Taking a Step Towards Solving the Foot Crisis:

Reducing Joint Impact with Magnetic Levitation

Engineering Goal

And Rationale

Problem:

To create a **cheap**, **soft, and flexible** shoe sole using magnetic levitation **without too much extra weight with greater compression** when compared to a shoe without magnetic levitation when compared to the data of an old shoe

Rationale/Need:

Humans are constantly on their feet and walking around to go about their day, yet the items we walk on aren't optimized for the force of the human heel and the joint pain that can result from the lack of adequate cushioning. **Current shoe technology has reached its maximum, as there's only so much that foam can do**. I decided to do this project after my mom had recently been diagnosed with Plantar Fasciitis. It is my hope that this project can provide hope to those in pain, and the human population. This project will combat the problem of joint pain.

Testing and Constraints:

Constraints include a budget of **$20**, **12 oz of total weight**, and **access to regular machines** available in a common workshop.

These constraints **ensure that the shoe remains practical enough for everyday wearing**. The budget makes sure that the shoe won't cost too much more and the weight limits the amount of extra weight that can be added on, which could greatly reduce the practicality.

Solution

The proposed method is a magnetic levitation system embedded in the sole of the shoe to reduce the footsteps' impact force, which therefore reduces the force exerted on joints as well. By using magnetic levitation, the force is spread out across the fields which absorb the impact shock of the footstep much better than foam could. Because magnets push more when they have more force on them, they can adapt to the situation they are put under, not to mention the greater durability when compared to current shoes. This makes it **many times more practical** than before.

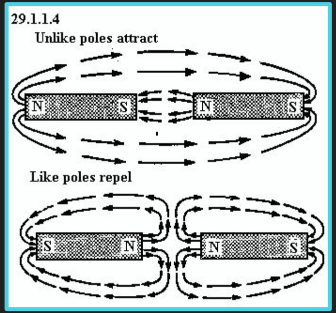
Research and Concept Review

Magnetic Principles

Law of Magnetism: Opposite poles attract each other and similar poles repel

Basis of magnetic suspension: repulsive properties

- Magnetic Repulsion will provide a contactless suspended feeling for less impact, and therefore less shoe midsole compression



http://www.lewpaxtonprice.us/magnet.htm

Research and Concept Review

https://www.sneakerfreaker.com/articles/material-matters-eva-foam/

Current Technology

Foam-based Cushioning: Largely limited to the amount of cushioning it can provide

- Types of Shoe Foam in Midsoles
  - BEVA: Lightweight, foam-based cushioning.
  - Dual-Density EVA: When you double the density of something it gets stronger, firmer and heavier (twice the mass in the same amount of space). The dual-density EVA is called a "medial post". 'Medial' because it is on the inside of the shoe and 'post' because it has a beginning and an end. The length of the post determines the amount of control.
  - Polyurethane: Very durable cushioning. More durable/stable than EVA and weighs more than EVA.
- Limitations and Flaws
  - **The lifespan**, comfort wise, of this foam **is poor** (more strength requires a harder sole)
  - The technology **isn't going much further**, as it's been around for a long time, leading to its perfection over time
  - Foam **can't** provide **more support at high forces** and more cushioning at lower forces
    - Adapting to the situation and forces applied is the key to a comfortable shoe

Tools and Instruments

Provided by the school

- 0.7 Hole Saw Drill Bit
- Autodesk Inventor Software (3D Modeling)
- Drill Press
- Hand Saw
- X-Acto/Utility Knife
- Sharpie
- A Pencil
- Compass
- Hot glue gun
- Dial Caliper

Cost: $0 (graciously provided by the school)

Materials

Along with professional supervision

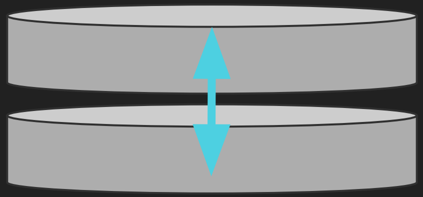
- 1 pair of Nike Free Runs 5.0 2016
- 2, 0.7 in Neodymium Ring Magnets
- 2, 0.7 in Neodymium Disk Magnets
- Industrial Strength Super Glue
- Safety Goggles
- Random pieces of paper
- 1, 1 ft x .5 ft piece of aluminum foil
- 1, 0.125 in x 0.125 in x 1 ft balsa wood
- 1, 4 in Rubber Band
- 1, Standard Size Straw
- 2, 1 in Thick Plastic Washers
- 1, 0.5 in Black Plastic Disk

Cost: $12 (under budget constraint of $20)

Designing and Concept Sketches

Ideology

- After experimenting with the magnets for an extended period of time, it was noticed that…
    - The magnets **seem to repel** each other on their top, bottom, and side face.
    - Repeled at a height of 1.125 in (without weight)
        - **Total time taken: 1 weeks**

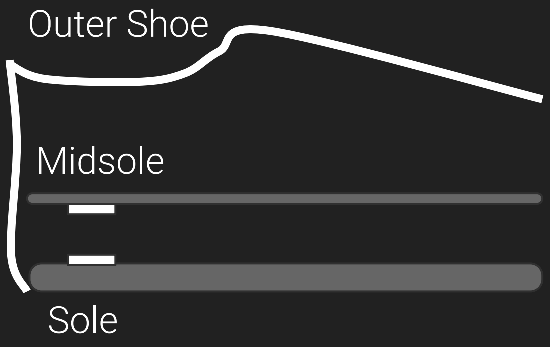


- Initially, the **hole magnets were used** to repel (with a flexible rod in the middle)
    - Various designs were made involving this
    - Conceptual **Issues** were **instability, unfeasible, and difficulty**
        - Having a rod (straw) in a shoe wouldn't be the best idea
    - The thought of **3D Printing** occurred as well but the process was too **tedious and weak** for this purpose
        - **Total time taken: 2 weeks**

Designing and Concept Sketches *cont.*

Plan for construction

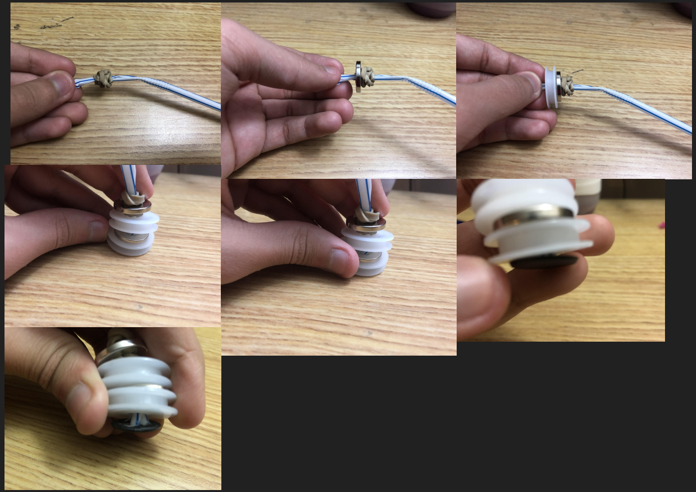
- Utilize the engineering lab to **create a small working prototype** with an old pair of sneakers
    - These sneakers are the **most popular running** shoes in the US.
- The magnetic fixture would be made with **solid disk magnets**, instead of hole magnets which were proposed earlier, but were discluded due to their complexity and lack of practicality
- The magnets can be placed directly onto the shoe components (sole and midsole) to increase simplicity
- Industrial Strength Glue was used to join the midsole onto the sole instead of hot glue, which is much easier to remove in case of a mistake, to reduce lumps and bumps under the midsole
- The sole magnet is recessed incase the midsole magnet gets pushed into the sole to ensure that the body's weight is held up properly by the shoe's original padding without damaging the magnets after contact between the two
        - **Total time taken: 2 weeks**



Prototype X Construction Procedures

Levitation Fixture

1. Take the straw and wrap the rubber band in a loop until it looks like a ball 1 in from the bottom
2. Slide the magnet on from the 1 in side and push the hole in it so that it sits firmly on top of the rubber band
3. Slide the first thick plastic washer next to the other face of the magnet
4. Slide the next hole magnet on with the polarity matching that of the other magnet so that they repel
5. Immediately after adding the second magnet, add the second thick plastic washer
6. Glue the Black Plastic Disk onto the end of the straw to seal the stack of magnets and thick washers



Issues/ Redesigning

With Prototype X

- The magnetic levitation was quite unstable and unsuitable for its intended purpose
  - The levitation moved the magnets in all directions and did not provide a stable levitation system as needed by the design
- The straw, which was meant to provide structure, wasn't a good thing to put inside of a sole because it wouldn't hold up against the constant pressure
  - **Fix:** Build the magnets directly into the midsole and sole to have greater structural integrity (replacement for the straw) and to more accurately levitate the magnets by finding the point of levitation and gluing around it to keep that a constant
  - Add **onto the shoe**

Prototype Y Construction Procedures

Shoe Preparation

1. Remove the midsole from the shoe to reveal the sole
2. Locate the center of the heel (roughly 0.5 in away from back and sides)
3. Drill a hole at that center mark with a 0.7 in Hole Saw Bit using the Drill Press

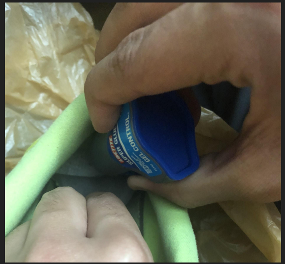
Magnetic Fixture

4. Place a 0.7 in disk magnet with some scrap paper on top to have a height of 1 in
5. Cover the entire piece in 2 rounds of aluminum foil to seal it
6. Locate the center of the heel on the midsole that was removed that corresponds exactly to the location of the center of the heel on the sole
7. Glue a 0.7 in disk magnet onto the center of the heel with the polarity of the face matching that of the face of the magnet in the fixture that's not covered with paper so that the magnets repel

Final Assembly

8. Insert the midsole back into the shoe in the same position as when it was removed
9. Glue the midsole back onto the sole
    a. Don't add glue within a radius of 0.5 in around the magnets
10. Push the Magnetic Fixture up into the hole that was drilled with the magnet side facing the inside of the shoe until it's rough 0.1 in from the surface of the shoebed







Testing

1. A dial caliper, with a balsa wood extension who's length was 5 in (later changed to 3 in) to help measure the compression inside of the shoe as accurately as possible.
2. A crutch was modified so that the hand grip was replaced with a metal rod that could hold the required barbell weights for testing and the rubber on the bottom leg was removed to simulate a more accurate barefoot-style test.
3. With the help of someone else, the crutch was placed onto the center of the heel and the dial caliper was used to find the compression depths.

Results

Table 1 shows the data of the inches of compression due to the placement of various different light weights on the heel.

*3 decimal places on the averages to show the disparity more clearly

Total Spent: $13 (under $20)

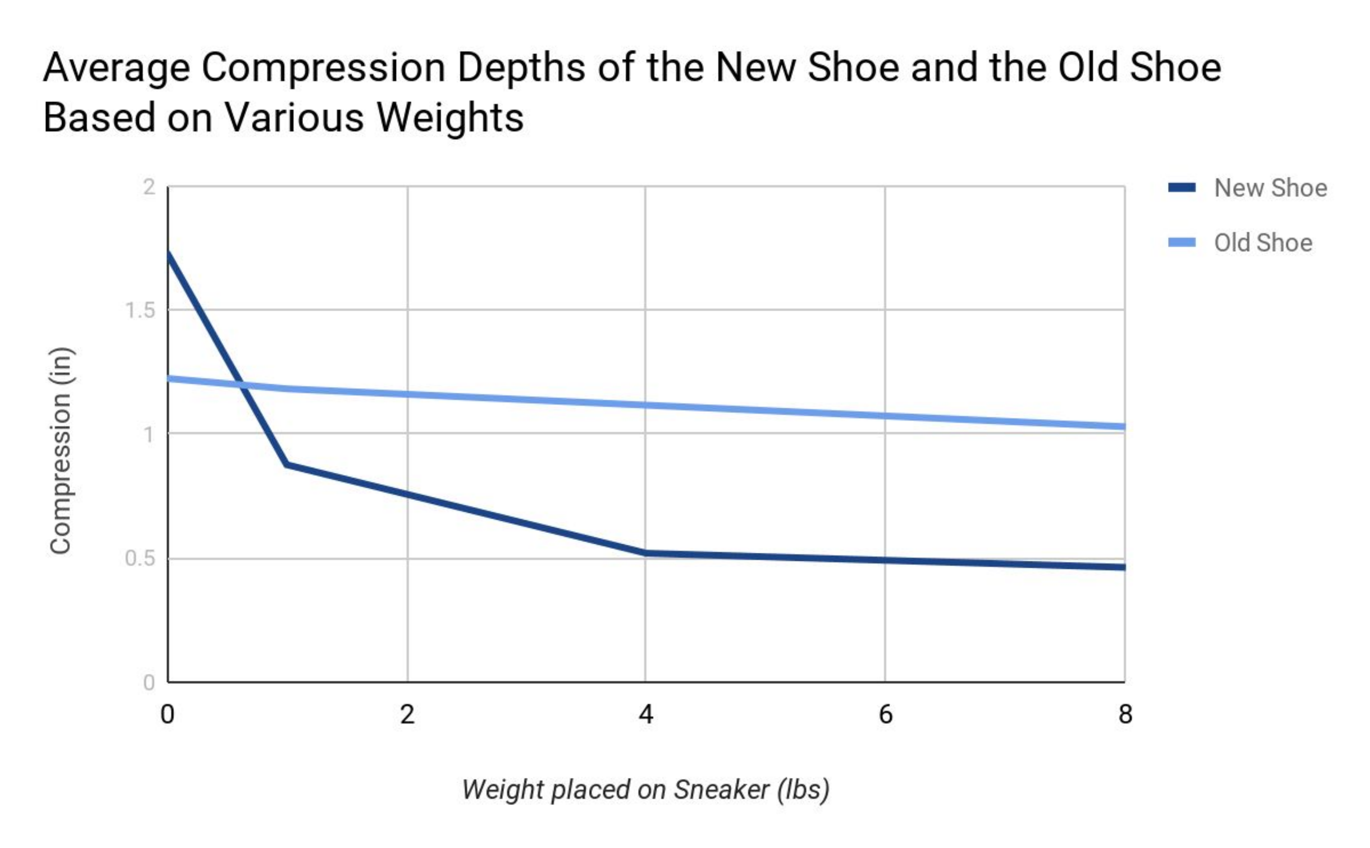
***Total Weight**: 11oz (under 12 oz)

Table 1: Raw data table for the new wind turbine

	0 lbs	1 lbs	4 lbs	8 lbs
Trial 1 New Shoe Old Shoe	1.73 in 1.22 in	0.86 in 1.19 in	0.54 in 1.12 in	0.46 in 1.02 in
Trial 2 New Shoe Old Shoe	1.72 in 1.22 in	0.88 in 1.19 in	0.50 in 1.13 in	0.48 in 1.02 in
Trial 3 New Shoe Old Shoe	1.75 in 1.23 in	0.89 in 1.17 in	0.52 in 1.10 in	0.45 in 1.05 in
Averages New Shoe Old Shoe	1.733 in 1.225 in	0.877 in 1.183 in	0.520 in 1.117 in	0.463 in 1.030 in

Figure 1:
Averages for the Compression Depths of both shoes

*New Shoe has a logarithmic graph due to the logarithmic nature of the repulsion force of magnets



Discussion

The new shoe surpassed the old shoe in every low weight test. Between 0 and 8 lbs, the compression depth of the new shoe was had a difference of 1.27 in, as compared to the 0.195 in difference in the old shoe. This data shows that this project was a complete success, as it is stayed under the $20 budget, was far softer than the old shoe due to the compression testing, and remained equally as flexible as the old shoe because the magnets didn’t interfere with any part of the shoe that was responsible for flexibility. It is very practical mainly because, unlike the old shoe, it can adapt to the force that’s being applied, making it better suited to provide more comfort. In addition to that, it is light and relatively cheap and is surprisingly easy and simple to understand, despite the complex concepts Behind it. The intent of this project was to redesign the shoe and find a solution for those people how have foot problem, and it seems that this project will be new hope for those people living in pain.

Future Ideas

Or Improvements

- Implement Arduino Circuit Boards and an testing mechanism with an accelerometer **(currently being done)**
  - This would make testing far more accurate and deceleration is another major factor of impact forces that could be looked into further
- Test various different sizes of magnets to see their impact **(currently being done)**
- Use electromagnetic levitation
  - This can provide greater strength and more control over the magnetic field to optimize performance, though extra weight and power might be an issue
- Apply this same technology to other areas that require greater cushioning
  - Football helmets could be a great example of an area requiring redesigning due to the amount of head injuries that occur from the lack of sufficient cushioning

Applications & Benefits of the Redesigned Shoe

Current Applications of Magnetic Levitation

- Trains in China and Japan

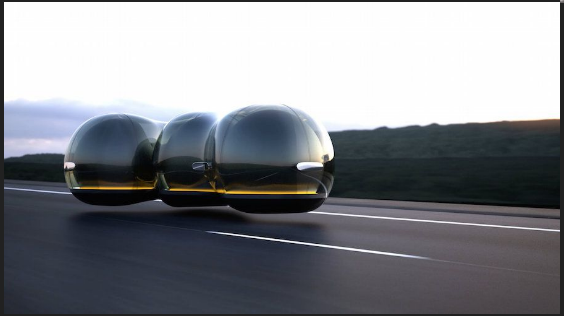
Possible Applications

- Future Cars
- New Magnetic Bearings
- Rapid Travel Shuttles

Benefits of the New Shoe

- A **more effective** form of cushioning
- It's a **foam** alternative
- **Simpler** technology
- It has **more opportunity** (it's a new field)
    - Foam has roughly reached its peak in terms of capabilities

http://www.telegraph.co.uk/technology/0/hyperloop-will-future-transport/



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