Study of adhesive squeezing flow using a modified hele-shaw cell device

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1. Introduction

Adhesive flow during compression plays a key role in the performance of bonded joints. A custom Hele-Shaw cell, integrated with a Universal Testing Machine, was developed to perform controlled squeeze flow experiments on polypropylene and aluminum substrates under different surface conditions. In parallel, a 3D numerical model was implemented in OpenFOAM using a Volume of Fluid approach with dynamic mesh motion and contact angle boundary conditions, enabling accurate simulation of the adhesive spreading process and direct comparison with experimental data.

2. Methodology

A 7075 aluminum Hele-Shaw cell was mounted on a UTM for controlled compression tests. A transparent top substrate with a vertical camera enabled real-time visualization of adhesive spreading on various treated substrates.

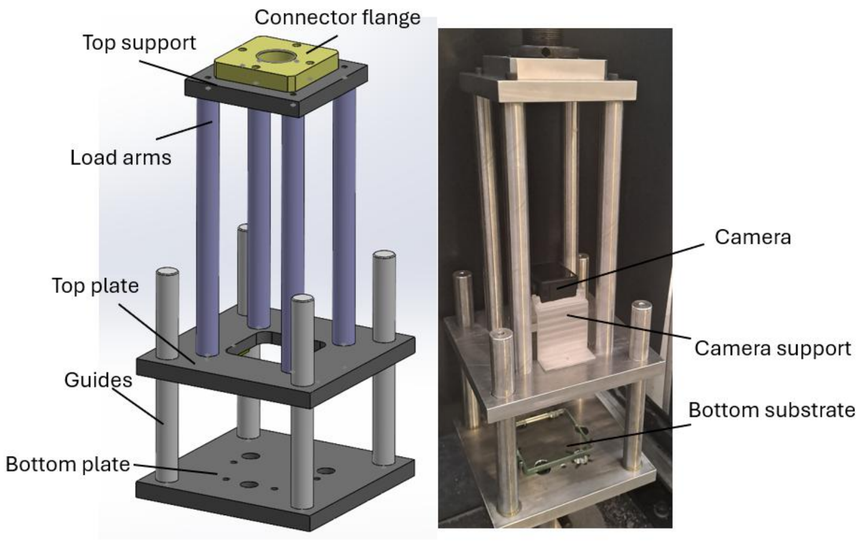

Figure 1. Hele-Shaw cell used for experimental tests.

3. Experimental results

Tests on PP flame-treated and Al laser-treated substrates showed reaction force–thickness curves nearly identical to those of untreated samples, indicating minimal influence of these surface treatments on adhesive squeeze flow.

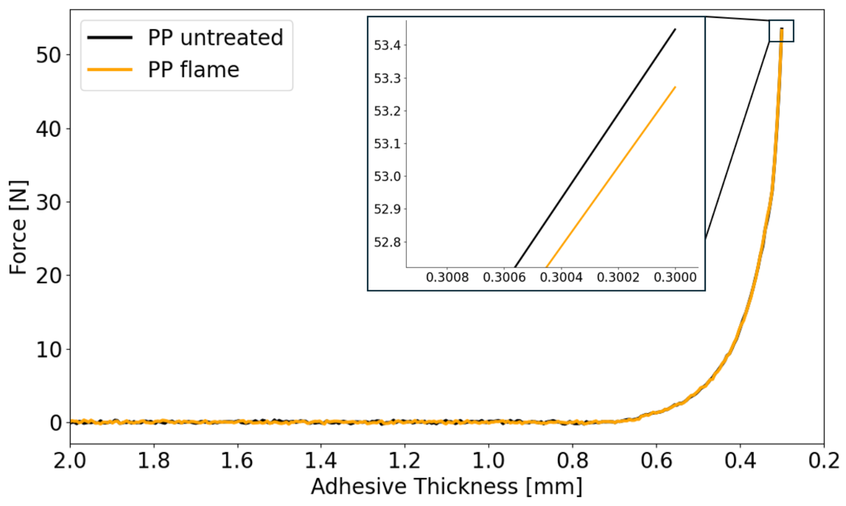

Figure 2. Reaction force as a function of adhesive thickness for PP flame and PP untreated.

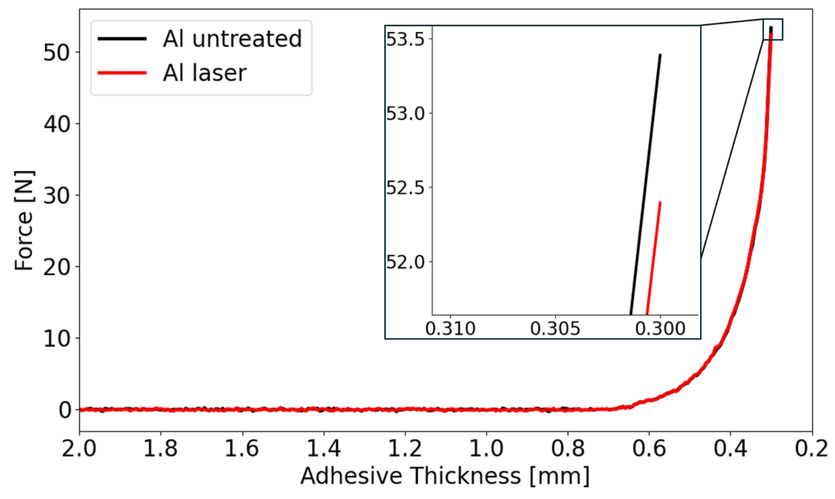

Figure 3. Reaction force as a function of adhesive thickness for Al laser and Al untreated.

4. Numerical results

Numerical predictions showed excellent agreement with experiments, both in reaction force vs. adhesive thickness and in adhesive spreading behavior.

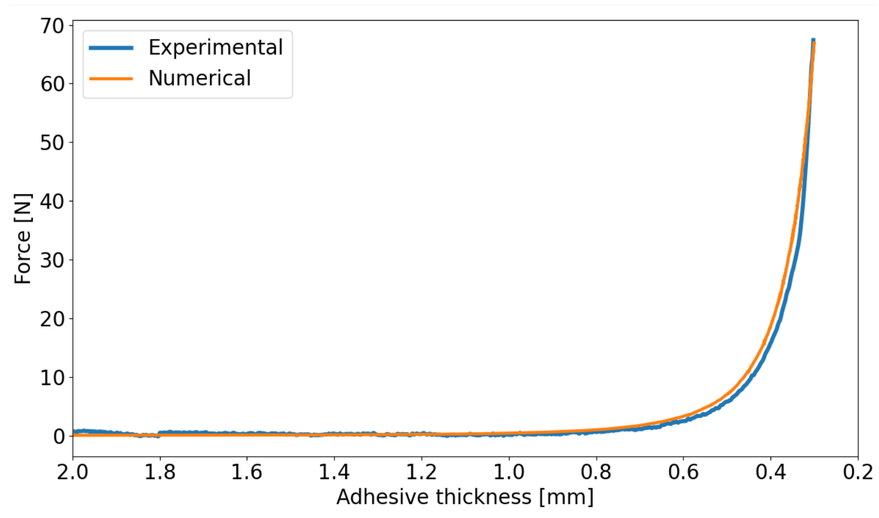

Figure 4. Comparison of force vs. adhesive thickness curves for experimental and numerical data.

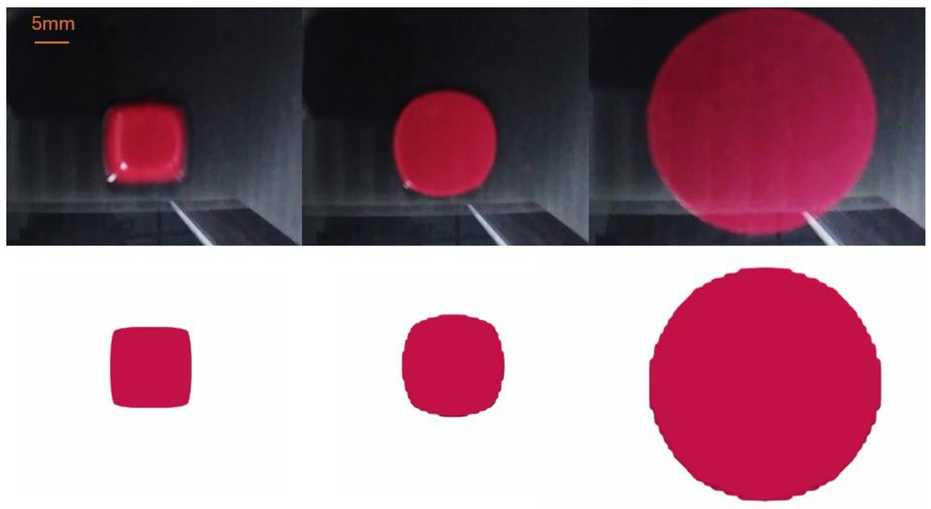

Figure 5. Adhesive shape at different times – comparing numerical and experimental spread.

5. Conclusions

- Hele-Shaw cell device enabled controlled and repeatable adhesive spreading tests.
- Experimental results showed minimal effect of surface treatment.
- Numerical simulations accurately reproduced experimental results.