DESIGN AND FABRICATION OF PORTABLE OXYGEN VENTILATOR

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ABSTRACT:

This article presents the design and development of a portable oxygen ventilator that utilizes a bellows compression and expansion motion driven by a slider crank mechanism. The ventilator incorporates a purifying filter to convert air into oxygenated air. The stroke rate of the bellows is adjusted by a motor, whose RPM is regulated by an Arduino microcontroller using an L298N motor driver and a potentiometer. The stroke rate, volume of air, and RPM are displayed on an LCD screen. This ventilator has the potential to provide oxygen therapy in emergency situations or in areas with limited access to medical facilities .The objective of this project is to design and implement a portable ventilator system capable of providing reliable, adjustable, and cost-effective respiratory support in emergency scenarios. Traditional ventilator systems, while effective, are often bulky, expensive, and require specialized personnel for operation. These limitations make them unsuitable for use in resource-limited settings, remote locations, or disaster-stricken areas. This project seeks to address these challenges by developing a compact, user-friendly, and affordable solution that can be deployed in a variety of critical care environments. The proposed ventilator incorporates adjustable breath control, allowing users to customize parameters such as breath length and the number of breaths per minute (BPM). This level of adaptability ensures that the device can accommodate diverse patient needs, ranging from mild respiratory distress to severe cases requiring critical care. This makes the system versatile and suitable for use across different patient demographics, including paediatric and adult patients. Portability is a core focus of design. By creating a lightweight and compact device, the ventilator becomes easily transportable, enabling deployment in ambulances, field hospitals, disaster relief operations, and even home care settings. Its portable nature ensures that lifesaving respiratory support is always accessible, particularly in scenarios where traditional ventilators are impractical or unavailable. Affordability is another key objective of this project. By utilizing cost-effective components such as DC motors, microcontrollers, and basic electrical circuits, the ventilator minimizes production costs without compromising functionality or reliability. This makes it a viable option for healthcare providers operating on constrained budgets and in low-resource environments.

1. INTRODUCTION

Respiratory diseases and critical health conditions often require the use of ventilators to assist or replace spontaneous breathing. While conventional ventilators are effective, they are often bulky, expensive, and unsuitable for emergency or remote applications. Portable ventilators provide a viable solution by offering mobility and ease of operation, making them ideal for on-site medical emergencies and low-resource settings.

This study focuses on designing a cost-effective and efficient portable ventilator that employs a bellows mechanism for air compression and decompression. The stroke rate of the bellows is controlled by a slider-crank mechanism powered by a 12-volt DC motor. To achieve precise control over motor RPM, the system incorporates an Arduino microcontroller and an L298N motor driver. A potentiometer enables manual adjustment of the stroke rate, while an LCD display provides real-time feedback on system parameters. The device also integrates a purification filter to convert ambient air into oxygen-enriched air, ensuring the delivery of clean and safe air to the patient.

The objectives of this study include:

Designing a portable ventilator with an efficient bellows mechanism. Developing an Arduino-based control system for motor RPM regulation. Ensuring real-time monitoring of critical parameters like stroke rate, motor RPM, and air volume. Evaluating the performance of the device in simulated conditions.

2. RESEARCH AND METHODOLOGY:

System Design The portable ventilator comprises three main subsystems: the mechanical subsystem, the control subsystem, and the air purification subsystem.

Mechanical Subsystem:

The bellows mechanism forms the core of the device, responsible for compressing and decompressing air. A slider-crank mechanism driven by a 12-volt DC motor powers the bellows.

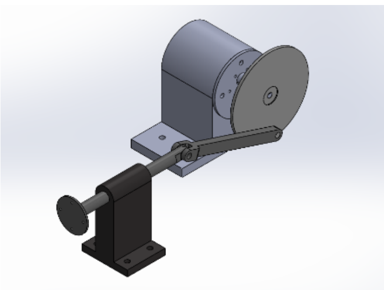

Fig.1 Slider crank mechanism

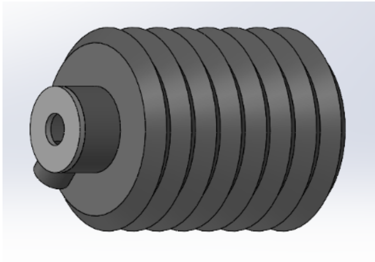

Fig.2 Bellows with intake and exhaust valves

The stroke length and rate of the bellows are optimized to deliver the required air volume and pressure for effective ventilation.

Control Subsystem:

The motor speed is regulated using an Arduino Uno microcontroller and an L298N motor driver .A potentiometer allows the user to manually adjust the motor RPM, thus controlling the stroke rate of the bellows. The microcontroller calculates and displays the stroke rate, motor RPM, and air volume on a 16x2 LCD.

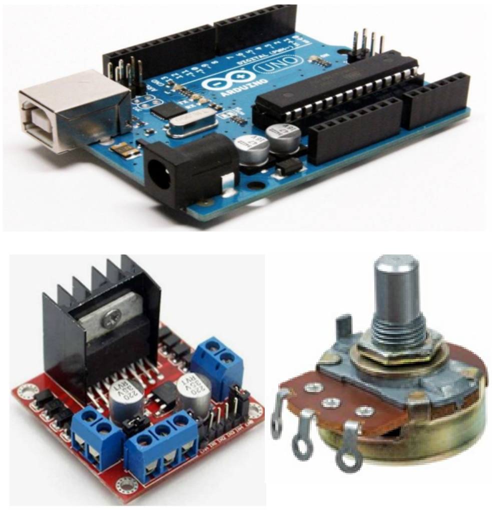

Fig.2 Various electrical components i.e. Microcontroller, Motor driver and Potentiometer.

Air Purification Subsystem:

. For the air filter, the primary focus was on delivering clean, contaminant-free air to the patient. High-efficiency particulate air (HEPA) filters were selected for their ability to trap fine particles, bacteria, and viruses, ensuring medicalgrade filtration efficiency of ≥99.97% for particles ≥0.3 microns. Activated carbon filters were also considered to remove chemical contaminants and odors. Filtration efficiency and pressure drop across the filter were tested to ensure minimal airflow resistance while maintaining high purification standards. The filters were strategically placed at the air intake points and designed for easy replacement to ensure hygiene and long-term functionality. This methodology ensured that both the bellows and air filter met the requirements for reliability, safety, and efficiency in the portable ventilator design.

Power system:

Fig.4 SMPS

The system is powered by Switching Mode Power Supply(SMPS) which will produces 12v output voltage from standard 220v AC power supply.

CIRCUIT CONSTRUCTION:

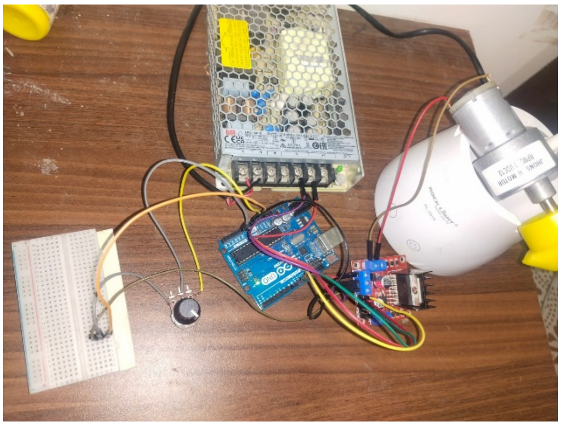

Fig.5 Electronics circuit connections for motor speed modulation using Potentiometer, SMPS.

The circuit design for the portable medical ventilator focused on simplicity, reliability, and precision in controlling the motor-driven system. A microcontroller, such as an Arduino, was used as the central control unit to regulate the operation of the DC motors responsible for compressing and releasing the bellows. The circuit included a motor driver module to provide the necessary current and voltage for motor operation, ensuring smooth and precise control of speed and torque. A power supply unit, consisting of a rechargeable lithium-ion battery and a voltage regulator, was integrated to ensure portability and stable operation. User inputs were facilitated through adjustable knobs or potentiometers connected to the microcontroller, allowing real-time control of parameters like breaths per minute (BPM) and breath duration. A toggle switch was added for simple activation and deactivation of the ventilator. Safety features, such as an overcurrent protection circuit and low-battery indicator, were incorporated to enhance reliability. The circuit was designed on a compact printed circuit board (PCB) to maintain the device's portability while ensuring efficient electrical connections and minimal power loss.

System Implementation

Hardware Components:

Bellows and Slider-Crank Mechanism: Designed to ensure consistent air delivery.

12-Volt DC Motor: Drives the slider-crank mechanism.

Arduino Uno: Serves as the control unit.

L298N Motor Driver: Interfaces the motor with the Arduino.

Potentiometer: Adjusts motor RPM manually.

LCD Display: Displays real-time system data.

HEPA Filter: Purifies the air.

Software Development:

Arduino IDE was used to program the microcontroller.

The code includes modules for motor speed control, sensor data acquisition, and LCD interfacing.

Testing and Calibration:

The system was tested under various conditions to optimize performance.

Calibration of the potentiometer and motor driver ensured accurate control of the stroke rate.

3. RESULTS AND DISCUSSION

Performance Evaluation of the portable ventilator was evaluated for its efficiency, reliability, and adaptability. Key performance metrics included:

Stroke Rate:

The stroke rate was adjustable between 12 and 30 strokes per minute, aligning with typical respiratory rates for adults.

The motor RPM was found to vary linearly with potentiometer adjustments, providing precise control over the bellows mechanism.

Air Volume:

The bellows delivered a consistent air volume of 500-600 mL per stroke, suitable for average tidal volumes in adults.

Air volume fluctuations were minimal, indicating a stable mechanical design.

Air Purification:

Ambient air is drawn into the bellows and passes through a high-efficiency particulate air (HEPA) filter. The filter removes particulate matter and enhances oxygen concentration, delivering purified air suitable for medical use

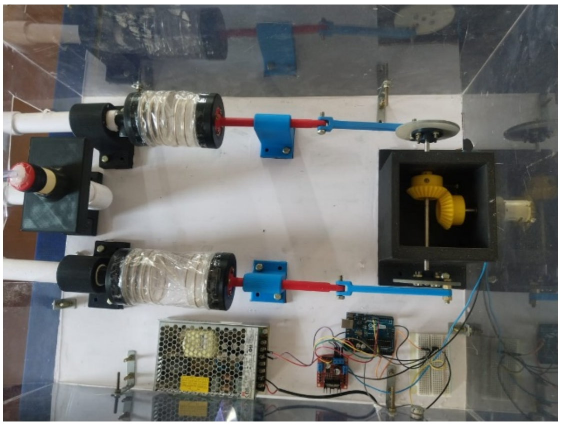

Fig.6 The Top view of the portable ventilator displaying the system arrangements and power transmission using bevel gear mechanism.

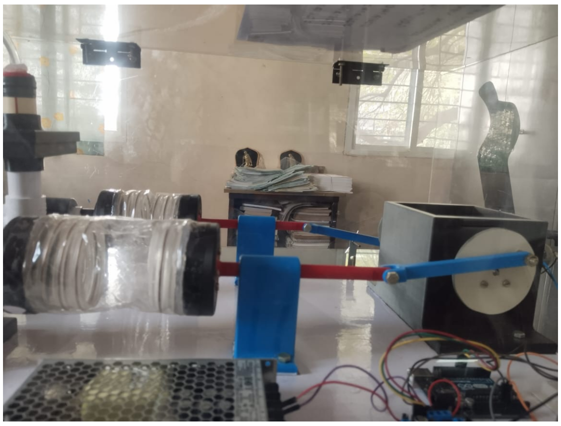

Fig.7 The Slider Crank Mechanism

Real-Time Monitoring:

The LCD display accurately displayed stroke rate, RPM, and air volume in real-time, enabling user-friendly operation.

Discussion the results demonstrate that the proposed ventilator design is effective in delivering consistent and purified air for respiratory support. The integration of Arduino-based control and real-time monitoring enhances the device's usability and adaptability. The slider-crank mechanism proved to be a reliable choice for driving the bellows, offering smooth and controlled operation. Additionally, the use of a HEPA filter ensures that the delivered air meets medical standards.

One of the key advantages of this design is its simplicity and cost-effectiveness, making it suitable for low-resource settings. However, further improvements could be made to enhance the device's functionality and scalability. For instance, incorporating sensors to monitor oxygen concentration and patient feedback could improve the ventilator's performance and safety.

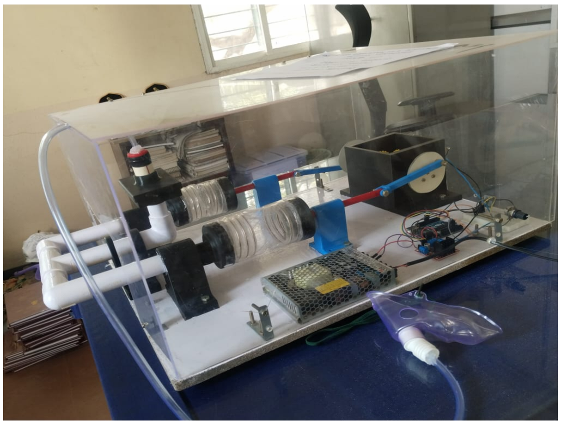

Fig. 8 Isometric View of Oxygen Ventilator.

Fig.9 The Project displaying Oxygen purifying process using bellows and slider crank mechanism to the breathing channel using mask.

4. CONCLUSION AND FUTURE SCOPE

In this paper presented a compact and cost-effective portable oxygen ventilator employing a slider-crank mechanism for bellows operation. The integration of an Arduino microcontroller, L298N motor driver, and LCD display ensures precise control and real-time monitoring of critical parameters. The ventilator successfully delivers purified air, making it a viable solution for emergency healthcare and home-based medical care. The results demonstrate the potential of the proposed design to address the challenges of portability, affordability, and ease of use in ventilator technology.

Future Scope

Enhanced Monitoring:

Integration of oxygen concentration sensors to ensure the air meets specific medical requirements.

Incorporation of patient feedback mechanisms, such as pressure sensors, to adapt ventilation parameters dynamically.

Automation and Connectivity:

Development of automated control algorithms for adjusting stroke rate and air volume based on patient needs.

Incorporation of IoT capabilities for remote monitoring and control.

Scalability and Customization:

Scaling the design to cater to paediatric and neonatal patients by adjusting stroke length and air volume.

Customization of the device for specific medical conditions.

Safety Features:

Integration of fail-safe mechanisms to detect and mitigate malfunctions.

Addition of backup power systems to ensure uninterrupted operation.

By addressing these areas, the proposed ventilator can evolve into a robust and versatile solution, meeting the diverse needs of healthcare providers and patients in various settings.

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