

FABRICATION OF A FRICTIONLESS AIR-BASED MATERIAL HANDLING SYSTEM

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Abstract - This project presents a compressed air conveyor system that replaces traditional moving belts with directed air jets for material handling. An acrylic platform with angled perforations allows compressed air to generate thrust, moving parcels smoothly across the surface. The design minimizes mechanical components, reducing wear, maintenance, and operational complexity. It focuses on improving energy efficiency by limiting dependence on electric motors. The system also ensures clean and hygienic operation, making it suitable for sensitive industries. Testing shows effective transport of lightweight parcels with reduced energy consumption. Overall, it offers a sustainable, low-cost, and innovative alternative to conventional conveyor systems.

Key Words:

- Compressed Air Conveyor
- Air Jet Propulsion
- Material Handling System
- Energy Efficient Design
- Beltless Conveyor
- Fluid Dynamics
- Laminar Flow
- Industrial Automation
- Low Maintenance System
- Acrylic Platform Conveyor
- Sustainable Engineering
- Smart Material Transport

1.INTRODUCTION

Conveyor systems play a vital role in modern industries by enabling efficient and continuous material handling.



Fig. 1

Traditional belt conveyors, though widely used, suffer from high energy consumption, mechanical wear, and frequent maintenance. These limitations increase operational costs and create challenges in industries requiring cleanliness and reliability. To overcome these issues, a compressed air conveyor system is proposed as an innovative alternative. The system uses angled perforations on an acrylic surface to direct airflow and move parcels without mechanical motion. This approach reduces maintenance, improves energy efficiency, and ensures hygienic operation. Overall, the project aims to develop a sustainable, cost-effective, and low-maintenance solution for industrial material transport.

LITERATURE REVIEW

[1] Gupta, R., & Kumar, S. "Design and Analysis of Pneumatic Conveying Systems." International Journal of Mechanical Engineering Research, Vol. 5, No. 2, 2019. – Case study on pneumatic transport efficiency and design considerations.

[2] Zhang, Y., et al. "Optimization of Air Jet Systems for Material Handling." Journal of Manufacturing Processes, Vol. 42, 2020. – Explores hole geometry and airflow distribution for improved thrust.

[3] Singh, A., & Rao, P. "Energy Efficiency in Pneumatic Conveyors." Renewable Energy and Sustainable Systems Journal, Vol. 8, No. 1, 2021. – Comparative analysis of pneumatic vs. mechanical conveyors.

[3] Gayathri¹, S. Sathishkumar², B. Benix Sajo³, S. Selvam⁴(2023) Design and Fabrication of automated air conveyor for transporting of an object faster and smoothly using air pressure, where mechanical contact is said to be avoided during transportation of the products to minimize contamination.

[4] PVN Sai Chandu¹, MR. Chandu Kurla², MR. Bhaskar Ranganagiri³, MR. Prashanth Devaraya⁴ (2024) Developed design and fabrication of contactless conveyor using air pressure for transporting light weight goods such as square and rectangular objects without coming in contact of conveyor by improving efficiency.

Design Concept

The compressed air conveyor replaces a moving belt with a stationary perforated acrylic sheet that uses angled air jets to move parcels forward. Compressed air passes through 45° holes, generating thrust that propels items smoothly across the surface.

COMPONENTS

Acrylic Sheet

An acrylic sheet is a transparent, lightweight, and durable plastic material commonly used as an alternative to glass. It offers high strength, good impact resistance, and excellent clarity, making it suitable for industrial and mechanical applications. In this project, the acrylic sheet acts as the

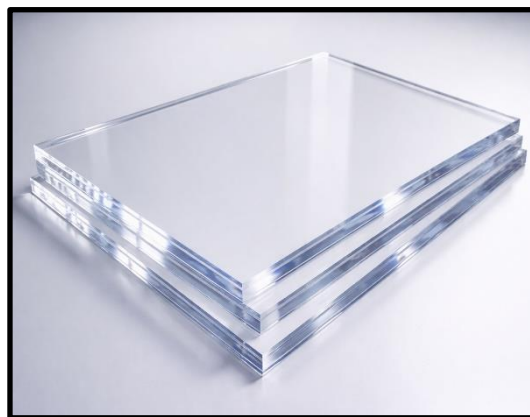


Fig.2: acrylic sheet

stationary platform through which compressed air is passed. Tiny angled holes are drilled into the sheet to allow controlled air flow, creating thrust to move objects placed on its surface. Its smooth finish reduces friction, helping parcels glide easily. Additionally, acrylic is easy to machine, cost-effective, and resistant to corrosion.

Plenum Chamber Construction

The plenum chamber is a sealed enclosure designed to distribute compressed air uniformly beneath the acrylic sheet. It is typically fabricated using materials like mild steel, aluminium, or rigid plastic to ensure strength and airtightness. The chamber is constructed as a box structure with proper sealing at all joints to prevent air leakage. An inlet port is provided to connect the air compressor, allowing high-pressure air to enter the chamber.



Fig.3: Plenum Chamber Construction

Inside the plenum, air is evenly distributed before passing through the drilled holes in the acrylic sheet. Proper gasket sealing and fastening are used between the chamber and the acrylic sheet to maintain pressure and efficiency. The design ensures consistent airflow, which is essential for smooth and uniform movement of objects on the conveyor surface.

Assembly

The assembly of the compressed air conveyor system begins by securely fixing the plenum chamber onto the supporting frame to ensure stability. The acrylic sheet is then carefully placed on top of the plenum chamber, with a rubber gasket in between to prevent air leakage.



Fig.4

Both components are tightly fastened using bolts and screws to maintain an airtight seal. Next, the air inlet of the plenum chamber is connected to the air compressor using PU pipes. All joints and connections are checked thoroughly to avoid leakage and ensure proper airflow. Finally, the system is tested by supplying compressed air to verify uniform air distribution and smooth movement of objects over the acrylic surface.

Air Compressor

An air compressor is used to generate compressed air required for the system. It operates with a capacity of 3–5 bar pressure output.

The flow rate can be adjusted between 50–150 L/min as per requirement. Its main function is to supply compressed air to the plenum chamber for operation. Fig. 5.3 shows the air compressor and pressure control setup.



Fig.5: Air Compressor

Perforations (Air Holes)

Perforations (air holes) are small, precisely drilled openings provided on the acrylic sheet.

These holes are typically angled to direct the airflow in a specific direction. Compressed air passes through these perforations to create a thin air cushion. This reduces friction and helps in smooth movement of materials. Proper design of hole size and spacing ensures uniform airflow and efficient conveying.

Diameter: 3 mm (optimized for lightweight parcels).

Angle: 45° drilled forward to generate directional thrust.

Spacing: 20 mm apart in a grid pattern to ensure uniform airflow.



Fig.6: Perforations (Air Holes)



METHODOLOGY

Fluid Dynamics Explanation

The working principle of the system is based on the generation of thrust using compressed air jets. The thrust force produced by each jet is derived from Newton’s second law of motion, where force is equal to the rate of change of momentum of the fluid.

$$F = \dot{m}xv$$

Where:

- (F) = thrust force (N)
- \dot{m} = mass flow rate of air (kg/s)
- (v) = velocity of the air jet (m/s)

The mass flow rate of air through each perforation is calculated using:

$$\dot{m} = \rho Av$$

Where:

- \dot{m} = density of air (kg/m³)
- (A) = cross-sectional area of the hole (m²)
- (v) = velocity of air jet (m/s)

By substituting the mass flow rate into the thrust equation, the force becomes dependent on-air density, hole area, and velocity. Hence, the system performance can be controlled by adjusting parameters such as hole diameter, air pressure, and jet velocity.

Example Calculation

To evaluate the feasibility of the system, a sample calculation is performed using the following values:

- Hole diameter = 3 mm

Cross-sectional area, A=7.85×10⁻⁷ m²

- Air density, ρ = 1.2, kg/m³
- Jet velocity, (v = 50 m/s)

First, mass flow rate is calculated:

$$\dot{m} = 1.2 \cdot (7.85 \times 10^{-7}) \cdot 50 \approx 4.7 \times 10^{-5} \text{ kg/s}$$

$$F = \dot{m} \cdot v = (4.7 \times 10^{-5}) \cdot 50 \approx 2.35 \times 10^{-3} \text{ N}$$

System Implementation Insight

Although the thrust generated by a single hole is small, the use of multiple perforations significantly increases the total force. When hundreds of air jets operate simultaneously, the cumulative thrust becomes sufficient to move lightweight parcels smoothly across the surface

Thus, by optimizing hole size, spacing, and air pressure, the system achieves efficient and controlled material transport without mechanical motion.

RESULTS

The compressed air conveyor system successfully demonstrated the transportation of parcels using directed air jets without any mechanical motion. Lightweight parcels (200 g) moved smoothly even at low pressures, while medium-weight parcels (500 g) required moderate pressure for stable operation.



Fig: 7

Heavier parcels (1 kg) needed higher pressure, indicating a limitation in load capacity. It was observed that parcel speed increased with air pressure, validating the jet propulsion principle. The system consumed less energy for lightweight loads compared to traditional conveyors and required minimal maintenance due to the absence of moving parts. Additionally, it provided a clean, contact-free transport method suitable for hygienic industries. However, noise levels increased at higher pressures, suggesting the need for noise control measures. Overall, the system proved to be an efficient and low-maintenance solution for lightweight material handling applications.

CONCLUSION

Conclusion and Future Outlook

The compressed air conveyor belt system developed in this project presents an innovative and practical alternative to conventional conveyor systems by utilizing fluid dynamics instead of mechanical motion. The prototype successfully demonstrated that angled air jets can effectively transport lightweight parcels across a stationary acrylic surface with smooth, consistent motion. The system showed clear advantages in terms of reduced energy consumption for light loads, minimal maintenance due to the absence of moving parts, and improved hygiene through contact-free operation. These features make it highly suitable for industries such as food processing, pharmaceuticals, and logistics, where cleanliness and reliability are critical. However, the study also identified limitations, including restricted load capacity for heavier parcels and increased noise levels at higher operating pressures.

From an industrial perspective, the compressed air conveyor fills a valuable niche by offering a low-maintenance and energy-efficient solution for lightweight material handling. While it may not replace traditional belt conveyors in heavy-duty applications, it provides a specialized alternative aligned with modern automation and sustainability goals.

Looking ahead, the system has strong potential for further development. Future improvements can focus on optimizing hole geometry and airflow distribution to enhance efficiency, integrating sensors and automation for smart control, and implementing noise reduction techniques for better working conditions. Additionally, modular design enhancements can allow scalability for larger industrial applications. With these advancements, the compressed air conveyor system can evolve into a more robust, sustainable, and industry-ready technology, contributing to the future of smart and eco-friendly material handling solutions.

**REFERENCES**

- [1]. F.M. *Fluid Mechanics*. McGraw-Hill Education, 2016. – Provides fundamental principles of fluid dynamics relevant to airflow and jet propulsion.
- [2]. Munson, Young, and Okiishi. *Fundamentals of Fluid Mechanics*. Wiley, 2013. – Detailed explanation of airflow behavior, pressure, and velocity relationships.
- [3]. Anderson, J.D. *Introduction to Flight*. McGraw-Hill, 2017. – Discusses jet propulsion concepts applicable to compressed air systems.
- [4]. Gupta, R., & Kumar, S. “Design and Analysis of Pneumatic Conveying Systems.” *International Journal of Mechanical Engineering Research*, Vol. 5, No. 2, 2019. – Case study on pneumatic transport efficiency and design considerations.
- [5]. Zhang, Y., et al. “Optimization of Air Jet Systems for Material Handling.” *Journal of Manufacturing Processes*, Vol. 42, 2020. – Explores hole geometry and airflow distribution for improved thrust.
- [6]. Singh, A., & Rao, P. “Energy Efficiency in Pneumatic Conveyors.” *Renewable Energy and Sustainable Systems Journal*, Vol. 8, No. 1, 2021. – Comparative analysis of pneumatic vs. mechanical conveyors.
- [7]. World Energy Council. *Industrial Energy Efficiency Report, 2022*. – Highlights energy consumption trends in manufacturing and logistics.
- [8]. Food Processing Technology Review. *Clean Conveyor Systems in Food Industries*, 2021. – Discusses hygiene requirements and suitability of non-mechanical conveyors.
- [9]. International Logistics Association. *Automation in Warehousing and Parcel Handling*, 2020. – Examines conveyor technologies in logistics hubs.
- [10]. ISO 22000:2018 – *Food Safety Management Systems*. – Relevant for hygienic transport systems in food industries.
- [11]. OSHA Guidelines – *Noise Control in Industrial Environments*. – Provides standards for acceptable workplace noise levels.