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BREATHING ASSISTANCE AND MONITORING DEVICE

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Abstract: Ventilators are a crucial medical device that aids patients to breathe, they provide breathable air to the lungs for patients who physically cannot breathe themselves. The proposed design is based on AMBU technology and an Arduino microcontroller to control the compression mechanism eliminating the need for a human operator. It is powered by a 12V power adapter with a 12V DC backup battery featuring adjustable tidal volume and breaths per minute and assist control mode. The device incorporates various sensors to offer real-time monitoring of the patient's vital sign data for timely medical intervention such as heart rate, temperature, SpO2, and breathing pressure. The patient's vitals are transmitted to a web server where they can be monitored. It monitors over-pressurization, abnormal heart rate, and temperature and alerts the required personnel using an alarm system.

KEYWORDS: Ventilators, AMBU, Arduino, BPM, Tidal Volume

I. INTRODUCTION

Ventilator is a vital medical device, which assists patients by pushing breathable air into and out of the lungs under specific parameters. The tidal volume (VT) is the amount of air that moves in or out of the lungs with each respiratory cycle. VT is dependent on the height and gender of the person and ranges between 8-10 mL/kg ideal body weight [1]. In mechanical control mode the breath is initiated by the machine and in assist control the breath is initiated by the patient, when the patient tries to take the breath negative pressure is detected and the required air delivered volume of air is delivered to the patient.

In Volume control mode Tidal Volume (VT) is set based on the person's predicted body weight whereas the different parameters such as breaths per minute and flow rate are fixed. The proposed design incorporates volume control mode as well as respiration rate control mode. The BPM mode ensures that the patient takes the necessary set number of breaths per minute [2]. Ventilators should be present in every medical facility, however, due to the cost of obtaining standardized equipment and maintenance costs, ventilators are usually not found in most facilities in developing countries [3] and the number of devices is very limited compared to humans. Modern commercial ventilators have complex control modes and feedback loops with a variety of respiratory parameters and ventilation modes [4]. Specialized medical staff are required to operate such complex machinery which result in limited number of staff and devices to face a massive outbreak like COVID-19.

Several respiratory diseases require the use of modern medicine and electronic medical equipment for effective treatment. Previous studies have highlighted the inadequacy of intensive care units (ICU) for ventilatory support during a pandemic [5]. Even after treatment, patients often suffer from muscle weakness, dry cough, and a slight decrease in oxygen saturation. Consistent, high-quality oxygen administration has been observed to significantly reduce cough in COVID-19 patients [6]. The COVID-19 pandemic led to an increased demand for ventilators due to the large number of patients seeking medical attention, which overwhelmed hospitals. The increasing need for emergency ventilators has led to many designs and ideas. These designs prioritize affordability, portability, and compact, user-friendly setups and can act as a worthy replacement for commercial expensive ones. The cost-effective solutions can be easily set and allow us to monitor the patient vitals and provide required minimal breathing assistance.

Historically, the development of mechanical ventilators dates back to the mid-20th century and was initially used primarily in surgical and intensive care settings. Early ventilators were bulky, expensive, and required specialized training for their use [7]. However, advances in technology have led to smaller, more versatile ventilator systems that can provide different modes of ventilation to suit different patient needs [8]. In recent years, factors such as air pollution, an aging population, and the emergence of new pathogens such as the SARS-CoV-2 virus, which caused the COVID-19 pandemic, have led to a rapid increase in the prevalence of respiratory diseases [9]. This increase in respiratory diseases has put unprecedented pressure on healthcare systems worldwide, leading to an increased demand for ventilators to support patients with acute respiratory failure [10].

A study by Smith highlights the critical role of ventilation in the management of respiratory failure, particularly in the context of the COVID-19 pandemic. The authors highlight the challenges faced by the healthcare system in meeting the growing demand for ventilators and emphasize the importance of innovative solutions to address these challenges [11]. Furthermore, advances in ventilator technology have led to the development of portable and affordable ventilators. For example, a study by Jones et al. investigated the design and implementation of a low-cost Arduino-based ventilator prototype that can provide basic respiratory support in resource-limited settings [12].

However, despite these advances, the literature highlights ongoing challenges in the accessibility and affordability of ventilators, particularly in low-resource regions; a study by Patel examined the barriers to ventilator access in developing countries and calls for concerted efforts to improve access to affordable ventilator solutions to address the global burden. In summary, this literature review highlights the evolution of ventilator technology from bulky and expensive systems to more compact and affordable solutions. It highlights the increasing prevalence of respiratory diseases and the growing demand for ventilators, especially in the context of the COVID-19 pandemic.

II. METHODOLOGY

The proposed emergency ventilator is just a smaller version of the commercial ventilator that assists in the breathing of patients who suffer from breathing problems. It operates using an Arduino MEGA microcontroller to control a motor mechanism that compresses the AMBU bag. The proposed system consists of a designed mechanically operated compressing lever to imitate the compression of air in and out of the lungs. It also consists of an LCD screen, a pressure sensor, a temperature sensor, and a pulse oximeter sensor to display important medical vital parameters that are helpful in monitoring the patient. The design criteria of this ventilator are based on key factors like mobility, cost, accuracy, reliability, and ease of use.

The DC geared motor mechanism is a rack and pinion setup running a 3:4 gear ratio. The DC geared motor is a 40-rpm high torque motor driven by an LN298N H bridge motor driver capable of controlling the direction and speed of the motor. The user enters ventilator parameters Tidal Volume and BPM where Tidal volume through potentiometer knobs. Tidal volume controls the extent of compression of the AMBU bag and BPM controls the respiration rate and the number of breaths to be taken by the patient. Tidal Volume is measured based on an ideal body weight of 8-10 ml/kg.

The input parameters are displayed on the LCD screen which is connected to Arduino using the I2C port. After choosing the required parameters the ventilation mechanism starts. The microcontroller sends the PWM signal to operate the compression mechanism to LN298N which operates the motor. The rack shaft compresses the AMBU bag during the inhalation cycle and decompresses the bag during the exhalation cycle. The sum of inhalation times and exhalation times sums up to a single breath cycle. The inhalation time is calculated based on the required volume specified and the speed(S1) of the DC motor(cm/ms).

$$T_{in}(ms) = \frac{V_t}{S_1} \quad (2.1)$$

$$T_{total}(ms) = \frac{60}{BPM} * 1000 \quad (2.2)$$

The inhalation time Tin is calculated based on the volume travelled the compression mechanism for the given speed(S1) which is dependent of the PWM signal given to the motor driver. The total time is dependent on breaths per minute. Dividing 60 by bpm gives us time taken to perform one breath. Multiplying by 1000 gives the results in milli seconds. The exhale time is calculated from the total and inhale times which is usually half of the inhale time as the IE value is generally considered to be 2 for ventilation. IE is the ratio of inhalation time to exhalation in a single breath cycle. The sensors allow real-time monitoring of the temperature, pressure, heart rate, and SpO2 levels of the patient through a 20x4 LCD interface. The system can be powered by a 12V battery backup or directly through a 12V DC adapter. It consists automatic power switching module that switches to a backup battery in case of emergencies. The 12V lead battery can last up to 3-4 hrs. without any external power. The device transmits the real-time patient data to the server via NODEMCU which allows for central real-time monitoring of patients. Fig.1 is the system block diagram showing different sensor and the architecture of the device.

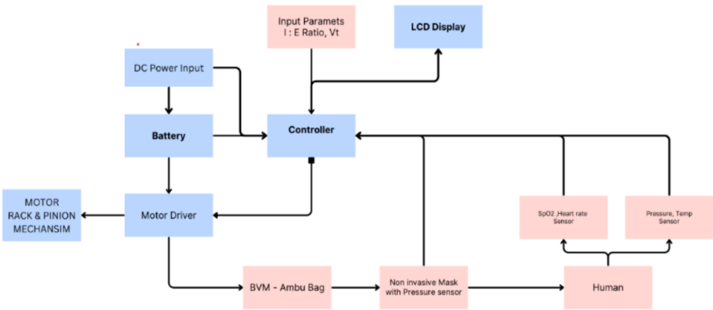

Fig.1 Ventilator System Block diagram

The device is capable of a Tidal volume of range 200 – 800 mL and 5 – 15 breaths per minute set based on adjustable potentiometer knobs. These parameters are controlled by varying the stroke length of the pinion during the breath cycle, and the speed of each cycle by adjusting the PWM signal of the motor driver and introducing necessary delays and adjustments to achieve proper ventilation parameters. The system includes warning systems, temperature above 38 and over-pressurization in the tube produce warnings. Pressure is typically around 10-11Kpa and > 13Kpa is considered over-pressured and the process has to be halted. The pulse oximeter sensor (MAX30100) monitors the heart rate and oxygen levels in the patient. These sensors are interfaced using an I2C port on the MEGA. The device displays a warning in case oxygen saturation levels drop 90%. Fig.2 shows the functional flowchart of the system software.

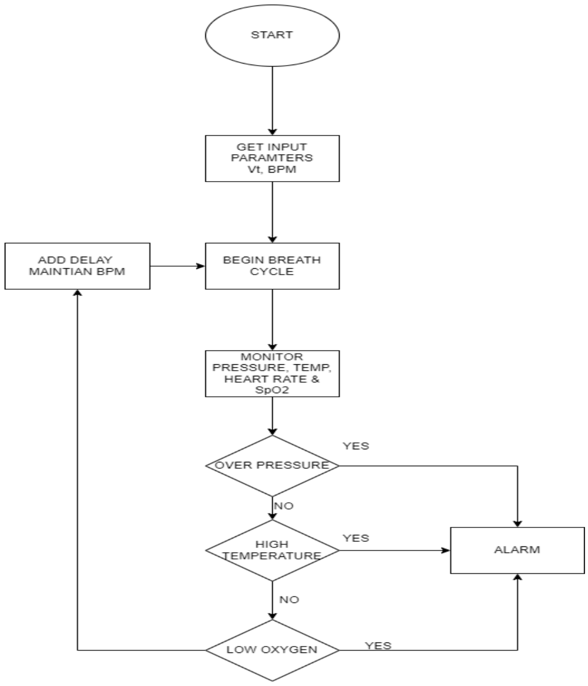

Fig.2 Functional Flowchart of the system software

The software design of the system consists of setting up the correct parameters Vt and BPM to control the DC geared motor. The AMBU bag used is around 1500 ml with a PEEP valve to relieve excess positive pressure. The respiratory rate is controlled based on the IE value and programming required delays in the process to achieve the desired BPM. The operation can be stopped by pushing the start/stop button or if an emergency is encountered.

In addition to the built-in user interface, a web application is included for remote monitoring. The web application receives real-time data from the microcontroller via the Node microcontroller unit and displays it in a user-friendly interface accessible to healthcare professionals. This enables remote monitoring of multiple patients simultaneously and facilitates timely decision-making based on updated patient information.

IV. RESULTS AND DISCUSSION

The proposed compact cost-effective and user-friendly is designed and this is the final view of the project that performs breathing assistance using the AMBU bag mechanism and performs real-time monitoring of a person's vitals. Fig.2 shows the final view of the device. The device is capable of operating a 1500mL reservoir bag at a pressure of 1.2 PSI. It is powered by a 12V dc power adapter and has a 12V backup battery capable of running up to 3-4 hours when fully charged.

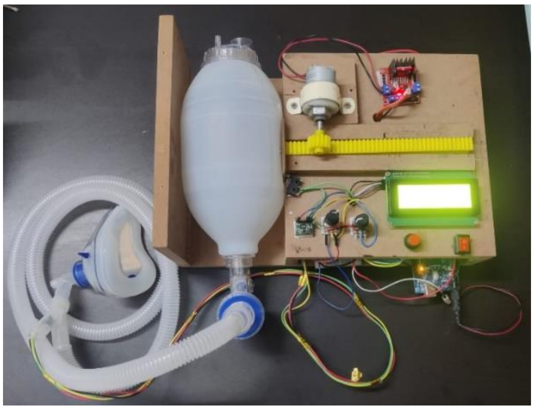
Fig.3 Final view of the project

The range 5 – 20 breaths per minute and tidal volume Vt in the range of 300mL to 800mL. The pressure ratings can be observed in the Fig.4 serial plotter graph.

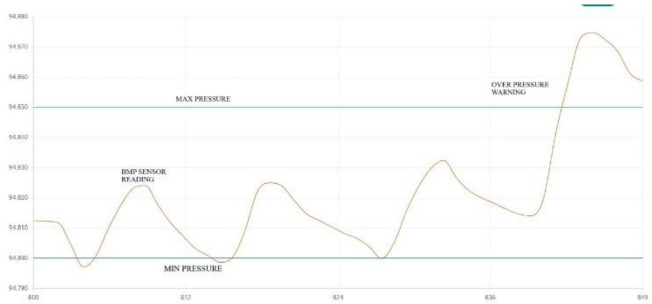

Fig.4 Pressure sensor output graph

The pressure in the ventilator pipe oscillates around 94,800 pa to 94,830 pa. Breathing attempt can be detected if the pressure in the ventilator tubing goes below 94,800 pa. Ventilator support can be provided by compressing the AMBU to assist the patient in the breathing. During the process if the pressure in the pipe exceeds max pressure threshold of 94,850 Pa, the process is aborted and warning is displayed for excessive pressure in the pipe. The process can be restarted once the problem has been resolved. The extent of bag compression and decompression depend upon the BPM and tidal volumes, altering the motor speed and times allow us to maintain the required BPM and tidal volume parameters efficiently.

I. CONCLUSION AND FUTURE SCOPE

In this paper, a portable, compact cost-effective emergency ventilator and health monitoring device was designed which can be a worthy replacement for the commercially expensive and complex models. The device consisted of user-controlled bpm and tidal volume parameters. It featured assist control and mechanical control mode. The device allowed for remote real-time health monitoring of patient vitals and allowed medical professionals to intervene promptly. The device contains a user-friendly setup and can be easily set and run by any person. The 1500mL AMBU bag with an additional reservoir of 1L can be used for the device and is capable of operation at a 300 – 700mL tidal volume with a 5 – 20 bpm. The compression mechanism consisting a DC-geared motor offering high torque and a pinion and rack setup to achieve linear compression and decompression of the AMBU bag. The motor speed and direction are controlled by an Arduino microcontroller through an H-bridge motor driver. It consists of various sensors which help in collecting real-time patient vital data and transmits the data to the server where it can be monitored and visualized by medical personnel.

The design can be improved by reducing the overall weight for portability and implementing more different modes of ventilation. The system can be integrated with an SMS service that sends notifications to the caretaker. Additionally, a filtration system can be installed to sanitize the exhaled air by the patient suffering from airborne diseases to minimize the risk of transmission. More vital sign monitoring can be included like ECG, Co2 levels, and pulse ratings. The device can be further improved by adding a larger battery backup and solar panels to charge the battery in rural areas and enhance its reliability and usability.

REFERENCES

[1] Hickey, Sean M. and Al O. Giwa. "Mechanical Ventilation." StatPearls, StatPearls Publishing, 26 January 2023.

[2] Tobin, M J. "Advances in mechanical ventilation." The New England journal of Medicine vol. 344,26 (2001).

[3] Oyekola, Peter Oluwatosin, et al. "COVID-19 Ventilator: A Variable Compression Model." IJSDA vol.11, no.5 2022: pp.1-12.

[4] Smetanin, Paul et al. "Potential intensive care unit ventilator demand/capacity mismatch due to novel swine-origin H1N1 in Canada." The Canadian journal of infectious diseases & medical microbiology = Journal canadien des maladies infectieuses et de la microbiologie medicale vol. 20,4 (2009): e115-23.

[5] Vasan, Aditya et al. "MADVent: A low-cost ventilator for patients with COVID-19." Medical devices & sensors vol. 3,4 (2020).

[6] Breathing Recovery Assistance Device (Brad) For Patients With Acute Respiratory Failur Amruta Amune, Kunal Pawar, Rohan Gujar Vishwakarma Institute of Technology, Pune, India. Page No: 352-361.

[7] Hess, Dean R. and Kacmarek, Robert M.. Essentials of Mechanical Ventilation, Fourth Edition. New York: McGraw-Hill Education, 2018.

[8] Chatburn, Robert L. "Classification of ventilator modes: update and proposal for implementation." Respiratory care vol. 52,3 (2007): 301-23.

[9] Grasselli, Giacomo et al. "Critical Care Utilization for the COVID-19 Outbreak in Lombardy, Italy: Early Experience and Forecast During an Emergency Response." JAMA vol. 323,16 (2020): 1545-1546.

[10] King, William P et al. "Emergency ventilator for COVID-19." PloS one vol. 15,12 e0244963. 30 Dec. 2020.

[11] Bhujade, Mukesh. (2021). Design and Implementation of Arduino based Low Cost Ventilator using Self Inflating Bag. International Journal for Research in Applied Science and Engineering Technology. 9. 544-549. 10.22214/ijraset.2021.34134.