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SPIROMETER: LUNG CAPACITY TESTER

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ABSTRACT

Covid-19 or Coronavirus a phrase with which many of us have been accustomed with over the past two years has taken millions of lives. The virus continued to mutate and suddenly people were testing covid positive without any of the symptoms. This created a huge scare in the public since the virus damaged the respiratory system i.e., the lungs. A measure to test the lung capacity is seeing the speed with which one can blow air out of their lungs. In order to test this, spirometers or pulmonary test analyzers came. But this were expensive. Our motivation for this project was achieve an equal and affordable access of spirometers. We used cheap materials like medium density fiberboard (MDF), acrylic sheets and thermoplastic. We even implemented the logic and made a real time displaying machine which showcases the amount of speed at which the impeller rotates which in turn rotated a slotted disc and we count the number of holes it rotated by using a sensor connected to a NodeMCU. One can see the rpm being displayed as the program is run on the computer.

Keywords: Covid-19, Spirometer, affordable, equal

1. INTRODUCTION

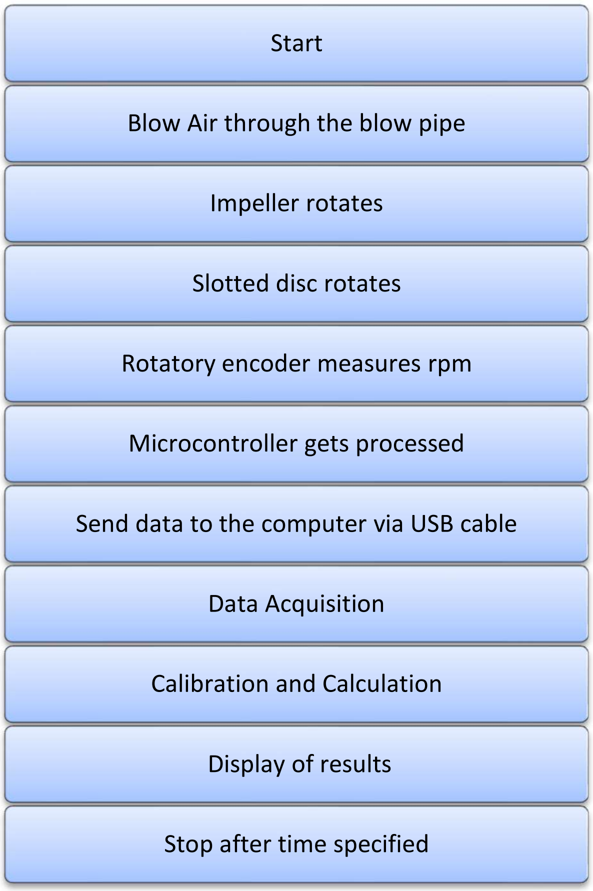
Exactly 100 years later the world experienced another pandemic. The previous one was the Spanish Flu in 2018. In 2019 when reports came in that Wuhan, China saw mysterious cases being reported, the world had become much more advanced and ready to combat this deadly to become pandemic. But alas, history repeats itself! In just one year, it spread rapidly throughout the whole world engulfing the most populous countries like India, USA, Brazil etc.

As people worried for their safety, the government itself was no aware of what the virus was capable of doing since it takes a lot of time to completely understand the biology and chemistry of a new virus. After six months, we were able to gather some information about the virus and news of development of a vaccine came too. Stock markets which were bleeding red were showing signs of recovery on the news of the vaccine. Just as we thought that all was going well. Bam, came the second wave in March 2021. This time the mutated virus directly attacked the lungs and the person did not even come to know about it. It was hence a handy precaution to check on the lung capacity through spirometers.

A spirometer is a device used to measure the functioning of a human lung. With the pandemic, the need and usage of spirometers has significantly increased. Modern Technology has also been incorporated which supports the ease of use. The spirometer can be used by the individual themselves and only requires a computer/desktop to see the results. As the number of patients grew exponentially and doctors were scarce in numbers in the second wave, these kind of cheap and easy to use machines can revolutionize the fight against the deadly virus.

2. DESIGN

The whole assembly consists of the following parts: A rectangular base plate which supports the whole assembly. A blow pipe wherein we blow the air to measure our lungs capacity. A housing which has the impeller inside it and two holes which are connected to the blow pipe and the shaft. An impeller which has a round base and blades on its surface which rotate when air is blown inside the housing via the blow pipe. A cylindrical shaft connecting the impeller and the rotating disc. A rotating disc which has symmetrical holes on its periphery which helps in detecting the rotating speed of the disc. A LM 393 speed sensor just below the rotating disc which is used to measure the rotational speed of the slotted disk, that provides an indirect measure of the lung capacity of the subject. An ESP-12E modules which communicates the measured rotational speed to a computer or a mobile device.



Steps involved in the
Whole process

3. MATERIALS AND METHODS

3.1 Materials:

The shaft and ball bearing are made up of stainless steel. The housing plates are made from the transparent acrylic sheets. The slotted disk and the rectangular base plate are made from medium density fiberboard (MDF) sheet. The impeller is made up of red colored PLA (Polylactic acid or polylactide). This type of thermoplastic is biodegradable and inexpensive. The blow tube is made of Polyurethane pipe.

3.2 Methods:

The housing plates made up of acrylic sheets were cut using a laser cutter. The slotted disc was also made using the laser cutter. The impeller was 3D printed using the FDM machine. It is made of the thermoplastic PLA which is inexpensive and biodegradable thus removing any environmental concerns one may have regarded its disposal in case it is mass produced.

Working of the model:

The user blows air through the blowpipe. This blowpipe is connected to such a hole that the flow of air is directed onto the impeller which is direct and accounts for maximum efficiency of the rotation of the impeller. The impeller is housed by a housing assembly. This is done in order to contain the air within and provide a safety housing for the impeller to rest in. The impeller rotates. As per the assembly the impeller is fixed onto a shaft and bearing assembly which has grooves on it's both ends. The impeller on one end and slotted disc on the other fit according to the design of the groove made. We have used adhesives to further strengthen this bond. As soon as the impeller rotates, the shaft and bearing assembly rotate which allows the slotted disc to rotate connected outside the housing assembly. This slotted disc is kept in such a way that the holes in it pass through a sensor. The sensor is a rotary encoder which helps to count the number of holes that passes through it by using the inbuilt light in it. As soon as something opaque blocks it, the light is not detected and if light is detected after that, the sensor understands that something opaque has passed through it which is a hole. The sensor is connected to the NodeMCU through jumper wires. We connect the GND (ground) terminal, D0 and VCC (supply) to their appropriate matching terminals of the NodeMCU which is itself connected on a breadboard.

The NodeMCU is programmed by connecting a USB cable to it to the computer where we code and then run the program.

4. ALGORITHMS

The code was written in Arduino IDE which is C++ with an addition of some more functions/variables. Also, the IDE has to be installed on the computer/laptop. We have used NODE MCU packages (ESP2866 module) which was installed in order to access the NodeMCU and code it.

We initialize the variables first.
Sensor pin – connected to D0 pin
start_time – denotes the start time of the program
end_time - denotes the end time of running program
holes– counts the present number of holes that the slotted disc passes through
holes_prev – this stores the previous value of holes in order to account for accurate reading for each time interval
temp – a temporary variable to update values of holes and holes_prev
rps – revolutions per second
rpm – revolutions per minute

```
void loop()
{
start_time=millis(); end_time=start_time+1000; while(millis()<en
d_time)
{
if(digitalRead(sensor))
{
holes=holes+1; while(digitalRead(sensor));
}
}
temp=holes-holes_prev;
holes_prev = holes;
int rps=(temp/16);
int rpm = rps*60; Serial.println(rpm);
}
```

Principle used: The sensor/ rotary encoder has an IR LED on one side and a light detecting module on the other side. The rotary encoder outputs whenever the module detects the infrared and vice versa. The slotted disc is aligned in between the sensor slot. Whenever it comes in between sensor slot encoder outputs 1, else 0. We also associate the variable steps in order to increment each time the output goes 1.

Thereafter we use a inbuilt function millis() which counts how much time has elapsed in milliseconds since the program began. While it is less than end_time which is 1000ms, we want that if digitalRead(sensor), another function which reads the light, holes are incremented by one. A while loop is used which has the condition that till the pin D0 is on, the sensor must also remain on and then we subtract the previous counted holes to get new holes and divide by the total number of holes in the slotted disc and multiply by 60 to get the answer in rpm.

5. RESULTS AND DISCUSSION

After the assembly was set-up, as soon as we blew air inside the pipe, the rotating speed of the disc was being displayed on the laptop screen. This indirectly gave as a measurement of the lung capacity which is extremely useful to track in the current era of pandemic.

We discussed about how mass producing this spirometer could go to great lengths at keeping the effect of the pandemic to a minimum. But also looking at the downsides, we realized that the slotted disc and the base plate is made out of processed wood and this is not a replenishable resource. However, this has a great potential to being a useful everyday product that is affordable and accessible to all.

6. CHALLENGES AND FAILURES

The first challenge that we faced was designing different parts like housing, impeller and then doing the assembly. Taking in consideration the dimensions and calculating of all it was difficult and enduring. It was difficult to design the housing assembly in inventor. We had to learn writing an Arduino code from scratch. We had to carefully choose the dimensions of the various parts to ensure smooth assembling of the spirometer.

After submitting the designs, the housing parts were fitting together in a friction fit but later on as the parts got smoothened out as days passed by, it became difficult to fit them completely. Hence, we had to use adhesive to make the housing assembly. During the assembly one of the plates was not fitting inside the already half assembled housing glued together. We had to use some force and take extreme care to ensure that any part does not break.

The housing assemble is not efficient enough to contain the noise generated by the impeller. The impeller itself is not very efficient with respect to its supposed aerodynamic design for maximum output and least wear and tear due to wind friction and heat.

7. RECOMMENDATIONS AND IMPROVEMENTS

Although the final model is sustainable and perfect in many aspects, there are still some improvements that we can do in order to make it better. The base plate and the slotted disc can be made out of recycled plastic so that the excess waste is utilized and no excess waste is generated.

The impeller design can be optimized to give better results and for long use and less wear and tear. The housing can be made more stringent such that it is more durable and strongly connected. It should also be made more soundproof as to reduce the amount of noise produced when one is testing himself/herself.

8. CONCLUSIONS

The spirometer that we have made is a cheap, efficient and an amazing alternative to the expensive one currently available in the market. It is complete with NodeMCU, jumper wires, sensor, casing, impeller and comes with a blow pipe also. We have also integrated it with Arduino IDE.

It is a portable lung capacity measurer and easy to carry also. It gives a fast output also.

9. ACKNOWLEDGEMENTS

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10. REFERENCES

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11. CONTRIBUTIONS

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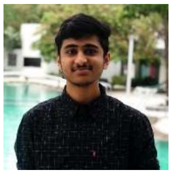

Designed the housing/casing parts and slotted disk. Determined specifications for the components. Prepared the assembly file, assembly drawing and exploded view drawing. Assembly of fabricated parts and demonstrated the model by making the 90-second video. Wrote the pseudo code, as well as the Arduino code. Edited the video submission for Project Task-2.

Aryan Gupta (20110026)

Designed the impeller and prepared the project report for the Project Task 3.