Synthetic Dry Adhesives For Human-Scaled Climbing of Vertical Surfaces

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Focus Area: Research

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Project Goals

Demonstrate Dry Adhesive Capabilities of Composite Materials
Show Feasibility For Human Climbing Using Dry Adhesives
Demonstrate Human Climbing Using Dry Adhesives
Gecko Biomimicry Overview

Gecko climbing adhesion is achieved through microstructures called setae \([1]\)

![Image Source: NISE](image.png)

These structures maximize molecular contact, multiplying the usually weak van der Waals interaction into large attractive forces.

Several methods of mimicry have been pursued, including:

- **Patterned synthetic setae from carbon nanotubes \([1]\)** - \(~200 \text{ kPa for } 16 \text{ mm}^2\) pad

- **Micro-molded polyurethane synthetic setae \([2]\)** - \(~40 \text{ kPa for } 300 \text{ mm}^2\) pad

- **Silicone micro-wedges for directional adhesion \([3]\)** - \(~80 \text{ kPa for } 650 \text{ mm}^2\) pad
An Accessible Approach: No Microstructures

Pioneered by Al Crosby and Duncan J Irschick (UMass Amherst) [4]

Simple composite materials (i.e. fiber-reinforced matrix)

Fibers are stiff, matrix is compliant

Scaling theory [5]:

\[ F_C \sim \sqrt{G_C} \sqrt{\frac{A}{C}} \]

Carbon Fiber and 60A Polyurethane

Center-loaded tendon for other loading angles [4]

\(~300 \text{ kPa for } 10,000 \text{ mm}^2\)

My Fabrication Approach

Borosilicate glass clamping
3D-printed molds

Center-loaded tendon

Defects: a learning curve

High quality adhesive is possible but rare

Image Source: [4]
Testing

Force capacity/cycles of a high quality 23,200 mm² pad

Force capacity is affected by angle of applied force

Scaling theory validation

Extra compliance from polycarbonate

~17 kPa for 23,200 mm²

Adhesives with multiple tendons

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Climbing Paddle Design

*Many Assumptions:*
- Multiple pads are loaded perfectly in parallel, share the load equally
- Adhesive pad is loaded in the same way as in the testing setup
- All adhesive pads are high quality

**Minimum** Measured Force
Capacity of One High Quality Adhesive Pad = **293 N**

Required Sustained Load of One Adhesive Pad if Three are to Share My Weight = **252 N**

Safety Factor For Design > 1.16

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*Tipping loads the top tendon—a weak point—more*

*What went wrong?*
- Inefficient scaling
- Low surface quality
- Multiple tendons add weak point
- Multiple pads are not sharing equal load

*And especially:*
- High handle placement leads to tipping condition about bottom contact

*Solution:*
- common woven tendon that is shared between pads, distributing equal load.

Why Stanford uses footholds:
References


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