Design And Development of Chimney Cleaning Robot

Mr.R.Mohanraj [a], S.Dhanush [b], P.Elumalai [c], G.Logapriyan [d], S.Logeshwaran [e]

Assistant Professor, Department of Mechanical Engineering, Paavai Engineering College. [a]
UG Scholar, Department of Mechanical Engineering, Paavai Engineering College. [b]
UG Scholar, Department of Mechanical Engineering, Paavai Engineering College. [c]
UG Scholar, Department of Mechanical Engineering, Paavai Engineering College. [d]
UG Scholar, Department of Mechanical Engineering, Paavai Engineering College. [e]

ABSTRACT:
This project focuses on designing and developing of chimney cleaning robot utilizing an Arduino microcontroller for precise control. The accumulation of soot, creosote, and other combustion residues inside chimneys poses serious safety hazards, including fire risks and toxic gas exposure. Manual cleaning of chimneys is labour-intensive, unhygienic, and potentially dangerous due to confined spaces and high vertical heights. To address these challenges, this project focuses on the design and development of a Chimney Cleaning Robot capable of performing cleaning and inspection operations with minimal human involvement. The proposed robot consists of a mechanical cleaning unit, mobility system, and control electronics integrated into a compact, lightweight frame. The mechanical cleaning unit employs rotating brushes driven by DC motors to scrub and remove soot deposits from the inner surface of the chimney. A mobility system, equipped with wheels or crawler tracks, enables the robot to move vertically while maintaining stable wall contact. The cleaning process is monitored and controlled through a microcontroller based system that processes data from sensors and a camera module, ensuring efficient and safe operation inside the chimney. For control and communication, the robot uses wireless connectivity (Wi-Fi or Bluetooth), allowing real time monitoring and manual or semi-autonomous operation through a mobile or computer interface. The system also integrates ultrasonic sensors for obstacle detection and IMU sensors for orientation stabilization. A rechargeable Li-ion battery provides power for extended cleaning cycles, and LED illumination aids visibility in dark environments.

I. INTRODUCTION:

chimneys play a crucial role in removing smoke, hot gases, soot, and harmful pollutants generated during combustion processes. Chimneys are widely used in industries such as power plants, chemical factories, food processing units, hotels, restaurants, and residential kitchens. Over a period of continuous operation, chimneys accumulate thick layers of soot, grease, ash, and carbon deposits on their inner surfaces. These deposits reduce airflow, lower combustion efficiency, increase fuel consumption, and create serious fire hazards.

Conventionally, chimney cleaning is performed manually using brushes, rods, and suction tools. This method is not only inefficient but also extremely dangerous. Workers are required to enter narrow and confined chimney spaces or work at great heights, exposing them to toxic gases, excessive heat, dust, and suffocation risks. Accidents such as falls, respiratory diseases, and long-term health issues are common among chimney cleaning workers. Moreover, manual cleaning does not guarantee uniform removal of deposits, resulting in frequent blockages and repeated maintenance.

With rapid advancements in robotics and automation, there is a growing need to replace hazardous manual cleaning operations with automated systems. The **chimney cleaning robot** is designed to address these safety and efficiency challenges. It is a specialized robotic system capable of moving inside chimney ducts and removing soot and dust deposits using motor-driven cleaning mechanisms such as rotating brushes, scrapers, or vacuum systems. The robot can be controlled remotely using wired or wireless control units, thereby eliminating the need for human entry into dangerous environments.

II.RESEARCH MOTIVE:

The primary motive of this research is to address the safety, efficiency, and reliability issues associated with traditional manual chimney cleaning methods. Manual cleaning exposes workers to hazardous conditions such as toxic gases, soot, dust, high temperatures, confined spaces, and working at heights, leading to severe health risks and accidents. There is a strong need to eliminate direct human involvement in such dangerous environments.

Another important motive of this research is to improve the effectiveness and consistency of chimney cleaning operations. Conventional cleaning methods often result in uneven removal of soot and carbon deposits, causing blockages, reduced airflow, and increased fire hazards. By developing a robotic cleaning system, uniform and thorough cleaning can be achieved, thereby enhancing chimney performance and extending its service life.

This research also aims to reduce maintenance time and operational costs for industries and commercial establishments. Manual cleaning is labour-intensive, time-consuming, and requires skilled workers, which increases overall expenses. A robotic chimney cleaning system can perform cleaning operations faster with minimal human supervision, leading to significant cost savings and improved productivity.

The advancement of automation, robotics, and control technologies further motivates this research. By integrating mechanical design, electric motors, sensors, and microcontroller-based control systems, the project seeks to develop a compact, efficient, and user-friendly robot. This also provides an opportunity to apply theoretical knowledge of robotics, automation, and mechanical engineering to solve a real-world industrial problem.

Fig:1.Chimney cleaning robot

III.EXPERIMENTAL DETAIL:

The experimental work was conducted to evaluate the performance, reliability, and practical feasibility of the designed chimney cleaning robot under conditions that closely resemble real-world chimney environments. A functional prototype of the robot was fabricated by integrating mechanical, electrical, and control components into a compact structure capable of operating inside narrow chimney ducts. The frame of the robot was designed using lightweight yet strong materials to ensure durability while maintaining ease of movement. DC geared motors were selected to provide sufficient torque for both locomotion and cleaning operations, enabling the robot to move smoothly along the inner surface of the chimney while simultaneously performing the cleaning task.

To simulate actual chimney conditions, a vertical cylindrical pipe was used as a test chimney. The internal surface of the pipe was coated with soot and carbon residues collected from real chimneys to replicate the accumulation that occurs during prolonged usage. This experimental chimney setup allowed the study of robot movement, traction, and cleaning effectiveness under realistic friction and gravity conditions. The robot was positioned at the base of the chimney, and a

collection tray was placed below to gather the soot and dust removed during the cleaning process. This arrangement helped in observing the quantity of deposits removed and assessing the overall cleaning efficiency.

3.1 Design and Fabrication details

The design and fabrication of the chimney cleaning robot were carried out with the primary objective of developing a compact, efficient, and safe system capable of operating inside narrow and confined chimney structures. Special attention was given to simplicity of design, ease of fabrication, and reliability of operation. The overall design integrates mechanical structure, drive mechanism, cleaning unit, and control system into a single compact module suitable for vertical and horizontal chimney cleaning application The mechanical design of the robot consists of a rigid frame constructed using lightweight materials such as aluminium or mild steel to ensure sufficient strength while reducing overall weight. A compact rectangular or cylindrical frame configuration was selected to allow smooth movement inside chimneys of varying diameters. The frame supports all major components, including motors, wheels, cleaning brushes, battery, and control circuitry. Proper spacing and alignment of components were maintained to achieve balance and stability during operation.

For locomotion, DC geared motors were used due to their high torque and speed control capability. These motors drive the wheels or track system mounted on the sides of the robot, allowing it to move vertically and horizontally inside the chimney. Rubber-coated wheels were selected to provide better grip and prevent slipping on soot covered surfaces. The motor selection was based on load calculations, frictional resistance, and chimney dimensions to ensure smooth movement without stalling.
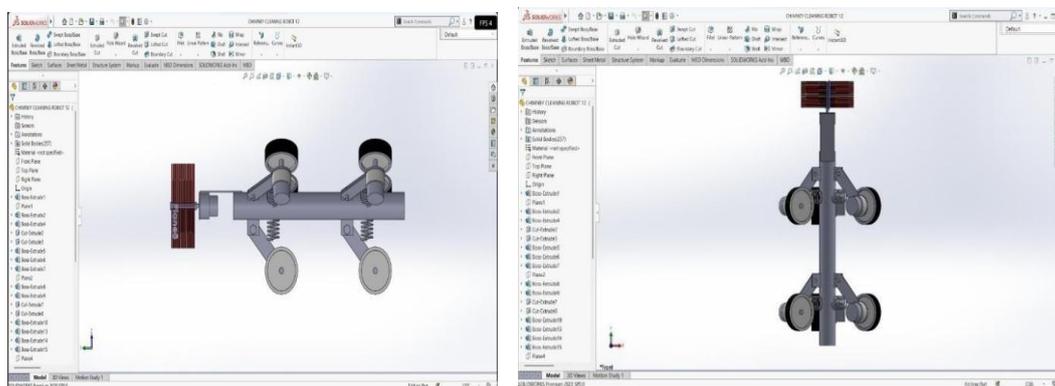

Fig:2.3D Design of chimney cleaning robot

DESIGN CALCULATION
For a 1500 RPM DC motor (12V):
Formula for torque:
$P \times 60$
$2\pi \times RPM$

Full-load power:
$P = 21.6W$

$$T = \frac{21.6 \times 60}{2\pi \times 1500}$$

$T = 0.137$ N\cdotpm Convert to kg-cm:
$0.137 \times 10.19 = 1.39$ kg-cm

BATTERY CALCULATION
BAH /CI = 8 ah/420ma
= 19 hrs
To find the Current Watt = 18 w Volt = 12v Current =?
P= V x I
18 =12 x I I = 18/12
= 1.5 AMPS
BATTERY USAGE WITH
 1.5 AMPS BAH /I
8/1.5 = 5.3 hrs
8.5 DC MOTOR CALCULATION
Formula
$2\pi \times RPM$

$\omega = 60$

For 1500 RPM

$$\omega = \frac{2\pi \times 1500}{60} = 157 \text{ rad/s}$$

IV.PRINCIPLE:

The working principle of the chimney cleaning robot is based on the concept of mechanical scrubbing combined with controlled robotic motion inside the chimney. The robot is designed to move within the confined chimney structure while continuously removing soot, ash, and carbon deposits from the inner walls. This is achieved by using motor-driven wheels for locomotion and a rotating brush mechanism for cleaning, thereby eliminating the need for direct human intervention in hazardous environments.

When electrical power is supplied to the system, the drive motors generate sufficient torque to move the robot vertically or horizontally inside the chimney. At the same time, a separate motor rotates the cleaning brush at a predetermined speed. As the robot advances, the rotating brush comes into contact with the chimney walls and scrapes off accumulated soot and grease deposits. The mechanical action of the brush loosens the deposits without damaging the chimney surface.

The loosened soot particles fall downward due to gravitational force and are collected at the bottom of the chimney or removed through a suction arrangement if provided. The movement speed of the robot and the rotational speed of the brush can be controlled to ensure uniform and effective cleaning throughout the chimney length. This controlled motion allows the robot to cover the entire inner surface systematically.

V.CONTROL SYSTEM:

The control system of the chimney cleaning robot is designed to ensure smooth movement, effective cleaning operation, and safe handling of the robot during cleaning tasks. It acts as the central unit that coordinates the functioning of the drive motors and the cleaning mechanism based on user commands. The control system reduces manual effort while providing precise control over the robot's motion inside the chimney.

The robot is controlled using a manual switch- based control unit or a microcontroller-based system. In a basic configuration, toggle switch are used to control forward and reverse movement, as well as the ON and OFF operation of the cleaning brush motor. In an advanced setup, a microcontroller such as Arduino or similar embedded controller is used to process control signals and operate the motors through motor driver circuits. This allows accurate speed and direction control of the motors .Motor driver circuits play a vital role in the control system by amplifying low-power control signals to drive high-power DC motors. These drivers enable smooth acceleration and deceleration of the robot, preventing sudden jerks and ensuring stable movement inside the chimney. Speed control is achieved using pulse width modulation (PWM), which allows the operator to adjust the robot's movement speed and brush rotation speed

VI.CONCLUSION:

The design and development of the chimney cleaning robot successfully demonstrate an effective solution to the safety and efficiency issues associated with traditional manual chimney cleaning methods. The developed robotic system is capable of operating inside narrow and hazardous chimney environments, thereby eliminating the need for direct human involvement. This significantly reduces health risks, accidents, and physical strain faced by workers during chimney maintenance.

The fabricated prototype integrates mechanical design, cleaning mechanisms, and a reliable control system to achieve efficient and uniform removal of soot and carbon deposits from chimney walls. Experimental results show that the robot performs stable movement, effective cleaning, and consistent operation with reduced time and effort compared to conventional cleaning methods. The rotating brush mechanism proved to be effective in removing deposits without causing damage to the chimney structure.

The control system provides smooth and user friendly operation, enabling precise control over movement and cleaning actions. The use of motor drivers and speed control techniques ensures reliable performance and prevents mechanical or electrical failures. The system also demonstrates acceptable power consumption and safe operation under continuous working conditions.

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