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Electro-Mechanically Actuated Resuscitator for Open Source Ventilator Support

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Abstract - This paper deals with a conceptual design of an innovative rack and pinion system into the existing ventilator system. The modified rack and pinion mechanism that converts rotary motion into a reciprocating motion for its forward stroke and return stroke. In this mechanism, the to-and-fro motion of the rack can be used to apply pressure on the Ambu bag or technically known as the manual resuscitator, which can be used to provide positive pressure ventilation to patients who are having breathing trouble. The major advantage being that the forward and return stroke of the rack and pinion can be used to apply pressure on two Ambu bags thereby providing ventilation to two patients, at a time. Ease of manufacturing and is added advantage when compared to the existing actuator unit used in ventilator systems. In the recent COVID-19 pandemic crisis, the world is facing the scarcity of ventilators. This proposal may help to produce open-source ventilator support to be used as an alternative in times of crisis.

Key Words: Reciprocating mechanism, Ambu bag, ventilation, tidal volume.

1.INTRODUCTION

The major purpose of the ventilator is to decrease the work of breathing until patients improve enough to no longer need it. The existing technology used in the ventilators is based on

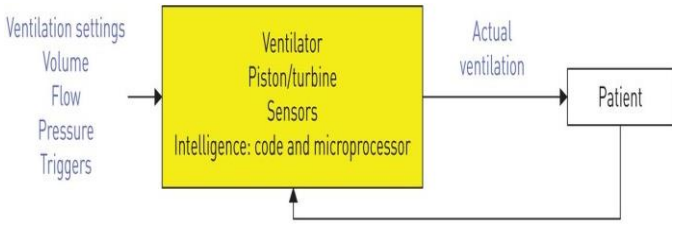

Fig -1: Schematic diagram of ventilator System

the usage of pistons, turbines to supply oxygen from the oxygen tanks to the patient. In other words, when inspiration is triggered on, the output control valve opens, the expiratory valve closes, and the only path left for the flow of oxygen is into the patient. The schematic diagram as depicted in Fig.1, explains visually the flow and feedback-controlled ventilator system functioning. The outlet flow valve that creates a pressure difference to draw oxygen from the cylinder to the patients.

Recently due to the COVID-19 pandemic, a lot of innovative ideas have been made in ventilators by using various kinds of actuator mechanisms to reduce the cost and manufacturing time. This includes replacing the existing technology with pneumatic actuators, CAM operated mechanisms, etc.

A UK based vacuum cleaner company, Gtech Ventilators [1], developed a ventilator by using pneumatic controls to apply pressure on the Ambu bags (refer Fig.2).

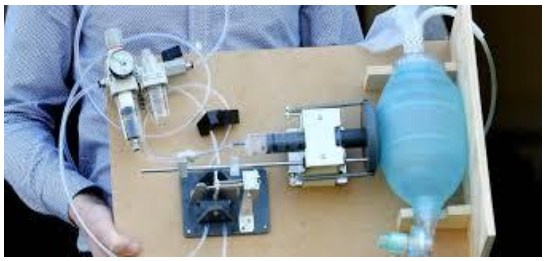

Fig -2: Gtech ventilator

Likewise, an interdisciplinary team of Vanderbilt University medical team has fabricated an open-source ventilator which is actuated by a windshield motor [2].

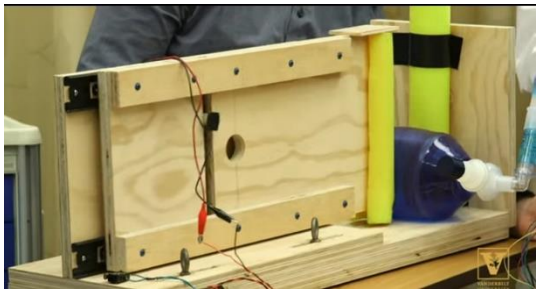

Fig -3: Open source ventilator

The proposed design includes a rack and pinion mechanism, that can be used to translate the rotary motion into reciprocating motion. The forward and backward stroke can be used to apply pressure on two Ambu bags. In other words, electromechanical actuation can be used to compress the Ambu bag, delivering positive ventilation to the patient consistently.

The proposed electromechanically actuated resuscitator, at a time, can deliver positive ventilation to two patients with incorporated digital metering valves providing digital feedback, ensuring controlled ventilation to treat patients.

2. VENTILATORS –MEDICAL REQUIREMENTS

Robert L. Chatburn[4] developed the simplest mechanical device we could devise to assist a person's breathing would be a hand-driven, syringe-type pump that is fitted to the person's mouth and nose using a mask. A variation of this is the self-inflating, elastic resuscitation bag. Both of these require one-way valve arrangements to cause air to flow from the device

into the lungs when the device is compressed, and out from the lungs to the atmosphere as the device is expanded. These arrangements are not automatic, requiring an operator to supply the energy to push the gas into the lungs through the mouth and nose.

Abdul Mohsen Al Husseini[5] developed 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. 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. The employed motor can produce a torque of 1.5Nm to 2.5Nm, effective to produce an average of 200 mL to 750mL tidal volume and 5 to 30 breaths per minute (bpm). This yields maximum minute ventilation of 21L and a minimum of 1.5L.

3. ELECTROMECHANICAL ACTUATED AMBU BAG

3.1. CONSTRUCTION

The most important elements of this mechanism are the motor, circular disk, slotted arm, and the rack as shown in Fig.3.The material used for making these elements is aluminum, considering the weight and anti-corrosive property of the material. The motor has provision to be operated at various speeds. The motor is connected to the circular disc. A rhino 230V AC 12V DC, 100rpm, and 2.8Nm torque planetary geared motor is found effective to deliver the functional requirement. The slotted arm is connected to the circular disk using a crankpin, and there is a rack that uses the reciprocating motion to apply pressure on the Ambu bags present at both the end surrounded by an enclosure with provisions for oxygen inlet and outlet.

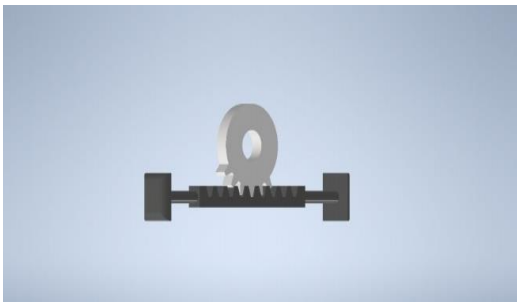

Fig -4: Rack and pinion mechanism

4.WORKING

When the power supply is switched on, an Alternating current of 230V is generated which is converted to a Direct current of 12V thus the circular disc connected to the motor starts rotating, a slotted arm is attached to the circular disk by the crank pin. The rotary motion is converted into reciprocating rectilinear motion which is imparted to the rack at the bottom by the vibration of the toothed sector. This reciprocating motion of the rack can be used to apply pressure on the Ambu bag.

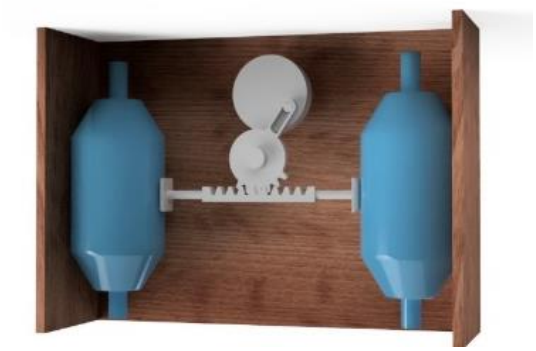

Fig -5: 3D Model of modified rack and pinion mechanism along with AMBU bags designed using AUTODESK FUSION 360

There is a forward and backward moment that takes place simultaneously, this can be used to apply pressure on two Ambu bags placed at each ends thereby providing positive ventilation to two patients at the same time. The working torque of the motor is 2.9Nm. Considering the length of the rack as 0.7m, then the force generated by the rack on the Ambu bag can be calculated to be 4.2N. Thus the force acting on each side would be approximately 2.1N.

If a force of 1.5-2.5N is applied on the Ambu bag it can produce 200-750mL tidal volume (references from journals of medical devices) and it can produce 10-15 strokes per minute (based on simulation) thus it can produce a maximum tidal volume of 11.25L and minimum tidal volume of 2L theoretically.

5.CONCLUSIONS

Our goal is to provide a new and inexpensive solution, that can be manufactured in a shorter period to manage the crisis caused by the shortage of ventilators. The major significance of this system is that the forward and reverse stroke can be used to apply pressure on two Ambu bags simultaneously thereby providing ventilation to two patients at the same time. In addition to this, the speed at which the motor operates can be varied by using a reduction speed gearbox to meet the requirement of the patients.

6.FUTURE SCOPE OF WORK

This system could be improvised and made more sophisticated by including

•A temperature sensor could be added to monitor the temperature of the air which is given to patients.
•A pressure sensor to monitor the internal pressure
•A Liquid Crystal Display screen to view all the readings from the sensor. In other words to view the output of the sensors.
•A low cost embedded board such as the Arduino board to control all the sensor-related activities.

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