THE IMPROVEMENT OF THE MECHANICAL VENTILATOR AND THE USE OF CAM AND FOLLOWER ARRANGEMENTS TO MAKE IT PORTABLE AND COST EFFECTIVE

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ABSTRACT

The most critical component for human survival is the respiratory system; without it, a person cannot survive. When a person is physically unable to breathe, a Ventilator is utilized to provide the patient with artificial breathing. In other words, a mechanical ventilator is a machine that exchanges oxygen and carbon dioxide in air that is transferred into or out of the patient's lungs.

In our research, we hope to create a system that is portable, simple to use, patient-friendly, and affordable. For that, we use a positive pressure ventilation and non-invasive technique; we employ two arrangements for that namely, a mechanical unit and a controller unit.

Different types of sensors, actuators, regulators, and valves are employed in controller units to facilitate quick, accurate flow monitoring and self-governing design. This device determines how much compressed air the patient needs and delivers the right quantity of a blend of air and oxygen.

In the mechanical unit, we use a cam follower arrangement to compress the Ambu Pack that was previously compressed by a person. This arrangement helps us compress the Ambu (BVM) Pack in accordance with the output of the controller unit and supply the right amount to the patient with the appropriate mixture.

Keyword: - *Cam-follower Mechanical Ventilator, Ambu pack arrangement, Portable, Emergency ventilation system, Economical, Cost -effective, positive pressure ventilation, Controller unit, Low Power and Automatic.*

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1. INTRODUCTION

The respiratory system is the most important part of the survival of a human being, without it one couldn't survive. For one who is physically unable to breathe, a device is used named a Ventilator which gives artificial breath to a patient. That means a mechanical ventilator is a device that transfers air into or out of the patient's lungs and exchanges the oxygen and carbon dioxide.

When an ICU patient approaches a ventilator, they have a specific desire in mind. The ventilator must be able to 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 rise.

1.1 Important terms and standards

a.) Tidal volume: The amount of air displaced between inhalation and exhalation during a typical respiratory cycle is known as tidal volume. It calculated on the basis of ideal body weight of a patient, historically, it varied between 4 and 12 mL/kg.

b.) Respiratory rate: The number of breaths taken each minute is known as a respiratory rate. The mechanical ventilator's respiratory rate ranges from 0 to 60 breaths per minute.

c.) Flow rate: The ventilator's maximum stream (flow) at which a given tidal volume breath is delivered is known as the flow rate. The majority of modern ventilators have stream rates of 60 to 120L/min [1]. The ratio of inspiratory/expiratory (I: E) for respiratory cycle is 1:2.

d.) Modes of Ventilation: Assist-control, Synchronized intermittent mandatory ventilation, Pressure-control ventilation, Pressure support ventilation, Positive pressure ventilation, Negative pressure ventilation, Invasive ventilation, Non-Invasive ventilation.

According to ASTM F920-93(1999) [2] a set of mechanical, medical, economic, user-interface, and repeatable functional requirements were devised in light of the mentioned constraints.

Table-1: Medical Device Requirements [3]

Mechanical	-Portable - -Stable electrical, mechanical, and software systems -Accessible and repairable components -Low power consumption , Powered by batteries -Sustain all types of stresses
Medical	-Tidal volume -Breaths per minute selected by the user -Minimum I:E ratio -Assist control -FiO2 (Fraction of Inspired Oxygen) can be minimum -Positive end-expiratory pressure (PEEP), -Pressure limiting at maximum, -Humidification exchange -Preventing infections -Minimal dead space
User-interface	-Alarms for low battery life, high airway pressure, and loss of breathing circuit integrity -Displays settings and status, LED Light for warning -Standard connector ports -Sensors and Actuators -Accurate Power supply
Repeatability	Indicators are accurate to within 10% of the reading -one breath per minute for frequency
Economic	Low Cost

1.2 Importance and relevance of the study

Ventilators cost a lot to purchase (up to $30,000), making them a common item in modern hospitals in the US. Due to high expenses, such technologically advanced equipment cannot be used in nations with low resources. According to a report, imported machines with the same features cost between Rs. 11 lakh and Rs. 18 lakh while Indian machines cost between Rs. 5-7 lakh. "Assuming the worst, India must be prepared for 40 lakh ventilators if there are 40,000 in the country [4]."
However, given the limited supply of stocked portable ventilators and their high present price, there is a need for a low-cost portable ventilator whose production can be ramped up on demand. Our main desire is that we develop a

mechanism for a ventilator that reduces its cost, portable; less complicated, and main function is that fulfills all requirements of the patient.[5]
Therefore, we made the decision to base the mechanical ventilator's mechanism on a cam follower. We explain how it is possible to create a ventilator in an affordable and practical manner that may be made available to people all around the world.

2. METHODOLOGY

Initially, BVM ventilation is used to provide artificial breathing for a patient. In this BVM ventilation, the Ambu pack is manually compressed to start the flow by compressing the bag, increasing pressure inside the valve, and supplying highly pressurized air, or rather, oxygen, to the patient's airway through the mask. With the use of a cam-follower system, we modify this manually operated compression, making it automatic and independent. We also employ a few sensors to appropriately sense and detect the air supply with standard measures.

Table-2 Quantity of components required for a system with their ranges

Controller unit		
Component	Range	Quantity
Compressed Air and O2 Source	2000- 8000cm H2O	-
Pressure Regulator	20 to 60 cmH2O,	1
Proportional Valve	-	2
Pressure Sensor	3-4 bar	3
Solenoid Valve	60Hz	2
Flow Sensor	0-12 L/Min	2
Potentiometer	-	1
Pulse Oximeter	-	1
Display unit and Alarm system	-	1
Mechanical Unit		
Motor	100 Rpm	1
Shaft	To Transmit motion	Need Basis
Cam & Follower	1 Arrangement	
BVM	-	1 Unit
Tubes	-	Need Basis
Wires	-	Need Basis

2.1 Controller Management (Controller Unit)

Components like a pressure regulator, proportional valve, pressure sensors, flow sensors, etc. are used to control the compressed air and oxygen mixture's flow, pressure, the fraction of inspired oxygen (FiO2), respiration rate, I: E ratio, etc. These components' performance is observed and managed by the control unit to appropriately carry out mechanical ventilation. The flow of air oxygen mixture according to the requirement will flow like a flow diagram shown below-

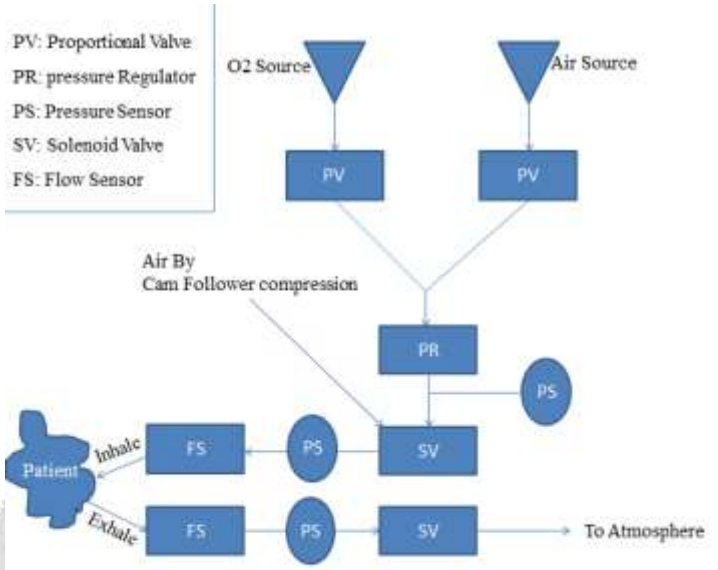


Fig -2: Flow Chart of controller Unit

2.2 Mechanical Unit (Cam & Follower Arrangement)

We required a ventilation system with a noise-proof mechanism. It specifies the RPM at which the cam rotates. It is a kind of higher pair or point contact between the Follower and the pair of Cams, thus there is less contact and friction between the setups. The AMBU bag consequently absorbs the most energy from the Cam. The quantity of air volume delivered can be accurately controlled by modifying the cam's shaft's angle, resulting in operation with the least amount of noise [4]. It was found that the cam mechanism utilized space and power more effectively than the roller chain arrangement.

Cam is a rotating component in this set-up and with the aid of a shaft attached to the motor the cam rotates; this rotation of the cam reciprocates the follower arm, which is further connected to the ventilator bag. By the application of force transfer through the follower BVM compresses and the pressurized air (oxygen) is transfer through the pipes to the patient's face masks.

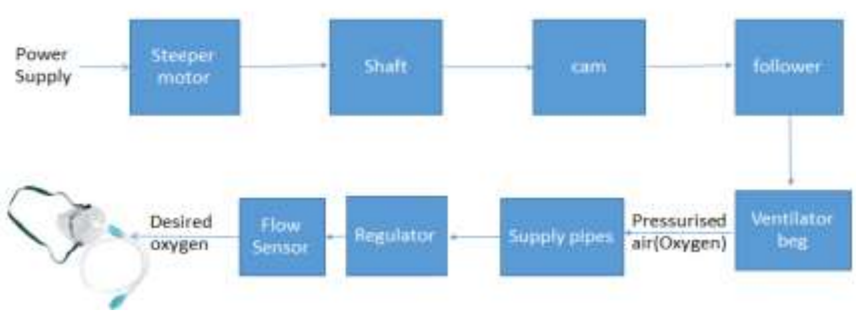


Fig -3: line diagram of Cam- Follower based MV

2.4 Procedure

The flow diagram is used to guide the design of the entire system. Mechanical unit and controller unit are combined to create a system; the main goal of this system is to deliver an adequate air-oxygen combination to the patient's lungs through the face mask. In our study, we use the positive pressure ventilation approach and a non-invasive technique for giving artificial breath to a patient. . We need to consider two main factors that 1.)There will be proper discharging of CO_2 by minute ventilation. 2.) For continuous oxygenation, one must deliver FiO_2 (Fraction of Inspired O_2) and maintain end-expiratory lung volume with positive end-expiratory pressure (PEEP).

Following electricity supply first, the ventilator gauges the patient's state using a pulse oximeter before beginning to generate compressed air and provide it to the ventilator in the appropriate amounts. FiO2 is supplied with, let's say, a minimum value of 0.21; the proportional valve then checks the flow and appropriate pressure; this proper ratio is then supplied to the pressure regulator to regulate the pressure and check the pressure; the motor receives the signal and starts rotating; the Cam Arm, which is connected to the motor by the shaft and also starts rotating; and the Follower, which is connected to the Cam, begins to reciprocate back and forth and compressing the BVM at the outlet of BVM pressure sensor and flow sensors are mounted to monitor the proper flow and properly compressed air is given to the patient's lung by the face mask with the assistance of the solenoid valve, this results in the inhalation of oxygen. After inhalation, cam is rotated and follower moves backward, which results in suction of air at this point, flow sensor is once more active and discharges the proper amount of CO2 to the atmosphere with the help of solenoid valve. Until the needs of the patient are met, this cycle will continue. The flow diagram is given in figure 2, 3 and 4.

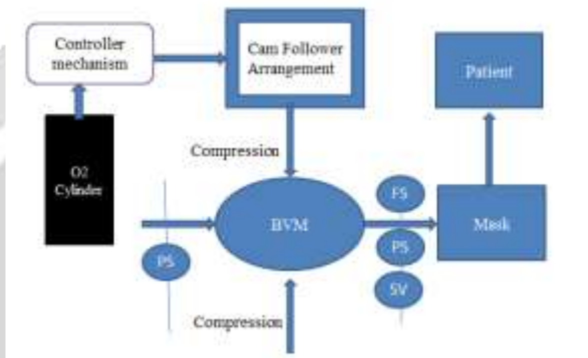
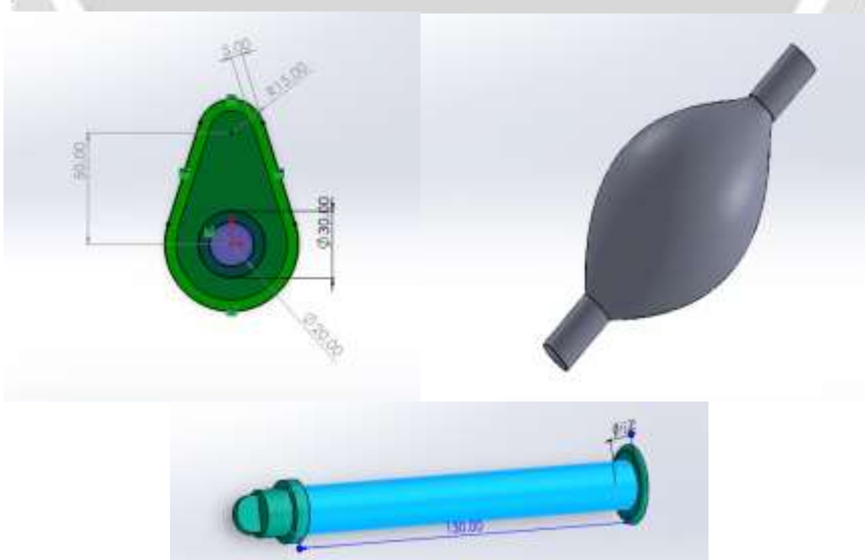


Fig -4: Flow Chart of whole System

2.3 Prototype Design

After deciding that the cam concept was the optimal technique for BVM compression, a first prototype was constructed to gauge the force and power needs. As a position feedback sensor, a potentiometer was connected to the shaft's end. The CAD model is displayed in an isometric view in given figure-



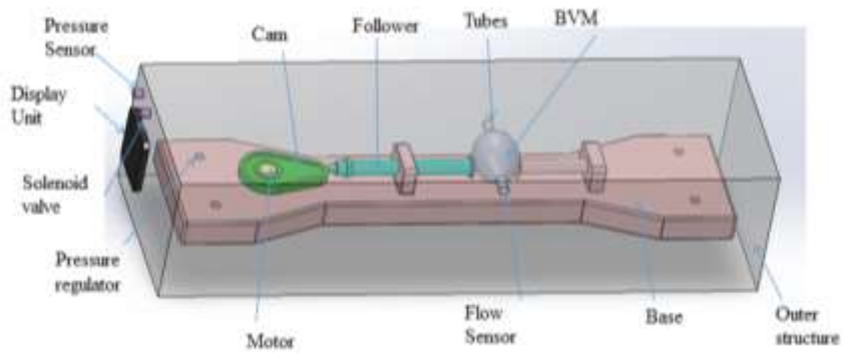


Fig-5: CAD Modals of Cam, BVM, Follower, and whole assembly

3. RESULT AND ANALYSIS

By integrating the flow rate over time, the delivered air volume as a function of cam angle was calculated. The volume delivered versus cam angle ratio is about linear, according to the results. A study of the data revealed that 1.5 Nm of maximum torque and 30 W of peak power were needed. The highest volume that could be given in a single stroke was around 750 mL. For adult human use, the goal tidal volume is 6-8 ml/kg, which is sufficient in the majority of positive circumstances.

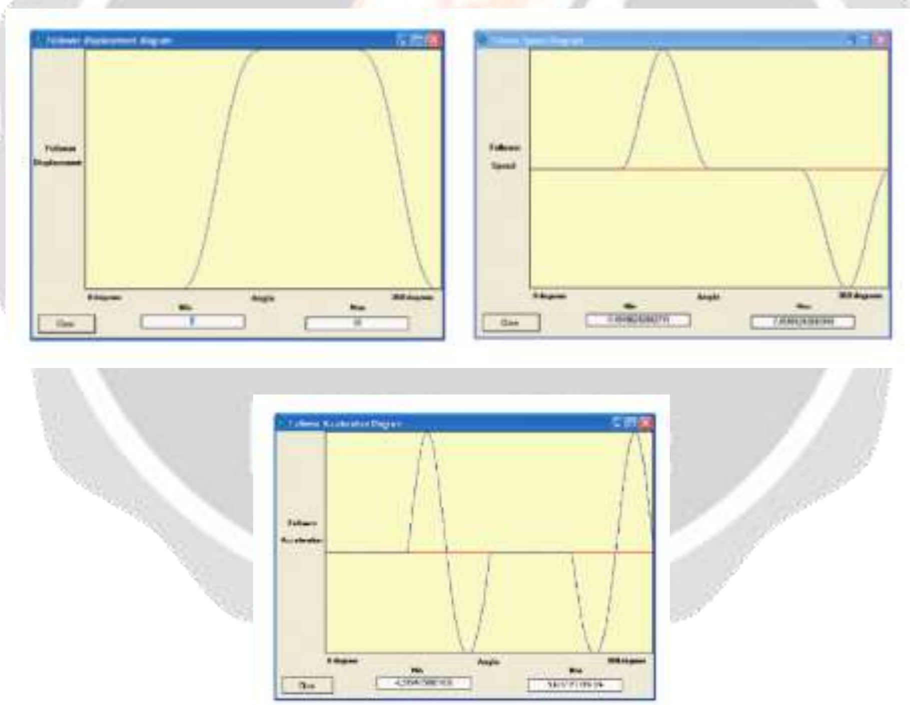


Chart -1: Cam Follower Displacement, Velocity, Acceleration Diagram

3.1 Result and Discussion

Three of our output data have been measured in relation to the input. They are information on the angle, tidal volume, and respiratory rate. The Initial and final angle measured according to cam follower mating point, which compresses the Ambu pack and produce compressed air. As a result, we were able to determine the system's efficiency while obtaining a different perspective for the same input both with and without load.

Table-3 Achieved tidal volume, Respiratory Rate, Minute Ventilation based on different mode

Mode	Initial angle (degree)	Final angle (degree)	Tidal Volume	Command RR (breath/minute)	Minute Ventilation
Adult	30	1	5-7	20	200
Pediatric	20	1	8-10	35	250

As a result we are able to achieve our targeted Standards with this arrangement.

3.2 Limitations

Despite the numerous benefits of the proposed study, the following few factors may be viewed as limitations of the current investigation. Because the cost of a ventilator rises as battery power is increased, battery life is not particularly adequate. We can observe that there was some inaccuracy in getting the precise breath volume. The state of the healthy and ill lungs is not detected. To enhance the quality of the breath, this gadget demands more sensors and mechanisms.

3.3 Future Work

The current approach provides a large window open for future research to investigate a variety of other Cam Follower Based Mechanical ventilator features. Use the best simulation software to analyze the functioning of the cam. Change the design of the cam and follower to increase efficiency. Use more sensors to improve efficiency of the ventilator Increase the capacity of battery and motor Work on the display unit and user interference so that the operator is able to input the values of tidal volume and set the respiratory rate for various patients.

4. CONCLUSIONS

We want to develop a Mechanical Ventilator which is reliable, transportable, highly effective, battery- or low-powered operated, simple to use, less noisy, risk-free, repairable, less costly, eco-friendly, and reusable. Our system automatically detect the requirement of breathe rate, number of breaths, which are technically called as tidal volume and respiratory rate. This system based on cam follower arrangement gives the desired result, also matches the standards set for respiration. We employ a controller unit to sense how much compressed oxygen the patient needs, and we made it an autonomous unit to carry out the required work as needed with the help of pressure sensors, flow sensors, regulators, solenoids, and proportional valves.

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