The effect of environmental conditions on the impact behaviour of adhesive joints for the automotive industry

D.N. Rosendo[1], L.F.M. da Silva[1], G. Viana[2], M. Costa[2]

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

[2]Institute of Science and Innovation in Mechanical and Industrial Engineering, 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. Toughened, high performance adhesives can provide exceptional strength while producing lighter structures and, therefore, improve vehicle safety and efficiency. When adhesive joints are used in this area, some factors such as impact loading, environmental moisture and temperature variations have a decisive role [1]. 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 (SLJ) using two crash resistant epoxy adhesives. 5 mm and 2 mm thick aluminium adherends were used in order to cause failure due to the average shear stress and due to the peel stress at the ends of the overlap respectively. The adhesive joints were tested under different environmental conditions: dry specimens and humid specimens (which had been kept immersed in distilled water for three months) were tested under -20oC, 23ºC and 80ºC, to simulate the environmental conditions in a vehicle. The joints were tested in quasi-static conditions and in impact conditions.

Objectives

- Analysis of Single Lap Joints behaviour under impact loads for the automotive industry;
- Tests were made for a wide range of temperatures (-20ºC to 80ºC);
- Moisture levels were varied in order to simulate the bonds under different environments;
- Two different adherend thicknesses were used so that the effect of the yielding of the substrate can be analysed.

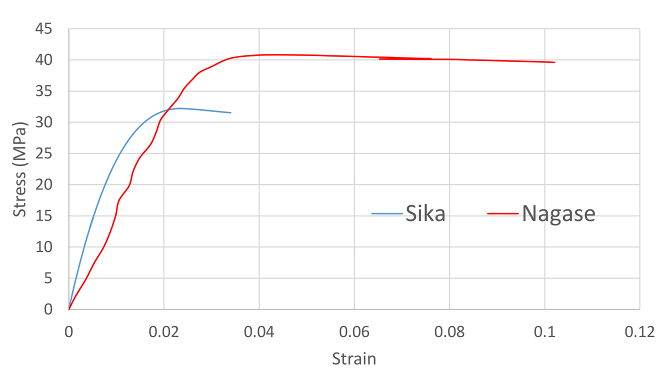
Research Methodology

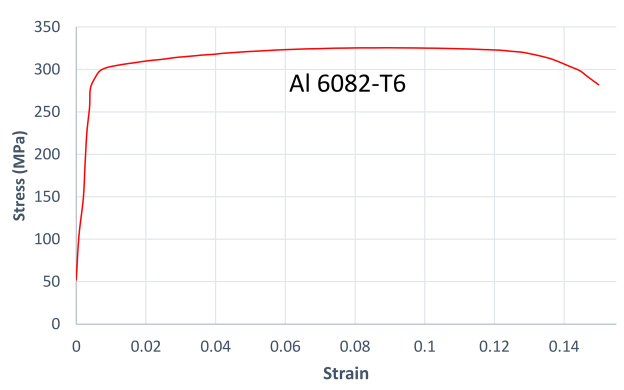
- Manufacture of the joints required to perform the tests under all conditions, after studying an optimized and efficient way to do so and to prepare the materials;
- Water absorption tests required to determine the unknown diffusion properties of one of the adhesives;
- Determination and testing of the methods used to heat up and cool down the joints for the different temperature tests;
- Impact and quasi-static tensile tests of the adhesive joints for all of the required property combinations.

Material:

Research was done for two different structural adhesives using the 6082-T6 aluminium alloy :

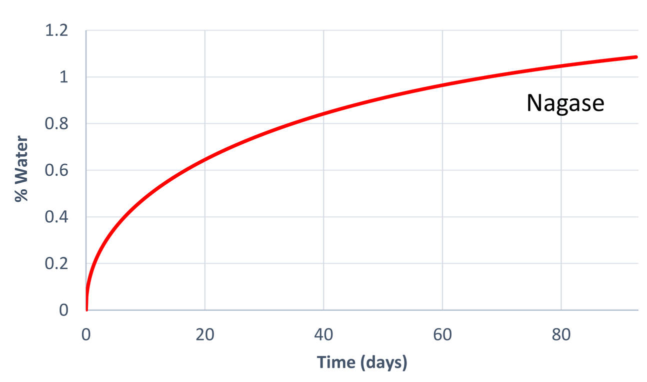
Material	Young's Modulus (MPa)	Tensile Strength (MPa)
Sika® SikaPower 4720	2170	32
Nagase® XNR 6852E-2	1833	41

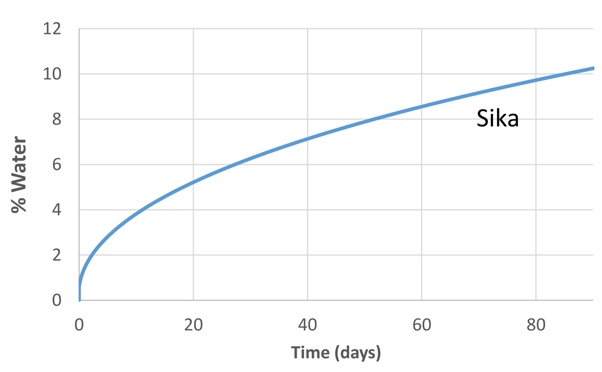




Determination of Water Absorption

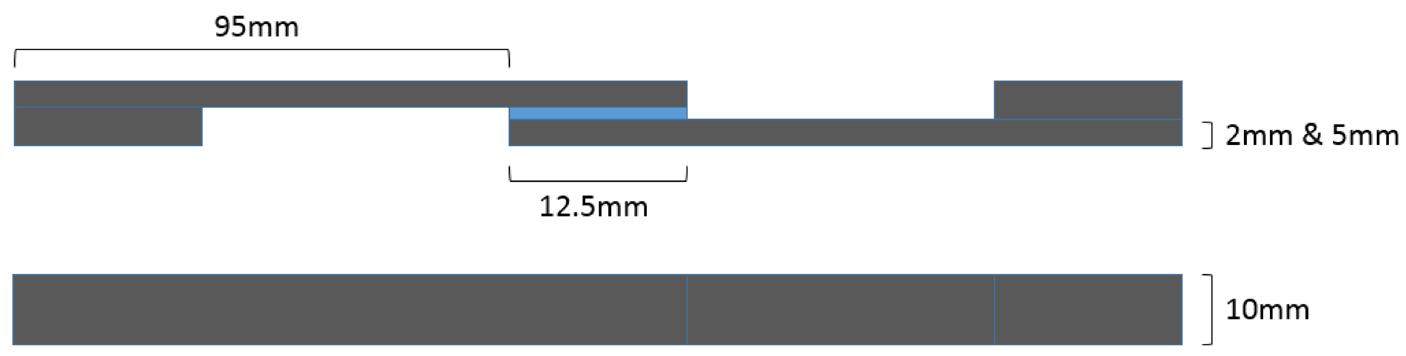
Determination of adhesive's water diffusivity by producing bulk specimens and studying their water uptake, applying Fick's laws of diffusion. Effect of temperature and coefficient of diffusion on water intake rate are reviewed as well as water distribution throughout an adhesive joint.





Average water content % over time for each studied adhesive.

Single Lap Joint Manufacturing



Dimensions of the manufactured single lap joints, using an adhesive layer thickness of 0.2 mm.

A large number of single lap joints were manufactured to test several combinations of temperature, moisture and adherend thickness. In order to improve adhesion, especially for the humid joints, surface preparation techniques were studied, such as phosphoric acid anodization.

Impact testing

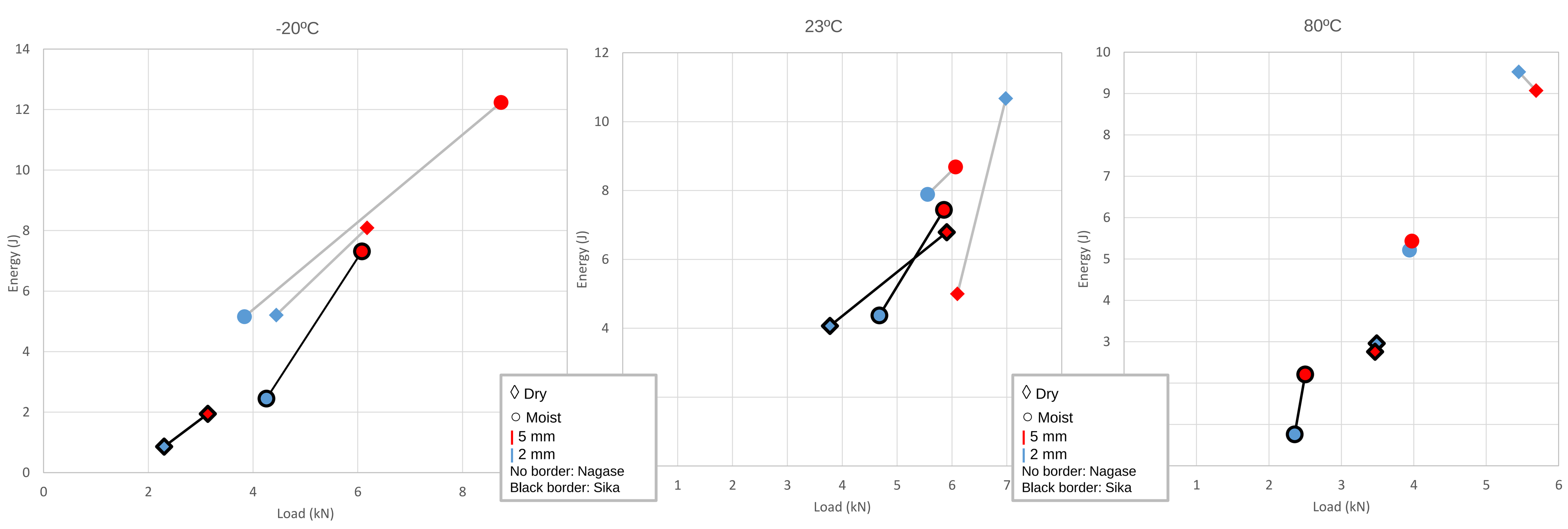
Using a drop weight impact machine, impact tests were performed using 20 J of impact energy. Applying a weight of 26 kg on the impactor, its height was adjusted so that the impact speed was 1.24 m/s.

Electromagnetic induction was used to heat up the joints for the high temperature tests, while liquid nitrogen was used to cool them down. The temperatures were controlled using a thermocouple and a thermographic camera, making sure that the required temperature was obtained throughout the bond length.

The results consisted in measuring the load, displacement and amount of absorbed energy.

Results and Conclusions

- At low temperature the Nagase joints absorbs more energy when they are moist, except for the thinner adherends where the maximum shear load is higher. The Sika adhesive loses its adhesion.
- At room temperature the moist joints absorb more energy than their dry counterparts, except for the Nagase joints with 2 mm adherends, where the yielding of the substrates absorbs a high amount of energy.
- At high temperature the adhesives present a very plastic behaviour so the adherend thickness is not as important to define the absorbed energy.
- The moist joints behave poorly at high temperature when compared to room temperature, even though the adhesive presents a more plastic behaviour. It is not good to mix high temperatures and moisture levels.



[1] L.F.M. da Silva, A. Öchsner, R.D. Adams, "Handbook of Adhesion Technology", Vol.1. 2011