DESIGN AND ASSEMBLY OF PROTOTYPE VENTILATOR USING CAM SHAFT MECHANISM

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***Abstract*—The project demonstrates the creation of a mechanically dependable, inexpensive prototype ventilator that uses a cam shaft mechanism.. The primary objective is to automate the process of manual ventilation (such as AMBU bag operation) with precision, ensuring consistent airflow and respiratory support in emergency or resource-limited settings. The camshaft allows for rotary movement to be converted to linear compression and decompression movements. This action mimics the inflating and deflating an airbag. The system uses mechanics instead of electronics to variably control the rate of breathing and the tidal volume without complex electronic devices. This mechanical method preserves adjustable tidal volumes and breathing rates while reducing the need for intricate electronic control systems. The design emphasizes simplicity, durability, ease of maintenance, and rapid deployability, making it suitable for emergency backup, field hospitals, and rural healthcare facilities. Experimental results demonstrate that the prototype can provide stable ventilation cycles, and the modular structure allows further upgrades for monitoring and safety enhancements.**

***Keywords* —Respiratory disease, AMBU Bag, automation, developing world, COVID – 19, Portable emergency ventilations system.**

I. INTRODUCTION

The COVID-19 pandemic is an infectious disease caused by the new strain of coronavirus. The illness started in Wuhan, China in December 2019, and has since spread to almost 220 countries in 3 months, infecting over 2.1 million people and resulting in more than 145 thousand deaths. It reaches now at 147,904,276 Coronavirus cases and 3,124,980 deaths . When an ICU patient approaches a ventilator, they have a specific desire in mind. The ventilator needs to be capable of change modes under the doctor's prescribed medications; successfully alter settings for the stream, weight, tidal volume, respiratory rate, and oxygen; sound an alarm if the patient's weight or volume changes or their lung compliance changes; provide a steady pressurized stream to the needy; and move sufficiently to be carried calmly if the bed moves. The Charles Boyles law, upon which the mechanical ventilator is founded, holds that air naturally flows from higher pressures to lower pressures and that pressure inversely varies with volume while temperature is constant. This theory states that the volume of the Ambu pack decreases as pressure inside the container has to the rise.

The multi country survey (on breath) reported the maximum number of people facing the diseases problem of COPD in

Additionally, the initial work on this project was supported and funded by the Information Technology University (ITU) Lahore, Pakistan. Many patients (mainly children and elderly) must tolerate seasonal respiratory diseases and require acute treatment in critical circumstances. Many such patients do not die every year, available on time. The situation in terms of respiratory disease and its treatment in other countries with moderate incomes is also very similar. Then the Covid-19 pandemic situation create the adverse conditions in globally.

The global medical community is currently experiencing a serious shortage of medical devices to deal with the Covid-19 outbreak. In particular, this is the case for ventilation devices required during intensive care units and longer recreational periods during Covid-19 treatment. Depending on whether mechanical ventilation equipment is required, we design and test emergency ventilation (EV) that can control patient breath pressure and patient breathing rate, while simultaneously maintaining pressure at the end of breath (PEEP). Companies will increase production, but this is not sufficient to meet demand according to current forecasts. During this period of modern science, microcontrollers have increased daily. Improved through integration into automated systems. Manual resuscators, commonly known as bag valve masks (BVM) fans (bag valve masks), are used in mechanical ventilation systems. For operators operating in unknown airspace, manually compressing and mitigating AMBU bags is imprecise and painful. This particular problem reduction requires automated systems to provide air to people who do not ingest breasts. AMBU stands for artificial manual breathing unit. It was created in 1956 by a colleague and German engineer named Dr. Holger Hesse. Matteo Raldo Colombo, an Italian anatomy professor, described the Trachenotomy procedure in great detail in 1559. To boost output, the AMBU bag's approximate control mechanism is kept in place. This article retrieves the necessary edition from the system using a particular method. Normal adults (aged older than 18 years old and older) generally gain 12-20 breaths within a minute. The AMBU-Bag system is manually operated. It goes without saying that children breathe more frequently than adults. The rate respiration of children between the ages of 6 and 11 is 18 to 25 breaths per minute.

In our project prototype ventilator, the variation in breaths per minute is controlled by a pusher arm mechanism driven by a camshaft system. The camshaft rotates at a specific speed, and its lobes push the arm in a rhythmic motion, simulating the breathing cycle. By adjusting the camshaft's rotational speed or the design of its lobes, we can control how frequently the pusher arm moves, thus regulating the number of breaths delivered per minute. This mechanical setup ensures consistent and adjustable airflow to meet different patient needs.

II. MATERIAL AND METHODOLOGY

(1) FLOW DIAGRAM FOR PROPOSED STUDY

The fundamental structure of our suggested research project is displayed in below Fig.

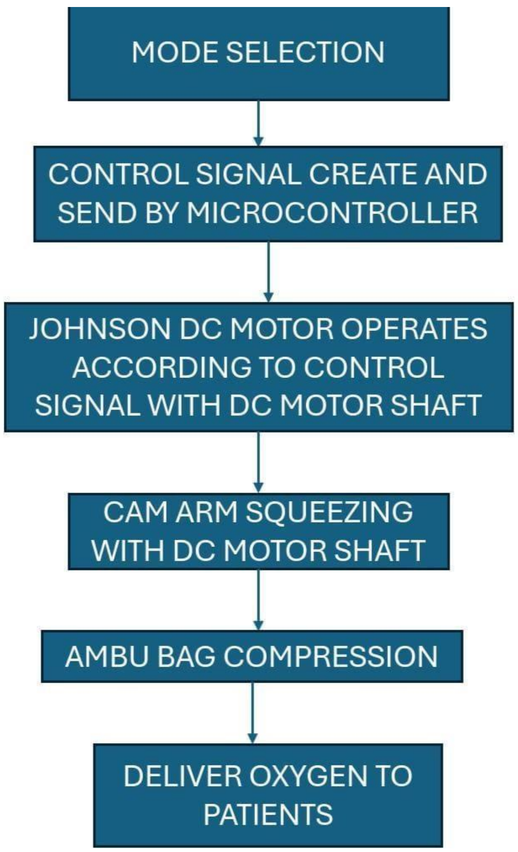

Figure 1. The proposed work's flowchart. Three modes are shown simultaneously in the flowchart: adult, pediatric, and child.

Telecontrol mechanisms exist and are integrated into the system. Any noise or extra sounds will then be eliminated by a different mechanism known as the CAM mechanism. Actually, the sounds produced by this mechanism are different from those produced by the Ruler Chain mechanism. The rack and pinion mechanism places the gear platform for more precise control. The lead mechanism uses thread screws to operate the motor and mechanical arms that simultaneously compress and relax the AMBU bag.

(2) EXISTING SYSTEM

A variety of mechanisms, such as crank, lead screw, and rack and pinion mechanisms, control AMBU bags. By combining a vowel coloring system with an existing ventilation system, hospital retreat noise is reduced. The ruler chain mechanism is the preferred mechanism due to its prior availability and the high torque advantages of DC motors. It produces noise when it works, which could contaminate the care environment.

(3) PROPOSED SYSTEM

The CAM shaft mechanism serves as the foundation for our project, which also includes features for precise control, portability, battery operation, size reduction, and noise reduction. A number of modes, including child, pediatric, and adult modes, were chosen for control operations. These modes are selected based on the patient's heart rate, SPO2 level, and the ratio of the I:E process. The patient's age typically affects each of these factors. A Johnson DC engine, potentiometer, and microcontroller are necessary for automation. As opposed to a 180-degree angle, the DC motor is positioned face-by-face. After that, the motor receives power, rotates the pulley or torque to generate tension in the DC motor, and then uses a shaft mechanism to compress an AMBU bag.

(4) AMBU BAG

An AMBU bag, sometimes referred to as a Bag-Valve-Mask (BVM) resuscitator, is a medical device that helps patients with respiratory issues by providing positive pressure ventilation. The figure 2 shows the internal flow mechanism of an AMBU bag system. It consists of several components, including a ventilation bag, an oxygen reservoir bag, and various valves such as the intake valve, outlet reservoir flap valve, and patient valve. When the Oxygen passes through the inlet valve of AMBU bag then it fills the oxygen reservoir bag. During use, as the ventilation bag is compressed, oxygen flows through the intake disc membrane and outlet valves toward the patient. A pressure relief valve (especially important in pediatric models) ensures that excessive pressure is not delivered to the patient, preventing lung injury. The AMBU bag is a lifesaving tool commonly used in emergency situations, during anesthesia, or in intensive care settings to manually support or completely take over a patient's breathing

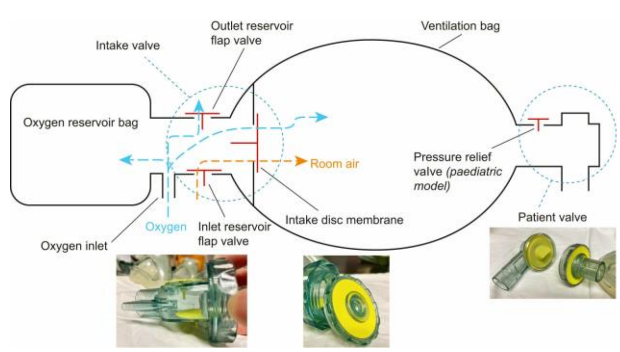

Figure 2 This figure show that specifications regarding AMBU bag

(5) CAM SHAFT MECHANISM

In a prototype ventilator that uses a camshaft mechanism, the cam arm plays a critical role in simulating the action of human breathing by mechanically compressing and releasing a ventilation bag (such as an AMBU bag). The camshaft is a rotating shaft fitted with specially shaped cams-projections that convert rotary motion into linear

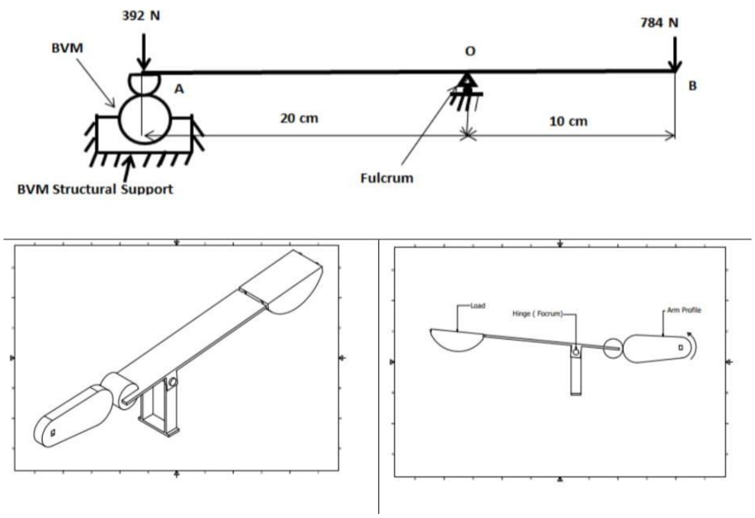

Figure 3. Space diagram depicting the kinematic of the design concept

motion. As the camshaft rotates, the attached cam arm moves up and down (or back and forth), pressing on the ventilation bag in a controlled, cyclic manner. This compression forces air or oxygen into the patient’s lungs, mimicking natural inhalation. When the cam arm lifts away, the bag re-expands, allowing passive exhalation of the patient.

(6) SYSTEM DESIGN

The syasyte is to provide controlled breathing support, the prototype ventilator's camshaft mechanism system design automates the compression and release of an AMBU bag (Bag-Valve-Mask). The central component of the design is a camshaft that rotates to drive a cam arm or follower mechanism. It is driven by a low-speed electric motor. In order to compress the AMBU bag and give the patient a predetermined amount of oxygen or air, the camshaft rotates, pushing the cam arm downward. The AMBU bag can expand and fill with fresh air when the arm lifts as the cam lobe rotates away. The cam’s shape and profile regulate the amount of compression applied to the bag, which in turn controls the patient's volume of tides and air pressure. A controller unit, which frequently includes microcontrollers like Arduino, keeps track of and modifies variables like motor speed, which influences breathing rate, and stroke depth, which influences volume. To guarantee precise and safe delivery, sensors such as temperature, heart rate, and SPO2 sensors are integrated. This mechanical system is simple, cost-effective, and can be made portable, making it ideal for emergency or low-resource settings where conventional ventilators are unavailable.

Figure 4 This figure show that System design

III. LITERATUR REVIEW

Rathore, P. K., & Kumar, R. [1], focusing on cam-follower is the soul of mechanical ventilator. AMBU pack arrangement is used in mechanical ventilator system. A control unit adjusts the cam follower to regulate the ventilator's operating speed. A mechanical ventilator is a device designed to alter the levels of oxygen and carbon dioxide in the air delivered to a patient’s lungs. The method in this paper that transformation of oxygen into the by the compression of the AMBU bag by cam follower arrangement. That was previously compressed by a person. Then the terms and standard in this paper included tidal volume (calculated basis on ideal body and weight of patient but it is veried between 4 to 12 ml per kg), modes of ventilation and other. This study demonstrates that ventilators, which can cost up to $30,000, are utilized in hospitals in the United States. Then the ventilator cost is approx Rs.5-7 lakh in Indian currency. The entire mechanism is run by 12 volt lithium-ion battery and the variation in the oxygen level from AMBU bag compression is regulate by potentiometer was connected to the shaft end. The limitation or research gap in the research manuscript is focusing on the cost of ventilator rises as battery power is increased, battery life is not adequate. There was some inaccuracy in determining the exact volume of the breaths.

Islam, Md Rakibul, Mohiuddin Ahmad, Md Shahin Hossain, Muhammad Muinul Islam, [2] suggested a streamlined design for a bag valve mask (BVM) ventilation system that makes use of a mechanical valentation based on a microcontroller. The computer agger factory (CAM) arm I worked with was controlled by a microcontroller and a manual switch that sent a control signal to a mechanical system. Umbu's bag. Around the corner of the inlet and outlet is a self-incision bag that functions similarly to a disposable valve. Before putting the Ambu bag through a mechanical AA-eter, it is compressed and relaxed. Three breathing rate-based modes—adult, pediatric, and child—are built into the control signal. After identifying all clear control signals, the device switches to an authorized control mode.

The BioPAC Student Clinical Laboratory System is a platform that visualizes control signals. The suggested gadget is small, light, portable, and effective. At the expense of efficiency and risk aversion, it can be transported to rural hospitals for prompt medication.

Muralidharan, S., Arun, S.V., Raghul, I. and Rajkumar, A., [3] During crisis condition like Covid-19 pandemic to help the people who have suffocation. During this pandemic the lack of production in supply of ventilator than the death rate as reaches to more than 20%. In the developing countries are faces the respiratory disease is more in public issues, due to various reasons like asthma and chronic obstructive pulmonary disease etc. The ventilator system then provides real-time data through the use of internet of things (IOT) technology. Then, using the ventilator system's data, the doctor gave treatment. The methods employed in this paper included components of the traditional ventilator system (if a healthcare professional or worker uses the Ambu bag compressors for a long time and gets tired, the patient is at serious risk). The mechanism then compresses the Ambu bag and sends it through the worm gear transmission, which is where the wheels are carried. When the input is supply to worm then the wheel at full expansion at 180 degree. Then the system contains the IOT components are pressure sensor, relay, Node MCU unit, MG 995 and servo motor etc. then the research paper is the given the information about the 30 breathe per minute and that the ventilation up to 100 ml at pressure 5-10 pascal.

Morales, Sergio, Styven Palomino, Ricardo Terreros, Victor Ulloque, Noé Bazán-Lavanda, María Palacios-Matos, Julio Valdivia-Silva, [4] The creation of a mechanical ventilator system is essential due to the symptoms of the SARS-COV-2 virus. The bag valve mechanism is the foundation of this type of non-invasive ventilator. Many deaths during the COVID-19 pandemic were caused by inadequate healthcare systems and a lack of ventilators in many developing countries. The ICU emergency ventilation system is provided by these manual and automatic bag valve mask ventilators (UTEC-AE EMV-ICU). The methodology used in this paper included segments of A study population and resuscitation bag-based principles. The oxygen supply in the prototype is then started and managed by the system using the UTEC-AE EMV-ICU mechanism. The bag is compressed using DURALIMINIO aluminum, and the mechanical parts are composed of AISI 304 alloy.

Acho, Leonardo, Alessandro N. Vargas, and Gisela Pujol-Vázquez. [5] An example of a low-cost, open-source mechanical ventilator. The development of this type of ventilation device is motivated by the lack of mechanical ventilation devices for the treatment of COVID-19 patients around the world. In certain places, the COVID-19 pandemic has had an especially detrimental effect. Reducing the impact of this flaw on these areas is the main objective of the paper, which is based on the development of an open-source, inexpensive mechanical ventilator. The equipment outlined here uses only commercial spare parts. This paper also includes numerical methods for monitoring lung disease in patients. Regardless of whether the patient is in a healthy or unhealthy state, this technique uses the inspiratory link to measure pressure and instantly notify the clinician.

Prajapati, K. H., Patil, V. S., Jain, A. R., & Sulakhe, V. N. [6] By pressing the bag valve mask (BVM) with the arm, the suggested system removes the need for the user to wear a personal bag valve mask (Ambu bag). The patient's BPM was then shown on the LCD screen by the paper. Insufficient ventilation in developing countries during the COVID-19 pandemic. Then, these ventilator systems are the cheapest, simplest, and lowest level ventilators. The arm that elliminates the user's actions in compressing the Ambu bag and delivering oxygen is the subject of this paper. After that, the ventilator was designed to be portable, which means it is lightweight and can help patients anywhere, in any emergency. This paper's methodology involved using a pusher arm mechanism that is connected to a motor and controlled by a Skoda Octavia wiper motor to compress and decompress.

Kwong, Man Ting, Glen Wright Colopy, [7] Long-term use of a mechanical ventilator (MV) system increases the length of stay and expense by causing various medical complications that increase morbidity and mortality. This study demonstrates the widespread need for this kind of ventilator and the clinical and financial benefits of using it to lower MV. Methods of machine learning (ML) or artificial intelligence (AI) hold promise for improving patient outcomes. The techniques used in this paper included determining the breath rate based on the patient's age group. Adult patients require 12–20 breaths per minute, pediatric patients require 18–25 breaths per minute, and children require 30–60 breaths per minute. Empirical approaches (like machine learning) to enhance ventilator component management are of special interest because of the high volume of components used, as well as the associated expenses and adverse events.

IV. RESULT AND ANALYSIS

Discharge:

Volume of Ambu bag = 1600 ml
Compression ratio of Ambu bag= 75% = 0.75
Motor RPM= 30

ACCORDING PATIENTS AGE:

STAGE 1 ()= 20 rpm

STAGE 2()= 24 rpm

STAGE 3()= 30 rpm

Final Discharge = AMBU Bag Volume × Compression ratio × RPM …….[unit:mg/litre]

Stage 1 for Adult:

Final Discharge = AMBU Bag Volume × Compression ratio × RPM

$$\text{Final discharge} = 1600\times0.75\times20 = 24000 \text{ mg/litre}$$

Stage 2 for pediatrics:

Final Discharge = AMBU Bag Volume × Compression ratio × RPM
Final discharge = 1600×0.75×24
=28800 mg/litre

Stage 3 for children:
Final Discharge = AMBU Bag Volume × Compression ratio × RPM
Final discharge = 1600×0.75×30
= 36000 mg/litre

Discharge fluctuate as the Oxygen (O2) level fluctuations. It is direct proportion.

Graphical Analysis:

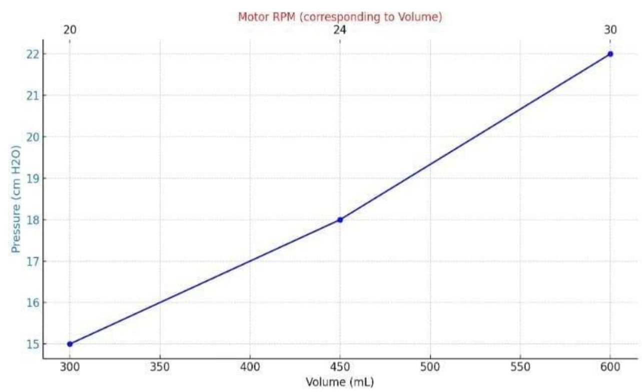

Figure 6 It shows that graphical representation between pressure, volume and motor RPM

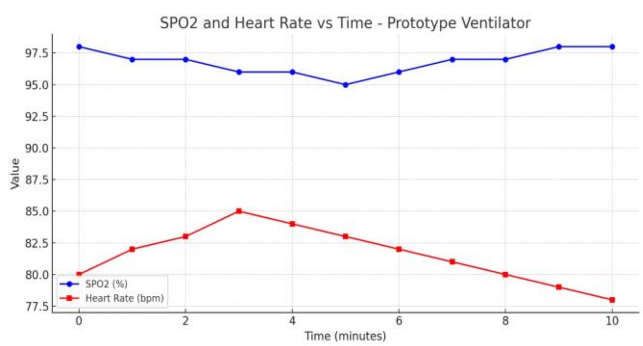

Figure 7 It show that graphical representation between SPO2, heart rate and time (minutes)

Pressure Calculation:
Motor torque = 2 NM
Cam radius = 0.05 m
Surface area = 0.13 m²

Then,
Force (F) = Torque/radius
Force (F) = 2/ 0.05 = 40 N

After that,
Pressure = Force/ Area
Pressure = 40/0.13 = 307.7 Pascals (Pa)

When the force 40N is exerted on AMBU Bag by Cam shaft mechanism then the pressure is 307.7 pascals.

V. FUTURE SCOPE

The future scope of the ventilator prototype using a camshaft mechanism includes several avenues for improvement and expansion. One potential direction is enhancing the system's automation and precision by integrating advanced sensors and control systems for better airflow regulation and patient monitoring. Furthermore, additional study could concentrate on optimizing the camshaft mechanism for scalability and adapting it to different patient requirements, such as variable respiratory conditions. Exploring lightweight and durable materials could also make the ventilator more portable and affordable for deployment in remote or under-resourced areas. Collaborating with medical professionals for real-world testing and refining the design to meet international healthcare standards would be essential for broader adoption. Lastly, the prototype could be adapted to support a range of applications, from emergency medical settings to long-term care facilities.

VI. CONCLUSION

In conclusion, the project prototype for a ventilator using a camshaft mechanism successfully demonstrates a novel approach to mechanical ventilation. By integrating a camshaft mechanism, the prototype provides an efficient and reliable method for controlling airflow in medical ventilators. This design is a viable substitute for medical systems with restricted funding because it may have benefits in terms of affordability, ease of use, and the accessibility. After that further development and testing are needed to optimize the system for real-world applications, but the project lays the groundwork for innovation in medical ventilator technology.

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