength to transmit the load without fracturing, and thus assure the car's integrity. Although several studies have characterized adhesives under both situations separately, very few have considered them at the same time.

In this study the impact strength of single lap joints using a new crash resistant epoxy adhesive and ductile adherends was characterized as a function of temperature. Drop impact tests were successfully conducted at -20, 23 and 80 ºC by developing a cooling system and a heating system.

The results obtained were discussed and analyzed, and a failure prediction was developed. At room temperature failure was dictated by the adherends yielding due to the high strength of the adhesive. At high and low temperatures, a high decrease in the adhesive strength was found with an increase of ductility and brittleness, respectively. Thus, in this case it was the adhesive which determined the joints strength.

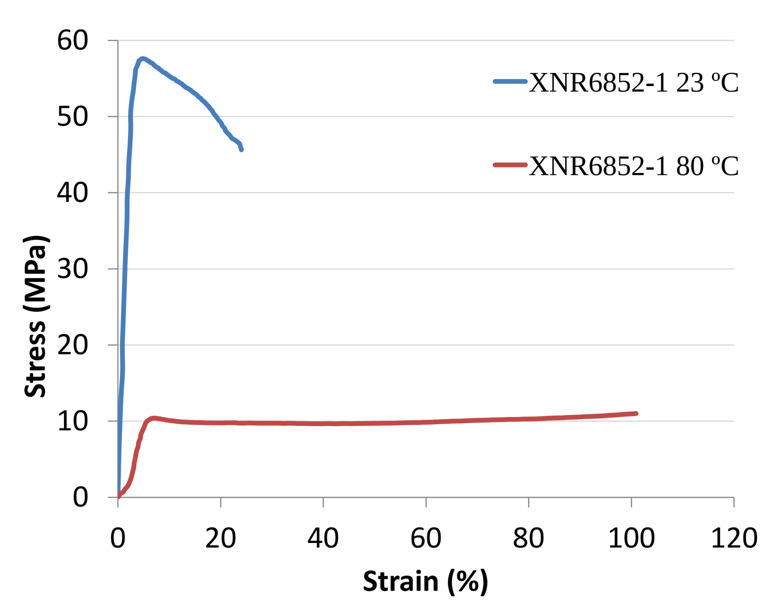
Failure prediction at room temperature gave accurate values due to the low sensitivity of the steel adherends to the high strain-rate. At +80 ºC the adhesive was much more sensitive to the high strain-rate, since the values obtained for the prediction using the static properties of the adhesive were far below the experimental results.

Specimen description

Adhesive

The characterized adhesive was XNR6852-1, a prototype developed and supplied by NAGASE CHEMTEX® (Osaka, Japan). It is a new crash resistant epoxy adhesive with a one-part system that cures at 150 ºC for 3 h. Unlike the network structure of conventional epoxy adhesives, this adhesive has a particular linear structure that allows more freedom of movement to the chains.

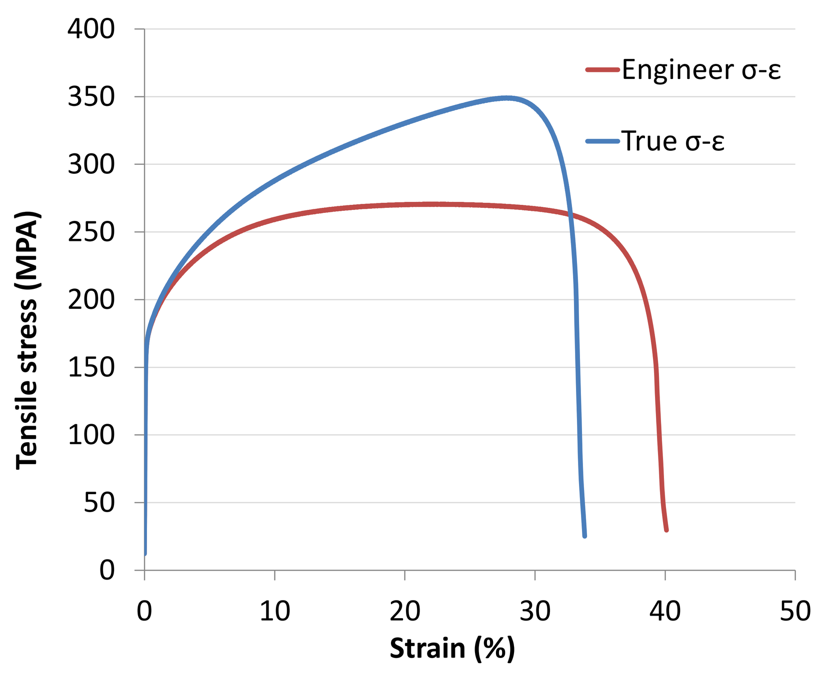
Static properties were obtained by performing adhesive bulk tests at room and high temperatures, showing the high effect of temperature variation in the adhesive's behaviour:



Steel adherends

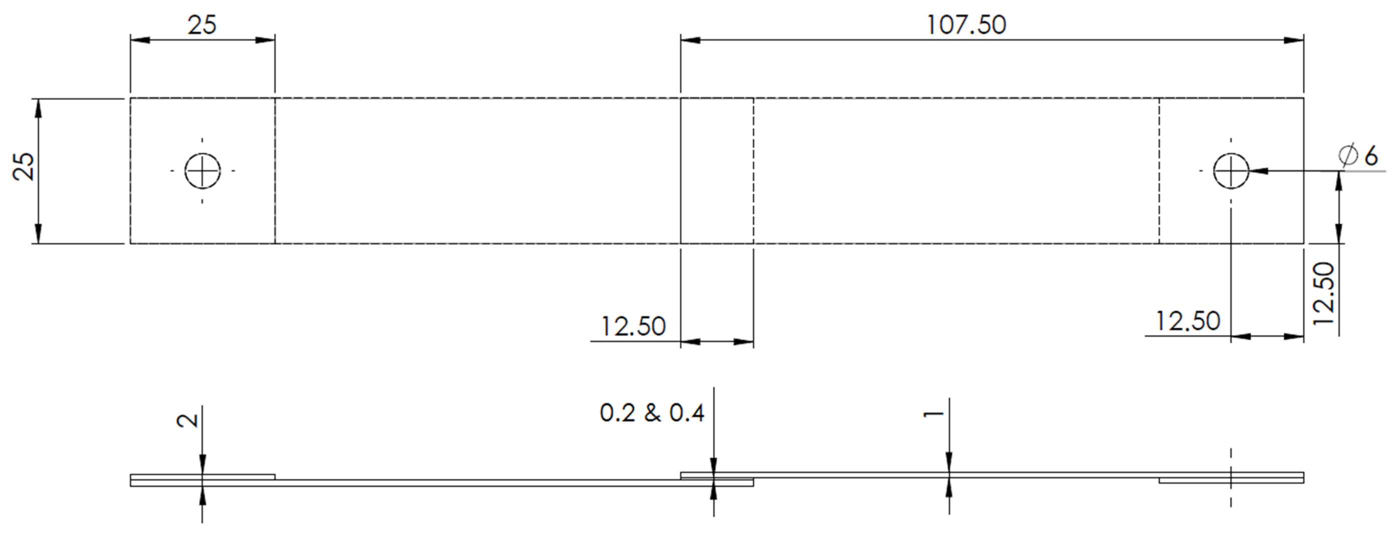
The adherends material used to manufacture the SLJ was mild steel (DIN St33) because of its strong presence in the automotive industry for car body shells.

Steel tensile strength value was necessary to predict failure strength at room temperature. Tensile tests were conducted to obtain this value, showing higher ductility than expected from catalogued properties (17.6 % strain at failure).



Geometry

Two groups of SLJs were used, with the only difference between them lying in the bondline thickness, which was 0.2 mm and 0.4 mm. This geometry was chosen because it is usually used in automotive industry and will therefore allow comparison with other academic work.



Impact tests procedure

The impact tests were conducted in the machine Rosand® Instrumented Falling weight impact tester, type 5 H.V. (Stourbridge, West Midlands, U.K.). This machine drops a mass guided from certain high until it impacts on the device that holds the specimen. The energy applied in the impact is controlled by the weight of the falling mass, and the speed can be set by the height.

Room temperature tests

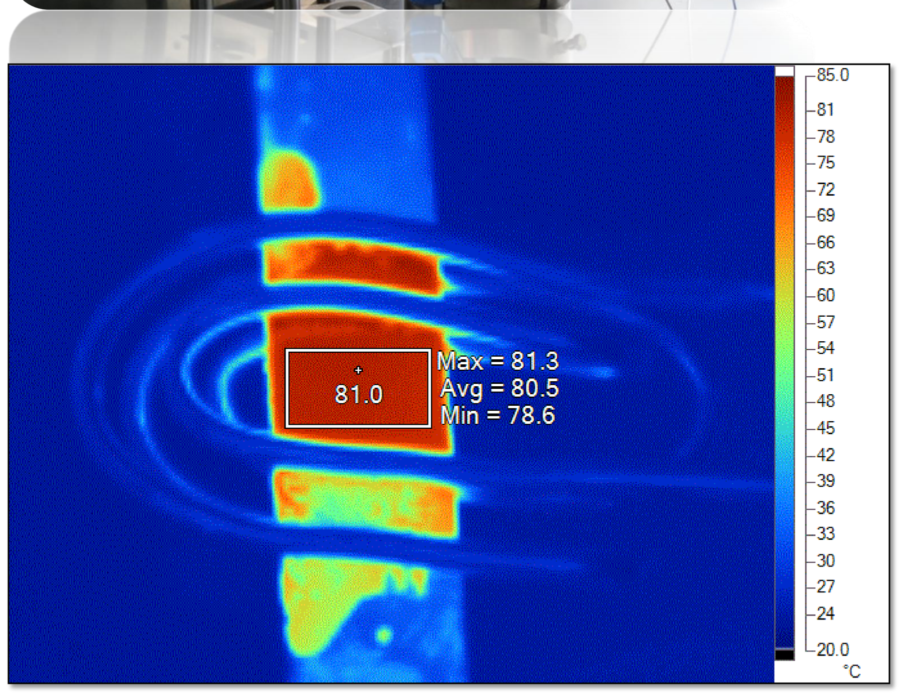
The room temperature tests were performed following the procedure explained in the past section. The holding device was calibrated to make sure that the load was correctly aligned when applied. After fixing the specimen, the mass was set to provide an impact energy of 320 J, which was the maximum capacity available with the specified machine. The height was set to give an impact speed of 4.55 m/s.

High temperature tests

Heating through electromagnetic induction was used to reach the temperature of +80 ºC in the SLJs overlap. The system implemented heated the specimen once it was assembled to the holding device. When the temperature was slightly above the +80 ºC, the system was removed and the mass was dropped to provide an impact of 150 J energy and 4.47 m/s speed.

Low temperature tests

The solution found to reach the -20 ºC was to throw gas nitrogen directly to the specimen overlap. The energy and speed used for the tests were also 150 J and 4.47 m/s respectively.



Monitoring temperatures:

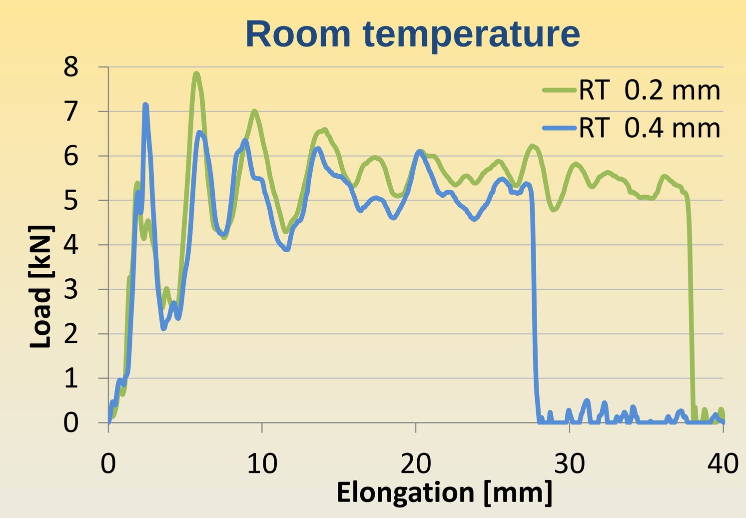
Thermographic camera:

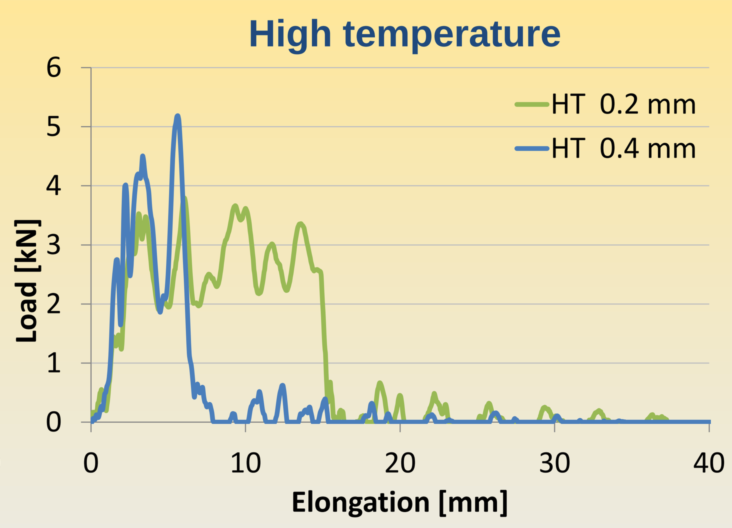
Used with both cooling and heating systems. Showed homogeneous and accurate temperature distribution along the overlap for high temperature tests.

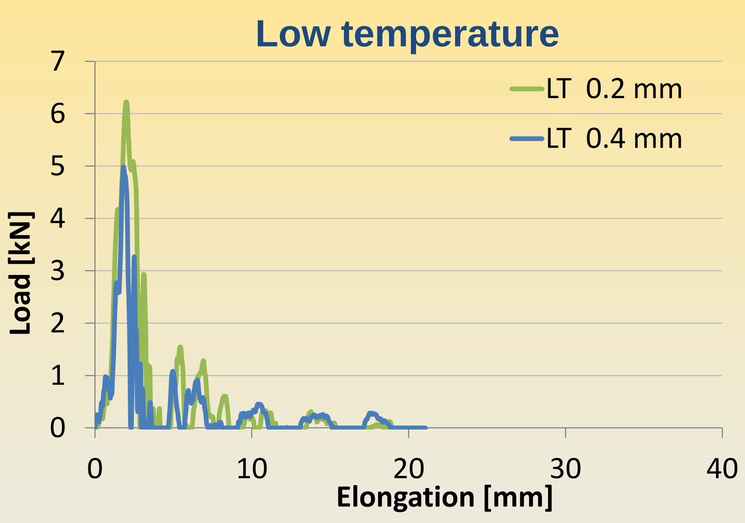
Thermocouple:

It was used in the low temperature tests to make sure that the temperature was -20 ºC.

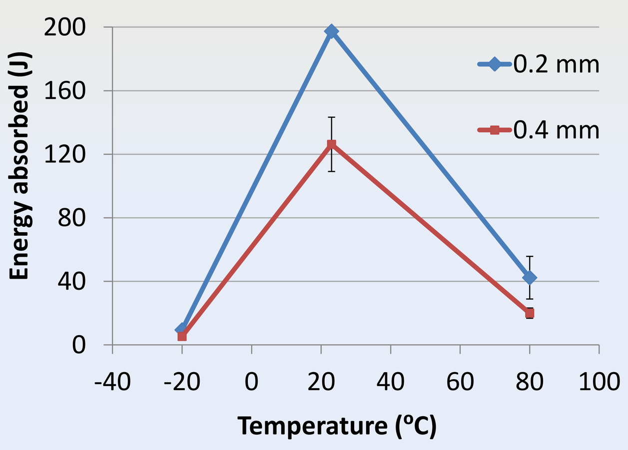
Experimental results

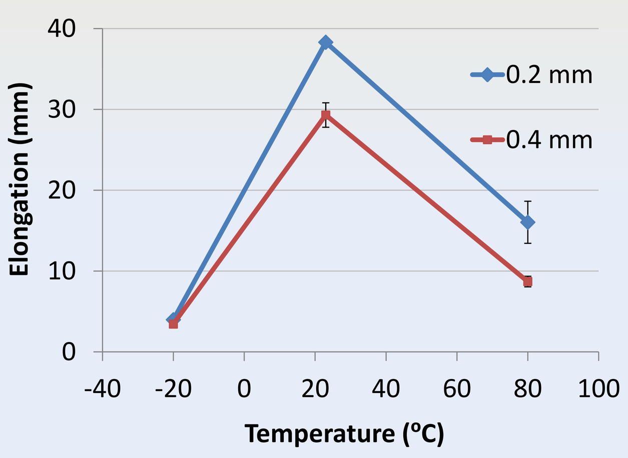


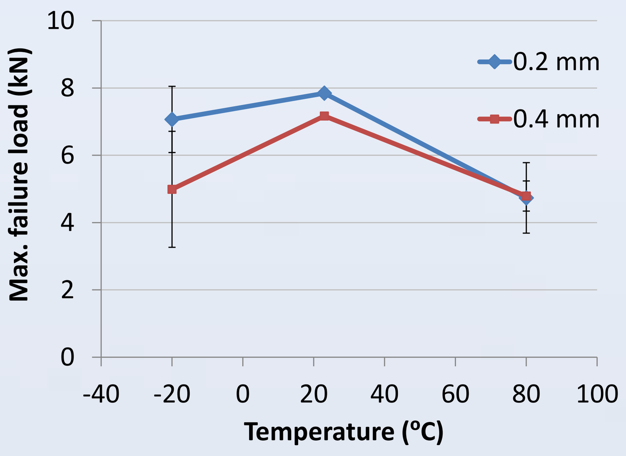


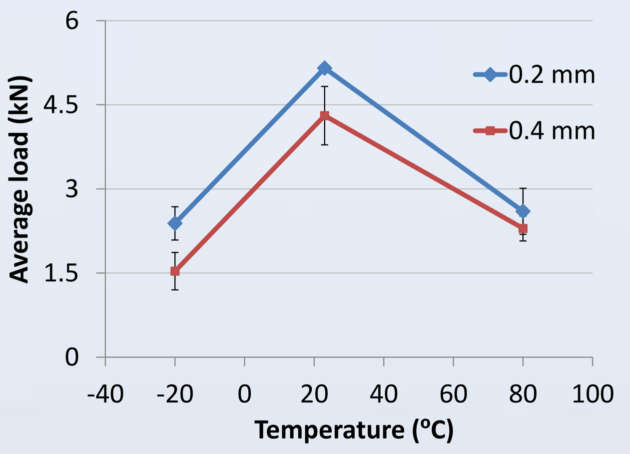


Temperature and adhesive thickness effect on impact strength

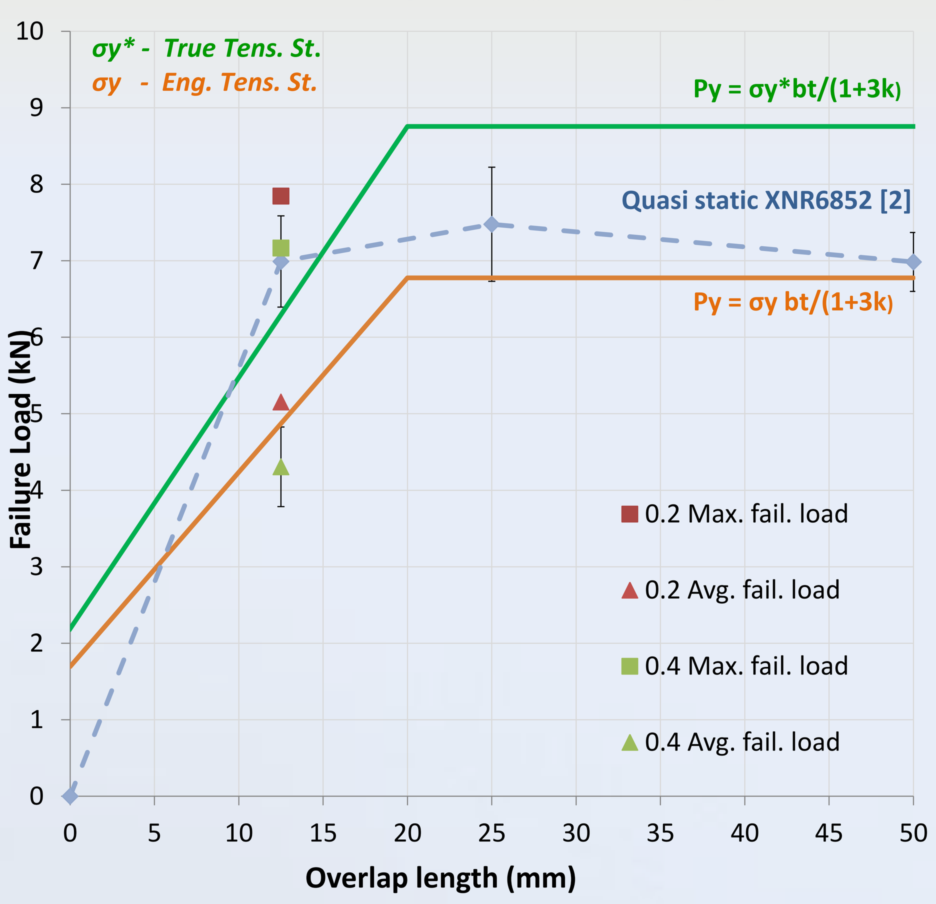








Failure prediction at +23 ºC using adherend yielding model [1]



Conclusions

At room temperature:

The adhesive showed high resistance under impact load, withstanding deformation and damage without brittle behaviour. Failure was dictated by the adherend yielding and could be predicted accurately considering static conditions due to the low senstivitiy of the steel to the high strain-rate.

At high temperature:

The resistance of the adhesive is strongly reduced, fracturing in a ductile manner before the steel adherends yield. The strong sensitivity of the adhesive to high strain-rate gives higher results for failure load than the prediction using static properties of the adhesive.

At low temperature:

The adhesive shows low resistance under impact load as at high temperature, showing a brittle behaviour in the fracture mode. Static properties at -20 ºC could not be obtained and therefore no failure prediction was developed. However, obtaining those properties in future work would allow to predict failure by Volkersen's model [3] due to the brittle behaviour of the adhesive [4].

References

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