Functionally graded adhesive joints using magnetic microparticles with a polyurethane adhesive

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Introduction

With the increased use of new high performance materials for structural construction, traditional mechanical joining techniques have in part been replaced by adhesive bonding. The single lap joint (SLJ) is largely used in industrial applications due to its simplicity and efficiency, they provide smooth stress distributions along the width of the overlap. The main problem associated with use of SLJs is the non-uniform stress distribution along the overlap length [1]. The goal of this work is to evaluate the reliability of the inclusion of hard magnetic particles on polyurethane SLJs. Functionally graded adhesive joints (FGA joints) were produced using an in house developed apparatus, shown in Figure 1.

Experimental methodology

To evaluate the influence of the iron microparticle content on the polyurethane, SLJs with three different particle contents (0%, 1% and 5% in volume) and two distinct particle distributions (uniform and graded distribution) were tested, schematic representations can be seen in Figure 2.

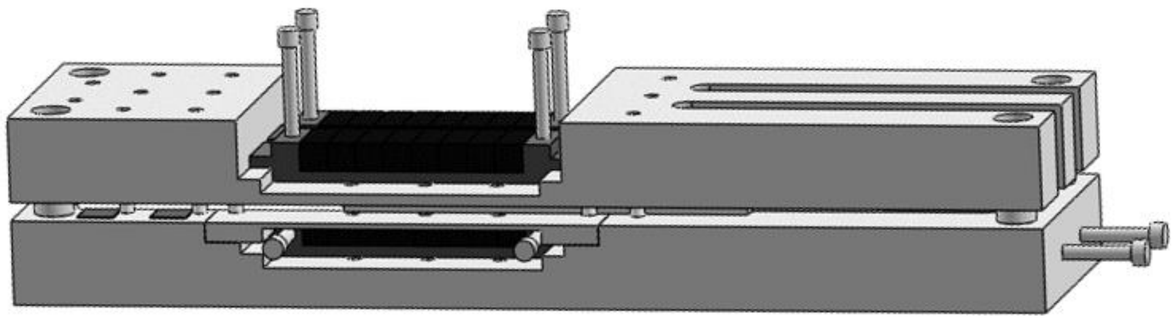

Figure 1 – Apparatus used to produce SLJs with graded particles distribution [2].

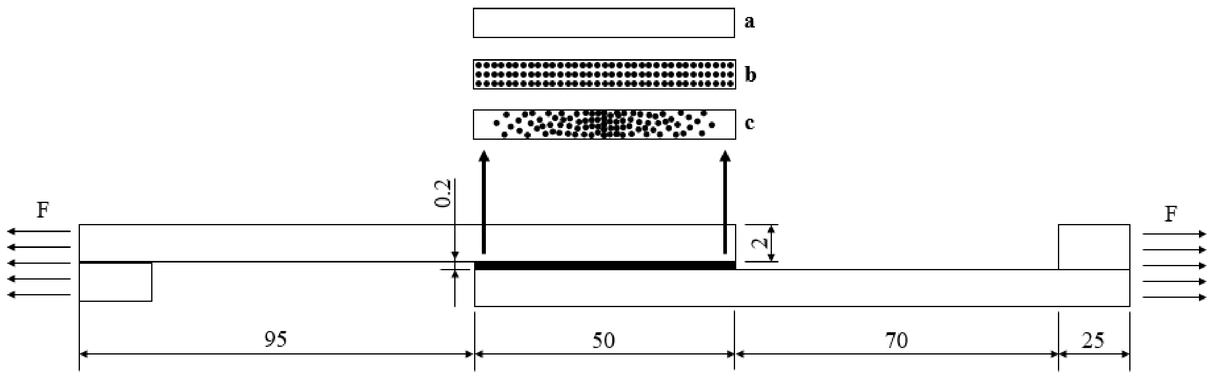

Figure 2 – Tested SLJs geometry: a) Neat, b) Uniform distribution, c) Graded distribution.

Numerical modeling

A magnetophoresis analysis was performed using COMSOL Multiphysics ® to predict the optimal arrangement of magnets to obtain the desired particle distribution.

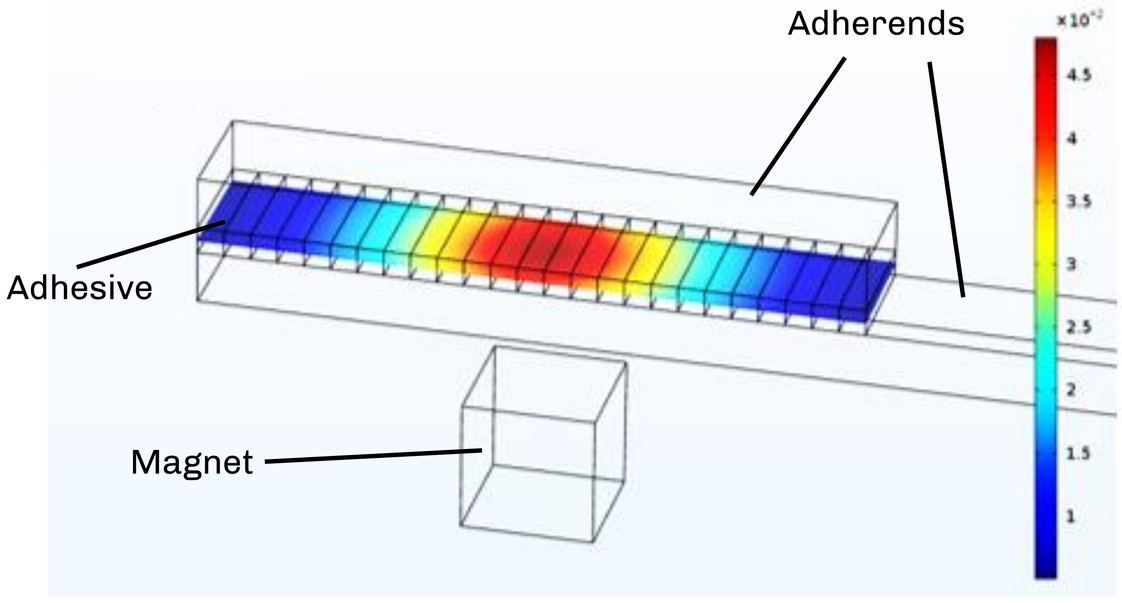

Figure 3 – Resulting magnetic field density on the SLJ.

Results and discussion

As seen in Figure 4, the SLJs with a 1% microparticles content and a graded distribution outperformed all other configurations.

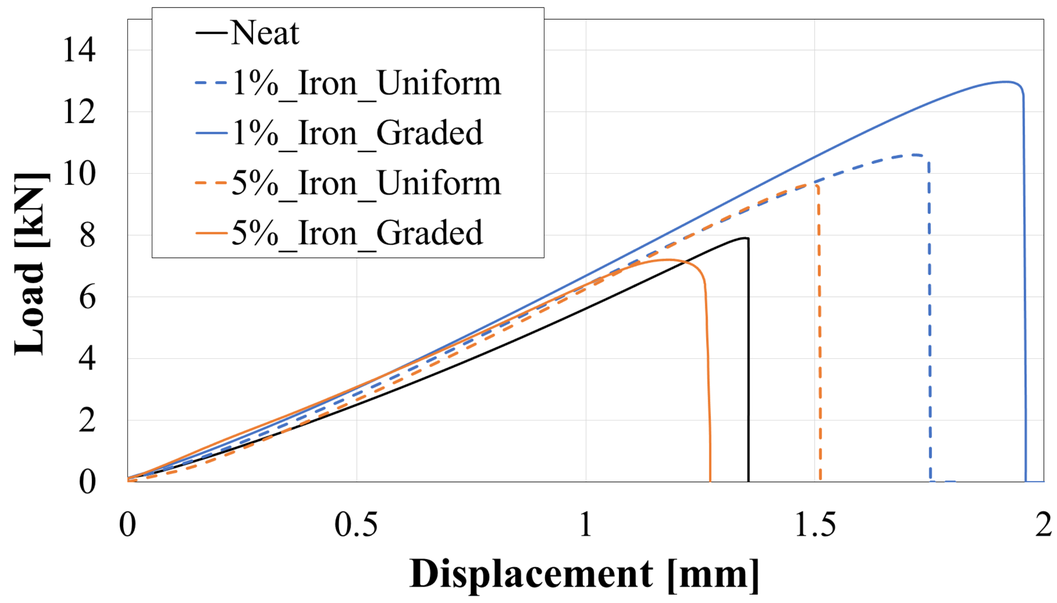

Figure 4 – Typical P-δ curves from SLJs tensile tests.

The experimental results showed that all neat joints had adhesive failure. The addition of iron microparticles modified the resulting adhesive system both visually and mechanically. In fact, the failure mode changed from adhesive to nearly cohesive (see Figure 5).

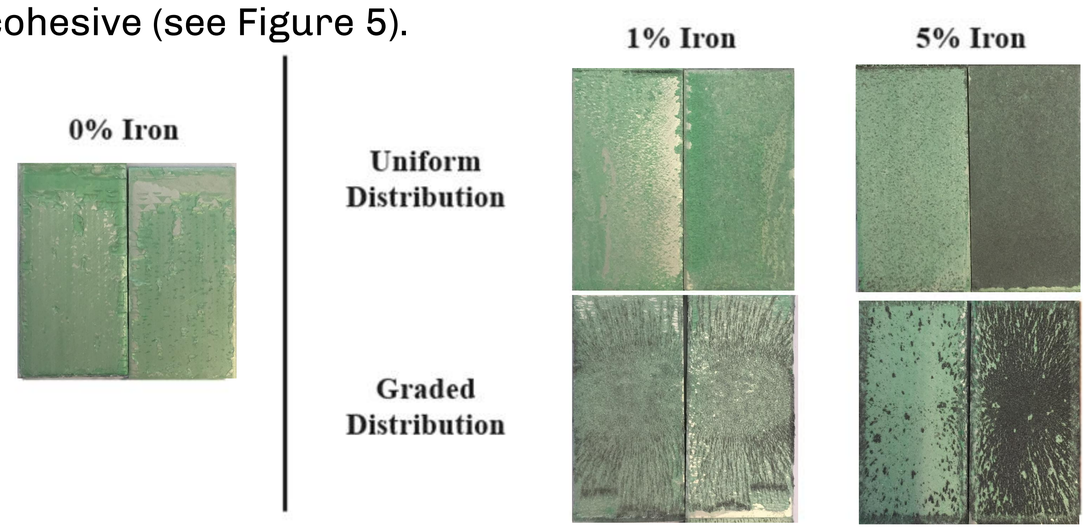

Figure 5 – SLJs fracture surfaces as a function of iron microparticles amount and distribution.

Conclusions

Iron microparticles can be used to enhance the mechanical properties of a polyurethane adhesive joint, however the effectiveness of this reinforcement is highly dependent on the particle amount and distribution. FGA joints were successfully made through the application of a magnetic field in the middle of the overlap. The numerical simulation was validated against experimental data: the predicted particle trajectories were in accordance with the experimental fracture surfaces of the correspondent SLJs.

References

[1] da Silva, Lucas FM, Andreas Öchsner, and Robert D. Adams, eds. *Handbook of adhesion technology*. Springer Science & Business Media, 2011.

[2] da Silva, Catarina I., et al. "Mechanical Characterisation of Graded Single Lap Joints Using Magnetised Cork Microparticles." *Advanced Joining Processes*. Springer, Singapore, 2020. 153-174.

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