DUST EXTRACTION TECHNOLOGY: DESIGN, CONSTRUCTION, AND OPERATIONAL GUIDELINES

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Abstract

Dust accumulation in domestic, industrial, and commercial spaces poses significant health, safety, and environmental risks. Prolonged exposure to airborne particles has been linked to respiratory issues, reduced productivity, and equipment inefficiencies. Traditional cleaning methods often fail to address these issues effectively, emphasizing the need for efficient and economical dust extraction systems. This study explores the design, construction, and operational optimization of a low-cost dust extraction machine to address these challenges.

The system utilizes a centrifugal blower to generate suction, a dust capture hood for localized particle collection, and a duct system to transport dust into an aluminium collection chamber. Key design parameters, including airflow velocity, suction capacity, and power consumption, were optimized for small-scale applications. Testing revealed a capture efficiency of 76%, validating the system's ability to effectively remove fine and coarse particles from various surfaces, including floors, tables, and machinery. The machine's compact and portable design, coupled with the use of locally available materials, ensures cost-effectiveness and accessibility for households and small businesses.

This paper provides detailed insights into material selection, fabrication processes, and testing procedures, emphasizing practical guidelines for operation and maintenance. Recommendations for future improvements, such as incorporating automation and noise reduction features, are also discussed. The results demonstrate that this optimized dust extraction machine offers a reliable, affordable, and sustainable solution for maintaining cleaner and healthier environments.

Keywords: *Dust extraction, Centrifugal blower, Duct collector, Suction efficiency, Fabrication, Operational optimization.*

Introduction

Dust particles are ubiquitous in industrial, residential, and commercial environments, adversely affecting air quality and posing health hazards. Traditional cleaning methods, such as sweeping and dusting, often stir up fine particles rather than eliminate them. This limitation has driven the development of dust extraction systems, which offer a more efficient solution for improving air quality and reducing health risks.

Statement of the Problem

Dust pollution continues to be a critical issue in residential, commercial, and industrial settings, posing risks to health, equipment, and productivity. Inhaling fine dust particles can cause respiratory problems such as asthma, bronchitis, and other chronic conditions. Dust accumulation also adversely affects electronic devices and machinery, leading to frequent malfunctions and costly repairs.

Existing dust removal methods, such as sweeping and mopping, are often inefficient, merely redistributing dust instead of eliminating it. While industrial-grade dust extraction machines are effective, their high costs and large-scale designs make them inaccessible to small-scale users, including households and small workshops. This creates an urgent need for a compact, cost-effective, and efficient dust extractor tailored to small-scale applications, addressing both health and operational challenges.

Aim of Study

This study aims to optimize dust extraction technology through a compact, efficient, and affordable machine designed for small-scale applications. The machine incorporates a centrifugal blower, ductwork, and a dust collection chamber, ensuring the effective removal of dust from surfaces and air. The research objectives include designing and fabricating a dust extraction system with high capture efficiency and evaluating its performance under various conditions.

Significance of the Study

This study is significant as it addresses the dual challenges of dust management: improving air quality and reducing the adverse impacts on equipment and health. By designing an affordable and efficient dust extractor, the project fills the gap between industrial-grade systems and small-scale needs. The proposed machine enhances indoor air quality by effectively capturing dust at its source, reducing health risks and promoting cleaner living and working environments.

The study also contributes to local innovation and manufacturing by utilizing readily available materials. This approach not only lowers production costs but also supports sustainable practices in equipment fabrication. Furthermore, the machine's compact design and ease of use make it highly versatile, offering practical solutions for homes, offices, and workshops while laying the groundwork for future advancements in dust management technologies.

Limitations

- Limited capability for handling large debris or industrial-scale operations.
- Lack of automation for speed and airflow adjustments, requiring manual operation.
- Noise levels during operation could be mitigated with additional insulation.

Literature Review

Efforts to develop effective dust extraction systems have led to various innovations in design and functionality. Dharmasena et al. (2005) introduced a filtration system using a centrifugal blower and wet filters, demonstrating the efficacy of detergent solutions in trapping dust.

Wallace & Cheung (2013) developed a compact excavator-mounted dust suppression system utilizing water storage tanks and nozzles to mitigate dust in construction environments.

Ogbeide (2015) designed a low-cost dust extractor featuring a cyclone separator, which effectively separates heavier particles from clean air. Similarly, Rohan et al. (2016) fabricated a domestic dust remover combining deodorizing effects with floor-sweeping capabilities. Singh et al. (2017) further contributed by designing a hand-operated vacuum cleaner that collects dust into a designated bag using a centrifugal impeller.

Other researchers have emphasized the role of airflow dynamics in dust extraction systems. Tanadecha & Khaothong, (2024) analysed the influence of duct length and bends on airflow efficiency, showing that shorter, straighter ducts minimize pressure loss. Similarly, Kshirsagar et al., (2019) examined the impact of blower blade design, concluding that larger blade surface areas improve suction power and particle capture rates.
Advances in material technology have also played a significant role in improving dust extraction systems. Zheng & Kanaoka (2018), demonstrated the effectiveness of lightweight composites in reducing the weight of collection chambers, thereby enhancing portability. However, despite these innovations, the high cost of advanced systems often limits their adoption in small-scale settings. This study addresses such challenges by combining proven design principles with affordable materials to develop an efficient and accessible dust extraction machine.

Comparison with Existing Systems

Unlike conventional systems that rely on complex mechanisms, this design simplifies dust extraction using a direct-drive centrifugal blower. The compact and portable design makes it suitable for small-scale applications. Furthermore, using locally available materials significantly reduces costs compared to imported systems.

Methodology

Conceptual Design

The machine design consists of a dust capture hood, centrifugal blower, duct system, and dust collection chamber. These components work together to ensure efficient dust capture, conveyance, and containment. The dust capture hood collects particles from the source, while the centrifugal blower generates suction to transport the dust through the ductwork into the collection chamber, where particles are stored for disposal.

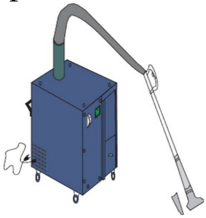
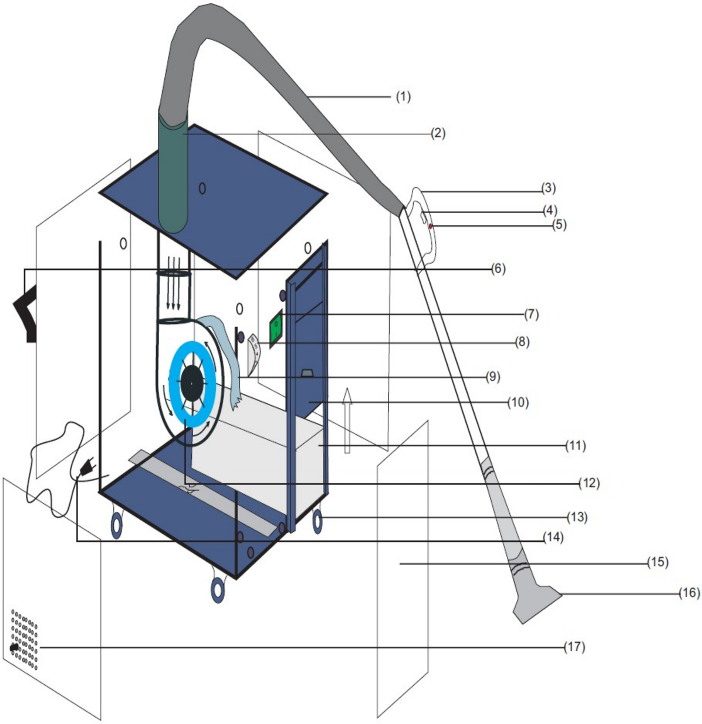


Fig 1: Dust Extractor Machine



(1) Air Duct Line (2) Connector (3) Duct line handle (4) Trigger switch
(5) Safety button (6) Case handle (7) Power switch (8) Regulator switch
(9) Dust Collection Bag (10) Slide door (11) Collection Chamber
(12) Centrifugal Blower (13) Roller (14) Power Cable (15) Casing
(16) Hood (17) Air Vent

Fig. 2: Exploded View of the Dust Extractor Machine

Material Selections

Materials were selected based on availability, cost, and mechanical properties. Mild steel was used for the casing and blower blades due to its durability, ease of fabrication, and resistance to wear. Aluminium was chosen for the collection chamber to reduce weight and facilitate easy handling. Rubber ducts were used to provide flexibility and minimize vibration during operation.

Design Calculation

Key calculations include:

- Suction Capacity: Where:

  Flow rate = 142 CFM
  Velocity of air = 4.75 m/s
  Blade diameter = 112 mm
  Outlet width = 0.04 m

- Torque (T): Calculated as: Where is the mass density of air and is air velocity.

Theoretical Power (P): Where the angular velocity of the blower impeller is ω

$$\omega = \frac{2\pi N}{60}$$

From the specification, N = 2650rpm

$$\omega = \frac{2 \times 3.142 \times 2650}{60}$$

ω = 277.54rad/s

Theoretical power required to move air

P = Tω
= 2.28 × 277.54
= 632.79 watts

P = 633 watts

1Hp = 746 watts

Fabrication Process

The fabrication process involved:

- Cutting and welding mild steel for the casing and ductwork to ensure structural stability.
- Assembling the centrifugal blower with a direct-drive motor to enhance efficiency and reduce mechanical losses.
- Installing flexible rubber ducts to facilitate smooth airflow and prevent pressure loss.
- Constructing the dust collection chamber from aluminium sheets, ensuring durability and ease of maintenance.

Testing Procedure

The machine was tested by measuring the weight of dust collected over fixed time intervals. Suction performance and capture efficiency were analysed under varying conditions, such as different dust densities and particle sizes. Multiple tests were conducted to validate repeatability and reliability.

Results and Discussion

Performance Evaluation Initial tests revealed that an excessive duct length reduced suction power due to increased pressure losses. After optimizing the duct design by reducing its length, the machine achieved a capture efficiency of 76%, effectively removing dust from surfaces such as floors, tables, and car seats. The tests confirmed the system's capability to handle fine and coarse particles.

Table 1: Test Results

Test No	Dust Collected (kg)	Time (s)	Capture Efficiency (%)
1	0.11	**10**	**76**
2	0.12	**15**	
3	0.11	**20**	
4	0.11	**25**	
5	0.12	**30**	

Capture efficiency $\eta c ¿ \frac{Output}{Input} \times 100$

$$\frac{0.57}{5} = 0.114$$

where input is 0.15kg the weight of dust collected

$$\frac{0.114}{0.15} = 0.76$$

$$= 0.76 \times 100$$

$$= 76\%$$

Operational Guidelines

1. Position the dust capture hood close to the dust source to maximize efficiency.
2. Connect the power supply and switch on the machine ensuring all components are securely attached.
3. Adjust the speed regulator to the desired suction level based on the density level.
4. Use the machine continuously for 30 minutes, then empty the dust collection chamber to prevent clogging.
5. Perform routine maintenance, including cleaning the ductwork and inspecting the blower for wear or damage.

Conclusion

The optimized dust extraction machine effectively addresses dust-related health and safety challenges. Its design ensures high capture efficiency and ease of use, making it a practical solution for small-scale applications. The machine's affordability and use of locally sourced materials further enhance its appeal. Its compact design ensures versatility, allowing usage in various environments.

Recommendations

- Incorporate sensors for detecting foreign objects to enhance safety and prevent damage.
- Enhance duct flexibility to improve manoeuvrability and reach in tight spaces.

- Explore automated speed controls to optimize performance for different operational requirements.
- Conduct additional testing under industrial conditions to validate scalability and durability for larger applications.
- Introduce noise-reduction mechanisms to improve user experience during operation.

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