Shape of adhesive fluid controls insect adhesion in air and underwater

Pranav Sudersan, Thomas Endlein, Michael Kappl, and Hans-Jürgen Butt*

Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

E-mail: butt@mpip-mainz.mpg.de

Phone: +49 6131 379 111. Fax: +49 6131 379 310

Abstract

Insects like beetles and flies can stick to various surfaces using hairy pads mediated by adhesive fluid. The pads can even attach underwater, presumably due to an air bubble trapped around the pad. There is however a lack of understanding on the exact role of the bubble for underwater adhesion. Here, we develop a simple theoretical model to estimate the net adhesion of a hairy pad due to capillary forces. We perform *in-vivo* adhesion measurements of a constrained ladybug pad as well as image its contact against smooth hydrophilic and hydrophobic substrates in air and underwater conditions. Our experiments reveal that on hydrophobic substrates, even without a bubble, the pad can show adhesion underwater comparable to that in air. Only on hydrophilic substrates, a trapped bubble is essential to generate adhesion underwater. Based on the model, this observation is explained qualitatively. The shape of the adhesive fluid has a negative curvature when on contact with a hydrophobic substrate underwater, resulting in capillary forces due to the negative Laplace pressure. Our results demonstrate that capillary forces governed by the shape of the adhesive fluid well explains insect adhesion under different conditions.

1 Introduction

Many[1,2]

2 Theoretical

2.1 Capillary Bridge Model

This is a cool model

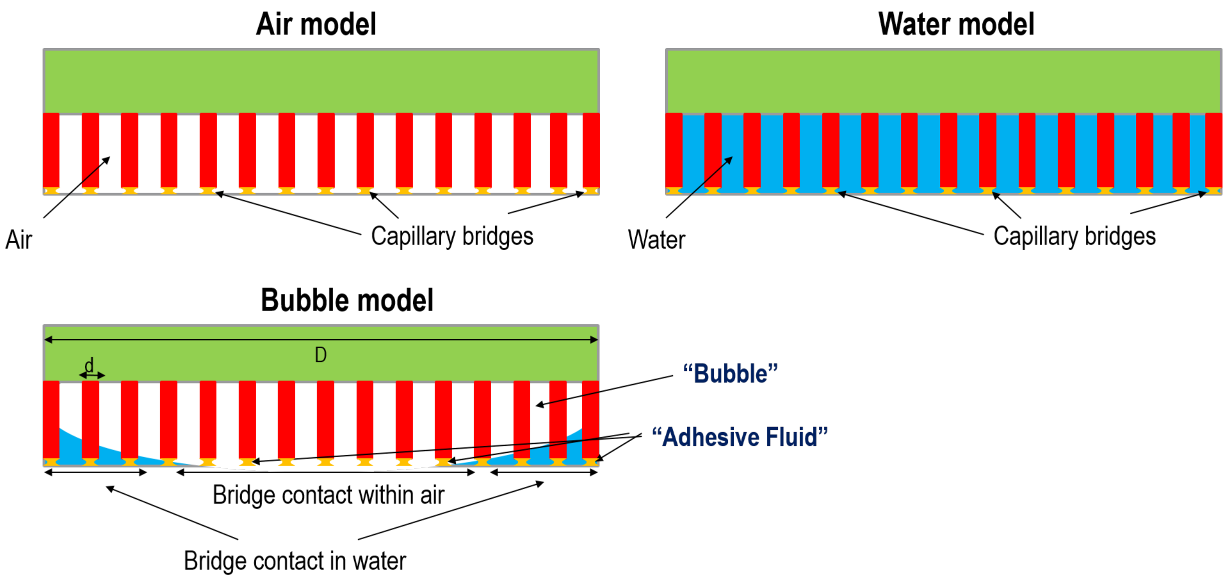

Figure 1: Model

2.2 Results

Wow! Nice results!

3 Experimental

3.1 Material and Methods

I bought XYZ from PQR.

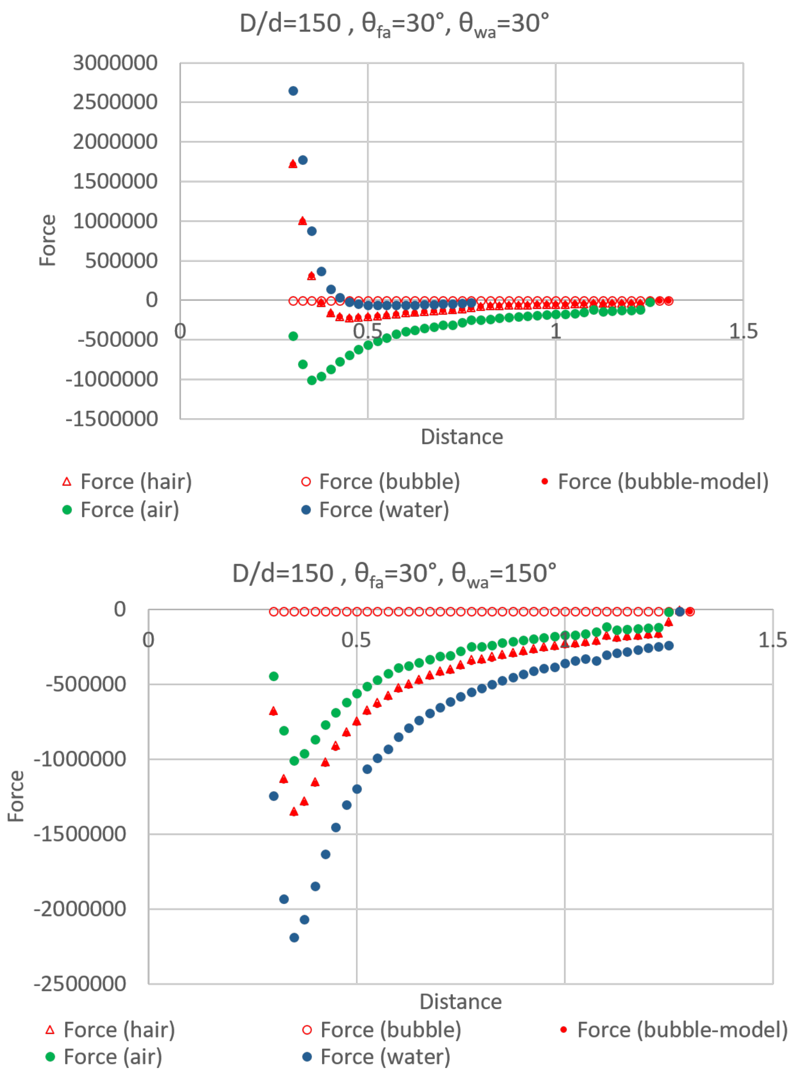

Figure 2: Effect of substrate

3.1.1 Substrate preparation

I made glass and fluorinate surface

3.1.2 Contact angle measurement

Settings for dynamic contact angle measurement

3.1.3 Adhesion measurement

Describe setup and protocol. I measure forces.

3.1.4 Data analysis

Describe image processing, statistical techniques.

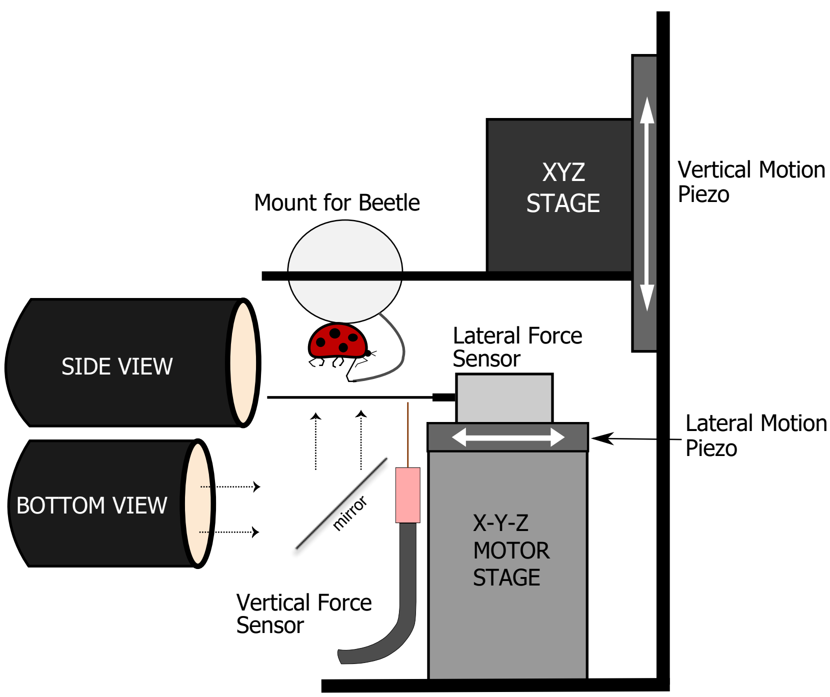

Figure 3: Setup

3.2 Results

Super results!

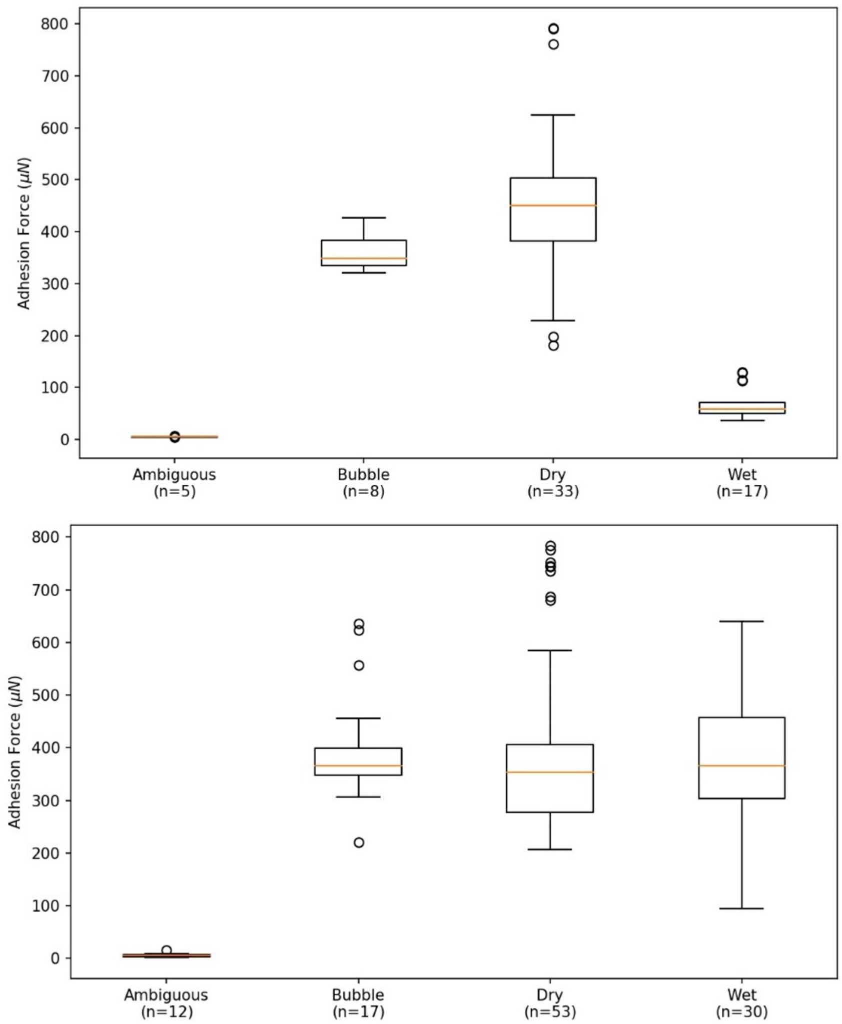

Figure 4: Effect of contact

4 Discussion

talk talk

Figure 5: Comparison with model

Figure 6: Oil contact images

5 Conclusion

that's all folks!

References

(1) Hosoda, N.; Gorb, S. N. Underwater locomotion in a terrestrial beetle: combination of surface de-wetting and capillary forces. *Proc Biol Sci* **2012**, *279*, 4236–42, DOI: 10.1098/rspb.2012.1297.

(2) De Souza, E. J.; Brinkmann, M.; Mohrdieck, C.; Arzt, E. Enhancement of Capillary Forces by Multiple Liquid Bridges. *Langmuir* **2008**, *24*, 8813–8820, DOI: 10.1021/la8005376.