Design and Modeling of an Economical & Transportable Mechanical Ventilator

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Abstract:- COVID-19 has caused significant health crises in 2019-2021, affecting lungs and limiting lung capacity. Ventilators play a crucial role in delivering 10-30 breaths per minute, adjusting air volume, and monitoring patient blood oxygen and exhaled lung pressure. A reliable and affordable DIY ventilator is designed using a silicon ventilator bag coupled with a stepper motor. The ventilator uses a double arm mechanism for inflation and deflation, with the rate of inflation and deflation based on the motor's RPM. To alter inhalation duration and BPM values, the device employs a toggle switch and an additional pot. Blood oxygen and pressure sensors monitor vitals, and an emergency alarm is fitted to alert patients in emergency situations.

Keywords:- *Ventilator bag, double arm, stepper motor, pandemic, push mechanism.*

I. INTRODUCTION

Pulmonary illnesses and injury-induced breathing disorders are serious public health concerns that affect nations that are both developed and developing. Respiratory ailments like asthma and COPD are prevalent, and factors like air pollution, smoking, and biomass burning are on the rise in developing countries. Mechanical ventilation support is essential for patients with pre-existing lung conditions, but the acquisition costs of advanced ventilators can be prohibitively expensive, reaching up to $30,000, making them prohibitively expensive for resource-poor countries. Mechanical ventilators are frequently unavailable in rural and distant places, necessitating the need for a low-cost, portable ventilator.

In developed nations with well-equipped medical centers, there is a lack of preparedness for mass mortality such as flu pandemics, natural disasters, and hazardous chemical releases. The expense of collecting and deploying cutting-edge mechanical ventilators for such circumstances is prohibitively expensive, as demonstrated by Hurricane Katrina. However, due to the limited number of ventilators on hand and their high cost.

II. LITERATURE SURVEY

A. Acute Respiratory Infections in developing nations: Prevention, Management Strategies

Chronic respiratory disorders, due to their frequency, magnitude, and economic operation, supply a substantial challenge to public health in nations that are developing. Healthcare planners must prioritise limited resources while implementing smoking prevention and standardised asthma and COPD treatment programmes. To reverse cigarette smoking patterns and boost the use of generic medications, particularly corticosteroids, international action is required. Customising guidelines to local settings, improving equipment, obtaining high-quality pharmaceuticals at affordable prices, educating health-care workers, and assessing performance are also recommended. Through social activation, professional associations, non-governmental organizations, and the media can increase government commitment to tobacco control and standardised case management.

B. Field Mobile Ventilator Devices Developed For Civilian And Military Emergency Medical Response.

Emergency medical response is crucial in mitigating fatalities during military operations. In the absence of medical support, injured soldiers face the challenge of being transported to a facility for definitive care. The urgency for domestic mass casualty support has gained attention due to the persistent threat of terrorism. These innovative approaches are intended to meet the stringent demands of forward conflict circumstances and mass losses among civilians. The lightweight, portable ventilators provide immediate respiratory support to injured soldiers and victims in remote or inaccessible areas, making them compact, easily transportable, and capable of withstanding challenging environments. Their lightweight nature allows medical personnel to deploy them quickly to the scene of emergencies, enabling timely intervention and significantly improving survival chances for those in need.

C. Low-Cost Portable Mechanical Ventilation Designed And Prototyped.

This paper presents the design and development of an affordable, portable mechanical ventilator for mass casualty scenarios and resource-poor environments. The ventilator uses a pivoting cam arm to compress a conventional bag-valve mask, eliminating the need for manual operation by a human operator. The prototype, made of acrylic, has dimensions of 11.25 x 6.7 x 8 inches (285 x 170 x 200 mm) and weighs 9 lbs. It is powered by an electric motor and has adjustable tidal volume up to 750 ml. User-friendly input knobs allow for easy ventilation settings. Future iterations will include an assist-control mode and alarm system to detect over-pressurization. The prototype's cost is just $420, and the estimated price for bulk-manufacturing is less than $200. This cost-effective solution demonstrates the viability of the cam-actuated BVM compression strategy, making it particularly valuable in resource-limited settings and situations with high casualties.

ISSN No:-2456-2165

D. COVID-19 And Future Pandemics: An Overview Of Free Software Ventilation systems

Threatens medical infrastructure, resulting to increasing death rates owing to a lack of key equipment such as ventilators.. This research examines existing and publically available ventilation system designs, analysing them for both spirit and practical aspects. The research also looks at current open source ventilator projects and designs on the Internet and in the grey literature. Small-scale technology for manufacturing, on the other hand, such as RepRap-class printers for three-dimensional printing and open source microcontrollers as have a chance to address shortages in supplies. With the current epidemic, these initiatives are likely to get more attention and money in order to make considerable progress towards a workable and readily replicable system.

III. METHODOLOGY

A silicon ventilator bag is used with a stepper motor and a double arm mechanism to achieve inflation and deflation. The stepper motor drives the mechanism, it converts rotary motion into linear motion. The pressing arm is mounted on top of the ambu bag and connected to a joint mechanism. The stepper motor rotates and pushes the arm upward, pressing against the bag on the other end. The rate of inflation and deflation depends on the motor's RPM. The RPM is varied to achieve the desired BPM rate. The individual's breathing duration and BPM values can be modified utilizing a switch with a toggle and adjustable pots.. The system uses a stepper motor and a driver system called "A4988 DRIVER" to control the stepper motor. The dual arm mechanism converts rotational motion into linear motion, while the lever arm pushes the ambu bag. The pressure can be varied using programmed codes. The LCD display provides information about the patient's condition and motor rpm, supported by the ARDUINO UNO R3 with appropriate codes. The stepper motor is also provided with air supply, current condition analysis, and data recording.

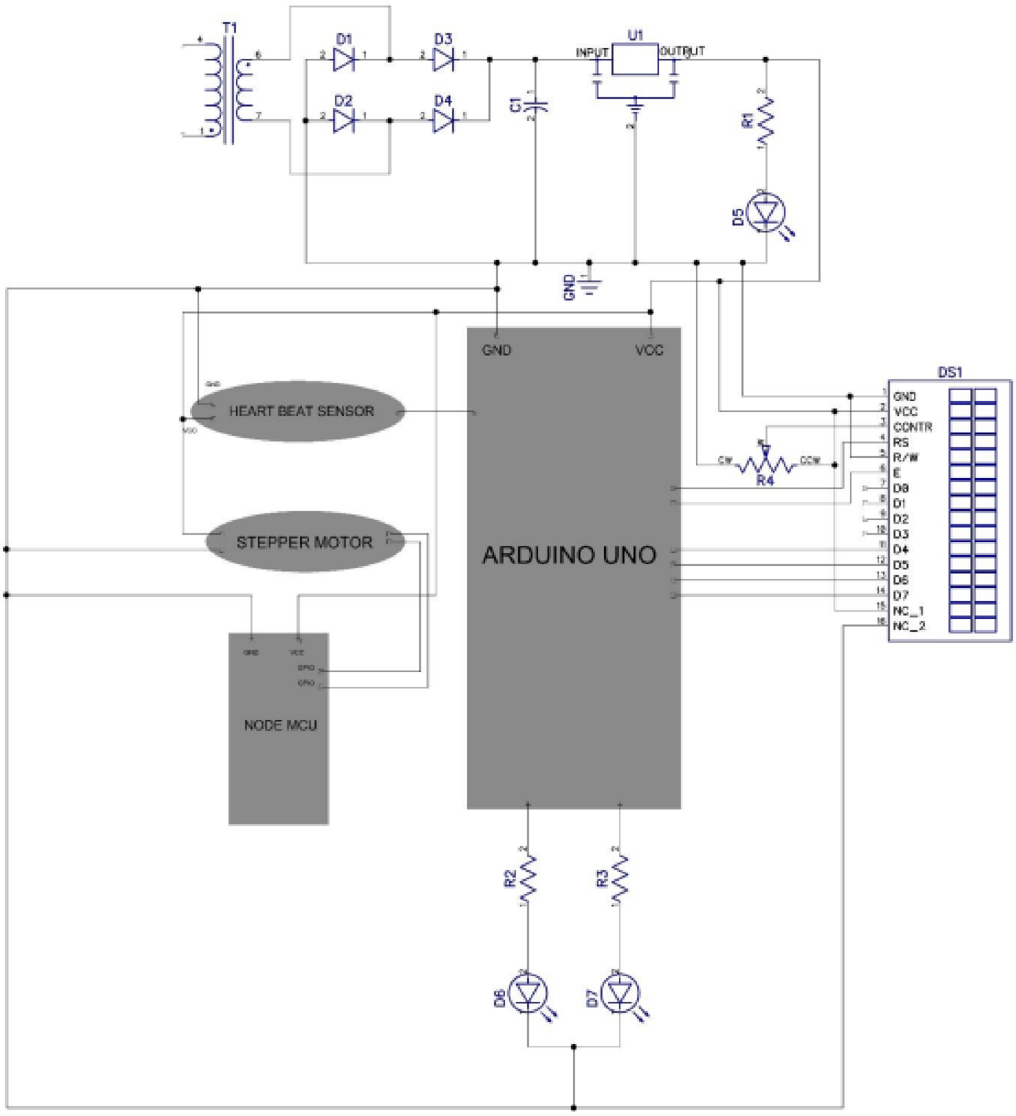

Fig. 1: Circuit diagram

IV. HARDWARE COMPONENTS

A. STEPPERMOTOR NEMA23

NEMA 23 is a stepper motor type with a faceplate dimension of 2.32.3 inches (58.458.5 mm) with 200 steps per revolution. Each phase uses 2.8 A at 3.2 V, resulting in a holding torque of 19 kg-cm. NEMA 23 stepper motors are frequently encountered in printers and CNC machine tools.

B. 3D PRINTED PARTS

The method that produces a three-dimensional object from a CAD model or a computer-generated three-dimensional model is referred to as 3D printing.

C. DUAL ARM MECHANISM

Arm mechanism is connected to stepper motor shaft. Provides the required torque and power to the push and retract mechanism. Regulates the push and controls the jerk.

D. PUSH AND RETRACT MECHANISM

The main purpose of the mechanism is to push the ambu bag in the required pressure. It provides the up and down of the lever arm. It is mounted on the push and retract mechanism supporting arms.

E. STEPPER MOTOR MOUNT

To support the motor system a mount is provided which support the entire mechanism of the motor and the lever arm.

F. AMBU BAG MOUNT

Ambu bag mount is used to support the ambu bag. It consists of 700ml volume of atmospheric air when the lever arm pushes ambu and provides air to the patient.

G. PUSH AND RETRACT MECHANISM MOUNT

The support push and retract system. It provide to ensure the strength and stability to the system.

H. AMBU BAG

It carries 700ml of atmospheric air, that the arm of the lever pushes and distributes to the patient. It is also known as a "self-inflating bag" and is a man-powered device that is widely used to deliver oxygen through high-pressure ventilation for individuals who are not inhaling or are not inhaling properly.

I. MICROPROCESSORS

- *NODE MCU*

The NODE MCU uses a driver system A4988 to control stepper motor operation and power the lever arm, also known as ESP8226. Programming code changes can achieve desired rotation based on patient requirements.

J. FRAME

The frame material used in the project is acrylic sheet of size 53×31×25 cms. The frame material supports the whole structure of the system and provides stability and strength to the entire structure. The base consist of 6mm thickness and other sides of the frame consist of 3mm.The lever arm and other 3D printed parts are attached to the system through screws and nuts. The stepper motor attached one end of the system and lever arm attached to the stepper motor and ambu bag connected to the other end of the system.

V. FIGURES

Fig. 2: Design of portable ventilator

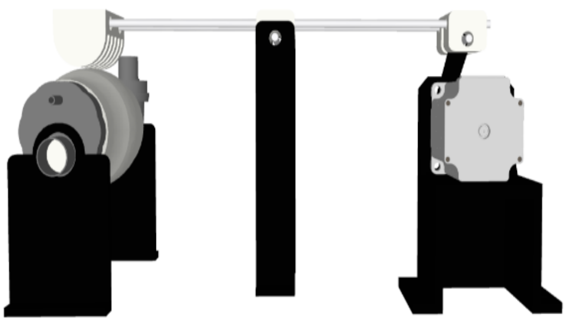

Fig. 3: Side View of Design

VI. RESULT AND DISCUSSION

The design and the prototyping of the portable and cost efficient ventilator according to the requirements and the specification was properly built by the effort of every member of the group. The prototype is tested with suitable subjects and datas are collected and analysed, the system is efficient as per the assumptions calculated earlier. The system is mounted on the frames which efficiently holds each components and provide proper strength and stability to the system. The dual arm mechanism which converts rotational motion into linear motion is perfectly established and inflation and retraction of the ambu bag is achieved the amount of air is provided through proper programme instructions that are given earlier, The sensors rapidly transmit accurate values of the test subject's heartbeat and blood oxygen level, and these data are assessed and collected; they are also compared with standard equipment, and maximum efficiency is attained quickly through the current setup. The project's goal was successfully met, and the results have been thoroughly looked at.

A. Advantages

- Mobility and Versatility.
- Battery Backup.
- Ease of Use.
- Advanced Respiratory Support.
- Higher Ventilation Capacity.
- Monitoring and Alarms.

B. Applications

- Intensive Care Units.
- Emergency Medical Services (EMS).
- Operating Rooms.
- Home Care.
- Transport Ventilation.
- Sleep Apnoea Treatment.
- Field Hospitals and Disaster Relief.
- Pulmonary Function Testing.

VII. CONCLUSION

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