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ijirset@gmail.com

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Affordable Ventilator: An Effective Solution to COVID-19

Boggavarapu Venkata Sangaiah¹, Syed Mohammad Haider Rizvi², Ashwani Sharma³

UG Scholar, Department of Mechanical Engineering, Amity University, Lucknow, India¹

UG Scholar, Department of Mechanical Engineering, Amity University, Lucknow, India²

Professor, Department of Mechanical Engineering, Amity University, Lucknow, India³

ABSTRACT: Human lungs use the reverse pressure generated by the contraction motion of the diaphragm to suck in air for breathing. A contradictory motion is used by a ventilator to inflate the lungs by pumping type motion. A ventilator mechanism which we designed here has the ability to deliver in the range of 10 – 30 breaths per minute and 10-500ml of Breath length with the ability to adjust rising increments in sets of 2. Apart from this the ventilator has the ability to monitor the patient's blood oxygen level and exhaled lung pressure to avoid over/under air pressure simultaneously. We designed a ventilator using all these requirements to develop a reliable yet affordable ventilator to help in times of pandemic.

KEYWORDS: Oximeter, Lung Pressure, Affordable Ventilator, Cost Effective, COVID-19

I. INTRODUCTION

The WHO (World Health Organization) declared the coronavirus disease a global pandemic on March 11, 2020. Coronavirus disease (COVID-19), caused by a novel coronavirus (SARS-CoV-2), is in part so dangerous because it threatens to overwhelm our medical infrastructure at the regional level, causing spikes in mortality rates. Within the medical infrastructure, there are critical technologies that are generally available, but simply do not exist in a high enough density to handle the excessive volume of patients associated with pandemics. Thus, people die unnecessarily throughout the world because of a combination of COVID-19 infections and the lack of access to some of these technologies. Ventilators are an example of technologies that are critical short supply during the pandemic. Mechanical ventilators are essential for treating both influenza and COVID-19 patients in severe acute respiratory failure. Past studies have shown that intensive care units (ICUs) will not have sufficient resources to treat all patients requiring ventilator support during a massive pandemic, and ethically challenging triage would need to be used to decrease mortality over first-come first-served basis for ventilator allocation among patients.

II. RELATED STUDY

The present ventilators are really expensive and too complex for anyone to operate or repair. So, a mechanical ventilator at an affordable cost should match the standard of the normal ventilator, and also it should have the control options to specify the pumping of the oxygen into the lungs as required for the patient's needs. To treat the person affected by the coronavirus the ventilator must have some basic factors like Breath per minute, Breath length, Blood oxygen sensing, lung pressure sensing. These factors are monitored constantly by the patient to provide a better oxygen supply using a ventilator. The ventilator should have less manual control as it will be easy to operate by a normal person. It should be compact in size as it can be used and carried anywhere for emergency purposes.

III. COMPONENTS AND MATERIALS

Adapter: we used a 12V AC power output adaptor to supply power to the ventilator, it is capable of 0.8-5A variation in input to output current. It has a input voltage capability of 100V -240V AC



Fig. 1: Adapter of 12V

Stepper Motor: we used 2 phase stepper motor having a 1.8° stepping angle, which can hold torque of 28 N*m (3965 oz-in). This stepper motor has the features of high precision, smooth movement, low motor heating, low movement noise.



Fig.2: Stepper Motor

Stepper motor controller: we used 40 V DC 4.5A common Cathode motor controller, which has an operating voltage of 10V- 45V. Output current stepless adjustable to meet needs of our applications. Using TB6600H chip, the controller is capable of low voltage shutdown, overtemperature shutdown and overcurrent protection circuit, and short circuit protection. The back of the board is printed with a subdivision set description. With output short circuit protection function. Which Suitable for our 4.2A two-phase stepper motor

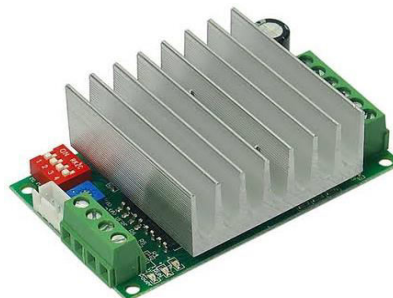


Fig.3: Stepper Motor Controller

DC-DC Converter Module: we used this for Converting high to low voltage. This DC-DC module is using the step-down switching regulator LM2596S that provides a stable power supply output. The input voltage range is from 3V to 40V, and it should be at least 1.5V higher than the desired output voltage. The output current cap is at 3A. The module is labelled with its input and output pins so that the connection wouldn't be a problem.

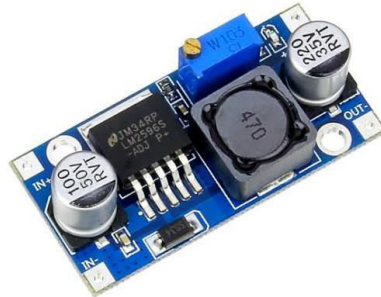


Fig. 4: DC DC Converter Module

ATMEGA328p microcontroller: This ATmega328P is a 32K 8-bit microcontroller based on the AVR architecture. Many instructions are executed in a single clock cycle providing a throughput of almost 20 MIPS at 20MHz. The ATMEGA328-PU comes in an PDIP 28 pin package and is suitable for use on our 28 pin AVR Development Board. We set of 2 microcontrollers in the project.



Fig.5: Atmega328-PU Microcontroller

Lunge Pressure sensor module: This is a 5V output signal lung pressure sensor module, which has a wide range of supply voltage from 8V to 36V. this module has High accuracy in measurement, Maintenance-free Product and Simple to install.



Fig.6: Lung Pressure Sensor

Blood oxygen sensor module: This module has IR and red LED combined with a photodetector Measures absorbance of pulsing blood I2C interface plus INT pin 3.3V power supply This pulse oximeter has an integrated LEDs, photo sensor, and high-performance, Ultra low power operation.

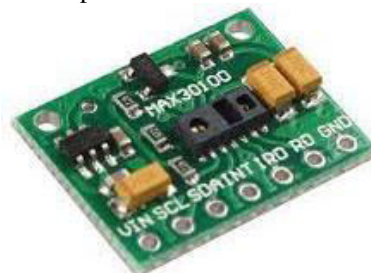


Fig.7: Blood Oximeter Sensor (MAX30100)



Display Unit: we used a LCD of 20*4 size , which has a little or no flicker depending on backlight technology, not affected by screen burn-in , no high voltage and no theoretical resolution limit.



Fig. 8: LCD Monitor

Buzzer: we used a piezoelectric buzzer for the indicating the anomaly or error in the ventilation system. This helps in warning the person that attention is needed.



Fig. 9: Buzzer

Push Button: we used a set of 2 push buttons in the project, one is for BPM and Other is for BL in the ventilator



Fig. 10: Push Button

Regulator: we set of 2 regulators in the project, one is for varying the BPM and other one is for varying the BL.



Fig. 11: Regulator

Resuscitator Bag: we used a silicon resuscitator bag of adult size for pumping the air to the patient. It has zero friction resistance and retains to its original oval shape the compression cycle is completed.



Fig. 12: Resuscitator Bag

Breathing Mask: we use a normal breathing mask which has a dust resistance surface. It is having the one oxygen intake valve and one small valve for monitoring the lung exhale pressure of the patient using the sensor.



Fig. 13: Breathing Mask

Arm Mechanism: Instead of the normal conventional mechanism, this arm mechanism will provide an accurate and efficient outcome. In this design, the arms are created using the 3D printing as the design is more adequate and simpler to use for manufacturing. This mechanism is controlled by the measure of the breath per minute the breath length and the amount of oxygen that has been supplied during the medication.



Fig. 14: Arm Mechanism

Side Plates: These side plates help in holding the resuscitator bag for the compression mechanism. In these plates there are grooves to reduce the tension, when the compression mechanism is working.

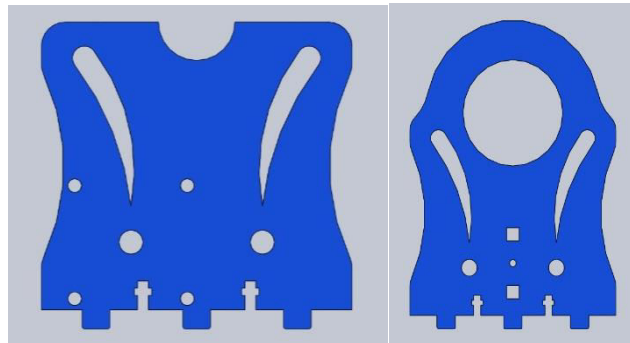


Fig.15: Side Plates

Casing: we used a fibre plastic casing, as this is a medical equipment it should not expose to the outer exposure. The casing is transparent which helps in detecting the error or any anomaly in the system easily.

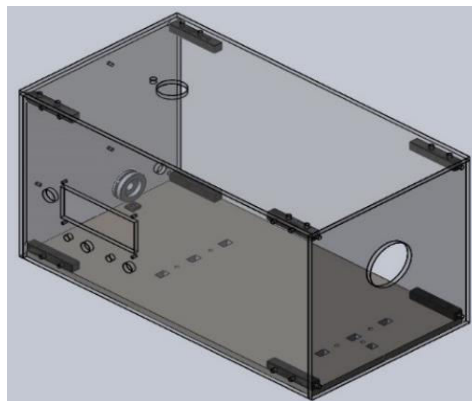


Fig.16: Plastic Fiber Casing

IV. WORKING

The ventilator we designed here work on modes like programmed and manual, as it tends to be controlled physically as per the directions given by the specialist/doctor, by varying the BPM and BL or it very well may be utilized in programmed mode (Using ventilation algorithm) which doesn't need any support from the specialist, by observing the blood oxygen concentration and the pressing factor detecting of the patients breathing circumstance. The ventilation algorithm works on the data collected from the sensors and delivers the oxygen as per the needs. the integration of this ventilation algorithm and the four modes (VC-CMV, PC-IMV, VC-IMV, PC-CMV) creates programmed mode.

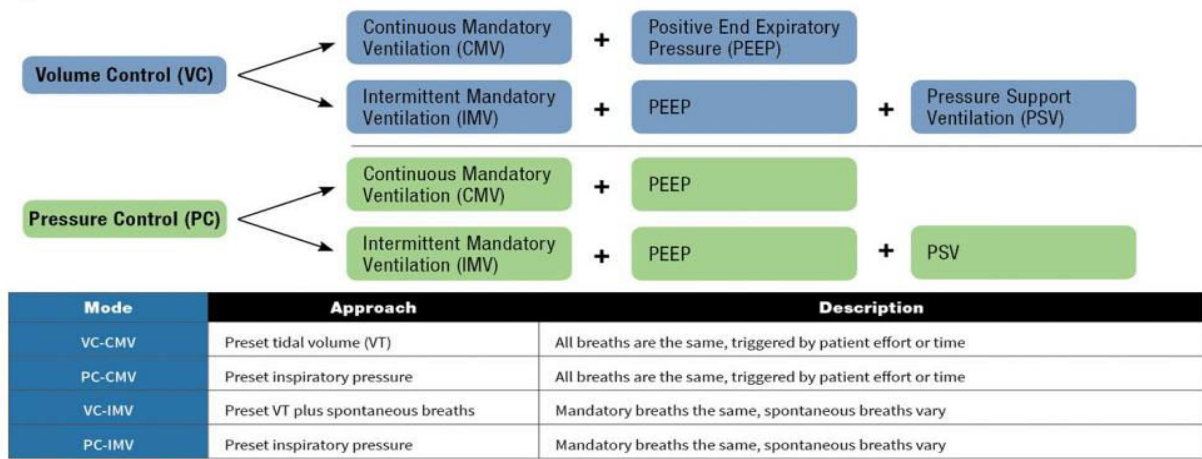


Fig.17: Control Modes of Ventilator

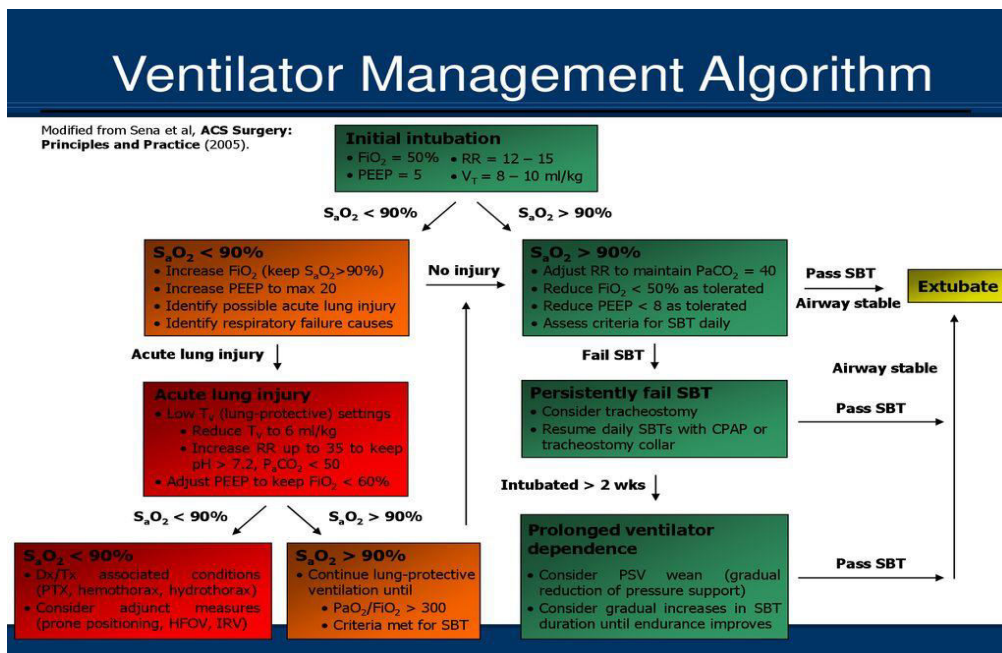


Fig.18: Flow Chart of Ventilation Management Algorithm



Fig 19- Completed Project Model



V. LIMITATIONS

- The power needs to be provided continuously because of the great voltage necessity.
- This ventilator is restricted to one individual
- Blood oximeter has a little delay in the detection of Spo2 level of blood
- The pipe connecting the pressing factor sensor and the mask must be consistently kept up clean to maintain the standard of pressure sensing factor detecting

VI. CONCLUSION

This project is mostly inspired by the situations happened all over the world in the time of pandemic where the lack ventilators became the hectic situation in hospitals to treat affected people. So, in this project we thought to make an affordable Ventilator which will be useful in the emergency situations and easy to carry and durable Ventilator. In this project we thought some aspects where the project fulfils the requirement of the situations in emergency.

Aspect like—

- Less components
- Durability
- Affordable cost
- Minimum maintenance
- Compact in size.

Our ventilator is more than capable of performing the basic operation and can be used as the complete kit in case of any lung disease or COVID 19 as it contains a blood oxygen sensor. Our goal was to design a simple, affordable and fully functioning ventilator using easily and widely available components and we have achieved our goal.

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