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IOT based SPIROMETER model

ABSTRACT

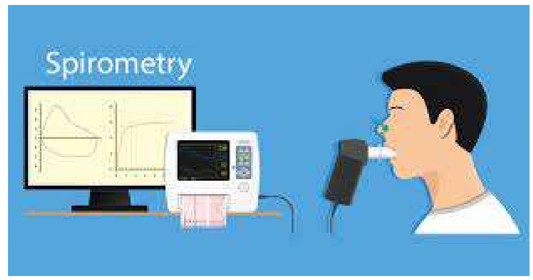
Spirometry is the most popular test for determining whether or not the lungs are working properly. It is used to diagnose a variety of lung conditions such as asthma and Common Obtrusive Lung Disorder (COPD). One of the most common uses of this test is to determine the patient's lung capacity. It is a very useful test since it allows the doctor to determine the patient's breathing rate, which then can be used to determine correct diagnosis that should be provided to the patient. This test may also be prescribed by a doctor in response to symptoms such as cough, wheezing, or bronchitis. Spirometry not only improves the diagnosis of chronic obstructive pulmonary disease, but it also improves the management of chronic obstructive pulmonary disease.

An instrument called a spirometer is used to perform a spirometry test. The initial step is to blow air through a blow pipe or a hole in the spirometer. The device then uses the rate of air blown to measure lung parameters to provide an overall report on lung health.

Keywords: Spirometer, Rotatory Encoder, Node MCU, Impeller, MDF, Polylactic Acid

INTRODUCTION

COVID-19 has been responsible for the most deaths worldwide in the last two years. Apart from that, both asthma and chronic obstructive pulmonary disease (COPD) are respiratory diseases that afflict millions of people each year. Spirometers are commonly used to identify and monitor respiratory air flow in people with lung problems. Any type of pulmonary problem can be easily confirmed with a quick spirometry test. Unfortunately, in developing nations like ours, a primary pulmonary examination can take a long time and be costly. As a result, millions of people do not have access to a pulmonary function test. The lack of a low-cost spirometer has resulted in a huge need for low-cost spirometry equipment.

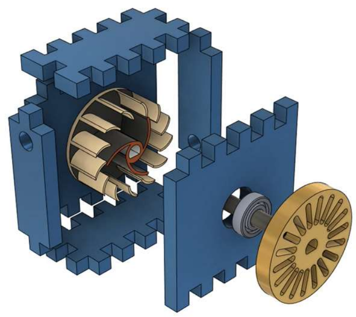


Current spirometry test, which is non-portable and requires huge setup.

With the fast growth of Internet-Connected equipment around the world, as well as improvements in the sensitivity and efficiency of sensors, we decided to create a model based on IoT to address the problem of a unavailability of a portable spirometer. We aimed to create a workable prototype of a low-cost spirometer that can be used for routine respiratory health checks at home as part of this project. The model calculates the rate of air expelled in terms of impeller rpm, which can be used to calculate lung capacity. This approach can also be tweaked to directly evaluate lung capacity.

DESIGN

An impeller is housed within a housing block in the spirometer model. With the help of a bearing shaft, this impeller is attached to a slotted disc. The slotted disc protrudes entirely from the housing. One of the housing walls has a hole large enough to friction fit the bearing, which has a 13mm diameter. The bearing is mounted on the wall with the impeller on one end of the shaft and the slotted disc on the other. This guarantees that the slotted disc rotates in the same direction as the impeller. The 18 holes on a slotted disc are evenly spaced around the perimeter of the disc.



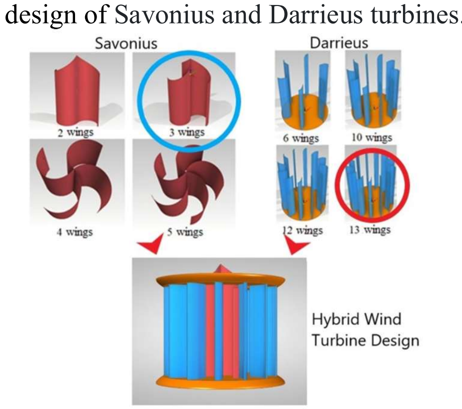
Exploded view

A short blow pipe with a diameter of 6mm is fastened to the front wall of the housing block at a precise height so that the air flowing through it strikes the blade perpendicularly, imparting maximum torque. As a result, the impeller rotates at a faster rate. A rotary encoder is slid and secured beneath the slotted disc, with the disc positioned between the encoder's optical coupling sensors.

The rotary encoder is coupled to the microcontroller Node MCU (ESP2866), which is mounted on a small breadboard. Only three pins are used for connections: VCC, GND, and DIGITAL PIN. The power source for the Node MCU is connected to a computer through a cable. The entire unit is supported by a 110mm x 65mm base plate.

Design of the impeller:

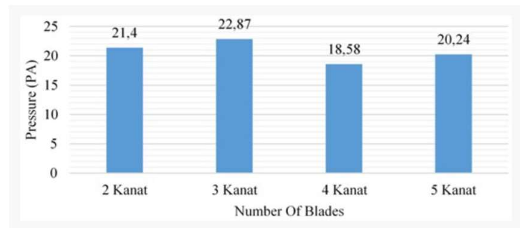
The impeller is the most important component that determines whether the spirometer is working properly or not. More the impeller rotates for a constant blow of air, more sensitive the spirometer. So we decided to use hybrid design of Savonius and Darrieus turbines.



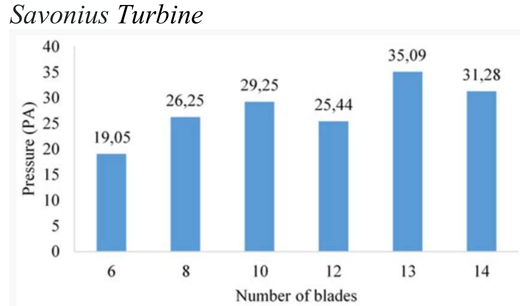
Blades should be designed in such a way that it facilities easy flow of air and generates more torques due to the air flow in caparison to other blades. And so, we decided to use Blackbird blades as it has a perfect airfoil shape.

Blackbird blade

Another question was choosing number of blades of each type, such that net result gave higher-pressure difference value. As more the pressure difference more is the net force on blade and more is the rotation of the blades.



Savonius Turbine



Darrieus turbines.

After studying the graph of pressure-difference vs number of blades of Savonius and Darrieus turbines, we decided to take 13 Darrieus turbines and 3 Savonius Turbine. Since in both these conditions, pressure difference is highest.

MATERIALS AND METHOD

MATERIALS:

Carbon chromium steel is used for the shaft and bearing. The translucent acrylic sheets of 5mm thickness each, are used to make the housing plates. Medium density fibreboard (MDF) sheet is used to make the slotted disc and the rectangular base plate. Polyurethane pipe is used to make the blow tube. The impeller was printed using red PLA 3D printing filament (Polylactic acid or polylactide). It's the most popular type of filament. This popular thermoplastic is both biodegradable and affordable.

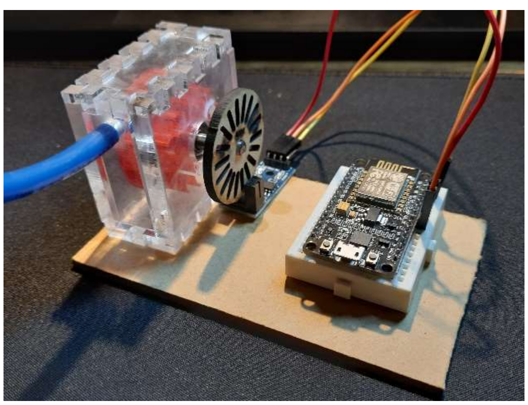
Parts:

1. Shaft and Bearing Assembly
2. Impeller

3. Slotted Disc
4. Base Plate
5. Rotary Encoder (LM393)
6. NODE MCU (ESP2866)
7. Breadboard
8. Blowpipe
9. Jumper wires

Method:

The laser cutting machine is used to make the housing plates and the slotted disc. Friction fit is used to assemble all of the housing components. The housing assembly was adhered to the base plate with adhesive. The slotted disc and the impeller are friction-fitted to the bearing shaft. Filing on parts has been done based on the requirements. Friction fit has been used to attach the bearing and shaft assembly to a hole in one of the housing components. The encoder's digital pin is connected to the Node MCU's D0 pin. The Arduino IDE was used to upload the source code to the Node MCU and track the impeller's rpm in reaction to the air blow. The Arduino IDE has been updated to include the necessary libraries and modules to support the operation of the Node MCU.



ALGORITHM

In reaction to the air blow from the blow pipe, the designed algorithm determines the impeller's RPM. The ARDUINO IDE was used to create the algorithm. Before you can start coding, you must first install the IDE on your PC or laptop. In order for the IDE to be accessible to the NODE MCU, NODE MCU packages (ESP2866 module) must also be set up.

The algorithms function as follows:

On one side of the sensor slot, an infrared LED is positioned, and on the other side of the sensor slot, an NPN photo transistor is positioned. When the transistor detects infrared, the rotary encoder outputs, and vice versa. The slotted disc is aligned with the sensor slot. The sensor slot encoder outputs 1 when it is in the middle; otherwise, it outputs 0.

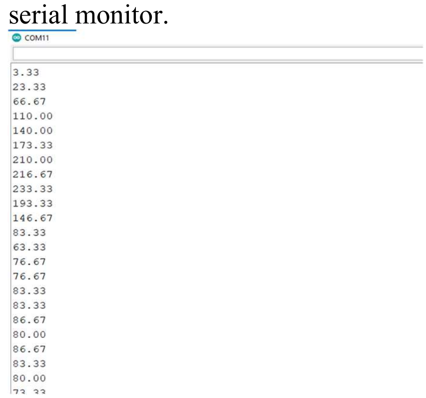
The time interval for which the air is blasted is 1s=1000ms and the encoder resets after every 1second. Algorithm keeps track of the number of holes that pass for 1 second. Then divides that amount by the number of holes in the slotted disc. This provides the speed of rotation of slotted disc in rounds per second. Multiplying the result by 60 gives us the RPM value.

The code is as follows:

```
void loop()
{
 start_time=millis();
 end_time=start_time+1000;
 while(millis()<end_time)
 {
   if(digitalRead(sensor))
   {
    counter=counter+1;
    while(digitalRead(sensor));
   }
 }
    long steps_per_second=counter-
counter_old;
    counter_old=counter;
    rps=(steps_per_second/18);
    Serial.println(rps*60);
}
```

RESULTS AND DISCUSSION

As air is blasted via the blow pipe, the impeller begins to rotate, driving the rotary motion of the slotted disc. The encoder quickly detects the holes, and RPM is displayed for multiple instances at a rapid pace on the Arduino IDE serial monitor.



This is the Arduino IDE serial monitor, displaying values in rpm.

This rpm value changes from person to person, based on the amount of air pressure they apply. While normal fluctuation among healthy persons is to be expected, a low rpm could suggest a reduction in lung function. This could necessitate medical treatment.
A higher rpm number suggests better lung function. As a result, certain particularly fit populations may have substantially higher rpm values. Take, for instance, athletes. Similarly, certain demographics, such as senior citizens, may have a lower rpm value.

CHALLENGES AND FAILURES

1. It was extremely difficult to specify the dimensions, tolerances, and suitable design for components such as the housing parts, impeller, slotted disc, and so on. The designs were finalized after numerous adjustments and consideration of tolerances, ensuring that the components were correctly aligned.
2. Another significant issue was assembling the various spirometer components without damaging them. We had to file some of the pieces because the dimensions were slightly changed owing to manufacturing concerns.

RECOMMENDATIONS AND IMPROVEMNETS

There were certain points that could be included in our model that can make is more useful and user friendly. Some of the improvements and future works are as follow:

- More than just rpm should be measured and shown by a spirometer. Tidal volume, inspiratory reserve volume, expiratory reserve volume, and other lung characteristics can be displayed.
- Not only should the spirometer display readings, but it should also alert problems based on the value.
- A monitor should not be required for display. A portable display that provides readings can be added to a spirometer. People's mobile phones could be used to display the values.

CONCLUSION

The methods used in hospitals or the instruments available on the market to perform lung capacity tests are time consuming and costly. Furthermore, individuals residing in rural places are unable to visit their doctors on a regular basis for lung examinations.
So, we designed and assembled a spirometer which gives an indirect measurement of the human lung capacity. Since disease like COPD and asthma are characterized by limitation in airflow. So, by finding the patients lung capacity the such disease can be diagnosed.

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[2]https://www.ruralhealthinfo.org/rural-monitor/office-based-spirometry/

ACKNOWELDGMENTS

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We'd want to express our gratitude to the lab personnel as well as our TA, who served as our guide and provided us with helpful input. Their assistance helped us in building a fully functional prototype.

CONTRIBUTIONS

Dwip Dalal: Did intensive research on design of impeller. Made Cad model of impeller. Worked on planning the overall layout and dimensions of each part, so that parts fit properly. Wrote the pseudo code as well as the final working code that was compiled in IDE for final working. Prepared the complete project report for the Project Task-3.
Tanmay Wagh: Designed the housing parts and slotted disk. Prepared the assembly file, assembly drawing and exploded view drawing. Assembled the fabricated parts and demonstrated the model by making the 90-second video. Edited the video submission for Project Task-2.