

“A Review On Automatic Ambu Bag Operating Device for Low Cost Ventilator”

Jayant Moundekar¹, Purushottam Choudhari², Kalpesh Sahare³, Abdul Rahman Ali⁴, Yogesh Ambadkar⁵, Vikram Kewate⁶, Yugal Gaidhane⁷

¹⁻⁸Undergraduate Student,
Department of Mechanical Engineering,
Suryodaya College of Engineering and Technology, RTMNU, Nagpur, India.

Abstract: The main objective of this paper is to review the design and working of automatic ambu bag operating device for low cost and cheap ventilators. Existing ventilators are very efficient but it has certain drawbacks due to which they are not very helpful during Covid -19 pandemic. The standard ventilator machine can provide medical assistance to single patients at a time. It is difficult to operate the system in remote areas. No backup system in case of an emergency such as failure in the supply of oxygen, low level of oxygen in the reservoir, the pressure of air. The system is require high maintenance. Future work is needed to achieve the potential of this approach by developing policies, updating regulations, and securing funding mechanism for the development and testing of open source ventilators for both the current covid-19 pandemic as well as for future pandemics and for everyday use in low-resource settings.

Index Terms - Ambu bag, Portable Ventilator, Pandemic, Emergency ventilation system, Mechanical Ventilator, Low Cost Ventilator, Covid-19.

I. INTRODUCTION

A ventilator is a device that is needed when a person can't breathe properly or they can't breathe on their own. Medical ventilators are very important for sufferers of COVID-19 & other breathing problems. Existing ventilators in hospitals are very complex & are very expensive. The availability of existing ventilators is not sufficient to meet the demand when the patients in hospitals are more due to pandemic like situations and many countries will struggle to afford expensive conventional ventilators, and so many critically ill patients are dying because of lack of ventilator facility, so we need an alternative to meet the demand. In this paper we are going review methods to make a automatic ambu bag operating device ventilator with a simple mechanism and cost-effective.

II. LITERATURE REVIEW

In the following literature review, here discuss pertinent information about the topics involved in our research, as well as recent, pertinent studies.

Leonardo Acho, Alessandro N. Vargas and Gisela Pujol-Vázquez., [1] Designed and construct a low-cost, open-source mechanical ventilator. The ventilator compresses ambu bag with actuator and its shaft to deliver breaths. They also shows a numerical method for monitoring the patients' pulmonary condition. The method considers pressure measurements from the inspiratory limb and alerts clinicians in real-time whether the patient is under a healthy or unhealthy situation. Experiments carried out in the laboratory that had emulated healthy and unhealthy patients illustrate the potential benefits of the derived mechanical ventilator.

Sazzad Hossain Sazal, B. Tech. in ME (JNTU-A, India) M.Sc. Engg student & TA Dept. of Mechanical Engineering, KUET, Khulna -9300. [2] Desigend and developed a low-cost portable ventilator that can help pneumonia cases of COVID-19 patient in Bangladesh. This low-cost ventilator delivers breaths by compressing a conventional Bag Valve Mask (BVM) or Ambu bag with a pivoting motor drive mechanism, eliminating the need for a human operator. Among other features, the machine had invasive and non-invasive feature, and supports 500- 600 mL tidal volume, with a continuous working capability for several days. Based on calculation, 12 Respiratory rate (RR)/min can provide required amount of tidal volume to the pneumonia patient.

Rajeev Chauhan, Raman Sharma, Nidhi Chauhan. [3] Designed a prototype of device was work on the principle of an electric linear actuator which converts the rotary motion into a linear motion. The designed device was connected to a regular adult AMBU. It has mechanism to rhythmically compress the AMBU. A direct current (DC) motor (12–24 V) was given the linear motion through electric linear actuator arrangement. In addition, this DC motor has speed regulator which is used to modulate the frequency of respiratory rate (varying from 12 to 20 squeezes per min) for supplying the air oxygen mixture into the lungs of the patient. There is a provision of the common platform so that the AMBU bag can squeeze automatically as per the regulated speed setting in the speed regulator of the DC motor.

Adamos Christou, Markellos Ntagios, Andrew Hart, and Ravinder Dahiya. [4] Design and implementation of one such emergency ventilator called GlasVent is presented, which an automated version of manual resuscitator device, commonly known as big valve mask or artificial manual breathing unit bag and widely used prior to initiating the mechanical ventilation. GlasVent uses 3D printed mechanical parts, widely available materials and off-the-shelf electronic and sensing devices which can be fast assembled. Furthermore, it requires minimal training and can be operated manually by hands or legs, thus meeting the emergency requirements even in the low-resource settings or regions with less developed healthcare systems.

Aditya Vasan, Reiley Weekes, William Connacher, Jeremy Sieker, Mark Stambaugh, Preetham Suresh, Daniel E. Lee, William Mazzei, Eric Schlaepfer, Theodore Vallejos, Johan Petersen, Sidney Merritt, Lonnie Petersen, James Friend, Acute Ventilation Rapid Response Taskforce (AVERT) [5] They show the development and validation of a simple, portable and low-cost ventilator that may be rapidly manufactured with minimal susceptibility to supply chain disruptions. This single-mode continuous, mandatory, closed-loop, pressure-controlled, time-terminated emergency ventilator offers robust safety and functionality absent in existing solutions to the ventilator shortage. Validated using certified test lungs over a wide range of compliances, pressures, volumes and resistances to meet U.S. Food and Drug Administration standards of safety and efficacy, an Emergency Use Authorization is in review for this system. This emergency ventilator could eliminate controversial ventilator rationing or splitting to serve multiple patients. All design and validation information is provided to facilitate ventilator production even in resource-limited settings.

Rather than rely on gear or cam mechanisms to translate the rotational motion of a control motor to a rectilinear motion for bag compression (MIT, 2020a; University of Minnesota, 2020), we use the bag compression arm as a lever to provide substantial mechanical advantage from the motor. Geared and cam mechanisms are subject to wear, have backlash, add cost and complexity and tend to be noisy, a significant issue in the critical care setting. Our approach permits simple direct motor drive via a lanyard attached to the top end of the lever arm and wrapped around a spool attached to the motor's shaft. Lengthening the lever arm or placing the bag closer to the pivot point increases the mechanical advantage.

Julienne LaChancea, Tom J. Zajdela, Manuel Schottdorfb, Jonny L. Saundersc, Sophie Dvalid, Chase Marshalle, Lorenzo Seirupf, Daniel A. Nottermang, and Daniel J. Cohena [6] Present a fully opensource, rapid-deploy ventilator design with minimal reliance on specialized medical devices and manufacturing equipment. The People's Ventilator Project (PVP1) is a pressure-controlled, fully automatic mechanical ventilator that can be built for less than \$1,300 by a single person in few days, requiring neither specialized tools nor specialist knowledge. As a point of reference, the lower-end average market values of open ventilators (such as the freely-released Puritan Bennett 560 (Medtronic, Inc.) or the Mechanical Ventilator Milano (Elemaster, Inc.)) cost approximately \$10,000. PVP1's parts were selected for widespread availability, and its modular software was designed to support component substitutions and extensions to new ventilation modes, thereby increasing global access to critical-care ventilation technology.

PVP1 is an automated ventilator that natively supports pressure-control ventilation (PCV), spontaneous inhalation monitoring ventilation (SIMV), and key alarms specified by regulatory agencies (e.g. high airway pressure, etc.). Pressure control was chosen over volume control because it is known to be safer with respect to barotrauma risk, and SIMV was implemented because it increases the range of patients and conditions for which PVP1 can be used. PVP1 operates as a computer-controlled, timed-cycle ventilator that requires only medical air and the patient-side respiratory tubing to be operated. To date, PVP1 has been set up three times by two different teams and run continuously for over 300 hours with no alarms or failures noted.

H. Jurb, M. Degner, H. Ewald. [7] Designed and construct an innovative, small-sized and low-cost lung ventilator. The essential part of the respirator is the full face mask, which includes a ventilation blower and integrated sensors. Due to this structure, there is no need for respiration tubes or other external devices. The low-cost as well as the small-sized and compact construction make the respirator suitable for stockpiling and easy transport – well suited for the usage in case of a natural disaster or a pandemic with a large number of patients. Integrated sensors for airflow and airway pressure enable safe operation and the monitoring of relevant respiration data. The designed and built prototype was tested and verified in a pneumatic testing environment. By using an approved mathematical lung model, disturbances like airway occlusion and leakages can be detected by the system and partly compensated. The measurements show the functionality of the developed respirator mask and verify the concept of a full face mask with a sensor controlled, integrated ventilation blower as a suitable respirator for emergency or resource poor environments.

D. G. Fahey, Department of Anaesthesia, Princess Alexandra Hospital, Brisbane, Queensland, Australia. [8] Based on animal experiments conducted in the sixteenth century by Vesalius, the Royal Humane Society recommended fireside bellows to resuscitate victims of drowning. In the mid-twentieth century, the bellows concept was adapted by Kreiselman and others, though none of these devices gained widespread popularity. However, in 1957 the "Ambu Bag" appeared and was an immediate success. The revolutionary design was the creation of Danish anaesthetist Dr Henning Ruben. A similar product was soon developed by Åsmund Laerdal of Norway, in collaboration with American anaesthesiologists Drs Elam and Safar. The self-inflating bag is such a simple device, yet it is extremely effective – it has enabled rescuers around the world to support life in virtually any environment, simply by squeezing a bag.

Abdul Mohsen Al Husseini, Justin Negretel, Stephen Powelson, Amelia Servi, Alexander Slocum, Jussi Saukkonen, Massachusetts Institute of Technology, Department of Mechanical Engineering, Boston University, School of Medicine. [9] Designed and made a prototype of a low-cost portable mechanical ventilator for use in mass casualty cases and resource-poor environments. The ventilator delivers breaths by compressing a conventional bag-valve mask (BVM) with a pivoting cam arm, eliminating the need for a human operator for the BVM. An initial prototype was built out of acrylic, measuring 11.25 x 6.7 x 8 inches (285 x 170 x 200 mm) and weighing 9 lbs (4.1 kg). It is driven by a stepper motor powered by a 14.8 VDC battery and features an adjustable tidal volume of up to 900 mL, adjustable breaths per minute (bpm) of 5-30, and inhalation to exhalation time ratio (i:e ratio) options of 1:2, 1:3 and 1:4. Tidal volume, breaths per minute and i:e ratio are set via user friendly knobs, and the settings are displayed on an LCD screen. The prototype also features an assist-control mode and an alarm to indicate over-pressurization of the system. Future iterations of the device will be fully calibrated to medical standards and include all desired ventilator features. Future iterations will be further optimized for low power-consumption and will be designed for manufacture and assembly. With a prototyping cost of only \$420, the bulk manufacturing price for the ventilator is estimated to be less than \$100. Through this prototype, the strategy of cam-actuated BVM compression is proven to be a viable option to achieve low cost, low-power portable ventilator technology that provides essential ventilator features at a fraction of the cost of existing technology.

Mike Fogarty, Joseph Orr, Dwayne Westenskow, Lara Brewer, Derek Sakata. [10] The purpose of this research is to develop a replacement device for the bag valve masks by using an electric blower based portable emergency ventilator. The bag valve mask is the only form of life support for an unconscious patient before they are intubated and mechanically ventilated. The bag valve mask consists of a flexible air chamber attached to a facemask via a shutter valve. This manual form of ventilation is a difficult technique to master and requires the full attention of the person performing the ventilation. There is no indicator for the clinician signaling adequate respiratory rate or tidal volume. Clinical studies reveal that trained clinicians give on average 25-35 breaths per minute, not the 10-12 prescribed by guidelines. Hyperventilation results in decreased cardiopulmonary function, which results in decreased absolute survival. Excessive pressures during ventilation have also been shown to cause traumatic brain injury, hemorrhagic shock, gastric insufflation, and lung injury.

Current methods of non-invasive ventilation (NIV) require strict conditions that make operating room or emergency ventilation impossible. Current NIV machines require precise and constant leak conditions in the ventilation circuit. To ensure those leak conditions the clinician must perform a time consuming fitting process of the mask to each patient. This process is not possible in an emergency situation. NIV machines also cost upwards of \$20,000, which makes their large-scale implementation costly.

This research aims to overcome the limitations of current NIV machines in order to develop a replacement to the bag valve mask. This device will provide constant positive airway pressure (CPAP) to the patient while also delivering increased pressures at intervals to ventilate the patient. Most importantly, it will eliminate the need for precise mask fitting by constantly adapting to changing leak conditions, which has yet to be accomplished in NIV. It will give the clinician the ability to deliver specific pressures and tidal volumes to their patient. Traditional bag valve mask used to deliver rescue breaths during CPR. ELECTRIC BLOWER BASED PORTABLE EMERGENCY VENTILATOR at regular intervals. It will provide visual feedback to the clinician assuring proper ventilation. Unlike the expensive current NIV machines, this device will be portable and powered by a rechargeable battery pack.

Subha Hency Jose P, P. Rajalakshmy, P. Manimegalai, K. Rajasekaran, [11] Developed a prototype of device to assist patients who can partially breath by their own, they made it by using minimum number of components. They used needle valve with potentiometer to replace the flow analyzer and to make it cost effective.

Carrie S. Sona et al. [12] Determined the effects of a simple low cost oral care protocol on ventilator associated pneumonia rates in a surgical intensive care unit, the implementation of a simple, low cost oral care protocol in surgical ICU led to a significantly decreased risk of acquiring ventilator associated pneumonia.

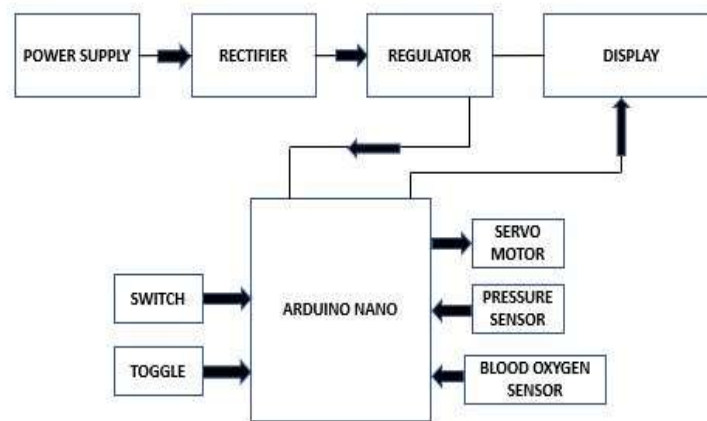
III. CONCEPT

The basic idea of ventilation comes from the BMV (bag valve mechanism). In this project, we are designing a mechanism that will compress the Ambu bag which in turn will provide the necessary breathing to a patient, and also there is an electronic circuit that will control various parameters such as PEEP, tidal volume, breath per minute.

Parameters	Age limit	range
Respiratory rate	Adult (More than 18 years)	12 – 20 breaths per minute
	Child (1 – 12 month)	30 - 60 breaths per minute
	Paediatric (6 – 11 years)	18 – 25 breaths per minute
Tidal volume	Adult (More than 18 years)	7 ml/kg
	Child (1 – 12 month)	4 – 6 ml/kg
	Paediatric (6 – 11 years)	5 – 8 ml/kg

A. PROPOSED CIRCUIT DIAGRAM

The proposed circuit diagram generally consists of Arduino nano, servo motor, Push button, LCD Display, pressure sensor and a power supply. This circuit diagram is simple in construction and user-friendly. The ventilator we here design and develop using arduino encompasses all these requirements to develop a reliable yet affordable DIY ventilator to help in times of pandemic. We here use a silicon ventilator bag coupled driven by servo motors with rack and pinion mechanism to push the ventilator bag. We use toggle switch for switching and a variable pot to adjust the breath length and the BPM value for the patient. Our system makes use of blood oxygen sensor along with sensitive pressure sensor to monitor the necessary vitals of the patient and display on a mini screen. The entire system is driven by arduino controller to achieve desired results and to assist patients in COVID pandemic and other emergency situations.



IV. CONCLUSIONS

From the detailed study of various automatic ambu bag operating device for low-cost mechanical ventilator, we conclude that ventilation is a very critical process and Ambu bag based mechanical ventilator can be a reliable substitute for standard ventilators in case of emergency.

This Automatic ambu bag operating device for low cost ventilator can provide a basic level of medical assistant to a patient although there are many mechanical ventilators which are providing similar output to that of a standard mechanical ventilator and they are also fulfilling the requirement which is stated in Medical norms stated by the Ministry of Health & Family Welfare and HLL Life Care Ltd.

A ventilator system can be created which can provide a basic level of medical assistance to patients and capable of producing its oxygen from surrounding ambient air which will be low cost, portable, and easy to use.

REFERENCES

- [1] "Low-Cost, Open-Source Mechanical Ventilator with Pulmonary Monitoring for COVID-19 Patients" by Leonardo Acho 1, Alessandro N. Vargas 2, Gisela Pujol-Vázquez 3 on 12 September 2020.
- [2] "DESIGN AND DEVELOPMENT OF A LOWCOST AUTOMATIC VENTILATOR" by Sazzad Hossain Sazal, B. Tech. in ME (JNTU-A, India) M.Sc. Engg student & TA Dept. of Mechanical Engineering, KUET, Khulna -9300 on April 2020
- [3] "Automatic AMBU bag operating device: creating a boon for high volume centers in low income countries" by Rajeev Chauhan, Raman Sharma, Nidhi Chauhan on July 2020
- [4] "GlasVent—The Rapidly Deployable Emergency Ventilator" by Adamos Christou, Markellos Ntagios, Andrew Hart, and Ravinder Dahiya on April 2020
- [5] "MADVent: A low-cost ventilator for patients with COVID-19" by Aditya Vasani, Reiley Weekes, William Connacher, Jeremy Sieker, Mark Stambaugh, Preetham Suresh, Daniel E. Lee, William Mazzei, Eric Schlaepfer, Theodore Vallejos, Johan Petersen, Sidney Merritt, Lonnie Petersen, James Friend, Acute Ventilation Rapid Response Taskforce (AVERT) on 26 May 2020
- [6] "PVP1—The People's Ventilator Project: A fully open, low-cost, pressure-controlled ventilator" by Julianne LaChancea, Tom J. Zajdela, Manuel Schottdorfb, Jonny L. Saundersc, Sophie Dvalid, Chase Marshall, Lorenzo Seirupf, Daniel A. Nottermang, and Daniel J. Cohena on October 5, 2020.
- [7] Subha Hency Jose P, P.Rajalakshmy, P.Manimegalai, K.Rajasekaran, "A Novel Methodology for the Design of a Portable Ventilator ", International Journal of Innovative Technology and Engineering(IJITEE), ISSN:2278-3075, Volume-9 Issue-1, November 2019.
- [8] "A new compact and low-cost respirator concept for one way usage" by H. Jurb, M. Degner, H. Ewald on 2018
- [9] "The self-inflating resuscitator – evolution of an idea" by D. G. Fahey, Department of Anaesthesia, Princess Alexandra Hospital, Brisbane, Queensland, Australia on 1, July 2010

- [10] “Design and Prototyping of a Low-cost Portable Mechanical Ventilator” by Abdul Mohsen Al Hussein, Justin Negretel, Stephen Powelson, Amelia Servi, Alexander Slocum, Jussi Saukkonen, Massachusetts Institute of Technology, Department of Mechanical Engineering, Boston University, School of Medicine on June 2010.
- [11] “Electric Blower Based Portable Emergency Ventilator” by Mike Fogarty, Joseph Orr, Dwayne Westenskow, Lara Brewer, Derek Sakata on 2008.
- [12] “Open Vent-Bristol V2.0 COVID-19 Rapid Manufacture Ventilator BVM Ambu bag” by Darren Lewis.
- [13] “Partially RepRapable automated open source bag valve mask-based ventilator” By Aliaksei Petsiuk a, Nagendra G. Tanikella on Published by Elsevier Ltd., 30 July 2020.

