Development of a Low-cost, Open Source, Easy-to-build, and Easy-to-use Ventilator

Eli Kindomba[1], Francis Iloeje[1], Haoyee Yeong[1], Sunday Folorunso[1], Shambhuraj Wadghule[2], Chris Cardoza[2], Jingzhi Pu[3], Zhengzhao Ji[4], Yafeng Li[1,4], Jing Zhang[1]

1. Department of Mechanical and Energy Engineering, Purdue School of Engineering and Technology
2. Department of Computer Science, Purdue School of Science
3. Department of Chemistry and Chemical Biology, Purdue School of Science
4. Tianjin Key Laboratory of Modern Mechatronics Equipment Technology, Tiangong University, Tianjin, P.R. China

IUPUI

IUPUI
CENTER FOR RESEARCH AND LEARNING
INDIANA UNIVERSITY–PURDUE UNIVERSITY
A Division of the Office of the Vice Chancellor for Research
Indianapolis

Abstract

This project is tasked to design a low-cost, open source, easy-to-build, and easy-to-use ventilator to serve COVID-19 patients during the incubation period. With earlier peaks of the pandemic, several hospitals ran out of ventilators, and many companies stopped their normal production and diverted their resources to the manufacturing of ventilators. This resource diversion has still led to a low resulting production. Our mechanical ventilator design can help in these critical situations.

A mechanical ventilator is a device that assists or replaces spontaneous breathing. There are two main types of mechanical ventilation: Positive Pressure ventilation in which air is pushed into the lungs through airways and Negative Pressure ventilation in which air is sucked into the lungs by stimulating the chest movement. In this project, we present our development of a simple ventilator that performs similarly to conventional commercial devices. We focused on refining, evaluating, and testing the design of the ventilator to meet the requirements of end-users. The design files are available at GitHub for open access. In parallel to the mechanical assembly of the ventilator, we developed a SolidWorks model to understand the motion mechanisms in the ventilator, which can further help optimize the system. Finally, with this project, we hope to serve as a backup to handle any surge of patients who may need breathing assistance in hospitals across the nation.

Introduction

Fig 1. Ventilator prototype

The purpose of our research study is to design a prototype of a mechanical ventilator that is inexpensive, lightweight, easy-to-build, and simple to use. The study uses accessible tools and materials, as well as computer aided design technology to measure, refine, and evaluate the design of the mechanical ventilator. Several design parameters were considered: breathing rate, air bag volume and pressure, patient requirements (adult, child, infant), system adjustability, and compactness.

Material and Methods

This study was divided in two components:

1. Computer simulation using SolidWorks: Using the power of 3D modeling, each of the components including the self-inflating bag, DC motor, wood frame, controller, power supply were designed, refined and evaluated.

2. Physical assembly using parts purchased online or in store to reduce costs and speed up the process. Parts selection was inspired from similar work in the topic. Other parts were obtained through 3D printing technology.

Fig. 2. Air bag

Fig. 3. DC motor

Results

- The first step towards our goal was to integrate the physical parts into a CAD model using SolidWorks as shown in Fig.4 and Fig. 5. We also conducted a motion study using SolidWorks.
- A horizontal orientation for the ventilator was selected because of strength and weight concerns. Wood was selected for the base frame.
- Through 3D printing technology, additional parts such as the bag base and side locks were obtained. The result of the physical assembly is shown in Fig. 1 and Fig. 5.

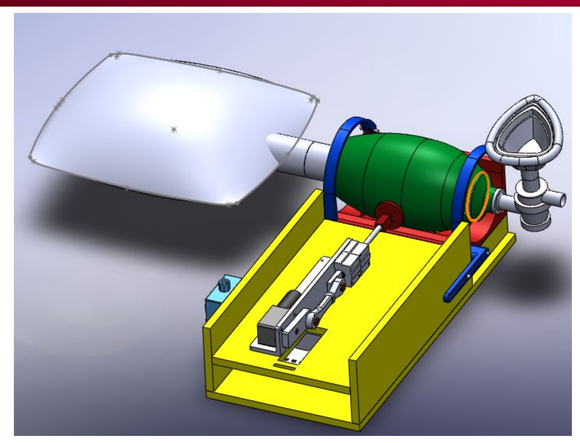

Fig 4. Ventilator SolidWorks model

Fig.5 Final Ventilator prototype

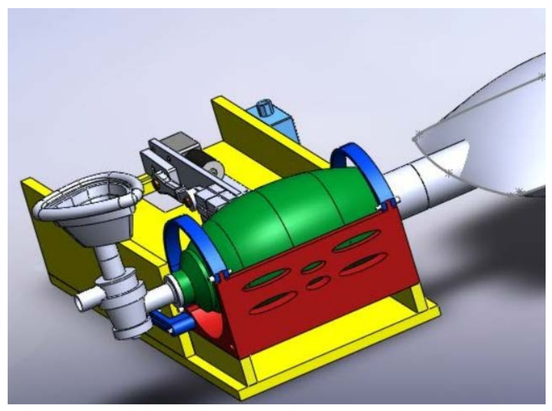

Fig 6. Side view of CAD model

Conclusions

In all, our project reached a satisfactory point in which we created a SolidWorks model with motion mechanism and build a lightweight working prototype; Design files can be found at **https://github.com/jzhang73/Ventilator-for-COVID-19/**
Further studies on the project for a complete ventilator should focus on:

- Testing the physical prototype for ranges of volumes, pressures, and breathing rates.
- Developing a solid physical and computer control system to handle complex breathing conditions and side effects that basic bag squeezing cannot achieve.