TEAM 2 BRINGS YOU

# GECKO GAINS

Sweaty palms disrupting your fitness routine?
Solved with gecko grip technology!

*IB 32*
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*R. Full*

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# INTRODUCTION

Fitness is an integral part of a healthy lifestyle. In addition to maintaining a balanced diet, exercise is necessary to stay in good health. More and more people are turning to the gym for their daily dose of physical activity. Strength training is an increasingly popular option, but can be detrimental to the physical state when performed wrongly.

Slippery hands after sweaty workouts cause gym equipment, such as dumbbells and  barbells, to be unsafe. Drawing inspiration from  the gecko's form and adhesive qualities, our team was inspired to apply bioadhesive technology to fitness equipment to improve their grip and make them safer to use. Using the hydrophobic and hydrophilic properties of setae on a Gecko's foot, the likelihood of it slipping and causing injury is minimized.

# PART A: TEST PROTOCOLS AND SUMMARY

**The team created a gecko-lamellae inspired adhesive out of two polymer compounds - PDMS - pressed into a lamellae mold with a spine sheet. To test the adhesive, the team independently changed the weight attached to the adhesive to measure the resulting angle of release of the adhesive-weight construct from an acrylic rotating surface. This surface is a clear, visibly even surface. It was able to pivot by one edge attached to the measurement contraption and was began with hanging vertically in respect to the ground to a position parallel to the ground, as well as beyond.**

**The angle was measured from 0° at initial attachment and preloading stage, and approached 90° as the rotating surface was lifted closer to being parallel with the ground surface. Attachment of weights was made consistent by threading a piece of yarn through the spine sheet and attaching washer weights to a metal ring. The lamellae weight was measured before any weights, as well as each weight and each metal ring (large and small).**

## Actions  taken to ensure controlled environments and factors:

**Process -** One team member attached the rings, another preloaded the adhesive onto the surface, and another leveraged the surface while another watched the angle until the adhesive released. Each team member was assigned their one task throughout the total experiment to ensure no extraneous variances or conditions.

**Surface -** Each trial required cleaning the adhesive and the rotating surface with solution and lens paper. This ensured that no dust would alter any results.

**Weights -** There were four different weights, each with three trials. Each trial used the small ring (of mass 4.2g). Each washer was averaged to be 13.3g in weight. The first trial was a control with 0 weights or rings.

**Loading -** Keeping the lamellae horizontal, the adhesive strip was gently placed onto the surface. Each time, team members ensured that the lamellae were facing the same directions and were uniformly bent. While pressing on the back of the adhesive, the string was pulled up and down on the string (preloading).

**Angle Measurement -** It was determined that the person raising the surface would stop once the adhesive detached. Following, the angle measurement would be recorded from a straight on point of view.

## RESULTS:

1. Our results from the trials are as follows:

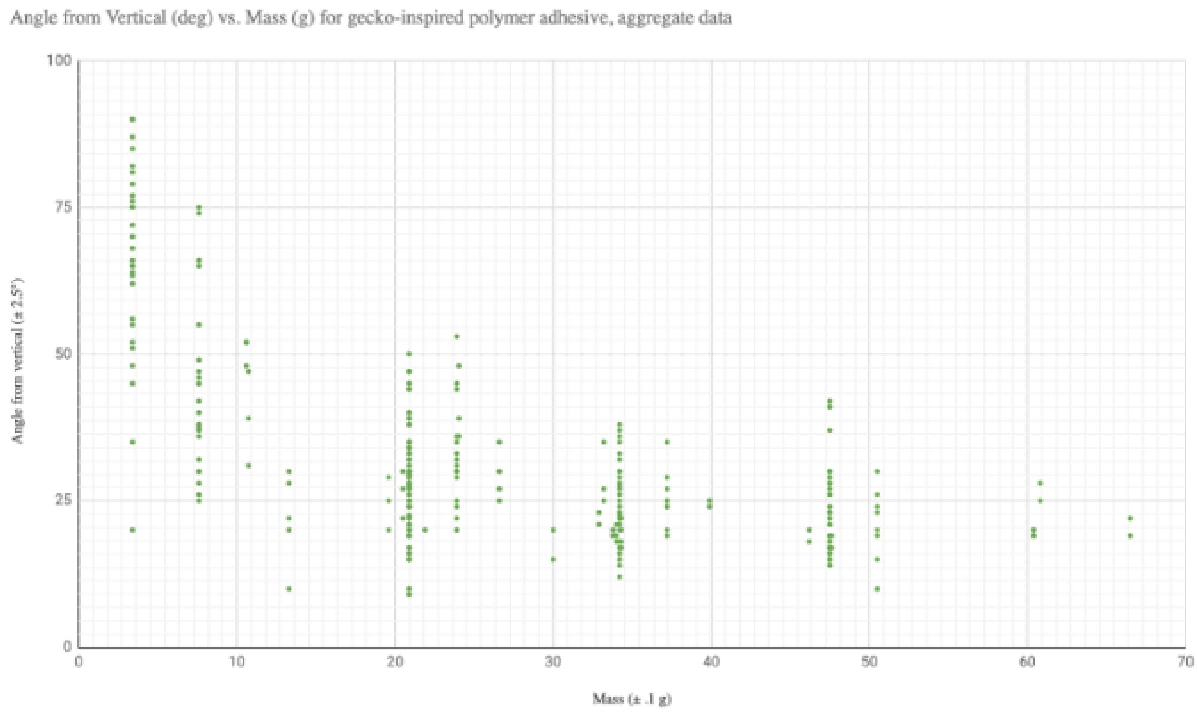
[Table 2.1*: Angle measures vs. Weights for gecko-inspired adhesive.]

| Weight (± .1g , no. washers) | Trial 1 (± 2.5°) | Trial 2 (± 2.5°) | Trial 3 (± 2.5°) |
|---|---|---|---|
| 3.4g (0 washers, no ring) | 85.0 | 90.0 | 90.0 |
| 20.9g (1 washer, small ring) | 16.0 | 15.0 | 9.0 |
| 34.2g (2 washers, small ring) | 17.5 | 22.5 | 20.0 |
| 47.5g (3 washers, small ring) | 15.0 | 17.5 | 12.5 |

*angles have been adjusted to account for the 2.5° degree margin of error as provided by the instructions. Trial with 20.9g excluded.

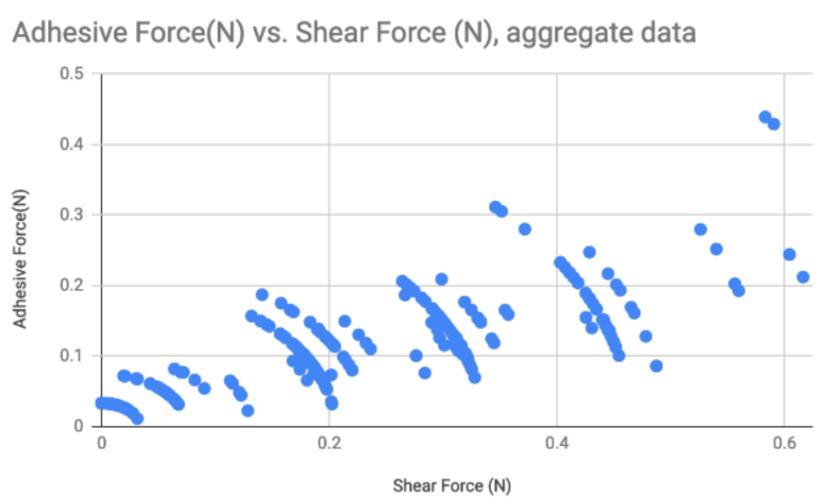
2. Data points from all sections of the class have been aggregated in the following plot:

[Figure 2.1: Angle vs. Mass for adhesive, aggregate data]




The aggregate data showed the Adhesive Force vs. Shear force correlation as follows:

[Figure 3.1: Adhesive Force vs. Shear Force for adhesive testing; aggregate data]



## Verified shear force calculations and adhesive force calculations:

Shear force = $F_{\parallel} = mg \cdot \cos a$

Adhesive force = $F_{\perp} = mg \cdot \sin a$

$g = 9.8$

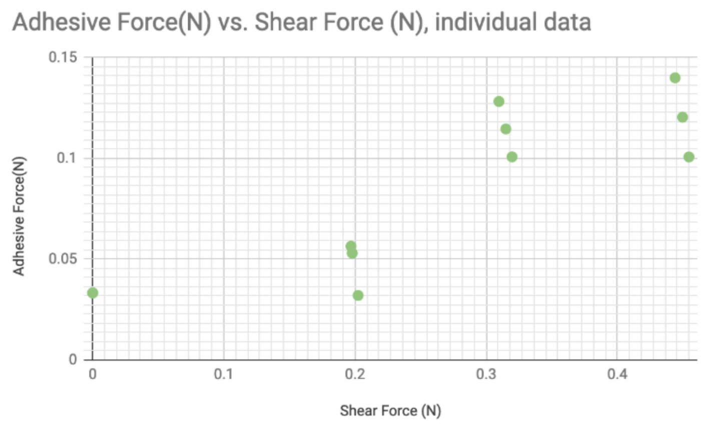
kg = g/1000

a (degree in radians) = angle(deg) * pi/ 180(deg).

[Table 3.1: Verification of expected and calculated shear and adhesive forces. Mass has been converted to kg from g for accurate gravitational force calculation.]

| Mass (kg) | Angle (deg) | Angle a (rad) | Expected Shear Force | Calculated Shear Force | Expected Adhesive Force | Calculated Adhesive Force | Verified? |
|---|---|---|---|---|---|---|---|
| .0034 | 85.0 | 1.483529864 | 0.002904029348 | 0.002904029348 | 0.03319320734 | 0.03319320734 | Y |
| .0034 | 90.0 | 1.570796327 | 0 | 0 | 0.03332 | 0.03332 | Y |
| .0034 | 90.0 | 1.570796327 | 0 | 0 | 0.03332 | 0.03332 | Y |
| .0209 | 16.0 | 0.2792526803 | 0.1968856206 | 0.1968856206 | 0.05645604322 | 0.05645604322 | Y |
| .0209 | 15.0 | 0.2617993878 | 0.1978409277 | 0.1978409277 | 0.05301131682 | 0.05301131682 | Y |
| .0209 | 9.0 | 0.1570796327 | 0.2022983259 | 0.2022983259 | 0.03204090713 | 0.03204090713 | Y |
| .0342 | 17.5 | 0.3054326191 | 0.3196477732 | 0.3196477732 | 0.1007845558 | 0.1007845558 | Y |
| .0342 | 22.5 | 0.3926990817 | 0.3096474641 | 0.3096474641 | 0.1282601792 | 0.1282601792 | Y |
| .0342 | 20.0 | 0.3490658504 | 0.3149473788 | 0.3149473788 | 0.1146314712 | 0.1146314712 | Y |
| .0475 | 15.0 | 0.2617993878 | 0.4496384721 | 0.4496384721 | 0.1204802655 | 0.1204802655 | Y |
| .0475 | 17.5 | 0.3054326191 | 0.4439552406 | 0.4439552406 | 0.1399785497 | 0.1399785497 | Y |
| .0475 | 12.5 | 0.2181661565 | 0.4544657913 | 0.4544657913 | 0.1007526403 | 0.1007526403 | Y |

[Figure 3.2.1: Adhesive Force vs. Shear Force for adhesive testing; individual data]




[Figure 3.2.2: Adhesive Force vs. Shear Force for adhesive testing; individual data, annotated]

## CONCLUSION:

By definition, frictional adhesive means that adhesion force requires a proximally directed shear force. In other words, there has to be a force that is pulled towards the adhesive body but still parallel to the surface. From the graphs and data values, it can be concluded that the adhesive force of the gecko-inspired adhesives are dependent on weight. The independent (weight) and dependent (angle) values are inversely related; as weight increases, the angle of detachment decreases. It is also evident that with heavier weights, both the calculated shear and adhesive forces increase.

The adhesive forces v. sheer force graphs of both the aggregate class data and our team data has both shown a strong positive correlation between the two forces: greater shear force will also result in a greater adhesive force. In figure 3.2, there are three clusters that indicate each the three trials. In each cluster there is a negative correlation between shear and adhesive force. This negative correlation is a result of detachment angle, where smaller detachment angles resulted in smaller adhesive force and greater sheer force. These variations between weight classes may be a result from not preloading or loading the adhesive exactly the same each trial. Overall however, generally the trend seems to show that both increase with weight increases. This indicates and supports the hypothesis that the lamellae act as a frictional adhesive. Friction increases as there are heavier weights by the nature of static friction and its dependency on the normal force on the surface, which is determined by the mass of an object.

The maximum adhesive performance measured in Newtons resulted in .1399785497 N with a weight of
.0475 kg and detachment angle 17.5° from the vertical, which was the heaviest weight class and largest angle of that weight class. This can be translated into atmospheres (N/Area). Surface area is calculated by taking the width * height of the spine sheet, which is .254cm * .3175cm = .0806 cm2. Dividing the Newtons from the former calculation with the surface area of the latter, maximum adhesive performance measured (atm) = .1399785497 N / .0806 cm2 = 1.73670657196 atm ≅ 1.74 atm.

# PART B:
# DESCRIPTION OF TRIAL DESIGN

## SYSTEM BEHAVIOR:

Gecko Gains will be an inherent property of your normal, everyday gym equipment. The gecko adhesive will allow you to have better grip — without the need for extra equipment like messy chalk and bulky lifting straps. It would also only cover sections where you would normally place your hands while working out, which makes transporting of Gecko Gains from one location to another extremely simple.

Another benefit of this adhesive is that it's waterproof. You no longer need to worry about your grip slipping and injuring yourself due to sweaty hands!

## STRUCTURE:

The dimensions of Gecko Gains will be extremely similar to that of normal gym equipment. For barbells, the dimensions will be 2.2 meters long and 50 millimeters in diameter at the outer ends. For dumbbells, the hand length will be 13.2 cm long and 2.9 cm in diameter. For pull up bars, it will be 1.1 meters long and 28 millimeters in diameter. For indoor rock climbing holds, the dimensions will vary from 6-4 inches in length and 3-2 inches in width.

## ENVIRONMENT:

Our ingenious gym equipment are designed to be great additions, not replacements, to your local gym. Ideally, there would be a section of the gym specifically sectioned off for Gecko Gains.

## FUNCTIONAL MECHANISM:

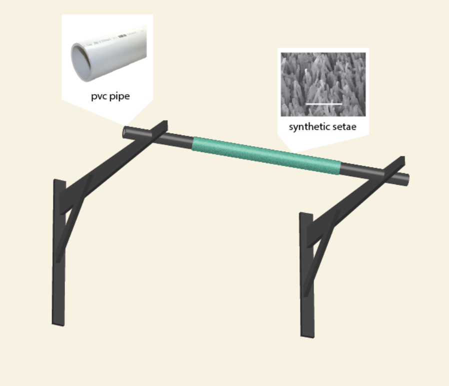
You will use Gecko Gains as you would with normal equipment, with the exception that the weight applied to the adhesive would prime it to activate. In order to let go of Gecko Gains, you must move your hand past a particular angle (it will take some time to get used to).

## PERFORMANCE/CONSTRAINTS:

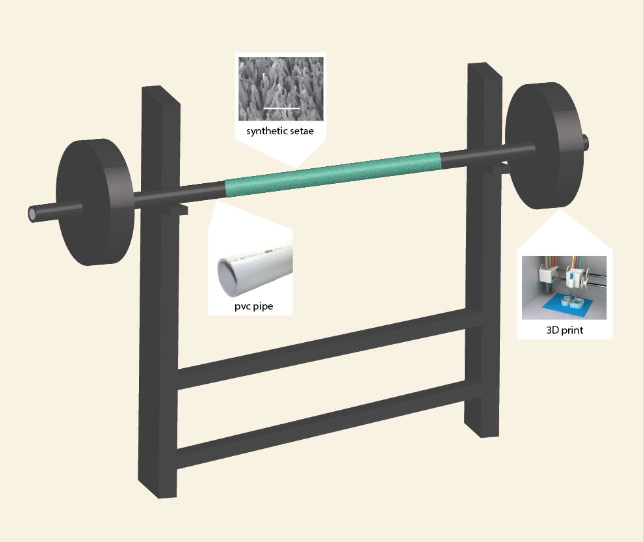
For optimal performance, the adhesive would need to be cleaned off after every few uses. Also, Gecko Gains would need to be replaced at the end of the year due to constant wear and tear.

Gecko gains should have a noticeable effect on grip strength up to, at the very least, 225 lbs. It should have minimal/no effect once you near the weight of 405 lbs. However, Gecko Gains prioritizes your health above all else. Accordingly, these weight constraints are actually a benefit to you. For instance, imagine you are deadlifting heavy with one of our special barbells and need to drop the weight. The weight constraint allows you to drop the barbell by moving your hand at a smaller angle than what you would have to with lighter weights.

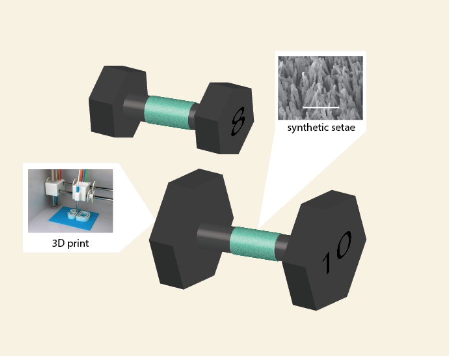
# REPRESENTATION OF TRIAL DESIGN



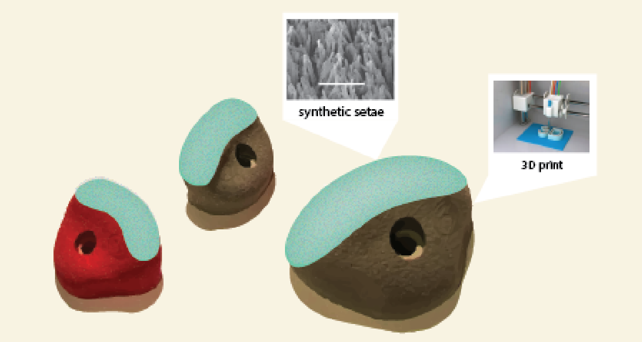
Trial design - pull up bar



Trial design - bench press bar



Trial design - dumbells



Trial design (model) - rock climbing holds

# TRIAL DESIGN EVALUATION

| Design Solution | Analogy Check | Design Problem |
|---|---|---|
| **Gecko Toes** | | **Gecko Gains (Gym Equipments)** |
| **Function**<br>(What does system or organism do?) | | **Function**<br>(What do you want system to do?) |
| Adhere to smooth surfaces with parallel pull | Similar | Adhere to surfaces when pulling the surface |
| Rapid release in perpendicular direction | Similar | Rapid peal release |
| **Structural Components**<br>(What is structure or organization of system?) | | **Structural Components**<br>(What can the structure be?) |
| Keratin | Similar | Gecko Adhesive |
| | | |
| | | |
| **Operating Environment**<br>(Where?) | | **Operating Environment**<br>(Where?) |
| Gecko toe against GaAs and $SiO_2$ wafer | Uncertain | Gym where extra grip is needed |
| | | |
| **Size**<br>(What is size?) | | **Size**<br>(What size needed?) |
| 1 by 1 centimeter (1/20 of body size) | Similar | 8 x 8 centimeter (1/20 of body size) |
| | | |
| **Mechanisms**<br>(How does system work?) | | **Mechanisms**<br>(How do you want the system to work?) |
| Preload | Similar | Preload |
| Orientation dependent | Similar | Orientation dependent |
| Peeling release | Similar | Peeling release |
| | | |
| **Characteristics/Specification**<br>(Which are distinguishing?) | | **Characteristics/Specification**<br>(What are your specifications?) |
| Adhere to smooth surfaces | Similar | Adhere to smooth surfaces (and hand if applicable) |
| No glue | Similar | No chalk (which is great!) |

## CONCLUSIONS:

**Step 1: Prototyping with 3D Printing**
We would prototype smaller items such as dumbells and rock climbing gloves, in order to figure out the best shape and structure to attach the Gecko adhesives, to fully take advantage of the sheer force and rapid release characteristics.

**Step 2: Trials in Gym Setting**
The next step is to take our prototype to the gym, and let real people who regularly attend gym to try out the prototypes of these smaller items. During the process we would observe the strength and weakness of our design in the gym setting, and most importantly ask for feedback on improving the design. Repeat this step a few times.

**Step 3: Communicating with Gym Equipment Companies**
This is the most important step of this process: taking a relatively mature prototype to a few gym equipment companies. It is also the part where difficulties are most expected, because it is hard to predict companies' reactions. Based on the outcome of the initial interaction, we will move in different directions.

**Step 4A: Seek Industrial Feedback**
If the companies do not appreciate the design, ask for feedback, and why the prototype fail to capture their interest. With those industrial advice, recharge, go back to the drawing board and start over at Step 1. Never give up!

**Step 4B: Industrial Prototyping on Small Items**
If some companies like the idea, it is time for some industrial prototyping. We might expect to slightly alter our design to incorporate the company's design principle. Since industry has a lot more resources than a regular students, we might have access to science researchers in the company.

**Step 5: Ask Industrial Researcher for Guidance on Big Equipments**
Since our ultimate goal is to make a Gecko-inspired gym, we would seek advice from Industrial Expert on properly designing the bigger equipments. We leave those towards the end because prototyping of these products can only be done in industrial level. But by now we would have made enough connections that it can be achieved with ease!