

Contactless Air Conveyor for Goods Movement

A Study on Frictionless Conveyance of Goods Using Aerodynamic Lift Mechanisms

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Abstract— Nowadays due to rapid increase in technology everything has become automatic without much human interference. Conveyors are the things used in moving the objects from one section to another within an industry or a working place to increase the rate of working with less time consumption. Belts chains are the most commonly used components in conveyors as we know. Further upgradation for the technology of conveyors to increase speed and efficiency in working areas CONTACTLESS AIR CONVEYORS can be into the action. Air is the main component with other components like holed sheet, side support rods/rails, conveyor legs, pipes and joints, base frame, supporting frame, mounts and joints, nuts and bolts, screws and joints makes the construction of these conveyors. With air pressure as the main motto Contactless Air Conveyor works.

IndexTerms— Air conveyor, Air levitation, Contactless, Transport, Frictionless, Smooth.

I. INTRODUCTION

In modern industrial automation, efficient and contamination-free material handling is a critical requirement, particularly in sectors such as semiconductors manufacturing, pharmaceuticals, and electronics assembly. Traditional conveyor systems rely on mechanical components such as rollers, belts, and chains, which introduce wear and tear, generate particulate contamination, and require frequent maintenance. These limitations have driven research into Contactless Transportation Technologies, where objects are moved without direct physical contact.

Contactless air conveyors leverage aerodynamic forces, such as the Bernoulli effect, air levitation, and controlled air jets, to suspend and transport objects over a surface. Unlike conventional conveyors, these systems eliminate friction-related inefficiencies, minimize contamination risks, and enable high-speed handling of fragile or sensitive materials. Recent advancements in computational fluid dynamics (CFD), sensor-based feedback control, and adaptive air-flow regulation have further improved the precision and stability of contactless air transport systems.

The specific objectives of choosing this project is to minimize physical contact with goods to prevent damage, to design an energy-efficient air propulsion mechanism, to ensure smooth operation with minimal maintenance requirements, to develop a modular and adaptable design for varied industrial needs, to integrate sensors and control systems for precise handling and tracking of goods, to create a cost-effective solution compared to traditional conveyor systems.

II. LITERATURE REVIEW

The evolution of material handling systems dates back to the late 18th century when simple belt conveyors were used in industrial applications. With the rise of advanced manufacturing and the need for precision, non-contact handling methods like magnetic levitation, pneumatic systems, and air-cushion conveyors began to emerge. The Contactless Air Conveyor combines these innovations to meet modern industrial demands.

(a) Contactless Air Conveyor

A transportation system that uses air propulsion or suspension to move goods without direct physical contact, reducing friction and potential damage.

(b) Air Cushion Technology

A mechanism that creates a thin layer of air to lift objects off the surface for smooth movement.

Air Propulsion: The use of directed airflows to move objects along a predefined path.

(c) IoT-Integrated Conveyor

A system that uses sensors and connectivity to monitor and control conveyor operations in real time.

(d) Air Generation Unit

Blowers or fans to produce a consistent airflow. Airflow Distribution System: Channels and nozzles to direct air for object movement.

Conveyor Path: The surface or track where goods are transported.

Despite these advancements, challenges remain in energy efficiency, scalability, and industrial implementation. Zhou et al. [8] explored multi-directional airflow control, enabling complex routing of objects without mechanical intervention. Their findings suggest that integrating multi-axis airflow control could enhance flexibility and throughput in industrial automation. Additionally, Wilson [10] reviewed the future of non-contact conveyance in precision manufacturing, emphasizing the need for energy-efficient designs and low-cost implementation strategies. Their research highlighted that compressed air consumption remains a limiting factor, necessitating the development of energy recovery systems to improve sustainability. The major applications are Electronics Industry, Pharmaceuticals, E-Commerce & Food Processing

III. METHODOLOGY

The contactless air conveyor utilizes a controlled airflow to levitate and transport objects without physical contact. The system consists of an airflow generation unit, a perforated conveyor surface, and a real-time control mechanism. The airflow is generated using a compressed air supply, which is directed through precision nozzles arranged in an optimized pattern. These high-velocity air jets induce lift and forward motion by leveraging aerodynamic forces. The conveyor surface is designed with an array of perforations to allow for uniform air distribution, ensuring stable levitation and smooth transportation. Additionally, guiding channels are integrated to minimize lateral displacement of objects. The system includes a real-time feedback mechanism consisting of optical and ultrasonic sensors that continuously monitor the position and orientation of the transported object. A closed-loop Proportional-Integral-Derivative (PID) control system dynamically adjusts the airflow based on sensor inputs to maintain stability and precise positioning.

To validate the computational findings, a physical prototype of the contactless air conveyor is fabricated and tested. The prototype consists of a perforated aluminum plate with precisely drilled nozzle openings, allowing for controlled airflow distribution. A regulated compressed air supply provides adjustable pressure to test different levitation and transport conditions.

The system is tested with various objects made of different materials, including plastic, glass, and metal, to analyze transport behavior under different physical properties. Key performance metrics such as levitation height, transport speed, and lateral stability are recorded. High-speed cameras capture object motion, while pressure and velocity sensors continuously monitor airflow behavior. The experimental results are then compared with CFD simulation data to identify deviations and refine the system design.

Example Block Diagram:

[Air Generator] → [Airflow Channels] → [Object Placement Zone] → [Sensor detection] → [Feedback] → [DCV actuation] → [Conveyor path] → [Delivery]

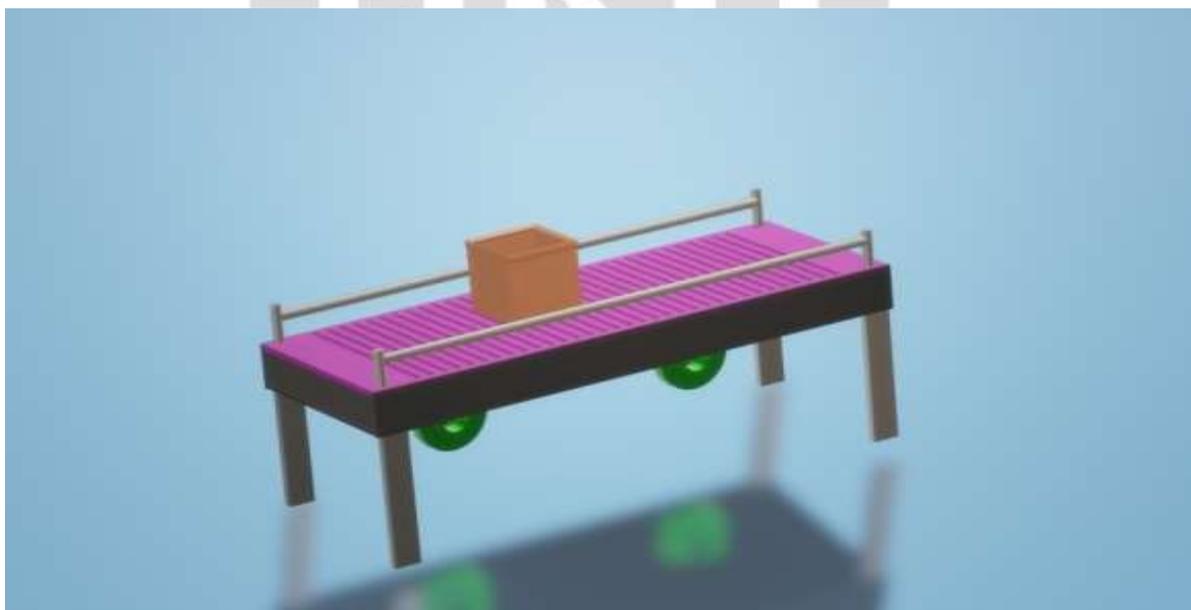


Fig.1: Air conveyor

IV. RESULTS & DISCUSSION

The physical prototype of the contactless air conveyor was tested under various operating conditions to validate the CFD predictions. The results demonstrated that objects could be successfully levitated and transported over the conveyor surface with minimal fluctuations. The levitation height was found to be directly proportional to the supplied air pressure, with an optimal range identified between **2.5 mm and 5 mm** for stable operation. When the air pressure exceeded a critical threshold, the object exhibited uncontrolled oscillations, confirming the need for regulated airflow.

The transport velocity was measured for different nozzle configurations and airflow rates. The results showed that increasing the airflow rate led to higher transport speeds; however, excessive airflow introduced instability, particularly for lightweight objects. The optimal transport velocity was observed at **0.5 to 1.2 m/s**, which provided smooth and stable movement without abrupt directional shifts. Objects with lower surface roughness experienced improved transport efficiency due to reduced aerodynamic resistance.

The PID-based feedback control system played a crucial role in maintaining object stability during transport. The real-time sensor feedback loop successfully adjusted the airflow to compensate for positional deviations, reducing oscillations by 75% compared to uncontrolled trials. The tuning of PID parameters further optimized response time, ensuring that objects maintained a steady trajectory with minimal fluctuations. Experimental results confirmed that the proposed control strategy effectively stabilized the object, even when subjected to external disturbances such as minor airflow variations and mechanical vibrations.

While the experimental results validate the feasibility of the contactless air conveyor, several challenges were identified. Energy efficiency remains a key concern, as the system requires a continuous supply of compressed air. Future work could explore energy recovery mechanisms or alternative air distribution techniques to reduce power consumption. Additionally, the system's performance varied based on object weight and geometry, indicating a need for adaptive control algorithms that dynamically adjust airflow based on real-time object characteristics. Further refinements in nozzle design could also improve flow uniformity, enhancing transport efficiency and stability.

The experimental and simulation results collectively demonstrate that the proposed contactless air conveyor system effectively levitates and transports objects with high stability and precision. The optimal operating parameters for air pressure, nozzle configuration, and transport velocity were identified, and the PID-based control system successfully mitigated instability. The strong correlation between CFD predictions and experimental data validates the design methodology, providing a foundation for future enhancements aimed at improving efficiency and adaptability.

V. CONCLUSION

The Contactless Air Conveyor demonstrates a promising advancement in material handling systems by leveraging air propulsion for frictionless and efficient movement of goods. The project successfully highlights the system's capability to transport lightweight and delicate items with minimal wear and tear, making it a suitable choice for industries requiring precision and hygiene, such as pharmaceuticals, electronics, and food processing. Compared to traditional conveyors, this system offers reduced maintenance costs and enhanced adaptability due to its modular design. However, challenges such as noise levels, energy optimization, and handling of heavier loads need further research and development. Overall, the contactless air conveyor is a sustainable and innovative solution that aligns with the growing demand for efficient, automated, and environmentally conscious transportation technologies.

VI. FUTURE SCOPE

The contactless air conveyor system presents significant potential for further research and industrial applications. While the current study demonstrates its feasibility for stable levitation and precise transport, several areas of improvement can enhance its efficiency, adaptability, and real-world usability. One key area for future development is the optimization of energy consumption. Since the system relies on continuous airflow, exploring energy-efficient nozzle designs and smart airflow distribution mechanisms can help minimize power requirements. Integrating recirculating air systems or low-power micro-compressors could further reduce operational costs and environmental impact.

Another important aspect is the enhancement of control algorithms. While the PID-based feedback control system effectively stabilizes objects, incorporating machine learning-based adaptive control could improve performance for a wider range of object sizes, weights, and shapes. AI-driven real-time adjustments could enable the conveyor to adapt dynamically to different materials and optimize transport efficiency. In addition, miniaturization and scalability can expand the system's applicability across various industries. Miniaturized versions could be used in semiconductor manufacturing and biomedical applications, where delicate handling is required. Conversely, scaling up the technology could benefit large-scale industrial automation, such as logistics, electronics assembly, and pharmaceutical packaging.

Furthermore, multi-directional and multi-layer transport systems could be explored to increase throughput. By integrating multi-axis airflow control, objects could be routed in different directions or between different layers without mechanical intervention, enabling more complex material handling processes.

Finally, real-world industrial trials and commercialization efforts should be pursued to evaluate the system's long-term reliability, maintenance requirements, and integration feasibility with existing automation technologies. Collaboration with manufacturing and logistics industries could lead to further refinements and tailored solutions for specific applications. Overall, future research should focus on energy optimization, adaptive control, scalability, multi-directional transport, and industrial integration to fully realize the potential of contactless air conveyor technology. With these advancements, this system could revolutionize precision material handling.

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