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Design and Development of Mechanical Ventilator

Nilesh Arjun Kumbhar[1], Rajendra Dilip Shinde[2], Shubham Ashok Shinde[3], Sagar Bapurao Awate[4], Akshay Vishwas Kamble[5], Ashish Kumar Parekh[6]

[1,2,3,4,5]*B.tech Student,*[6]*proffessor, Department of mechanical engineering, NMCOE, Peth ,Maharashtra, India*

Abstract: Respiratory diseases and injury-induced respiratory failure constitute a significant public healthiness in both developed and fewer developed countries. Asthma, chronic obstructive pulmonary disease and other chronic respiratory conditions are spread globally. These conditions are exacerbated by pollution , smoking, and burning of biomass for fuel, all of which are on the rise in developing countries1,2 Patients with underlying lung disease may develop respiratory failure under a selection of challenges and should be supported mechanical ventilation. These are machines which mechanically assist patients inspire and exhale, allowing the exchange of oxygen and CO2 to occur within the lungs, a process mentioned as procedure. Design and prototyping of a inexpensive portable mechanical ventilator to be utilized in mass casualty cases and resource-poor environments. The ventilator delivers breaths by compressing a typical bag-valve mask (BVM) with a pivoting cam arm, eliminating the need for an individual's operator for the BVM. Now a days, COVID-19 is one among the main issue goes on, and during this disease ventilator is plays the important role. during this project report, we've focused on to style and development of semi-automatic low cost mechanical ventilator.

Keywords: Ventilator, Mechanical linkages, COVID-19, Diseases, Oxygen

I. INTRODUCTION

Medical equipment availability issues related to the COVID-19 Pandemic highlight the need for broader involvement in medical device development by both individuals and thus the general industry. A comparatively small number of traditional ventilator manufacturers combined with supply chain disruptions continues to impact the medical industries ability to extend ventilator manufacturing capacity. To combat this, many non-medical manufacturing companies are stepping up to shift manufacturing capacity to create ventilators. Additionally, multiple companies and individuals are working to develop and promote open source ventilator technology as how to reinforce patient access to ventilators globally.

A. Ventilator Background

The role of the mechanical ventilator is to manoeuvre gas in and out of the lungs to provide oxygen and deduct CO2. Modern ventilators use positive pressure ventilation (PPV) to push gas into the lungs at a daily rate of respiration. Figure 1 shows an example of mechanical ventilator during simulation profile of the pressure ramps and flows for a inhalation and exhalation. A ventilator implements this type of profile with various limits and rates while treating a patient.

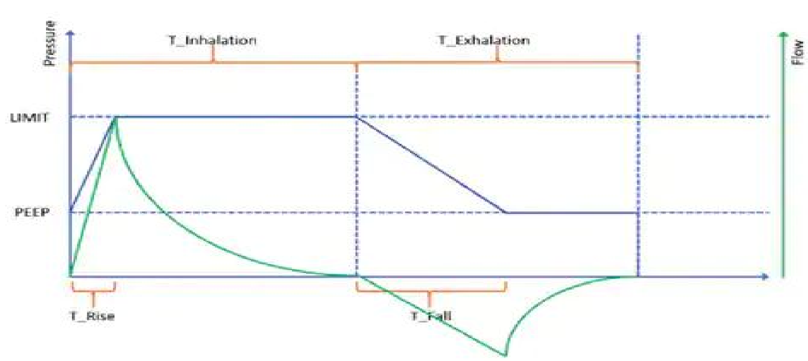

Fig.1 Ventilator Waveform.

Ventilators typically use pneumatic or electrical power to supply the pressure and flow used during ventilation. Various sensors and controls within the mechanical ventilator are wont to cycle between inspiratory (inhale) and expiratory (exhale) modes. Reference 1, Equipment in Anaesthesia and important Care: an entire guide for the FRCA, provides good background information and a baseline reference in understanding basic ventilator design and terminology.

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B. Objectives

1) To decreases the speed of death thanks to non-availability of ventilator.
2) To lower the value of ventilator.
3) To design the straightforward ventilator this may be ready to utilize by unskilled user.
4) To develop ventilator with light in weight and portable.

C. Scope

1) This system is suitable for all patient etc.
2) Patient who is facing COVID-19 problem will get reduce.
3) Low cost and straightforward design in order that , it'll have better potential in market.

D. Problem Definition

Fig. 2 Medical facility

While many emergency and portable ventilators are in the market, an adequate inexpensive ventilator is lacking.
Ventilators and COVID-19
Patients acutely suffering from the Coronavirus can require respiratory support. Those extremely affected may develop Acute Respiratory Distress Syndrome (ARDS). ARDS is the incapability of the lungs to absorb adequate oxygen on their own. ARDS patients suffer a better mortality and may require several days of mechanical ventilation during treatment.

1) Problem facing in existing situation
a) Cost is more.
b) Non Availability in remote area.
c) Complicated mechanism, Not simple to repair and do maintenance through ordinary mechanic.
d) Skilled operator is required.

By observing these problems we have tried to design and develop a simple prototype model of Semi-automatic low cost mechanical ventilator.

II. THEORY

A. Present Theory

The worldwide medical profession currently faces a critical shortage of medical equipment to deal with the COVID-19 pandemic. In particular this is often the case for ventilators, which are needed during COVID-19 related treatment at onset, during the medical care phase and through the much extended recovery times. Companies are scaling up production, but this may not be sufficient to satisfy the demand consistent with the present forecasts. There is a wide spectrum of devices, ranging from highly sophisticated through to simpler units useful in the milder phases of illness. Amid pandemic crisis in India we were motivated to cater the local shortage of this medical equipment and develop a somewhat semi-automatic mechanical ventilator that would be utilized in emergency medical units in hospital also as mobile medical units like ambulances to provide emergency ventilation using an Ambu bag based setup to patients affected with COVID-19.

B. Conceptual Design and working

We have described here the conceptual layout of the system. The targeted modes of operation, as explained above, are principally SIMV and CPAP alongside PEEP. The design has the patient safety built-in as a priority, in order that all failure modes revert to a situation which prioritises patient safety. In particular, if the patient stops inhaling pressure support mode, the ventilator shifts automatically onto mandatory ventilation. The conceptual schematic is shown in figure 1. The unit takes as input the quality compressed or mixed air supply available in hospitals; in such how that one supply might be connected to many units. We expect that typically the pressure supplied is going to be between 2 and 5 bar. A push feature is additionally provided for the patient who will help patient to call the doctor just in case of any discomfort/emergency.

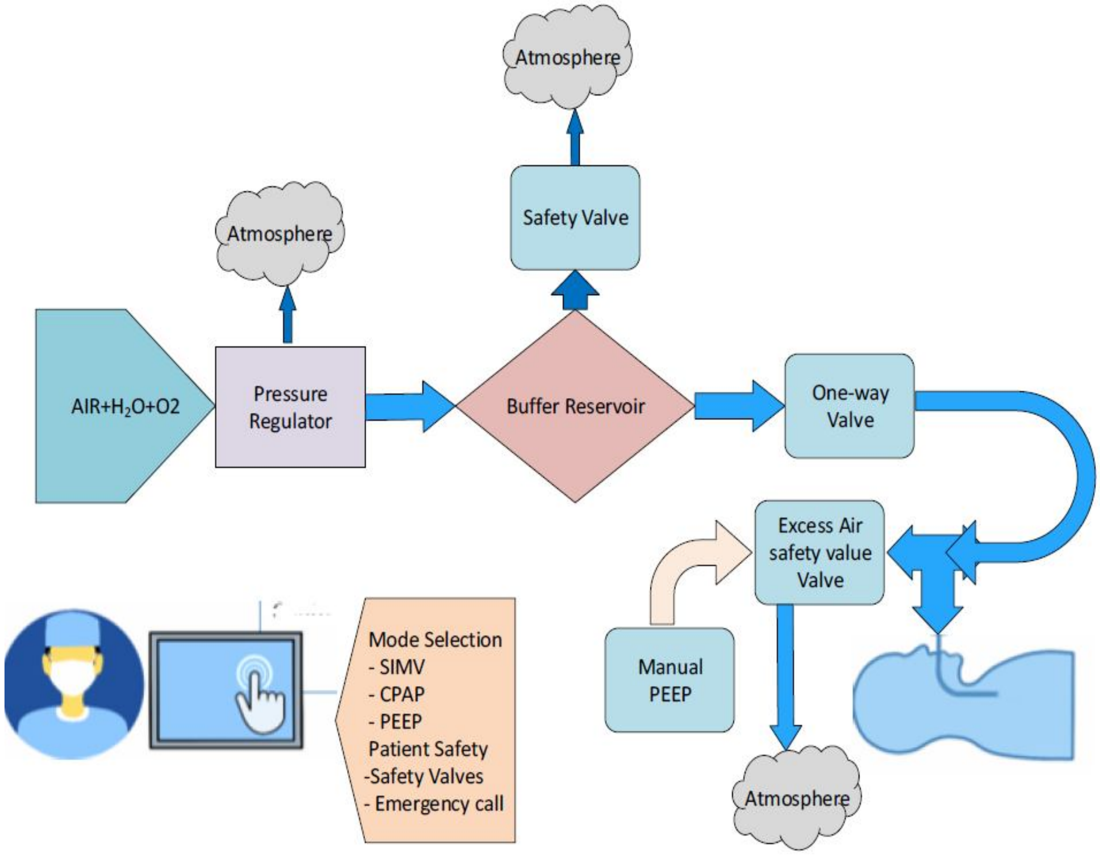

Fig.3 Block diagram of system

The connections to the unit external input/outputs will have to follow hospital standards. The supply pressure is reduced to approximately 200 mbar by a pressure regulator. The system concept is predicated around a buffer volume (ambulatory bag) of roughly 1.6 litres. The filling of this buffer is controlled by the input valve (valve in). By controlling of the opening time, one are able to do the specified target pressure within the buffer after which the valve (valve in) is shut. This buffer filling takes place during the expiratory a part of the breath cycle. If the buffer pressure is within tolerance of the specified pressure, the output valve (valve out) is then opened, initiating the respiratory cycle. The rate of respiration, inspiratory time (corresponding to the open time of valve out) and pause time are all governable. If a PEEP pressure is about, then the pressure within the lungs will have the minimum of the PEEP pressure. In the case where the tidal volume isn't achieved at a specific pressure setting, thanks to changes within the patient's airway resistance this will then be gradually adjusted. SIMV mode will allow the patient to require spontaneous breaths, and can assist the breathing when the spontaneous breath is taken. If the patient rate of respiration doesn't acquire the target value, additional mechanical ventilation is provided by the unit. During the operation all the parameters are measured and displayed employing a suitable indicator panel (operator panel) which comprises an OLED display board. The operator panel besides having necessary on off switches has emergency stop button also, that bring the device into halt state for any procedures to be done by the doctor.

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C. Specifications

The proposed ventilator is designed with following specifications:

1) Working Pressure: Up to 50 cm H2O.
2) Operation modes: SIMV-PC, CPAP.
3) Exhaust mode: PEEP available with a set range between 0 and 5 cm H2O.
4) Minute volume flow capability: Up to 5 litres/min.
5) Inspiratory flow capability: Up to 10 litres/min.
6) Respiratory rate: 10–30 breaths/min.
7) Inbuilt UPS functioning feature.
8) Low battery feature for Inbuilt UPS
9) Minimum calibrated air supplying capacity per stroke : 100 ml
10) Maximum calibrated air supplying capacity per stroke : 650 ml

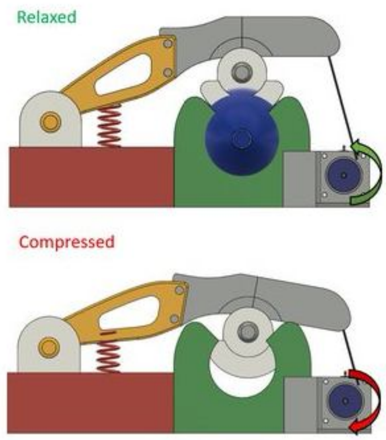

Fig.4 Schematic diagram of the system

D. Methodology

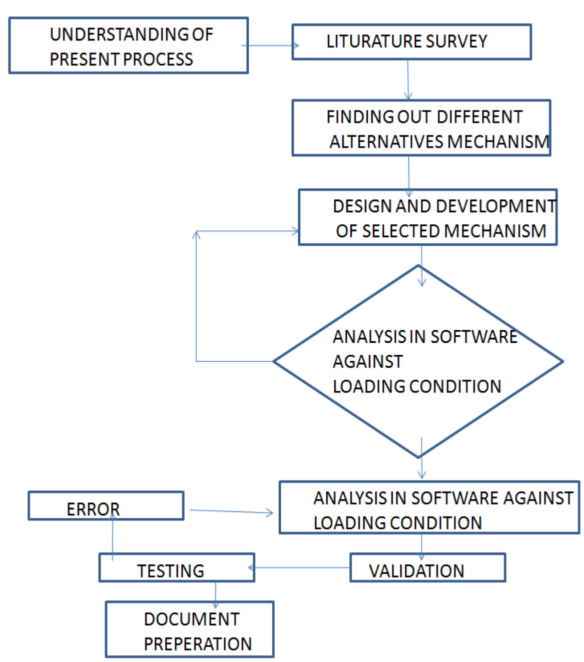

Fig.5 Methodology

III.DESIGN

A. Device Design

Two main categories were identified for the ventilator's air delivery system. One strategy uses a continuing pressure source to intermittently deliver air while the opposite delivers breaths by compressing an air reservoir. The latter approach was adopted because it eliminates the necessity for the continual operation of a positive pressure source. This reduces power requirements and therefore the need for expensive and difficult to repair pneumatic components. Where most emergency and portable ventilators are designed with all custom mechanical components, we chose to require an orthogonal approach by building on the cheap BVM, an existing technology which is that the simplest embodiment of a volume-displacement ventilator. Due to the simplicity of their design and their production in large volumes, BVMs are very inexpensive (approximately $10) and are frequently used in hospitals and ambulances. They are also readily available in developing countries. Equipped with an air reservoir and an entire valve system, they inherently provide the essential needs required for a ventilator. The main drawback with BVMs is their manual operation requiring continuous operator engagement to carry the mask on the patient and squeeze the bag. This procedure induces fatigue during long operations, and effectively limits the usefulness of those bags to temporary relief. Also, an untrained operator can easily damage a patient's lungs by over compression of the bag. Our methodology, therefore, was to style a robot to actuate the BVM. This approach leads to a cheap machine providing the essential functionality required by mechanical ventilator standards.

B. CAM Concept

The cam concept utilizes a crescent-shaped cam to compress the BVM, which allows smooth, repeatable deformation to make sure constant air delivery (Figure 3). As it rotates, the cam makes a rolling contact along the surface of the bag and in contrast to the roller-chain, achieving low-noise of operation. By controlling the angle of the cam's shaft, the quantity of air volume delivered is often accurately controlled. The cam mechanism was found to be more room efficient and have a lower power requirement than the roller chain concept, and was therefore the tactic of choice

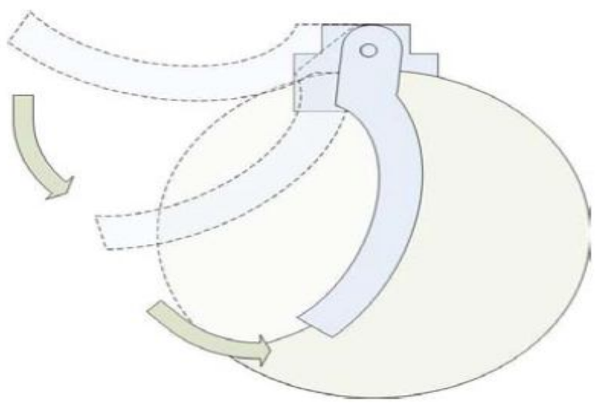

Fig.6 Sketch of cam based device

The dimensions of the frame and the arms are selected as such to be compatible with the physical dimension of the Ambu bag. The length of the arms is 0.15 meters and in uncompressed state the arms start to touch the bag at 0.15 meters from pivot. The frame and the arms deliver some mechanical advantage to compress the bag.

The length of the total arm = 0.4 meters.

The length of the portion from pivot to the bag = 0.15meters

Mechanical Advantage, M.A. = 0.4/.150 = 2.6

So, the arm will provide a M.A. of 2.6 to compress the bag.

Control Implementations The servo motors were coded to be controlled for compressing the BVM in required breath per minute (BPM) value. The Arduino MEGA 2560microcontroller was used to control the servo motors. A potentiometer was used to control the BPM. The use rcan use the knob of the potentiometer to adjust the BPM.A LCD screen was used to display the BPM of the device operating with.

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The Mega 2560 may be a microcontroller board supported the ATmega2560. it's 54 digital input/output pins (of which 15 are often used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz quartz oscillator , a USB connection, an influence jack, an ICSP header, and a push button . It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to urge started. The Mega 2560 board is compatible with most shields designed for the Uno and therefore the former boards Duemilanove or Diecimila

The air volume delivered was measured as a function of cam angle by integrating the flow over time. Results indicated that the quantity delivered versus cam angle relation is approximately linear (Figure 6). Data analysis showed that the height power required was 30 W, and maximum torque was 1.5 Nm. the utmost volume delivered per stroke was approximately 750 mL. The target tidal volume is 6-8 ml/kg for adult human use, so this is often adequate for many clinical situations.

Fig.7 Arduino MEGA 2560microcontroller.

C. Design of Project and Calculation.

Design considerations

When designing our attachment, the following considerations were taken into account

1) The device should be suitable for local manufacturing capabilities.
2) The attachment should employ low-cost materials and manufacturing methods.
3) It should be accessible and affordable by low-income groups, and should fulfill their basic need for mechanical power
4) It should be simple to manufacture, operate, maintain and repair.
5) It should employ locally available materials and skills. Standard steel pieces such as steel plates, iron rods, angle iron, and flat stock that are locally available should be used. Standard tools used in machine shop such as hack saw, files, punches, taps & dies; medium duty welder; drill press; small lathe and milling machine should be adequate to fabricate the parts needed for the machine.
6) Excessive weight should be avoided, as durability is a prime consideration

We have taken floater for 5 liter capacity and by taking manual experiments and reading it is seen that 10kg load is required for to press the float through mechanical likages.

So we have considered 10kg load on crank lever.

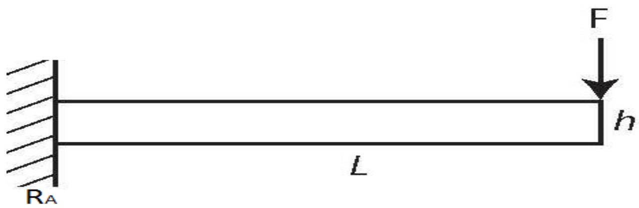

Fig. 8 BMD

In the proposed mechanism we have used stub shafts for crank and to rotate the crank motor is attached.
As per discussion with manufacturers technical team to consider frictional load in the mechanism the factor 1.5 is considered.

So total load W = 1.5 x 100 = 150N

Considered speed of machine N =30 rpm (it can be vary as per patient's condition and doctors requirement)
Radious of crank = 50mm (it is adjustable as per stroke requirement)

1) *Selection of Motor*

The load considered = 150N
Crank Diameter D = 100mm
So Maximum Torque T = Effort x Radius of wheel

Total torque on shaft = 150 x 50 = 7500 N-mm

we know power

$$P = \frac{2\pi \times N \times T}{60}$$

P = 23.55 watt

By considering application and extra jerk and safe design prime mover power considered = 24 watt

As per Design data book shaft material is selected Carbon steel C40

$$C40 \Rightarrow Sut = 580\ N/mm^2 \quad Yield = 330 N/mm^2$$

σ = 145 N/mm2

As per ASME code

0.3 X Yield strength N/mm2
0.18 X ultimate strength N/mm2} whichever is smaller
0.3 x 330 = 99 N/mm2 ………………………………………….(a)
0.18 x 580 = 104 N/mm2 ……………………………………..(b)
From equation (a) & (b)
Allowable stress value will be 99 N/mm2
If key ways will provide to shaft then
τ = 99 x 0.75 = 74.25 N/mm2

Max torsional moment equation is given by

we know,

$$T_e = \frac{\pi}{16} d^3 \tau$$

Where T = 7500 N-mm
By using above equation drive shaft dia d = 8.02 mm ……………….A

We know that,
Max bending moment equation is given by

we know,

$$M = \frac{\pi}{32} d^3 \sigma$$

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The Radial load at end point is considered maximum considered = 150 N
As per ergonomically consideration the one person can apply the radial load = p = 150N

P = 150 N

$$\sum F_Y = 0$$

As per consideration total load on wheel will be = 150N

RA =150 ……………………………………………………I

The length of stub shaft = L = 100 mm

Calculation of bending moment at loading point P,

BM at M = 150 x 100 = 15000 N-mm

we know,

$$M = \frac{\pi}{32} d^3 \sigma$$

Ϭ = 145 N/ mm2 considering factor of safety = 4
By using above equation drive shaft dia d = 12.85mm ………………..B

From equation A and B we have selected the diameter of shaft = 20mm considering extra jerk and for safe design.

According to maximum shear stress theory

Equivalent Torque :-

$$T_e = \sqrt{(K_b M_A)^2 + (K_t T)^2}$$

From design data book service factor K_b & K_t = 1.

Equivalent bending moment

$$Me = \frac{1}{2}\left[M + \sqrt{(K_b M_A)^2 + (K_t T)^2}\right]$$

Te = 16770 N-mm

Me = 23385N-mm

we know,

$$T_e = \frac{\pi}{16} d^3 \tau$$

we know,

$$M = \frac{\pi}{32} d^3 \sigma$$

ڂ = 10.67 < 74 N/mm2 and
Ϭ = 93.25< 145 N/mm2

2) *Selection of Bearing*

$$\frac{F_a}{F_r} = 0 \le e$$

so $x = 1$ & $y = 0$

Equivalent dynamic load

$$P = X F_r + Y F_a$$

P = RB = 150 N

Life in hrs = 10000 hrs

Life in million

$$L = \frac{60\, n\, L_h}{10^6}$$

L = 36 millions of rev

dynamic load capacity

$$L = \left(\frac{C}{P}\right)^a$$

a = 3 for ball bearing.

From SKF bearing catalogue we have selected the bearing static capacity for shaft dia 20mm = Co = 2.32 KN

From above equation = C = 201 N

So calculated dynamic capacity C < bearing catalogue dyanamic capacity C = 4.32KN

Hence from catalogue bearing selected = 61204

IV. CONSTRUCTION

A. *Observation And Discussion*

The most obvious means to actuate a BVM is to mimic the hand motion that the bag was designed. This requires the utilization of linear actuation mechanisms (e.g. lead screw or rack and pinion) which despite being simple to implement, require linear bearings and additional space. Other compression techniques were sought to require advantage of the cylindrical BVM shape. However, since BVMs were designed for manual operation, their compressible outer surface is formed from high-friction material to take care of hand-contact with minimal slippage. This eliminates the choice of tightening a strap wrapped round the bag as a way of actuation. To avoid the issues related to high surface friction, the 2 main candidates for actuation were a roller chain and cam compression. These options employ rolling contact with the bag instead of sliding contact, eliminating losses thanks to kinetic friction between the actuator and therefore the bag.

1) *Roller-chain Concept:* The roller-chain concept utilizes roller-chains with roller diameters larger than link width. The chain wraps round the circumference of the bag, and as a result's very space efficient. A sprocket Connected to the motor shaft; its clockwise/anticlockwise rotation compressing and expanding the bag for breath delivery. While this concept seemed initially feasible, preliminary experiments revealed that radial compression of a BVM requires significantly higher force than the vertical compression that the bag was designed. Additionally, its operation was noisy, and therefore the bag crumpled under radial compression, inhibiting the specified pure rolling motion, and preventing an accurate and repeatable tidal volume from being delivered. A trade-off was encountered; while small pitch/roller-diameter chains are more room efficient and yield higher angular resolution for compression, bag crumpling becomes a problem . On the opposite hand, a better pitch/roller-diameter chain overcomes crumpling but takes up more room and reduces angular resolution. In either case, the utilization of roller chains added a big amount of weight to the system suggesting the necessity for a simpler mechanism needing a smaller contact area.
2) *CAM Concept:* The cam concept utilizes a crescent-shaped cam to compress the BVM, which allows smooth, repeatable deformation to make sure constant air delivery (Figure). As it rotates, the cam makes a rolling contact along the surface of the bag and in contrast to the roller-chain, achieving low-noise of operation. By controlling the angle of the cam's shaft, the quantity of air volume delivered are often accurately controlled. The cam mechanism was found to be more room efficient and have a lower power requirement than the roller chain concept, and was therefore the tactic of choice.

B. Actual Design

1) *Working of Set Up:* In this proposed mechanism we have used mechanical linkages to compress and release the air bag for ventilation purpose. In the above figure the schematic prototype shows the working principle of the proposed mechanism. In this we have used the geared DC motor and we can adjust the connecting link as per requirement of air pressure and ventilation required to user.

Fig.9 Actual system

V. TESTING OF MACHINE

To test and confirm the working of developed mechanism for Medical application and comparison with existing manual method, we have taken practical demonstration at workshop. Also we have collected the feedbacks and improvements points in developed model.

A. Testing Points And Concluded Points As Below

Table 1 Medical Device Requirements

Sr. No	Points observed	Existing manual method	New developed mechanism
1.	Operator requirement	Skilled required	Skilled required
2.	Time required	As per experience of operator	*Standardize procedure but training is sufficient to operate.*
3.	Space required	*In manual method we have to carry the equipment. It is very tedious and stressful task.*	*Require to carry the equipment, but easy for use.*
4.	Manual effort	*Totally this methods is based on manual interference so here manual effort is required more or we can say 100%*	*Here we have used the mechanical mechanism or mechanical advantage, so the effort is required very less.*
5.	Material handling	*Material handling is more.*	Standardized method developed
6.	Accuracy	*Proportion we can't set and it is all depend on experience of operator.*	Standardization or proper procedure we can maintain so that Uniformity is there and accuracy is maintained by mechanical mechanism. Totally manual interference is avoided.
7	Maintenance	*Less*	10% of total cost of machine we are considering per year.

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In light of the aforementioned constraints, a set of mechanical, medical, economic, user interface and repeatability functional requirements were developed. These include the ASTM F920-93 standard requirements, and are summarized in Table 8.1.

Table 2 Device functional requirements

Sr No	Description	Summary
1	Medical	- User-specified breath/min insp./expansion ratio, tidal volume - Assist control - Positive end-expiratory pressure (PEEP) - Maximum pressure limiting - Humidity exchange - Infection control - Limited dead-space
2	Mechanical	Portable - Standalone operation - Robust mechanical, electrical and software systems - Readily sourced and repairable parts - Minimal power requirement - Battery-powered
3	Economic	- Low-cost (<15000 Rs.)
4	User interface	- Alarms for loss of power, loss of breathing circuit integrity, high airway pressure and low battery life - Display of settings and status - Standard connection ports
5	Repeatability	- Indicators within 10% of correct reading - Breath frequency accurate to one breath per minute

B. Testing and Observation

The following observations are recorded for developed prototype.

Table 3 Observations

Sr. No.	cam angle	air volume	Displacement of lever
Unit	Degree		Mm
1	10	0.05	5
2	20	0.08	8
3	30	0.11	10
4	40	0.2	12
5	50	0.34	15
6	60	0.4	18
7	70	0.7	20
8	80	0.81	22
9	90	0.9	27

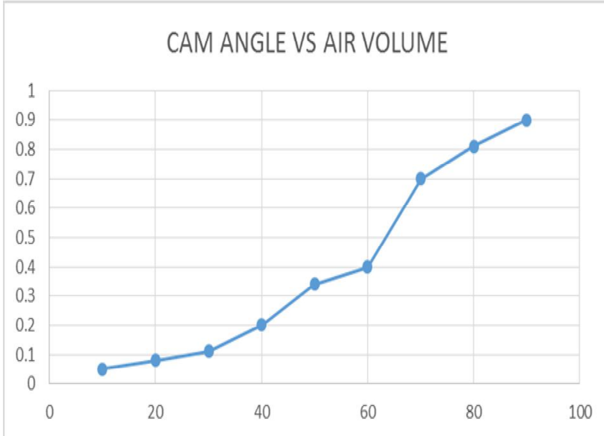


Fig. 10 Chart cam Angle VS Air Volume

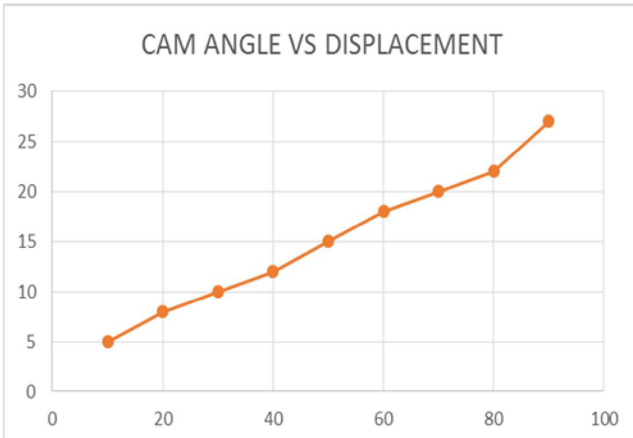


Fig.11 Chart Cam Angle VS Displacement

VI. CONCLUSION

A working prototype which will be operated on a test lung has been developed. The machine has user-controlled breath rate and tidal volume. It features assist control and an over-pressure alarm. It has low power requirements, running at constant required speed as its most demanding setting. It is portable, weighing 9 lbs (4.1 kg) and measuring 11.25 x 6.7 x 8 inches (285 x 170 x 200 mm) , and features a handle and straightforward to use latches. The machine can display settings and standing on a display screen.

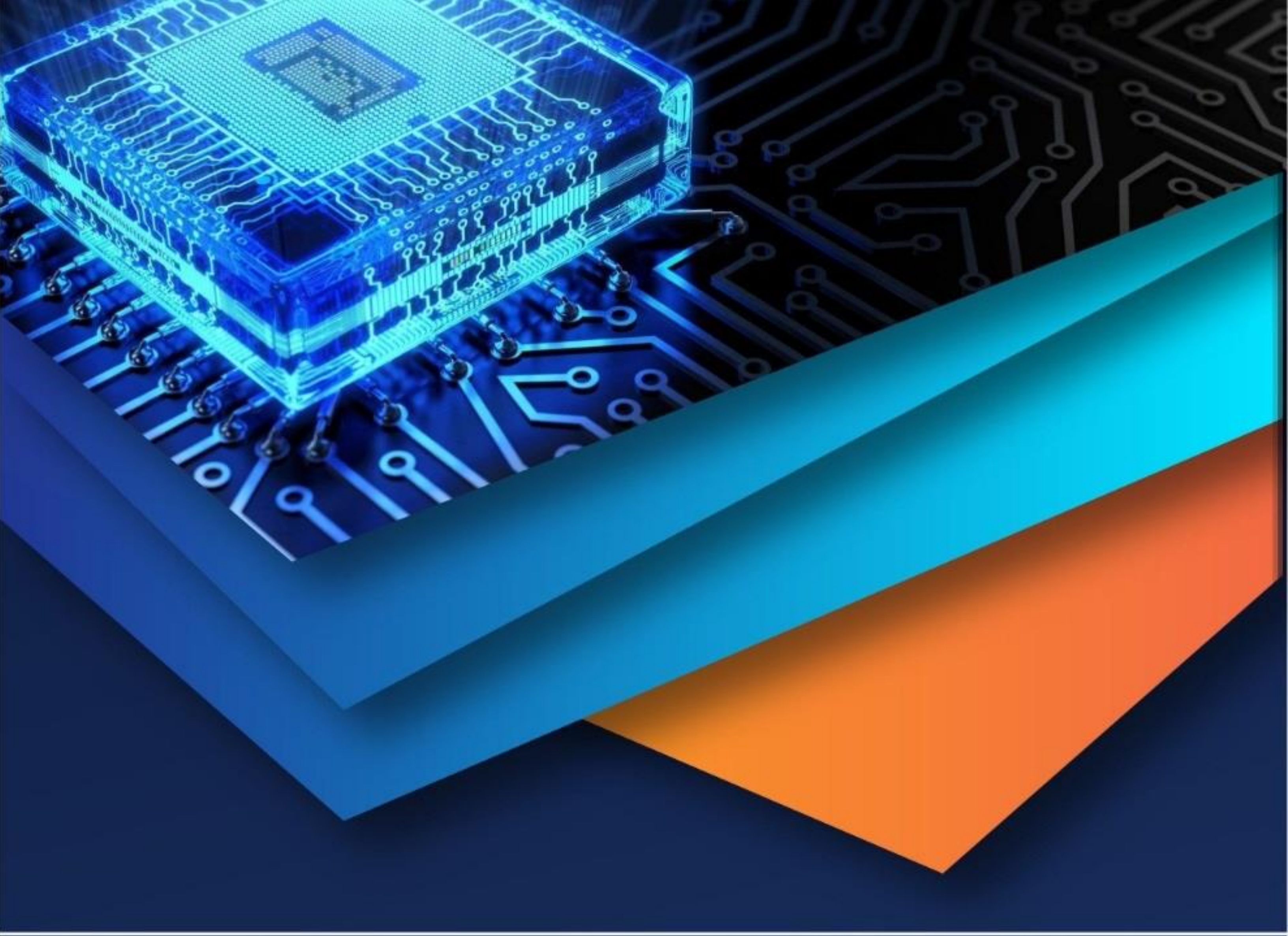
Further development for this concept is required as the COVID-19 pandemic is spreading. Future iterations will incorporate changes prompted by the results of our system testing. It will incorporate an adjustable inspiratory to expiratory ratio. We had also incorporated add- on features including a PEEP valve, a humidity exchanger and a blow-off valve. Since BVM infrastructure already supports commercial add- ones, these components can be easily purchased and incorporated. Ways to minimize dead space will be explored; including the option of using a BVM whose valves can be placed at the patient end of the tubing. In later iterations we hope to be independent by manufacturing our own bags or contracting their production. The design is going to be changed to be injection molded such the mass-produced a version would. Consideration to a pediatric version also will tend. Cam arm shape is going to be optimized to make sure the utilization of the foremost efficient rolling contact embodiment. An LCD screen is going to be included, and alarms programmed for loss of power, loss of breathing circuit integrity. Extensive testing of the ventilator's repeatability is going to be conducted. Finally, we'll test the ventilator on a lung model to satisfy ventilator standards and market the merchandise.

VII. ACKNOWLEDGEMENT

We express our deep sense of gratitude to our respected and kind guide Prof. A.K.Parekh for their valuable help and guidance. We are thankful to them for encouragement they have given us in completing the project. We are also thankful to all the other faculty and staff members of our department for their cooperation help.

REFERENCES

[1] “DESIGN AND PROTOTYPING OF A LOW-COST PORTABLE MECHANICAL VENTILATOR” by author Abdul Mohsen Al Husseini1 , Heon Ju Lee1 , Justin Negrete1 , Stephen Powelson, Massachusetts Institute of Technology, Department of Mechanical Engineering 2Boston University, School of Medicine.
[2] “LOW-COST, EASY-TO-BUILD NONINVASIVE PRESSURE SUPPORT VENTILATOR FOR UNDER-RESOURCED REGIONS: OPEN SOURCE HARDWARE DESCRIPTION, PERFORMANCE AND FEASIBILITY TESTING”, by author Onintza Garmendia, Miguel A. Rodríguez-Lazaro, Jorge Otero
[3] “DESIGN OF PLC CONTROLLED AUTOMATIC BAG PICKING MECHANISM FOR THE PACKAGING UNIT OF KMML” by author raju.c, udayakumar.s
[4] Chan-yeung M, Ait-khaled N, White N, IP MS, Taan WC "THE BURDEN AND IMPACT OF COPD IN ASIA & AFRICA "2004-Survey
[5] John Wiley & sons, “WEBSTER'S NEW WORLD MEDICAL DICTIONARY FIRST, SECOND AND THIRD EDITION. May 2008”-Survey
[6] Am J Respir Crit Care Med Vol.196, P3-4 2017 “ATS PATIENT EDUCATION SERIES 2017” American Thoracis Society. -Survey
[7] Fawcett J N 1981 "CHAIN AND BELT DRIVE - A REVIEW" Shock Vib Dig. 13(5)pp 265-278
[8] Juvinall R and Marshek, K 2000"FUNDAMENTALS OF MACHINE COMPONENTS DESIGN " Wiley, new york-Book
[9] Robert L Chatburn “ENGINEERING PRINCIPLES APPLIED TO MECHANICAL VENTILATION” -Book



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