Development of a cyclic creep testing station for testing PSAs

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Abstract

The characterization of the creep behaviour is important for the design of structures, allowing to assess durability and long-term behaviour. Furthermore, experimental testing is fundamental for observing the dependence of environmental effects such as temperatures and stress. In this paper, the development of a cyclic creep testing station is presented. A compact device is designed for testing single lap joints (SLJs) using pressure sensitive adhesives (PSAs) at different stress levels, and temperatures between -40 °C and 90 °C by placing the setup in a thermal chamber. The design is based on a mechanism that periodically supports a hanging weight resulting in a cyclic load. The assembled testing setup is then validated by comparing cyclic creep experimental data obtained using a servo-hydraulic testing machine adapted for cyclic creep, and the experimental results obtained with the setup developed in this paper are presented.

Design

Design requirements

The main requisites for the machine design was the maximum displacement and applied load at the joint, being around 13 mm and 80 N, respectively. Also, the machine should be compact in order to be able to fit in a thermal chamber available for testing at different temperatures between -40 °C and 90 °C . Also, the structure and the components must withstand this temperature range.

Cyclic creep machine design

The design of the cyclic creep machine is presented in Figure 1, being composed of a vertical tower with a lever arrangement for multiplication of the applied load on the specimen. The vertical tower is a Bosch Rexroth 50x50 [mm^2] aluminium profile since it's lightweight, strong, and an off-the-shelf product.

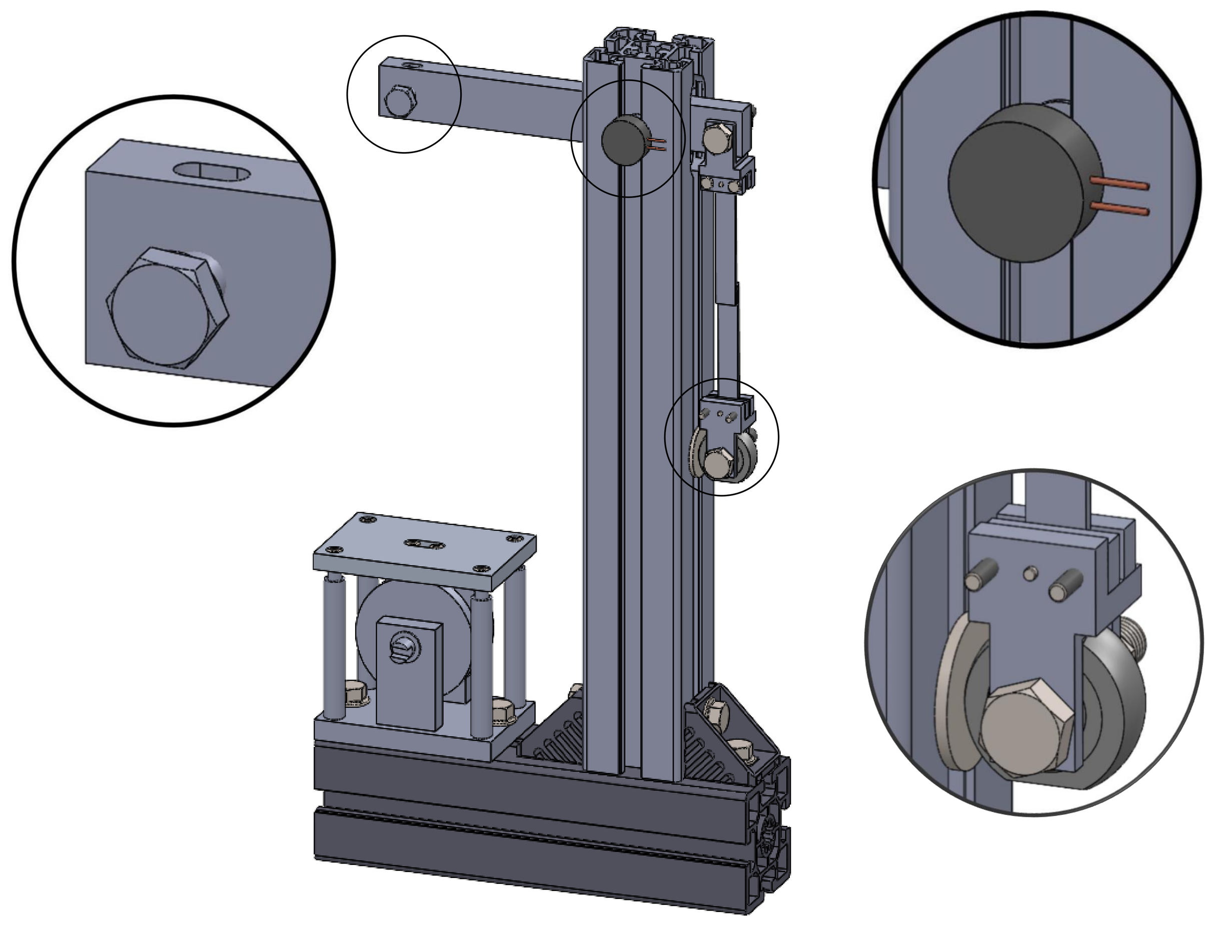

Figure 1 – Design of cyclic creep machine.

The grips were composed of a centred pin for aligning the joint, and two screws to clamp the specimen; these can also rotate due to the rotation of the lever (see Figure 1). Additionally, the lower support for the grips was a male threaded rod end to allow rotation of the grip. Then, the mechanical system for supporting the weight to unload the joint was composed of a crank system with a unique design of the central part that allows the platform to stay in the bottom
position for 50% of duty cycle, when the joint is loaded. The mechanical system is shown in Figure 2.

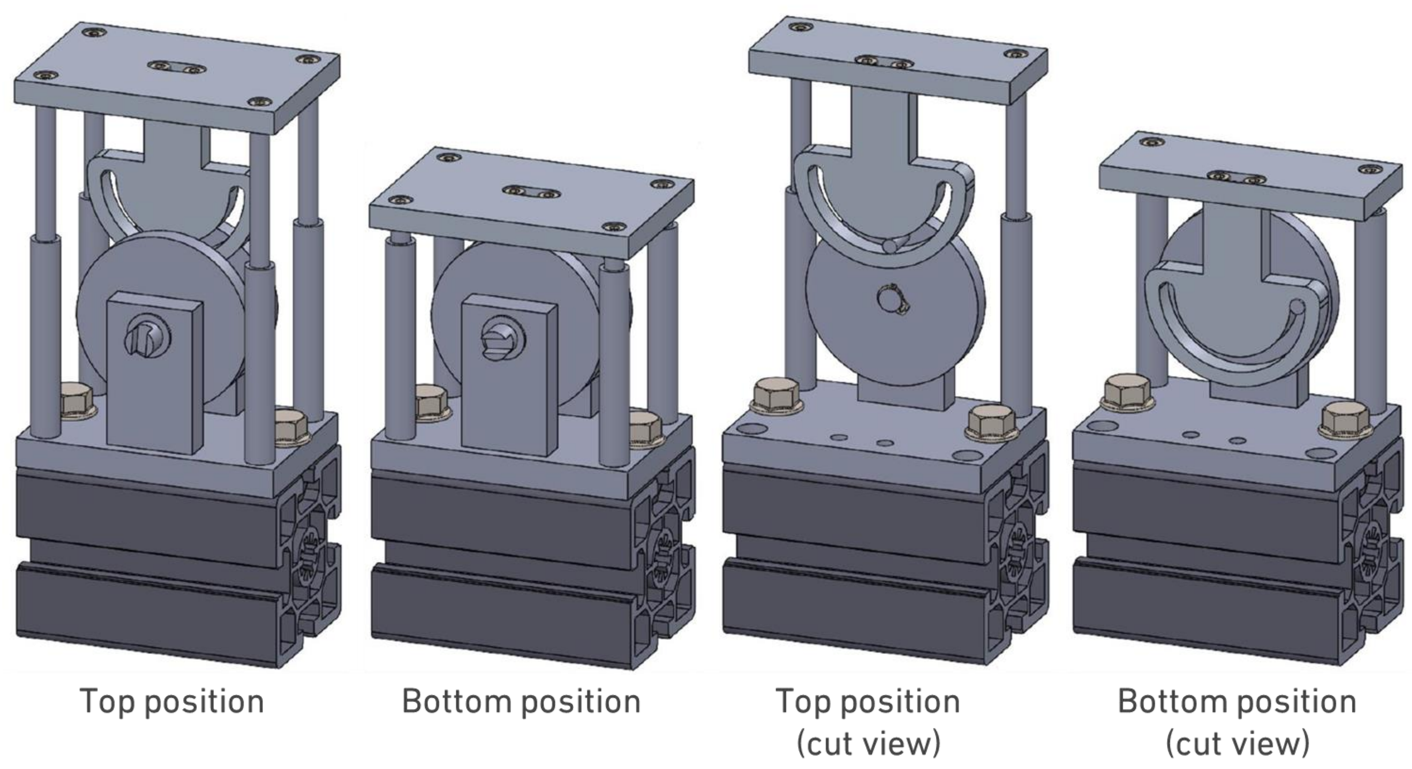

Figure 2 – Design of cyclic mechanism with electric linear actuator.

However, the crank system presented some problems in the upwards movement, where the platform would tilt, and the system would lock up. Therefore, an overhaul of the system was done, however the new design is not presented since it was submitted for a patent. Nonetheless, one of the changes performed was the replacement of the Hall's effect magnetic angular sensor with a potentiometer for measuring the angle of the lever.

Results

Joint geometries

The material used for the substrates was poly(methyl methacrylate), or acrylic, and aluminum alloy from the 6000 series. Regarding the adhesives, two different acrylic PSAs were studied: Adhesive 1 was a transparent acrylic PSA while Adhesive 2 was a foam acrylic PSA. Quasi-static tests in SLJs at 1 mm/min determined the failure loads of 78.22 ± 6.75 N for Adhesive 1, and 40.35 ± 1.17 N for Adhesive 2. The joint geometry is presented in Figure 3.

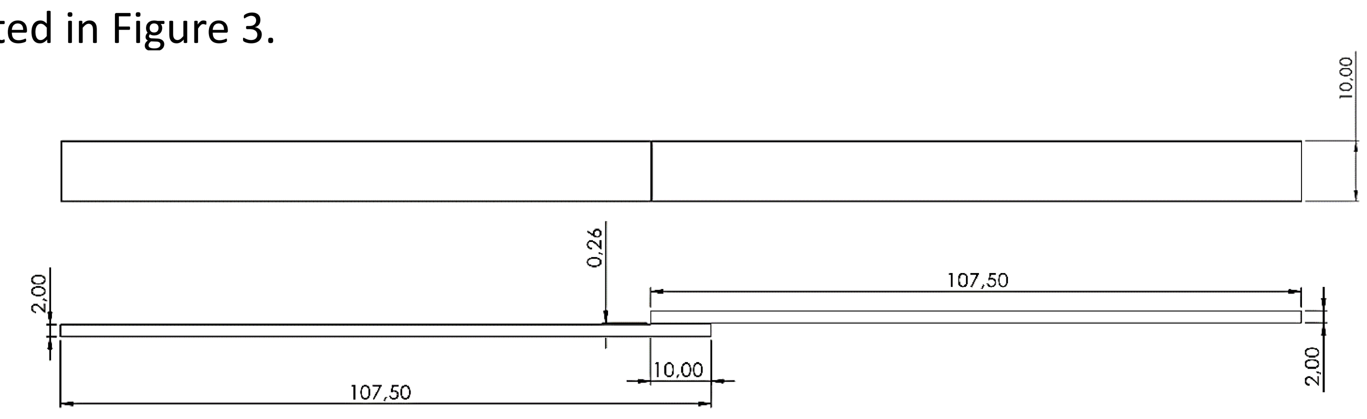

Figure 3 – Joint geometry, in mm.

Testing setup

For the reference cyclic creep tests, a servo hydraulic machine was used with a trapezoidal waveform defined to control a platform that periodically supports the weight. The frequency was set at 0.04 Hz. Two photographs were taken for each cycle, one at unloaded phase and another at loaded phase, being then processed with DIC.

For the designed cyclic creep machine, the setup was composed of a power supply for the potentiometer, a data acquisition device to collect the output voltage of the potentiometer, and an additional component to power the new cyclic mechanism.

Experimental results

The validation of the machine was done by comparing cyclic creep curves from the reference machine and the developed cyclic creep machine. Figure 4 shows the results for two conditions involving the two adhesives with acrylic substrates for two applied loads, at room temperature.

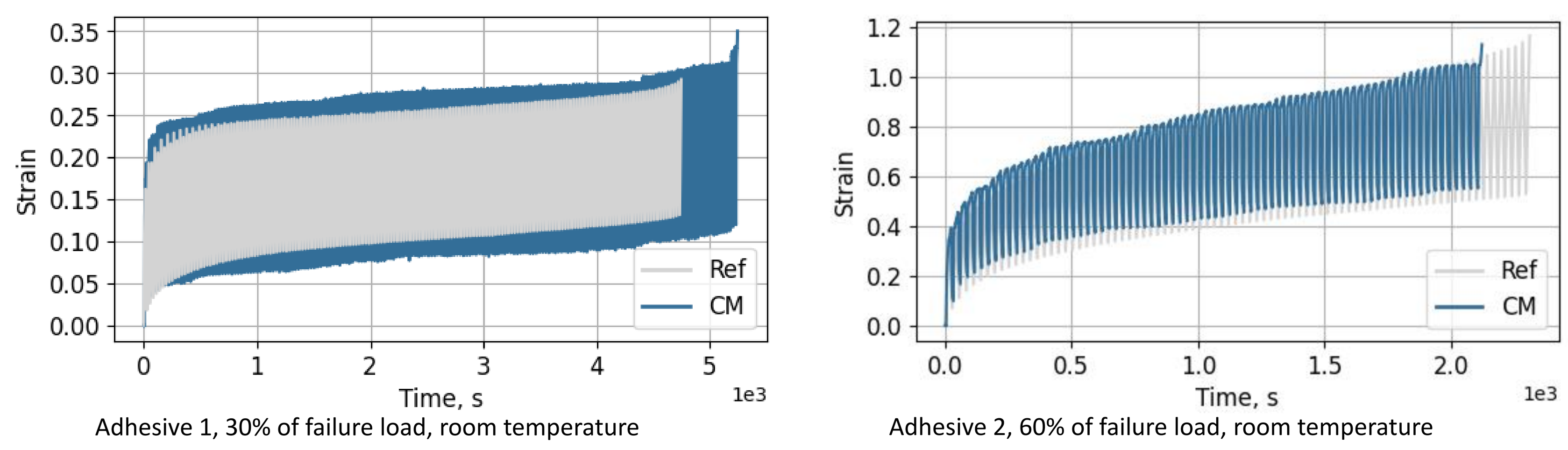

Figure 4 – Comparison of the experimental curves obtained from the reference machine (Ref) and the cyclic creep machine (CM).

After being validated, some tests were performed to evaluate the behaviour of Adhesive 2 for 30% load level, at 55 °C, under the same frequency cyclic loading. Figure 5 presents two curves of the preliminary tests.

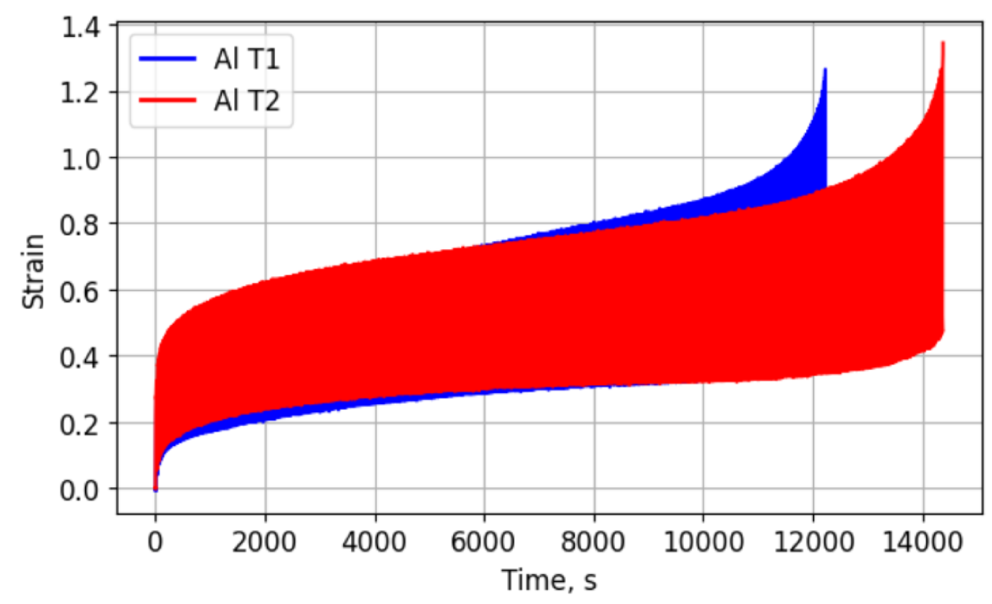

Figure 6 – Scheme of setup for cyclic creep testing with the developed cyclic creep machine.

Conclusions

The design of a cyclic creep testing machine for SLJs with PSAs was successful, resulting in a design that can capture the behaviour of the adhesives in the two testing conditions considered for validation. This design also allows for adjustability of the length of the adhesive joint as well as for the cyclic loading conditions by adjusting the waveform parameters to control the frequency and duty cycle. Finally, the preliminary results for testing with different substrate and temperature proved to capture the cyclic behaviour of the tested PSA.

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