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A REVIEW ON PORTABLE VENTILATOR WITH BUILT IN OXYGEN GENERATOR

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Abstract - *The main objective of this paper is to review the working of low cost and cheap ventilators and methods used to produce oxygen from the air for medical purposes. 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. The standard system requires oxygen cylinders externally. 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 costly and requires high maintenance. Keywords: Ambu bag, CAM operated arm, Emergency ventilation system, Oxygen generator, positive pressure ventilation, Portable, Splitter, zeolite crystal.*

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1. 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.

The present ventilators in hospitals use separate oxygen cylinders containing pure oxygen. In this paper we are going review methods to make a ventilator with a simple mechanism and cost-effective, also we are going to review various methods that can be used to produce high concentration oxygenated air from ambient air.

1.1 MECHANICAL VENTILATOR USING CAM MECHANISM.

[1] Mechanical Ventilator provides necessary breathing when a traditional Bag Valve Mechanism (BVM) is compressed with the help of pivoting cam arm. Due to this process, the delivery of breaths can be made automatically instead of any human operator for the BVM. This BVM with pivoting cam arm is operated by an electric motor having a 14.8v DC battery and also having a feature to adjust a tidal volume up to 750ml. The number of breaths per minute and tidal volume is set by convenient input knobs.

This cam-actuated BVM compression is one of the options to obtain low cost, less power, mobile ventilator technology which can fulfill the requirements of necessary ventilator parameters at a low cost than the current technology cost..

1.2 ROLLER-CHAIN CONCEPT

[1] The Roller Chain concept uses roller chains having the diameter of roller greater than link width. The circumference of the Bag is covered around by a very compact chain. The sprocket of the chain joints with the shaft of the motor. Its clockwise or anticlockwise rotating feature can deliver the breath by expanding or compressing the bag. Initially, this idea looks very feasible, but some of the experiments disclosed that BVM with radial compression needs a higher force than the BVM with vertical compression. Working on this mechanism is noisy, and under the radial compression, the bag was a squeeze. This mechanism does not provide the continuous and accurate tidal volume, also hampers the pure Rolling Motion.

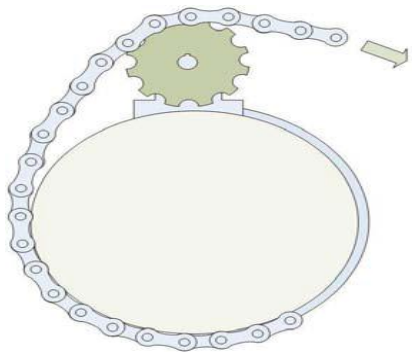


Figure 1. ROLLER CHAIN CONCEPT

1.3 CAM CONCEPT

[1] The CAM Concept uses a curved cam to compress the BVM, which gives constant air delivery with smooth and continuous deformation. When the cam rotates it makes rolling contact with the surface of the bag.

This concept requires lower power than the roller chain concept. This cam works with low noise by controlling the camshaft angle. Also, the delivery amount of air volume can be exactly controlled. Therefore, this concept method is a choice rather than a roller chain concept.

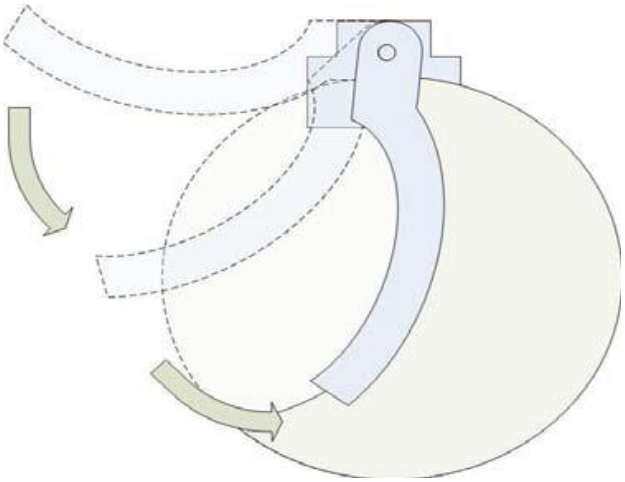


Figure no.2. Cam concept

[2] This is a very simple and low-cost design made using readily available components, this can be manufactured quickly and easily in small quantities or in large quantities at low cost to work reliably with the lowest risk to the patient. The use of this design is very simple and we can manufacture this in large quantities in a faster way due to the following reasons Automated production:

- The production of each part is fully automated.
- Minimal of- the - shelf components: Very few different components are needed and no exotic parts are needed (not even a motor coupling).
- Simple mechanism: It uses a super simple mechanism with just an arm mounted to a motor – no complicated mechanisms to go wrong, just one moving part
- Adjustable settings: Has full adjustment of breath frequency, pressure & tidal volume alarms.
- Low cost: £100 - £200 total cost is likely possible with volumes of 100s - 1000s

This device was tested at the National Physical Laboratory on 04/05/2020 against the MHRA testing plan with good results. An attached image (fig 4) is showing a comparison between a waveform measured from Open Vent-Bristol & an existing ICU ventilator. The Open Vent-Bristol produces an almost similar result as produce by the ICU ventilator. [2] For the purpose of safety, they have kept the value of pressure below 45 cm of H2O & Tidal volume below 800 ml with the tolerance of +100 ml, anything beyond this limit will risk barotrauma (lung damage). These limits are lower than those which would be necessary to meet MHRA requirements.

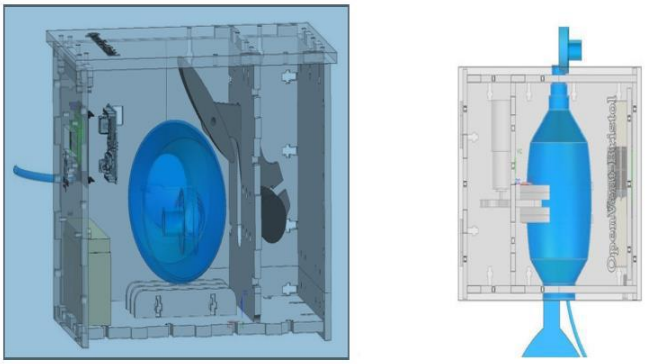


Figure 3

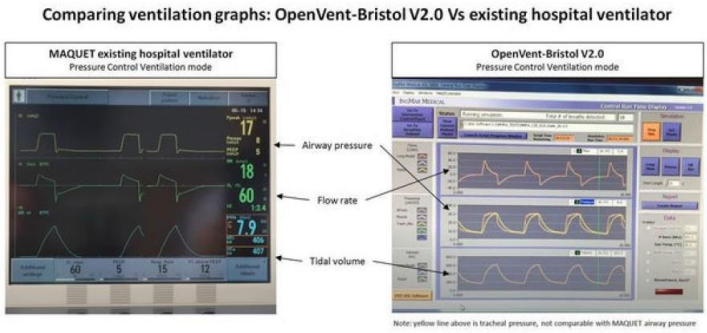


Figure 4. Comparing ventilator graph

1.3 COMPUTER-AIDED MANUFACTURING ARM MECHANISM

CAM is a device that converts the rotary motion of a servo motor into linear motion. This is used to compress the Ambu bag to deliver the required volume. The main advantage of selecting the cam mechanism is that it applied a higher torque, its value is approximately 1.5 N-M. These arms are not comparable, solid, and durable.

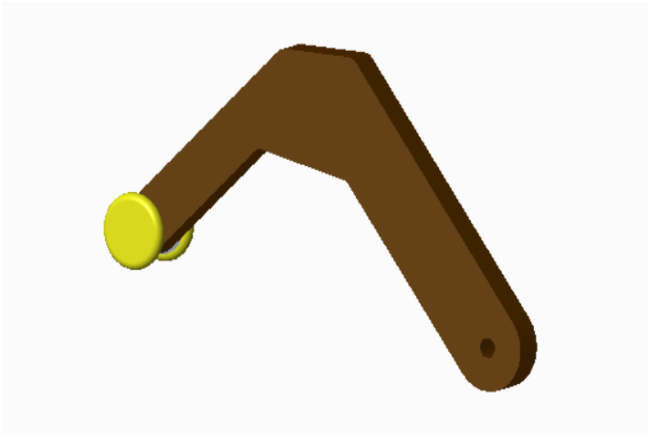


Figure 5. Cam lever arm

2. METHODS FOR OXYGEN GENERATION

[3] Pure oxygen can be generated by various methods to deliver for use in medical applications and many other applications. Two main areas of use for pure oxygen are breathing purposes for patients and the aerospace industry. Pressurized oxygen can be stored in cylinders as liquid oxygen in what is commonly called Dewar.

[3] Recently oxygen is being concentrated or generated in real-time using a variety of molecular sieves to separate and concentrate oxygen from a pressurized ambient air source. There are two methods to achieve this i.e. Pressure Swing adsorption process (PSA) or a vacuum pressure swing adsorption (VPSA) process. Oxygen generated by PSA is low cost and readily available. However, the oxygen concentration on these produced is about 90 to 95%. [5] Pelletized zeolite is used as the air separation adsorbent.

[3] Oxygen can also be generated using an electrochemical process known as a ceramic oxygen generating system (COGS). In this the oxygen molecules are ionized at one surface of a ceramic membrane then transports this ion through the membrane, and reforms them as oxygen molecules on the other surface of the membrane, and removes the excess electrons from the ions.

[4] An electrolysis process is the easiest method to separate oxygen molecules from water. In this, a voltage is applied between the two electrodes i.e. cathode and the anode which are dipped inside water. When voltage is applied electrolysis process occurs due to which the hydrogen and oxygen molecules get separated. Oxygen gas gets accumulated at the anode, this oxygen can be collected. The rate of oxygen produced through this method is quite low and it requires a humidifier.

3. CONCEPT

A system can be created which can provide medical assistance to more than one patient at a time and can generate concentrated oxygen from ambient air and is cost-effective. This system is consisting of two parts i.e. ventilation and oxygen generation.

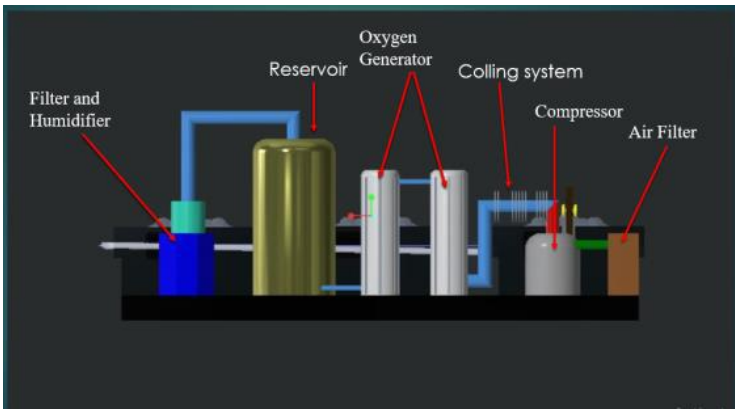
The basic idea of ventilation comes from the BMV (bag valve mechanism [1,11]. In this project, we are designing a mechanism that will compress the Ambu bag which in turn will provide the necessary breathing to a patient, and also there is an electronic circuit [2,11] that will control various parameters such as PEEP, tidal volume, breath per minute.

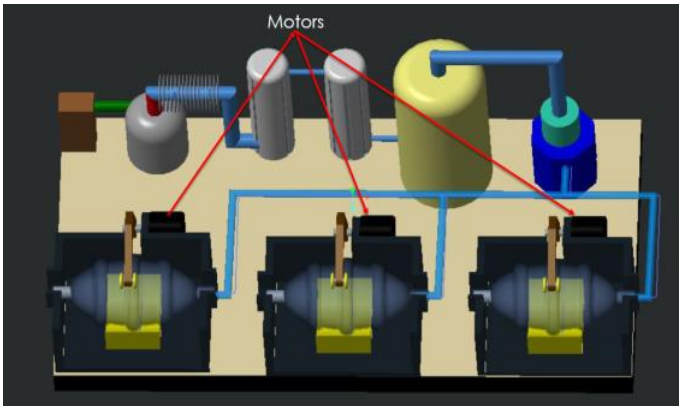
Another part of the project is the Oxygen generator, there are various methods to generate oxygen. The most feasible and efficient method we found is by using [5] **Pressure swing adsorption process which uses pelletized Zeolite crystals** as a separator.

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

So, for example generally, the tidal volume of 25 years and 63-kilogram weight adult person is equal to (7 ml/kilogram×63 kilogram) or 441 ml

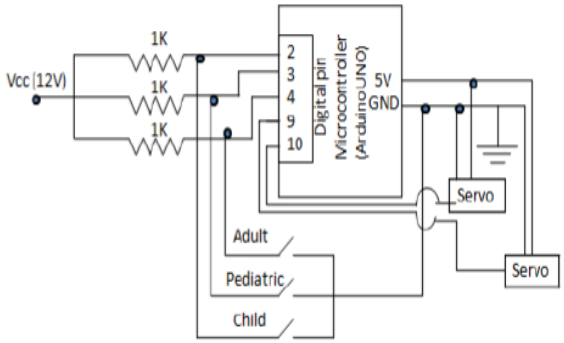
It can provide up to 98 % pure oxygen if used properly. The proposed concept for the ventilator and oxygen generator is shown.





3.1 PROPOSED CIRCUIT DIAGRAM

[11] This circuit diagram for a mechanical ventilator is proposed by "Md. Rakibul Islam" In his paper on" Designing an Electro-Mechanical Ventilator Based on Double CAM Integration Mechanism ". He designed the circuit for three modes of operation which are adult, pediatric, and child. The proposed circuit diagram generally consists of resistors, servo motors, microcontrollers, selector switches for selection of different modes of operation, and a 12-volt power supply is added to get high torque from the servo motor. The input and output pins are set to the digital pin of the microcontroller. This circuit diagram is simple in construction and user-friendly and can be used in any mechanical ventilator which is operated by cam.



4. CONCLUSIONS

From the detailed study of a various 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 Ambu bag based 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.

We have also observed that in the case of an emergency or rural area the supply of oxygen is a crucial problem in process of ventilation. So we have reviewed some methods to generate oxygen from ambient surrounding air which can solve the problem for the supply of oxygen in case of emergency.

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.

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