PneuNet Soft Wheel

Harkanwarveer Singh Kang, David Jimenez, Henil Naik, Jashanjot Singh

Department of Mechanical Engineering, University of Texas at Dallas

1. Abstract

A common issue in the field of robotics is the massive impact that rigid robots leave on their surroundings because of their inelastic bodies. This project aims to navigate this challenge by presenting a soft wheel that takes advantage of the principle of PneuNets. We will discuss an elastomer wheel composed of multiple individual chambers around the circumference that sequentially inflate and deflate to induce rotational motion. The wheel will be non-disruptive and be able to conform to its terrain, resulting in better maneuverability. While the working concept behind this soft robot is relatively simple, it offers a look into the possibilities of locomotion in the future of the field of robotics.

2. Design

The following were the design approaches taken to create the soft wheel:

1. Inspired by the soft engine developed by Rutgers University engineers
2. Actuation via PneuNet system with each air chamber being individually pressured
3. Incorporate soft elastomer material, EcoFlex 00-10, to give the soft robot **compliance** to its environment

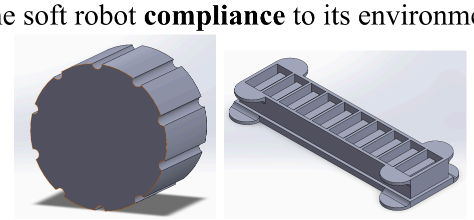


Figure 1: CAD Renderings of Wheel and PneuNet mold

The mold is used to create a PneuNet with 10 chambers. The length of the mold is equal to the circumference of the wheel, and the grooves are used to increase friction between the PneuNet and wheel.

3. Fabrication

The mold was fabricated using a 1:1 ratio of EcoFlex 00-10. The EcoFlex was put in a vacuum chamber for ~20 minutes at 25 psi to get rid of air bubbles. Then, the material was poured into the mold. However, there were issues in mold such as pieces of 3D printer supports as well as the walls of the Pneunet being too thin as seen below:

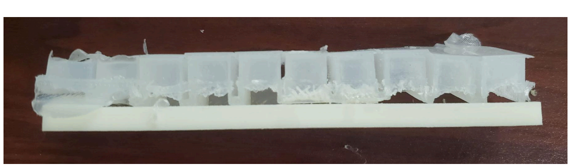


Figure 2: First attempt (3D printer support material present in mold)

A new mold was created using a thicker wall as mentioned which was more durable for testing. The full assembly of the setup is shown:

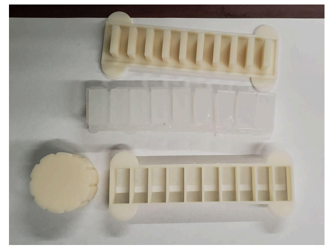


Figure 3: Mold of PneuNet

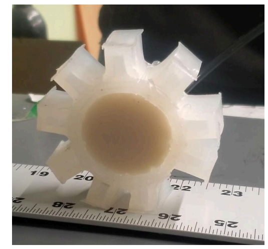


Figure 4: Full Soft Wheel Assembly

The PneuNet was held together by using another layer of EcoFlex around the circumference of the wheel and is now ready for actuation/testing.

4. Testing

The testing of the soft wheel consisted of using an air pressure valve for actuation. A small hole was cut into the chambers and a valve was inserted. The issues that were present during testing was air leakage which was resolved using small clamps and tape for extra security. The testing was done on one chamber of the wheel to prove its ability to rotate, however, sequential actuation can be achieved. Methods on how to do this will be discussed later.

The pressure values that were used in testing ranged from 5 - 15 psi by manually controlling the air valve. The wall thickness of the chambers was 3.25 mm and were sensitive to pressure changes, so a gradual increase in air was needed to actuate properly. To measure the distance the robot travelled, a ruler was placed alongside the wheel. The setup below shows where the air chamber is connected to the pressure valve and clamped:

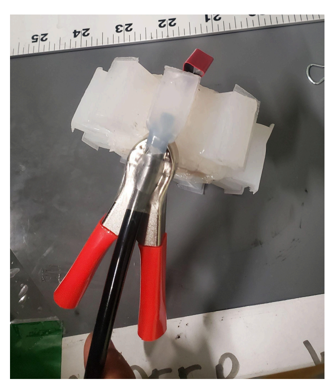


Figure 5: Pressure Source Connection

Due to various leakages within the system as well as unsecure connections inside the chamber walls, sequential actuation was not able to be performed. However, a procedure was made in order to achieve this. This involved using an Arduino board with a L298N motor driver. The circuitry involved the use of a solenoid valve connected to a power source, as well as resistors and other wired components such as the ground of the circuit. The following setup is seen below:

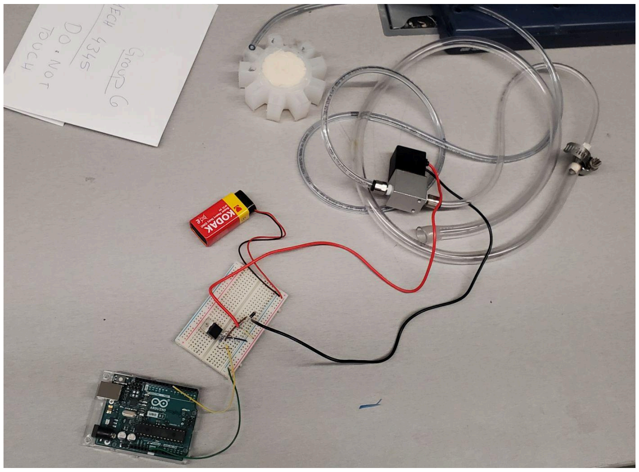


Figure 6: Complete Setup for Automated Actuation

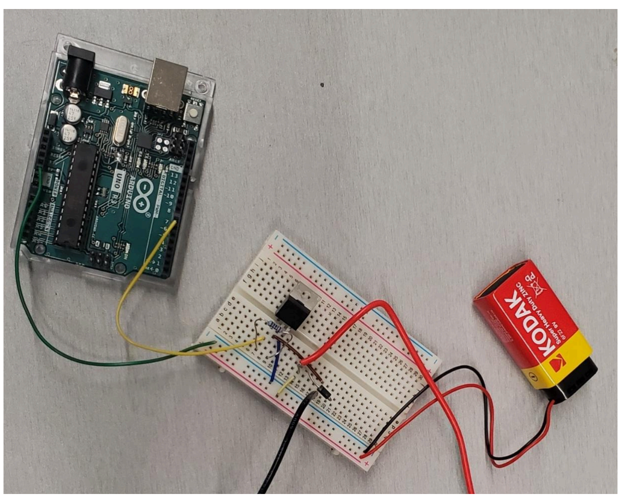


Figure 7: Arduino Board with Circuitry for Project

In order to attach multiple chambers to a single pressure source, a manifold needs to be used. Finding the right manifold was a challenge as this project is dealing with small diameter tubing for the air chambers.

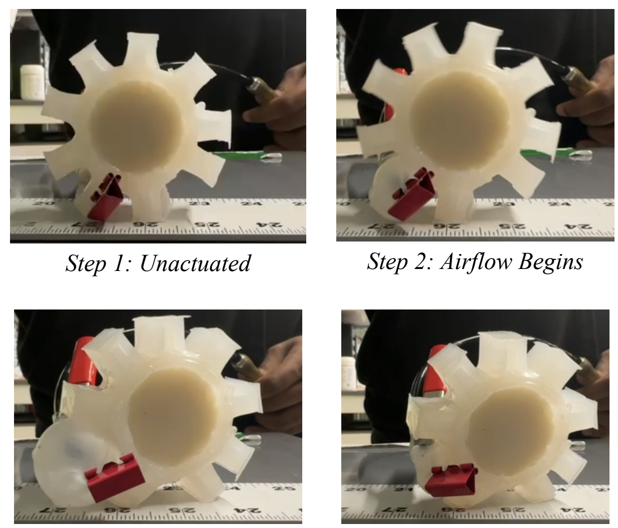
To achieve sequential actuation, the Arduino board needs to be connected to an operating system as well as have the associated code to communicate to the Arduino, when to turn on the pressure valve. The associated code is as follows:

```
const int RELAY_PINS[8] = {2, 3, 4, 5, 6, 7, 8, 9};
const int DELAY_TIME = 1000; // 1000 ms = 1 second

void setup() {
  for (int i = 0; i < 8; i++) {
    pinMode(RELAY_PINS[i], OUTPUT);
  }
}

void loop() {
  for (int i = 0; i < 8; i++) {
    digitalWrite(RELAY_PINS[i], HIGH);
    delay(DELAY_TIME);
    digitalWrite(RELAY_PINS[i], LOW);
  }
}
```

Figure 8: Associated Arduino Code for Sequential Actuation

5. Results

As mentioned, the pressure tested was 5 - 15 psi which was sufficient in actuating the robot. The robot was able to move 1.5 - 2.25 inches after doing multiple tests.



Step 1: Unactuated *Step 2: Airflow Begins*

Step 3: Fully Pressurized *Step 4: Deflated*

Figure 9: Different step of the actuation process

While this test was conducted using one air chamber, it can be applied to multiple using a sequential actuation setup mentioned in the Testing section of the report.

6. Conclusion

A soft robot wheel is a simple yet practical concept with many applications. It can be used for rough terrain and fragile environments due to its compatibility and compliance. This includes space terrain, underwater exploration, as well as aid in any deformation necessary to travel through an obstacle. The wheel in this project was able to actuate and can be replicated to produce continuous motion.