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ADVANCED JOINING PROCESSES UNIT

Analyzing adhesive squeezing flow in manufacturing hybrid bolted/bonded joints

F. Ricca | A. Akhavan-Safar (INEGI, Portugal) | R.J.C. Carbas | E.A.S. Marques| L.F.M da Silva

INTRODUCTION

Hybrid joints combining adhesive bonding with pre-tensioned bolts offer superior mechanical performance over solely bonded or bolted joints. However, the manufacturing process often results in a very thin adhesive layer, crucial for accurate load capacity predictions but previously only qualitatively characterized. Our research focuses on numerically predicting the adhesive layer thickness using computational fluid dynamics (CFD) and fluid-structure interaction (FSI). By modeling adhesive flow under bolt tightening and analyzing its rheological properties, we aim to understand its impact on the distribution of adhesive layer thickness.

METHODS

First, a CFD-only model was created to validate the chosen methodologies by comparing the normal force generated by the fluid pressure on the joint substrate during squeeze flow with both experimental and numerical values documented in the literature, using simplified cylindrical substrate geometries. CFD data from hybrid joint geometries was then exported to conduct various FSI simulations, replicating the rheological effects of the adhesives on the metal substrates in response to bolt tightening. This approach enabled the determination of the thickness distribution of the adhesive layer in such joints.

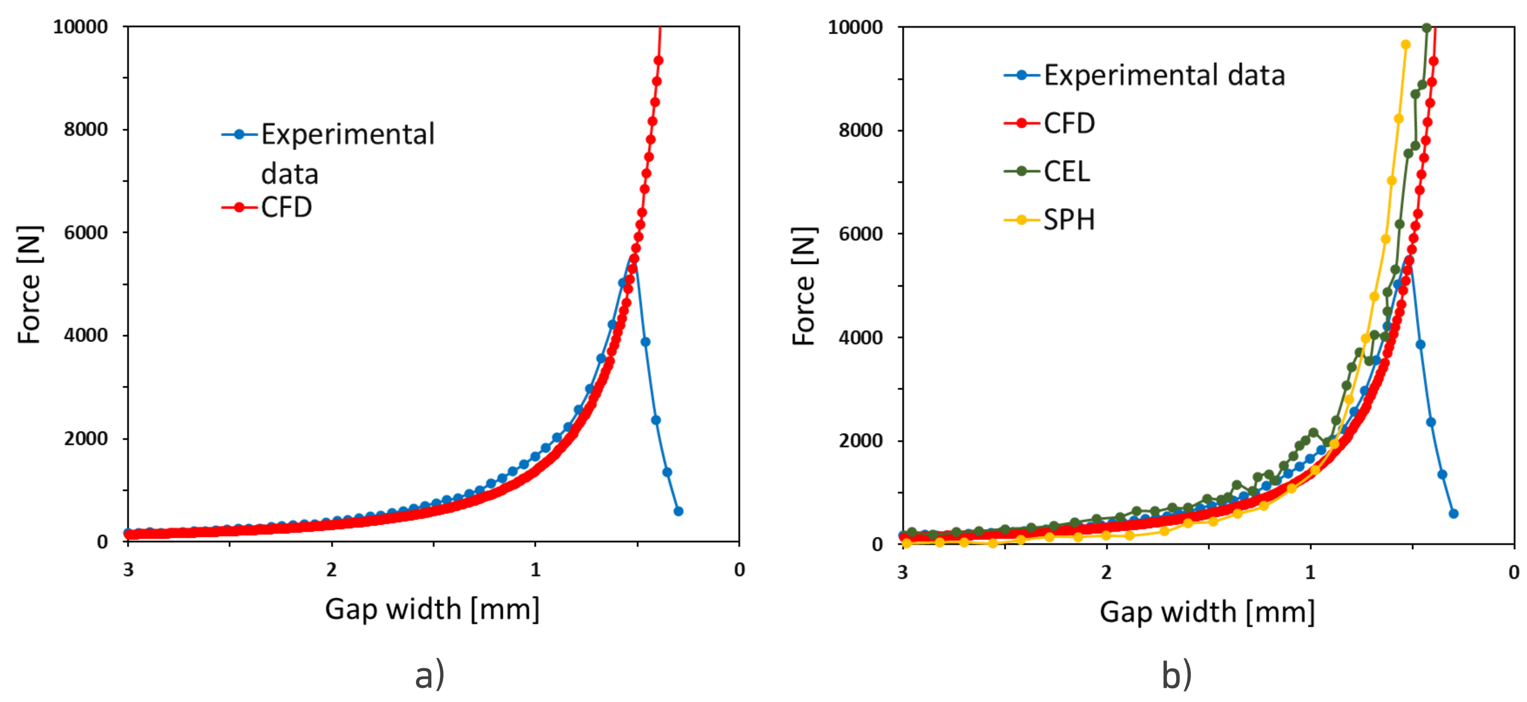
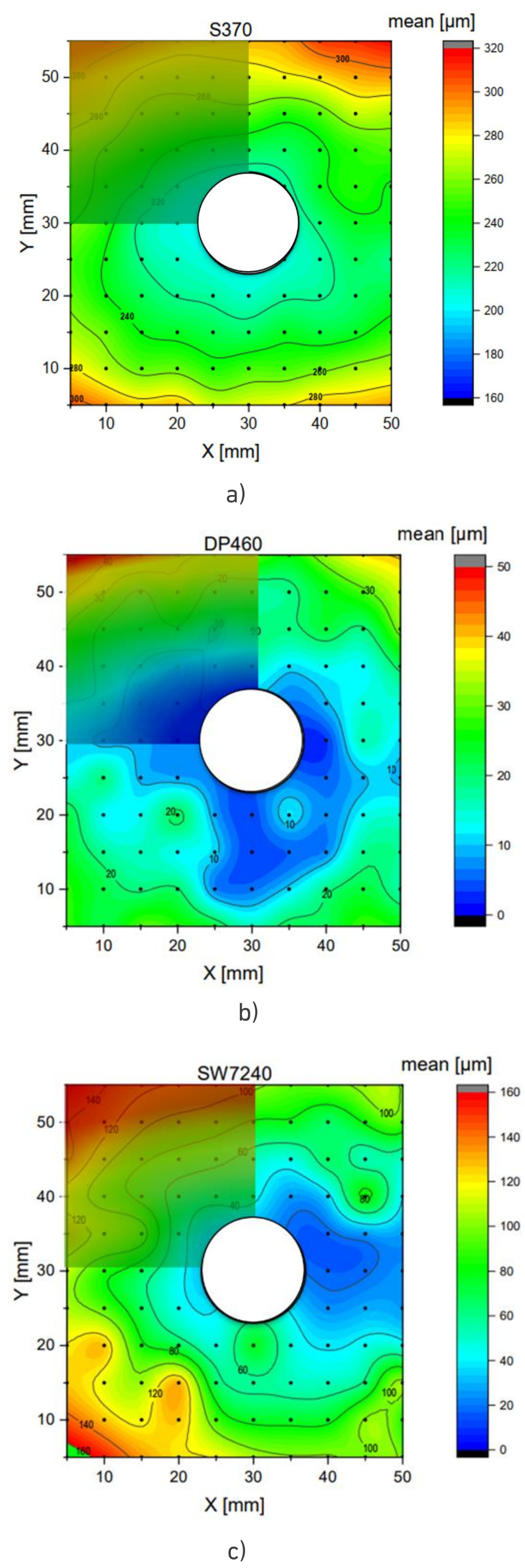


Figure 1 – Normal force comparison with a) experimental and b) numerical literature results of squeeze flows of viscous adhesive SIKA POWER 498.

RESULTS

The results shown in Figure 1 demonstrate the effectiveness of the selected methodologies, particularly when compared with other numerical methods such as Coupled Euler Lagrangian (CEL) and Smooth Particle Methods (SPH). The results obtained from the FSI simulations, represented in the top left quadrant of the hybrid joint geometries, are then superimposed with the experimental results in Figure 2 for three different epoxy adhesives used in steel construction applications. The results show good to very good agreement with the experimental results.



a)
- Numerical mean value: 246.5 µm;
- Experimental mean value: 256.1 µm;
- Relative difference: 4.3%

b)
- Numerical mean value: 22 µm;
- Experimental mean value: 18.7 µm;
- Relative difference: 15.0 %

c)
- Numerical mean value: 116.5 µm;
- Experimental mean value: 84.4 µm;
- Relative difference: 27.5 %

Figure 2 – Numerical and experimental results. Overlay of the adhesive layer thickness distributions for three different epoxy adhesives a) S370, b) DP490 and c) SW270.

CONCLUSION

The results were better for the adhesive in which the minimum thickness achieved was greater, as this guaranteed the accuracy of the numerical results. For adhesives where the minimum thickness achieved was quite thin, the results were not as good, but they were still positive, as can be seen visually in Figure 2. The results show that the rheology of the adhesives and the geometry of the joints are the main factors controlling the distribution of the thickness of the adhesive layer.

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