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PROJECT REPORT: SPIROMETER

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ABSTRACT

The goal of our project is to create a spirometer prototype for measuring lung capacity. It consists of a slotted disk, rotary encoder, and a NodeMCU to determine the speed of the impeller's rotation. The purpose of this model is to efficiently measure the lung capacity, built with simple electrical components which is easy to use. The primary premise of our device is to blow air over the impeller to measure the rotation speed of the slotted disc. Acrylics, PLA (polylactic acid), and MDF were used as basic modelling materials. Laser cutting was used for the casing, base plate, and slotted disc portion, and 3D printing (additive manufacturing) was used for the impeller. The encoder device's output was used to figure out the rotational speed of the disc using appropriate algorithms on the NodeMCU. We may be able to assess lung capacity in the future by adding the necessary data sets and numbers.

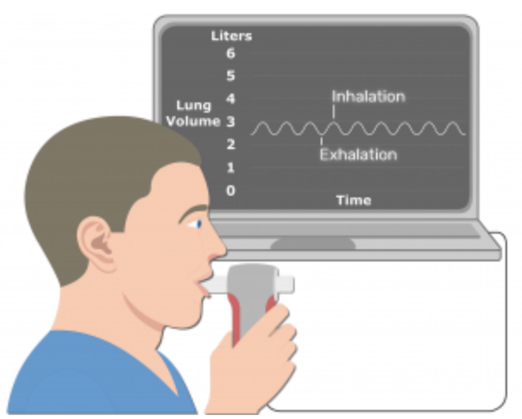


Figure 1: Electronic Spirometer

Keywords: Spirometer, lung capacity, Laser cutting, Slotted disc, acrylics, base plate, 3D printing, MDF, NodeMCU, Rotary encoder.

1. INTRODUCTION

A spirometer is an apparatus that is used to measure how much air capacity a pair of lungs could hold, by measuring the inhaled and exhaled air volume. These types of tests and diagnoses are critical in determining whether or not a patient has a lung condition. Spirometers come in a variety of shapes and sizes, and they use a variety of techniques and methods to carry out the process, including pressure-based, ultrasonic, water gauges, and many others. The primary aim of this instrument is to perform an initial pulmonary function test, which aids in the diagnosis of a variety of respiratory conditions, with the exception that a spirometer cannot identify diseases such as asthma.

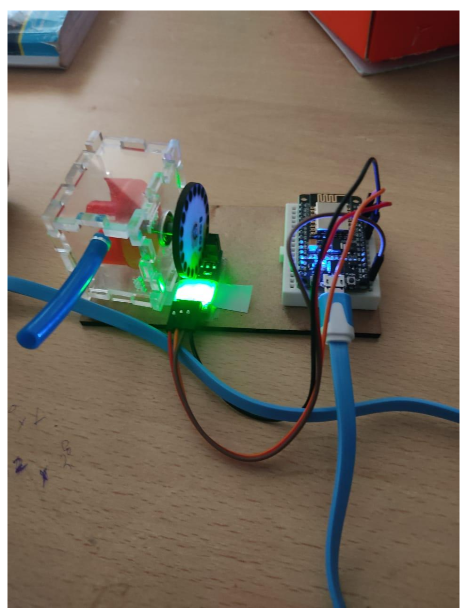


Figure 2: Model

2. DESIGN

The spirometer's main components are an impeller mounted on a freely rotating shaft within the housing and a slotted disc linked to the shaft's other end. The impeller, housing and the slotted disc are designed and fabricated through their CAD models. The housing design consists of six rectangular faces with some slots for friction-fit. The impeller has five vanes and are sufficiently thick. The rear part of the housing has a hole in the middle to remove the access air. The slotted disc in our design has twenty holes in it. The housing is forged to the base with the help of adhesives.

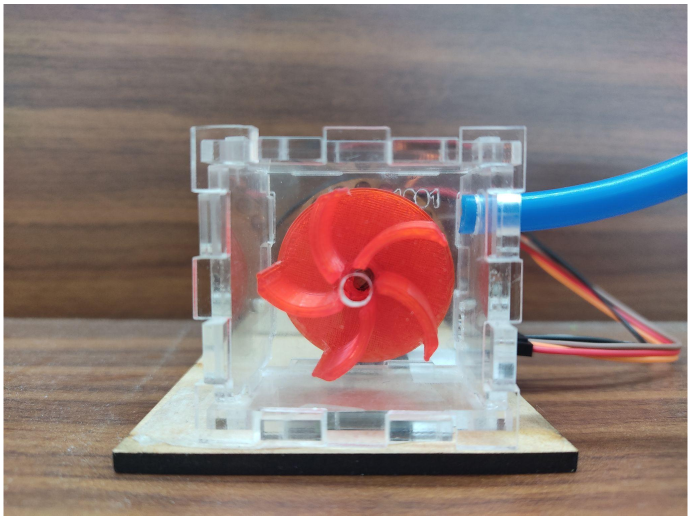


Figure 3: Impeller

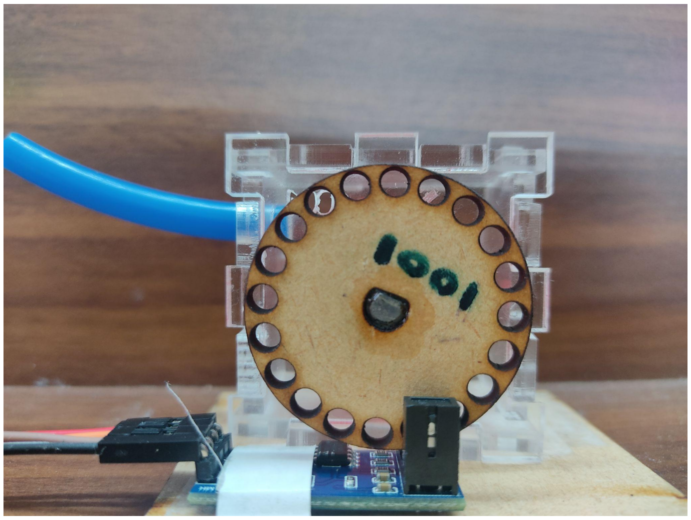


Figure 4: Slotted Disc

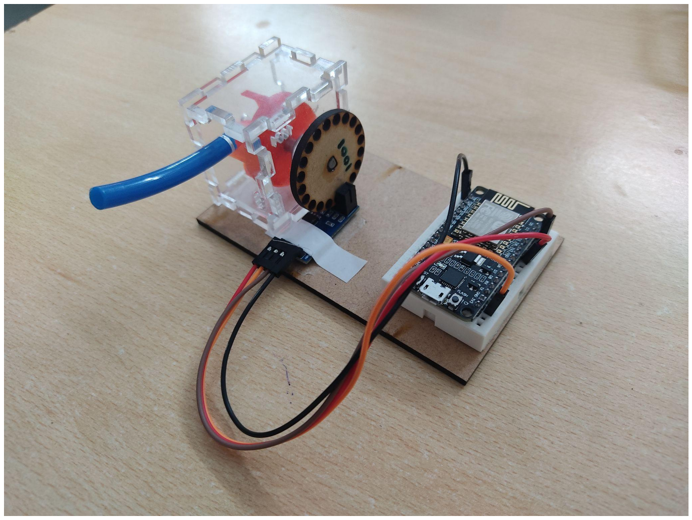


Figure 5: Final Assembly

When a subject blows air through the blowpipe, the impeller rotates, causing the slotted disc on the outside of the housing to rotate as well. The rotational speed of the slotted disc is measured using a rotary encoder, which offers an indirect assessment of the subject's lung capacity. A wifi-capable microcontroller is included, allowing the recorded rotational speed to be sent to a computer or mobile device.

3. MATERIALS AND METHODS

The choice of materials plays an important role in the design of a product. We choose materials on the basis of properties required, cost and stability in different conditions.
Materials used for the design of the spirometer are as follows:

3.1.1 Acrylic (Transparent)

Acrylic is a transparent plastic material with outstanding strength, stiffness, and optical clarity. Acrylic sheet is easy to fabricate, bond well with adhesives and solvents, and is easy to thermoform.
We used acrylic sheets of 3 mm thickness for the fabrication of the housing.

3.1.2 PLA

Polylactic Acid or PLA is a bioplastic made from lactic acid which is most suitable for 3d printers. It has a low manufacturing cost and is easy to cast in our required design. The impeller was made of a PLA material.

3.1.3 MDF

Medium Density Fibreboards or MDF have sufficient internal bond strength, modulus of elasticity, and water absorption capacity. It is lightweight and cheap.

We used MDF sheets of 5 mm thickness as our base and MDF sheets of 3 mm thickness for the fabrication of the slotted disk.

3.1.4 Polyurethane

Polyurethanes have high tensile strength and do not corrode easily.

The blowpipe in our model is a 50 mm long polyurethane (PU) pipe of 6 mm outer diameter and 1 mm wall thickness.

3.1.5 LM393 rotary encoder

The LM393 rotary encoder is a speed measuring sensor that uses an optical coupling sensor.

It is used to sense the speed of the slotted disk.

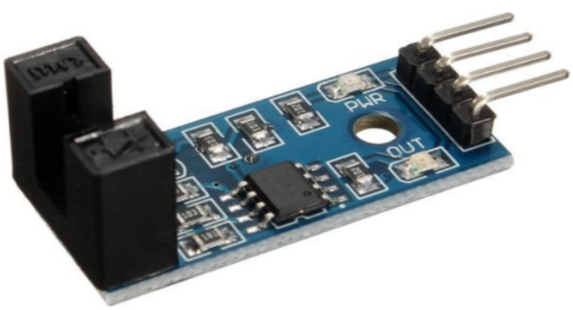


Figure 6: LM393 rotary encoder

3.1.6 NodeMCU

NodeMCU is a microcontroller unit based on ESP8266 that can connect objects and let data transfer using the Wi-Fi protocol. The conversions of data into physical signals and all other computations can be programmed on this Arduino-compatible component.

We used NodeMCU for reading the output of the LM393 sensor and displaying it on the computer.

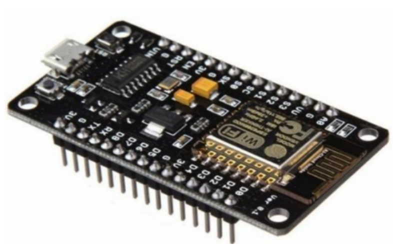


Figure 7: NodeMCU

3.1.7 Breadboard

A breadboard is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to prototype an electronic circuit.

The breadboard we used has 17 columns of 10 holes labelled properly.

The wires are connected to the pins of the NodeMCU through the breadboard.

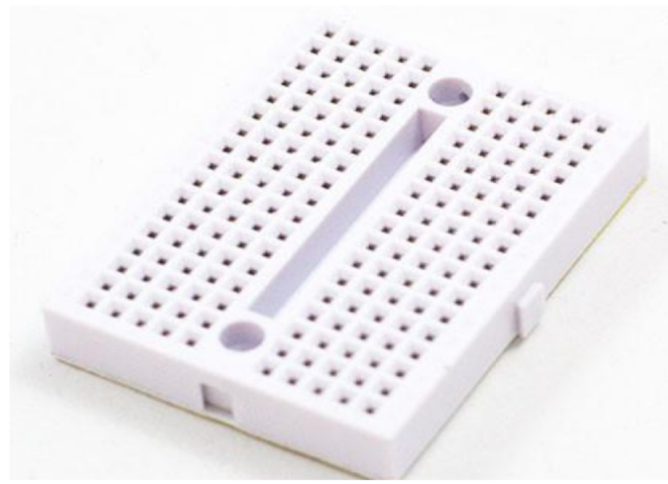


Figure 8: Breadboard

3.1.8 Male to female Jumper wires and Type-B USB cable

We used male to female jumper wires for connecting NodeMCU to the sensor and the USB cable to power the NodeMCU and connect to the computer.

Figure 9: Jumper Wires

Methods used for the fabrication are as follows:

3.2.1 Laser cutting machines

The slotted disk, base plate and housing parts are manufactured with the laser cutting machines.

3.2.2 3-D Printers
The impeller was manufactured in the 3D printer.

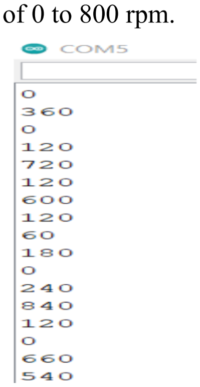
4. ALGORITHMS

The algorithm below is used to find out the rpm of the slotted disc. The rotary motion of the disc is sensed through the LM393 rotary encoder, whose digital output is used by the microcontroller NodeMCU to convert it into RPM.
The Infrared LED and the NPN Photo Transistor are placed directly facing each other in an LM393 sensor. When there is no object in the slot, the light from the Infrared LED always falls on the Photo Transistor and is registered as ‘1’ or else ‘0’. We will count the number of times it registers a shift from 0 to 1, which is equal to the number of holes or slits passed throughout the rotation of the disc.

```
steps=0                    //initialization
while(for 1 sec):
        if(digitalRead(sensor)):
                steps=steps+1      //counting the number of
holes/slots passed
        while(digitalRead(sensor))    //wait until the sensor
//value again becomes zero
rps=(steps/total number of holes or slots in slotted disk)
rpm=rps*60
print(rpm)
```

5. RESULTS AND DISCUSSION

- The spirometer prototype gave the rpm of the slotted disc giving the indirect capacity of the lung.
- We found that the rpm of the disc depends on the amount of air, the thickness of the vanes of the impeller and the number of the vanes of the impeller. The values obtained in the prototype were in the range of 0 to 800 rpm.



6. CHALLENGES AND FAILURES

1. Coming up with an ideal impeller design.
2. Adjusting for the laser cutting kerf on our designed parts.
3. Assembling them with precision so that all the parts fit together without misalignment.
4. Our impeller was not fitting into the ball-bearing shaft so we had to use the hot rod to make some extra space.
5. Ball-bearing had too much friction to rotate freely.

7. RECOMMENDATIONS AND IMPROVEMENTS

1. We can make the model more precise by taking into account the impeller’s number of vanes and its thickness to accurately get the actual lung capacity.
2. We can refer to some databases to see where the rpm set by the user is with respect to the rest of the people and display it.
3. An LCD module can be used to display the RPM instead of a computer so that it is portable.

8. CONCLUSION

This project helped us gain hands-on experience building a real-life model utilising basic manufacturing procedures as a learning outcome. We got to design parts that were eventually made into real objects using laser cutting and 3D printing. We got to learn about NodeMCU and other electronic circuit parts that we used in the project. By completing this project, we learned how to design various components of a product such that it is manufacturable by taking the tolerances into account and eventually understanding the caveats of assembly.

ACKNOWLEDGEMENTS

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REFERENCES

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CONTRIBUTIONS

Mann Jain (20110108): CAD modeling, Assembly, Project Report and compilation, MCU programming
Nokzendi Aier (20110173): CAD modeling, Assembly, Project Report and compilation, Video editing