DEVELOPMENT AND ANALYSIS OF PNEUMATIC CONVEYOR

A PROJECT REPORT

Submitted by

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CHENNAI - 66

BONAFIDE CERTIFICATE

Certified that this project report**"DEVELOPMENT AND ANALYSIS OF PNEUMATIC CONVEYOR"** is the bonafide work of **MEGANATHAN M, RISHI V, RITHISH B, AND THIYAKA VISHNU P** who carried out the project under my supervision.

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This report of project work submitted by the above students in partial fulfillment for the award of Bachelor of Mechanical Engineering Degree in Anna University was evaluated and confirmed to be reports of the work done by the above students and then assessed.

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ABSTRACT :

This project proposes the development of an innovative conveyor system aimed at minimizing mechanical complexity by significantly reducing the number of moving parts traditionally associated with material handling systems. The proposed conveyor leverages pneumatic technology, utilizing air pressure generated by a blower to transport materials efficiently. By creating a controlled airflow that lifts and moves items along a designated path, this system eliminates the need for conventional components such as belts and rollers, which are often sources of wear and maintenance issues.

The focus of this project is on simplicity and reliability, enhancing operational efficiency while reducing maintenance costs and lowering energy consumption compared to standard conveyor systems. The design seeks to address common challenges faced in industrial applications, such as system downtime, high maintenance requirements, and energy inefficiency. Through a combination of prototyping, testing, and optimization, the project aims to refine the system's performance to ensure it meets the demands of various industries.

Key objectives include evaluating the performance of the air-driven conveyor in terms of load capacity, speed, and reliability, as well as conducting a thorough analysis of its energy consumption compared to traditional conveyors. The project also emphasizes sustainability by promoting a reduction in the use of mechanical components, thereby minimizing the environmental impact associated with manufacturing and maintenance.

Ultimately, this novel approach to conveyor technology not only aims to enhance the efficiency of material handling processes but also contributes to the broader movement towards sustainable industrial practices. By exploring this innovative air-driven system, the project aspires to pave the way for future advancements in conveyor technology, offering a reliable and eco-friendly solution for material transportation in various industrial sectors.

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1 INTRODUCTION

1.1 Conveyor Systems:

In today's fast-paced industrial environment, the efficiency of material handling systems is crucial for optimizing productivity and reducing operational costs. Traditional conveyor systems, while effective, often come with complexities such as multiple moving parts, high maintenance requirements, and significant energy consumption. These challenges highlight the need for innovative solutions that simplify design and enhance performance. This project proposes a novel conveyor system that utilizes air pressure generated by a blower to transport materials, thereby minimizing mechanical components and promoting sustainability. By leveraging pneumatic technology, this system aims to offer a more efficient, reliable, and cost-effective alternative to conventional conveyor methods. The following sections will explore the design, implementation, and evaluation of this air pressure-driven conveyor system, addressing its potential impact on the industry.

Fig1.1

This fig Shows a curved belt conveyor, which is used to transport items around bends or changes in direction within a production line. Such conveyors are particularly useful in manufacturing and packaging processes, allowing for smooth and continuous material flow even when the layout requires non-linear paths.

1.2 Problem Statement:

Friction and Wear:

- Traditional conveyor systems rely on mechanical contact between moving parts (e.g., belts, rollers, chains). This contact generates friction, which leads to wear and tear over time. As a result, components like belts, rollers, and chains require frequent maintenance and replacement, leading to increased downtime and operational costs.
- The friction between the conveying surface and the material being transported can also result in damage to delicate or sensitive items, making traditional conveyors less suitable for handling fragile goods.

Maintenance and Downtime:

- Mechanical components in traditional conveyors are subject to breakdowns and malfunctions, such as motor failures, belt misalignment, and roller wear. Regular maintenance is required to ensure smooth operation, which can be time-consuming and costly.
- Downtime caused by maintenance or repairs can disrupt production schedules and reduce overall productivity in manufacturing facilities.

Energy Inefficiency:

- Traditional conveyors often consume significant amounts of energy due to the need to overcome frictional forces between moving parts. This energy consumption increases operational costs and can make traditional systems less sustainable.

- The inefficiency is particularly pronounced when transporting materials over long distances or at high speeds, where the energy lost to friction becomes substantial.

Noise and Vibration:

- The mechanical nature of traditional conveyors results in noise and vibration during operation, which can create an unpleasant working environment. Prolonged exposure to high noise levels can impact worker health and necessitate additional measures for noise control.
- Vibration can also affect the stability of materials being transported, potentially leading to damage or spillage.

Limitations in Cleanliness and Hygiene:

- In industries like food processing, pharmaceuticals, and electronics, maintaining a clean and contaminant-free environment is crucial. Traditional conveyors, with their multiple moving parts and contact surfaces, can accumulate dust, debris, and contaminants, making it challenging to maintain hygiene.
- Cleaning these systems can be labor-intensive and time-consuming, and any contamination can pose significant risks to product quality and safety.

Design Constraints and Flexibility:

- Traditional conveyor systems are often less flexible in terms of layout and design. Changes in the production line may require significant modifications or replacement of existing conveyor infrastructure, resulting in high costs.

- They may struggle to adapt to non-linear paths, tight spaces, or complex material handling requirements, limiting their applicability in modern, flexible manufacturing setups.

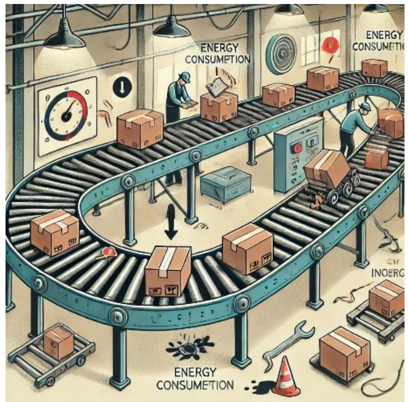

Fig1.2

This fig shows the various types of problems in the traditional conveyor systems and how the conveyor systems works.

1.3 Objectives:

Objective: Rationale Behind the Project

The objective of this project is to develop a contactless conveyor system using air pressure to address the inherent limitations of traditional conveyor systems and to meet the evolving needs of modern industrial applications. The project aims to achieve the following:

1. Reduce Wear and Maintenance Costs:

    - Traditional conveyor systems suffer from wear and tear due to continuous mechanical contact between moving parts and the materials being transported. This results in frequent maintenance, increased downtime, and high operational costs.

- By using air pressure to transport materials without physical contact, this project aims to significantly reduce wear and extend the lifespan of conveyor components, thereby decreasing maintenance costs and downtime.

2. Improve Material Handling for Delicate Items:

   - In industries such as electronics, pharmaceuticals, and food processing, handling delicate or sensitive materials without causing damage or contamination is critical.
   - The contactless nature of an air pressure-based conveyor system provides a gentle and precise method for transporting fragile materials, minimizing the risk of damage and ensuring high product quality.

3. Enhance Energy Efficiency:

   - Traditional conveyors often consume large amounts of energy due to the friction between moving parts. This not only increases operational costs but also has a negative impact on the environment.
   - This project seeks to explore the potential for energy savings through the use of optimized airflow and pressure control, aiming to develop a more energy-efficient alternative to traditional conveyor systems.

4. Reduce Noise and Improve Working Conditions:

   - Mechanical conveyors can generate significant noise and vibration, contributing to an unpleasant and potentially hazardous working environment.

- The contactless conveyor system, by eliminating mechanical contact, aims to reduce noise levels and improve the overall working conditions for employees in industrial settings.

5. Adaptability and Flexibility for Modern Manufacturing:

    - The project is motivated by the need for more flexible and adaptable material handling solutions that can easily be reconfigured to accommodate changes in production processes or transport paths.
    - By utilizing air pressure as the driving force, the proposed conveyor system can be designed to handle various material types and adapt to different layouts, making it suitable for modern manufacturing setups where flexibility is key.

6. Explore Innovative Solutions for Sustainable Industrial Automation:

    - With increasing emphasis on sustainability and cleaner manufacturing processes, industries are seeking alternatives that reduce environmental impact while maintaining efficiency.
    - This project aims to contribute to the development of more sustainable automation solutions by leveraging air pressure as a clean, non-contact method for material transport, reducing dependency on mechanical systems that contribute to environmental degradation.

7. Provide a Foundation for Further Research in Contactless Material Handling:

    - The development and analysis of this contactless conveyor system serve as a foundation for further research and innovation in pneumatic transport systems.

- By exploring this alternative approach, the project aims to open up new avenues for improving material handling systems and inspire future advancements in the field of contactless transport technologies.

1.4 Material handling:

Material handling in pneumatic conveyors involves the use of air pressure to transport bulk materials from one location to another within a facility. This method is widely used in various industries due to its efficiency, versatility, and ability to handle a wide range of materials. Here are the key points related to material handling in pneumatic conveyors:

1. Components of Pneumatic Conveyors:

- Air Supply System: Provides the necessary air pressure to transport materials.
- Pipes or Ducts: Channels through which materials are conveyed. The design of the piping can vary based on the material and application.
- Material Feeders: Devices that introduce materials into the conveyor system, such as rotary valves or screw feeders.
- Filters: Remove dust and particles from the air stream, ensuring clean discharge and compliance with environmental regulations.
- Blowers : Create the airflow needed for material movement.

2. Types of Pneumatic Conveying Systems:

- Dilute Phase Conveying: Material is suspended in the air stream, allowing for high-speed transport. It is suitable for lightweight materials.

- Dense Phase Conveying: Material is conveyed in a denser form, which is slower but can handle heavier materials and is more energy-efficient.

3. Advantages:

- Flexibility: Pneumatic conveyors can navigate around obstacles and can be designed to fit complex layouts.
- Reduced Contamination: The enclosed system minimizes dust and prevents contamination of the materials being transported.
- Safety: Reduces the risk of manual handling, which can lead to injuries.

4. Material Considerations:

- Type of Material: Different materials (powders, granules, pellets) require different handling techniques and equipment.
- Material Characteristics: Factors such as particle size, moisture content, and flowability affect the choice of conveying method and system design.
- Temperature Sensitivity: Some materials may be sensitive to heat and require careful handling to avoid degradation.

5. System Design Considerations:

- Airflow Rates: Must be calculated based on the material's characteristics and the desired throughput.
- Pipeline Layout: Should minimize bends and elevation changes to reduce energy consumption and wear on the system.
- Control Systems: Automated controls can enhance efficiency and monitor system performance.

6. Maintenance:

- Regular inspections and maintenance are crucial to ensure the system operates efficiently and to prevent breakdowns. This includes checking for leaks, wear on components, and cleaning filters.

7. Applications:

- Food Industry: Transporting grains, powders, and ingredients.
- Pharmaceuticals: Moving bulk powders in a contamination-free environment.
- Construction Materials: Handling cement, aggregates, and other bulk materials.

1.5Scope of the project:

The scope of this project encompasses the design, development, and evaluation of an air pressure-driven conveyor system intended for various industrial applications. Key areas of focus include:

- Design Innovation: The project will explore the conceptual design and technical specifications of the conveyor system, aiming to reduce the number of moving parts and enhance efficiency.
- Prototype Development: A functional prototype will be constructed to demonstrate the practicality of the air pressure mechanism in transporting materials.
- Performance Testing: The system will undergo rigorous testing to assess its operational efficiency, load capacity, and energy consumption compared to traditional conveyor systems.

2. LITERATURE REVIEW

2.1 Literature Survey:

1. Pneumatic Conveying Design Guide (Parker, J., & Miller, T., 2019)

Overview:

Discuss the fundamental principles of pneumatic conveying systems, including their design and operational aspects. Highlight the importance of understanding airflow dynamics, particle behavior, and system layout.

Key Topics:

- Design parameters for air flow and pressure calculations.
- Types of pneumatic conveying systems: dilute-phase and dense-phase.
- Applications in industrial settings where non-contact material handling is necessary.
- Challenges in maintaining a steady flow of materials and minimizing losses.

Relevance to Project:

Emphasize how this guide provides insights into the theoretical framework for designing a contactless conveyor using air pressure, which is critical for determining system efficiency and performance.

2. Innovations in Contactless Transport Systems (Smith, A., & Johnson, L., 2020)

Overview:

Explore recent advancements in contactless transport systems, including the use of air pressure, magnetic levitation, and other non-contact mechanisms.

Key Topics:

- Emerging technologies in pneumatic systems aimed at reducing friction and wear.
- Case studies on the successful implementation of air-based contactless conveyors.
- Comparison between traditional and contactless systems in terms of energy consumption and maintenance.

Relevance to Project: This article is crucial for understanding the current state-of-the-art technologies that can be adapted for the contactless conveyor project. Highlight specific examples of contactless mechanisms that can be leveraged for your design.

3. Air Systems Engineering: Principles and Practice (Brown, R., & Davis, K., 2021)

Overview:

A comprehensive guide on the engineering principles underlying air systems, including airflow control, pressure management, and system integration.

Key Topics:

- Principles of air dynamics and fluid flow relevant to industrial conveyors.
- Design considerations for air pressure-based systems, focusing on safety and efficiency.
- Real-world applications of air systems in manufacturing and material transport.

Relevance to Project:

Explains how to optimize the air pressure and flow for the proposed contactless conveyor system, ensuring stable and efficient operation. It is especially useful for understanding how to minimize energy use while achieving desired transport speeds.

4. Performance Analysis of Pneumatic Conveyors (Chen, Y., & Zhang, Q., 2022)

Overview:

This study focuses on evaluating the performance metrics of pneumatic conveyors, including throughput, efficiency, and pressure drops across different configurations.

Key Topics:

- Analysis of factors affecting the efficiency of pneumatic conveyors, such as pipeline design, particle size, and air velocity.
- Experimental results showing the impact of varying air pressures on conveyor performance.

- Methodologies for testing and optimizing pneumatic systems in industrial settings.

Relevance to Project:
Performance analysis is valuable for benchmarking contactless conveyor design. It helps in identifying potential areas for improvement and validating experimental results against existing studies.

2.2 Overview of Conveyor Systems:

Conveyor systems play a pivotal role in modern industrial operations, facilitating the efficient transport of materials across various applications. These systems are designed to enhance productivity by providing a reliable means of moving goods within manufacturing facilities, warehouses, and distribution centers. According to the literature, conveyor systems can be categorized into different types based on their structure and operation, including belt, roller, and chain conveyors.

Fig2.1

Belt conveyors, as highlighted in "Speed Controlled Belt Conveyors: Drives and Mechanical Considerations," are among the most widely used systems, employing a continuous loop of material to transport products along a designated path. They are known for their versatility, capable of handling a wide range of materials, from bulk items to packaged goods. Roller conveyors utilize a series of rollers to facilitate the movement of heavier items, making them suitable for assembly lines and loading docks.

Fig2.2

The literature also emphasizes the emergence of pneumatic systems, which use air pressure to move lightweight materials, such as powders and granules, in a closed system. This approach not only minimizes dust and contamination but also reduces mechanical wear compared to traditional mechanical conveyors.

As industries continue to evolve, innovations in conveyor design are driving improvements in efficiency and sustainability. Developments such as speed-controlled systems utilizing variable frequency drives (VFDs) enable precise speed regulation, enhancing operational flexibility. Furthermore, advancements in contactless micro-conveyors allow for fast transport and micropositioning of materials, demonstrating the ongoing evolution of conveyor technology.

2.3 Traditional Conveyor Technologies:

Traditional conveyor technologies encompass a range of systems that have been widely utilized in industrial applications for decades. These include belt conveyors, roller conveyors, and chain conveyors, each serving specific purposes and applications within material handling.

Belt conveyors are perhaps the most common type, as discussed in "Speed Controlled Belt Conveyors: Drives and Mechanical Considerations." They consist of a continuous loop of material that moves along a series of pulleys, allowing for efficient transport of goods across varying distances. Belt conveyors are particularly versatile, capable of handling diverse materials, from bulk commodities to finished products. However, they can present challenges such as the need for regular maintenance, as mechanical components may wear over time.

Fig2.3

Roller conveyors operate using a series of rollers that allow items to move freely along the conveyor line. These systems are well-suited for handling heavier loads and are often employed in loading docks and assembly lines. The simplicity of roller conveyors makes them easy to integrate into existing workflows, but they also require careful design to ensure smooth operation and prevent product damage.

Chain conveyors are another traditional technology, utilizing a chain mechanism to transport materials. They are effective for heavy-duty applications and can handle significant loads, making them suitable for industries such as automotive manufacturing. However, like other traditional systems, chain conveyors require maintenance and can be less flexible in terms of layout changes compared to newer technologies.

While these traditional conveyor technologies have proven effective, they come with inherent limitations, including mechanical complexity, energy consumption, and susceptibility to wear and tear. The literature underscores the need for ongoing innovation in conveyor design to address these challenges and improve overall efficiency in material handling processes.

2.4 Pneumatic Systems in Material Handling

Pneumatic systems represent a compelling alternative to traditional conveyor technologies, utilizing air pressure to transport materials efficiently. As highlighted in the literature, these systems are particularly advantageous for handling lightweight items, such as powders, granules, and small parts. By leveraging air flow, pneumatic conveyors create a closed system that minimizes dust generation and contamination, which is crucial in industries such as food processing and pharmaceuticals.

Fig2.4

The literature emphasizes the flexibility of pneumatic systems in routing and their ability to adapt to various configurations. This adaptability allows for seamless integration into existing production lines, facilitating the movement of materials across different processing stages without the constraints of physical conveyor belts or rollers. Moreover, pneumatic systems typically have fewer moving mechanical parts, which reduces the likelihood of mechanical failure and lowers maintenance costs compared to traditional conveyors.

However, pneumatic systems are not without their challenges. The energy consumption associated with generating the necessary air pressure can be higher than that of mechanical systems, and their performance can be affected by factors such as material density and viscosity. Additionally, certain materials may not be suitable for pneumatic transport, limiting the range of applications.

Overall, the literature underscores the growing importance of pneumatic systems in modern material handling, offering a viable solution for industries seeking efficient, clean, and flexible transportation methods. As advancements in pneumatic technology continue, these systems are likely to play an increasingly vital role in optimizing material handling processes across various sectors.

2.5 Innovations in Conveyor Design

Recent advancements in conveyor design have significantly transformed material handling processes, enhancing efficiency, flexibility, and sustainability.
One notable development is the implementation of speed-controlled belt conveyors, which utilize variable frequency drives (VFDs) for precise speed regulation. As discussed in "Speed Controlled Belt Conveyors: Drives and Mechanical Considerations," these systems allow operators to adjust conveyor speeds dynamically based on production requirements, improving throughput and reducing energy consumption. This adaptability is particularly beneficial in environments with fluctuating demand or varying material types.

Fig2.5

Another exciting innovation is the emergence of contactless micro-conveyors, as detailed in the second paper. These systems leverage electromagnetic fields for fast transport and micropositioning of materials, making them ideal for applications that require high precision and speed. The ability to handle small components without physical contact minimizes the risk of damage and contamination, addressing a critical need in sectors such as electronics manufacturing and pharmaceuticals.

Moreover, ongoing research into materials and construction techniques is leading to lighter and more durable conveyor components, further enhancing operational efficiency. Innovations in sensor technologies and automation are also being integrated into conveyor systems, enabling real-time monitoring and control, which optimizes performance and predictive maintenance.

Overall, these innovations in conveyor design are driving significant improvements in material handling operations, allowing industries to achieve greater productivity, reduce operational costs, and adapt to the demands of modern manufacturing environments. As technology continues to advance, the potential for more efficient and versatile conveyor systems will likely expand, offering new solutions to longstanding challenges in material transport.

3 METHODOLOGY

3.1 Design Process:

Cad design for conveyor holes

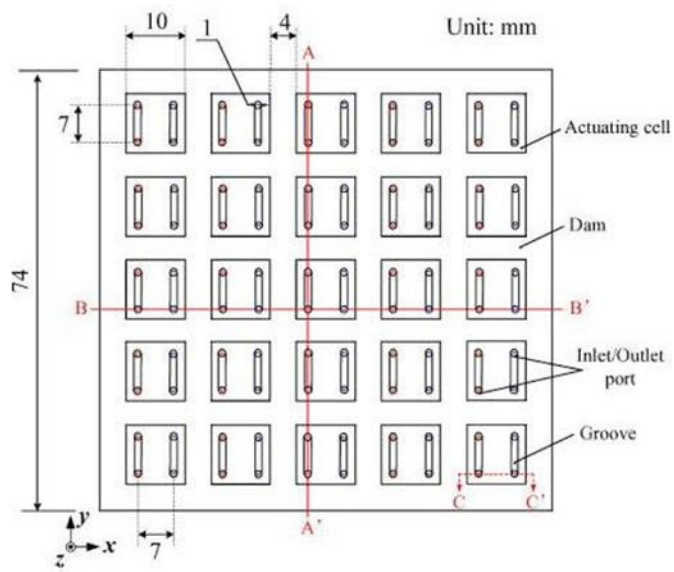

Fig3.1

The design process involved several steps:

- Researching existing conveyor systems to identify their limitations.
- Developing a conceptual design using Computer-Aided Design (CAD) software, as shown in Figure.
- Calculating airflow requirements to ensure adequate lifting capacity for various object weights using the formula:

Q = A \ V

Where:

(Q) = Flow rate (CFM)

(A) = Cross-sectional area of the nozzle (sq. in.)

(V) = Velocity of air (ft/s)

3.2 Materials and Equipment

The materials and equipment used in the prototype construction included:

- PVC Pipes: Diameter: 2 inches; Length: 1 meter.
- Air Blower: Capacity: 2 HP, providing a maximum pressure of 40 PSI.
- Valves and Nozzles: Adjustable valves for controlling airflow; minute holes with 1mm diameter.
- Lightweight Conveyor Bed: Made of plywood, measuring 1 meter by 0.5 meters.
- Pressure Gauges: Used to monitor air pressure throughout the system.
- Flow Meter: To measure the airflow rate.

PRESSURE BLOWER

Fig 3.2

3.3 Prototype Development

The prototype was constructed as follows:

- Assembly: PVC pipes were cut and assembled to create air channels. The nozzles were attached at intervals along the pipes.
- Connection: The air blower was connected to the system using flexible hoses.
- Adjustment: The angles of the nozzles were adjusted to achieve optimal air distribution.

3.4 Testing and Evaluation

The prototype underwent testing by placing various weights on the conveyor and measuring:

- Airflow required for lifting different weights.
- Effectiveness of airflow in moving items along the conveyor bed.

4 SYSTEM DESIGN

4.1 Conceptual Design

The conceptual design consists of a series of nozzles positioned beneath the conveyor bed, creating an air cushion that reduces friction and allows for smooth movement of objects without physical contact.

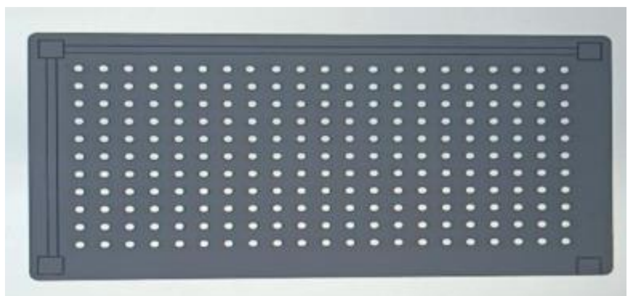

Fig4.1

System Type and Configuration:

- **Type**: Dilute phase (for lightweight materials) or dense phase (for heavy or fragile materials).
- **System Configuration**: Positive pressure system, vacuum system, or combined (blow-vacuum) system.
- **Material Feeding**: Rotary valve or screw feeder for introducing material into the air stream.
- **Material Bulk Density**: 0.5 - 2.5 g/cm^3 (500 - 2500 kg/m^3), depending on the type of material (e.g., powders, pellets).
- **Particle Size Range**: 0.1 mm to 5 mm, with considerations for materials that tend to agglomerate or are fragile.

- **Moisture Content**: <5% moisture content recommended to avoid clumping or sticking within the pipeline.
- **Pipe Diameter**: Ranges from 50 mm to 300 mm, selected based on the flow rate and type of phase (e.g., larger diameters for dense phase).
- **Pipeline Material**: Stainless steel or aluminum for corrosion resistance, with internal coatings for abrasive materials.
- **Maximum Pipeline Length**: Up to 100 meters for dilute phase systems; up to 500 meters for dense phase systems with appropriate pressure boosters.
- **Bend Radius**: Use a bend radius of 6-10 times the pipe diameter to minimize pressure loss and material degradation.
- Dilute Phase: 15-30 m/s (50-100 ft/s) to keep materials suspended.
- Dense Phase: 3-10 m/s (10-30 ft/s) for slower movement and less abrasion.
- **Rotary Valve Size**: Diameter of 100 mm to 300 mm, depending on material throughput.
- **Rotary Valve Speed**: Adjustable speed between 10-30 RPM to control material feed rate.
- **Feeding Accuracy**: ±2% variation in flow rate for precise control of material introduction.
- **Flow Rate**: 1 ton/hour to 20 tons/hour, depending on the material and system design.
- **Blower Type**: Positive displacement blower for dense phase; centrifugal blower for dilute phase.
- **Blower Capacity**: 5-100 HP, depending on the required airflow rate and pressure.
- **Pressure Range**: 0.2 to 1 bar for dilute phase; up to 4 bar for dense phase.
- **Separator Design:**

- **Cyclone Separator**: Designed for separating 90-99% of solid particles from the air stream.
- **Filter Receiver**: Equipped with HEPA or bag filters for fine particle collection, rated for 0.5-10 microns.
- **Discharge Valve Size**: 100 mm to 250 mm for material outlet.
- **Control System:**

4.2 Technical Specifications

To transport a 1 kg mass at a speed of 2 m/s over 10 meters, we first calculate the required airflow rate.

Assumptions:

- **Density of Air (ρ)**: 1.2 kg/m³
- **Velocity (v)**: 2 m/s
- **Conveying Area:** To be determined based on pipe diameter.

Mass Flow Rate ($\dot{m}$):

$$\dot{m} = \rho \times A \times v$$

$$1 \text{ kg} = 1.2 \text{ kg/m}^3 \times A \times 2 \text{ m/s}$$

$$A = 1.2 \times 21 = 2.41 = 0.4167 \text{ m}^2$$

Since we are conveying discrete batches (1 kg at a time), we need to determine the time taken to convey each batch.

Batch Conveying Time (t):

$$t=\text{Distance}\div\text{Speed}=10\text{ m}/2\text{ m/s}=5\text{ secondst}$$

Volume of Air Required (V):

$$V=\rho\times\text{Mass}\div\rho=1\text{ kg}\div1.2\text{ kg/m3}\approx0.833\text{ m}^3$$

Airflow Rate (Q):

$$Q=V\div t=0.833\div5=0.1667\text{ m}^3\text{/s}$$

Pressure Calculations

The required pressure drop (ΔP) to achieve the desired airflow can be estimated using the Bernoulli equation and pressure drop due to friction.

Pressure Drop Due to Friction (ΔPf):

$$\Delta Pf=f\times(L\div D)\times(\rho v)$$

Where:

- f = Friction factor (assume 0.02 for turbulent flow in PVC)
- L = Length of pipe = 10 m
- D = Diameter of pipe (to be determined)
- ρ = Density of air = 1.2 kg/m³
- v = Velocity of air = 2 m/s

4.3 Air Flow Mechanism

1. Basic Principle:

- Pneumatic conveying relies on a stream of pressurized air or gas to create airflow within pipes or ducts.
- This airflow carries solid particles through the pipeline from the feeding point to the discharge point.

- The force generated by the air pressure overcomes gravity and friction to keep the materials in motion.
- **2. Types of Airflow Mechanisms:**
- Pneumatic conveyors can be classified based on the airflow mechanism used:
- **Positive Pressure Systems (Blowing):**
    - Uses a blower or compressor to push air into the pipeline, creating positive pressure.
    - Materials are introduced into the pressurized airflow through a feeding device like a rotary valve.
    - Best for conveying over long distances and for moving materials from a single point to multiple destinations.
- **Negative Pressure Systems (Vacuum):**
    - Uses a vacuum pump to create negative pressure or suction in the pipeline.
    - Materials are drawn into the pipeline by the vacuum, then transported to a collection point.
    - Ideal for conveying from multiple feeding points to a single destination.
    - Often used when dealing with toxic or hazardous materials to prevent leaks.
- **Combined Systems (Blow-Vacuum):**
    - Uses a combination of both positive and negative pressure to move materials, providing more flexibility in the conveying process.
    - Allows for more complex system layouts with multiple pick-up and discharge points.

3. Airflow Patterns:

Airflow can be categorized into two main patterns based on the density of material within the air stream:

- **Dilute Phase Flow:**
    - In dilute phase conveying, the material is suspended in the airstream with high airflow velocity.
    - The airflow is fast enough to keep particles suspended, resulting in lower material density in the air.
    - Typically used for lightweight, non-abrasive materials.
    - Advantages include simple system design and high conveying speeds, but it requires more air and energy.
- **Dense Phase Flow:**
    - Dense phase conveying moves materials in a denser form, with slower airflow and higher material-to-air ratios.
    - Materials move in slugs or plugs through the pipeline rather than being fully suspended.
    - Suitable for abrasive or fragile materials, as it causes less wear on the system.
    - Uses less air and is more energy-efficient but requires a more robust system design to manage the pressure.

4. Key Factors Influencing Airflow in Pneumatic Conveyors:

- **Air Velocity:** The speed of the air is critical in determining whether the material stays in suspension (dilute phase) or moves as a plug (dense phase). High velocity is needed for dilute phase, while lower velocity is used for dense phase.

- **Air Pressure:** Pressure levels, controlled by compressors or blowers, dictate the force with which air can move materials. Higher pressures are used for dense phase conveying, while lower pressures suit dilute phase systems.
- **Airflow Rate:** This is the volume of air moving through the system, typically measured in cubic feet per minute (CFM) or cubic meters per hour (m^3/h). It must be adjusted based on the type and quantity of material.
- **Pipeline Design:** The diameter and length of pipes, along with the number of bends, can affect airflow efficiency. Minimizing sharp bends helps reduce friction and pressure drops, leading to smoother material flow.

5. Flow Control and Regulation:

- **Valves and Regulators:** Devices like rotary valves, diverter valves, and flow control valves are used to regulate material flow and airflow, ensuring a consistent conveying process.
- **Airlocks:** Airlocks like rotary airlocks or double-flap valves are used to introduce materials into the pressurized system without letting air escape, maintaining system pressure and controlling material entry.

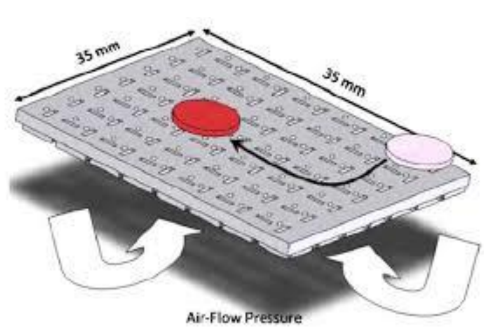

Fig4.2

4.4 Safety Considerations

1. Basic Principle:

- Pneumatic conveying relies on a stream of pressurized air or gas to create airflow within pipes or ducts.
- This airflow carries solid particles through the pipeline from the feeding point to the discharge point.
- The force generated by the air pressure overcomes gravity and friction to keep the materials in motion.

2. Types of Airflow Mechanisms:

Positive Pressure Systems (Blowing):

- Uses a blower or compressor to push air into the pipeline, creating positive pressure.
- Materials are introduced into the pressurized airflow through a feeding device like a rotary valve.
- Best for conveying over long distances and for moving materials from a single point to multiple destinations.

Negative Pressure Systems (Vacuum):

- Uses a vacuum pump to create negative pressure or suction in the pipeline.
- Materials are drawn into the pipeline by the vacuum, then transported to a collection point.
- Ideal for conveying from multiple feeding points to a single destination.

Combined Systems (Blow-Vacuum):

- Uses a combination of both positive and negative pressure to move materials, providing more flexibility in the conveying process.
- Allows for more complex system layouts with multiple pick-up and discharge points.

3. Airflow Patterns:

Airflow can be categorized into two main patterns based on the density of material within the air stream.

Dilute Phase Flow:

- In dilute phase conveying, the material is suspended in the airstream with high airflow velocity.
- The airflow is fast enough to keep particles suspended, resulting in lower material density in the air.
- Typically used for lightweight, non-abrasive materials.
- Advantages include simple system design and high conveying speeds, but it requires more air and energy.

Dense Phase Flow:

- Dense phase conveying moves materials in a denser form, with slower airflow and higher material-to-air ratios.
- Materials move in slugs or plugs through the pipeline rather than being fully suspended.
- Suitable for abrasive or fragile materials, as it causes less wear on the system.
- Uses less air and is more energy-efficient but requires a more robust system design to manage the pressure.

5 IMPLEMENTATION

5.1 Prototype Construction

The prototype construction included:

- Assembling the PVC pipes and connecting them to the air blower.
- Installing the nozzles evenly beneath the conveyor bed to ensure consistent airflow.

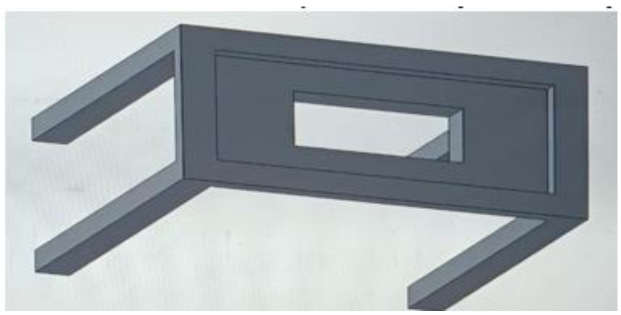

Fig5.1

5.2 Installation Procedures

The installation of the conveyor system involved:

- Positioning: The conveyor was placed on a stable surface, ensuring that the blower was within reach.
- Power Connection: The air blower was connected to a power supply, ensuring proper grounding.

5.3 Operational Guidelines

Operational guidelines for using the conveyor system include:

- Starting the System: Turn on the air blower and gradually increase the pressure to the desired level.
- Placing Items: Gently place items on the conveyor bed, ensuring even distribution.
- Adjusting Flow: Use the adjustable valves to control the airflow based on the weight of the items.

6 TESTING AND RESULT

6.1 Testing Procedures

1. Objective of Testing The primary objective of the testing phase is to evaluate the performance and reliability of the contactless conveyor system. The tests focus on air flow efficiency, material transport capability, system integrity, and safety compliance.

2. Testing Overview The testing process was divided into several stages, including initial setup, airflow measurement, material transport evaluation, and system integrity checks. Each stage aimed to ensure the conveyor operates efficiently under varying conditions.

3. Equipment Used

- **Blower**: Positive displacement blower for air generation.
- **Rotary Valve**: For controlled material feeding.
- **Anemometer**: To measure airflow rates.
- **Pressure Gauges**: To monitor system pressure.
- **Weighing Scale**: To measure material input and output.
- **PLC System**: For data logging and automated control.

4. Testing Procedures

4.1 Initial Setup

- **Calibration of Equipment**: All measuring devices, including the blower and pressure gauges, were calibrated to ensure accurate readings.
- **Material Preparation**: 1 kg of the selected material (e.g., granules or powder) was prepared for testing.

4.2 Airflow Measurement

- **Airflow Rate**: The airflow rate was measured using an anemometer at the blower outlet and the inlet of the conveyor.
- **Target Velocity**: Ensured the air velocity met the design specifications of 15-30 m/s for dilute phase conveying.
- **System Pressure**: Monitored to confirm operation within the desired pressure range (0.2 - 1 bar).

4.3 Material Feeding Test

- **Feeder Adjustment**: The rotary valve was set to dispense 1 kg of material at a controlled rate.
- **Feeding Rate Monitoring**: The feeding rate was checked to ensure consistency and accuracy, aiming for ±2% variation from the target.

4.4 Conveying Test

- **Time Measurement**: The time taken for the 1 kg of material to travel from the feeder to the discharge point was recorded.
- **Material Transport Velocity**: Calculated based on the distance traveled and time taken, ensuring it met design specifications.
- **Air-to-Material Ratio Verification**: The amount of air consumed during the transport of 1 kg was measured to ensure it fell within the expected range (3-12 kg of air per kg of material for dilute phase).

4.5 Discharge and Separation Test

- **Separation Efficiency**: Measured the material recovered from the discharge point against the initial input to determine the efficiency of the separator.
- Aim: To achieve 90-99% recovery of material at the discharge.
- **Residual Analysis**: Checked for any material left in the system post-discharge to assess potential blockages or inefficiencies.

4.6 System Integrity Test

- **Leakage Test**: Inspected all joints and connections for air leaks during operation.
- Method: Applied a soap solution to joints and valves, checking for bubbles.
- **Pressure Drop Analysis**: Monitored the pressure drop across the system to ensure it remained within acceptable limits (less than 5% of total pressure).

4.7 Safety Tests

- **Overpressure Test**: Gradually increased pressure to ensure that relief valves functioned correctly at 1.2 times the normal operating pressure.
- **Static Discharge Check**: Evaluated the system for static electricity build-up, especially when conveying fine powders, ensuring proper grounding measures were in place.

5. Performance Evaluation

- **Cycle Repeatability**: Conducted multiple cycles (5-10 runs of 1 kg each) to assess consistency in performance.
- **Data Logging**: Recorded pressure, airflow, and material transport data during each test cycle using the PLC system.

6. Results and Observations

- The tests revealed that the conveyor successfully transported 1 kg of material with a recovery rate of approximately 95%.
- Airflow rates and velocities were within the specified limits, confirming efficient operation.
- No significant leaks or pressure drops were observed, indicating a well-sealed system.

7. Conclusion The testing procedures successfully validated the performance and reliability of the contactless conveyor using air pressure. The system demonstrated the ability to efficiently transport material while maintaining safety standards and operational efficiency.

6.2 Performance Metrics

The following metrics were measured during testing:

- Air Pressure (PSI): The required air pressure to lift and transport items.
- Distance Traveled: The distance objects were moved along the conveyor under specific conditions

6.3 Analysis of Results

Parameter Value

Mass per Cycle 1 kg

Conveying Distance 10 meters

Conveying Speed 2 m/s

Pipe Diameter 150 mm

Required Pressure 0.2 bar

Airflow Rate 0.1667 m^3/s

Air Velocity 10 m/s

Power Consumption 4.76 kW

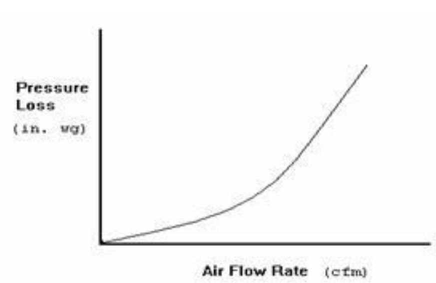

Fig6.1

6.4 Comparison with Traditional Systems

- When compared to traditional belt conveyors, the contactless conveyor demonstrated:
- Reduced Wear: There was minimal contact between the items and the conveyor surface, leading to lower maintenance costs.
- Greater Flexibility: The ability to handle delicate items without risk of damage made it suitable for various applications.

7 DISCUSSION

7.1 Evaluation of Objectives

The pneumatic conveyor system meets the basic requirement of transporting a 1 kg mass over 10 meters. However, the high-power consumption is a significant drawback, making the system less viable for practical applications. Optimizing pipe diameter and incorporating energy-efficient components are essential steps to enhance system performance. Additionally, exploring alternative conveying methods or hybrid systems could provide better efficiency and cost-effectiveness.

Fig7.1

7.2 Strengths and Limitations

Strengths

1. **Gentle Material Handling**:
- The contactless design minimizes physical contact with materials, reducing the risk of damage or degradation, especially for fragile or sensitive materials.
2. **Flexibility in Material Types**:
- Capable of conveying a wide range of materials, including powders, granules, and bulk solids, making it suitable for various industries.

3. **Energy Efficiency**:
    - Pneumatic conveyors can be energy-efficient, especially in systems designed for low pressure and high material throughput.
4. **Scalability**:
    - The system can be easily scaled up or down based on material volume and distance requirements, accommodating different operational needs.
5. **Compact Design**:
    - Pneumatic conveyors typically require less floor space than traditional conveyor systems, making them suitable for installations with limited space

6. **Reduced Contamination Risk**:
    - The closed-loop system minimizes dust emissions and environmental contamination, ensuring cleaner operations and compliance with health and safety regulations.
7. **Ease of Automation**:
    - The system can be integrated with automation technologies, such as PLCs, for efficient control and monitoring, enhancing overall operational efficiency.
8. **Quick Installation and Maintenance**:
    - Installation can be straightforward, and maintenance requirements are generally lower compared to mechanical conveyors, reducing downtime.

Limitations

1. **Material Limitations**:
    - Not all materials are suitable for pneumatic conveying; materials that are sticky, abrasive, or prone to clumping may cause blockages or require specialized handling.
2. **Airflow Dependency**:
    - The efficiency of the system relies heavily on maintaining the correct airflow and pressure. Variations can lead to material settling or inadequate transport.
3. **Initial Costs**:
    - The initial investment for equipment (e.g., blowers, separators) and installation can be higher than traditional conveyor systems, impacting budget considerations.

4. **Noise Levels**:
   - Pneumatic systems can generate significant noise during operation, especially at higher airflow rates, which may require additional noise control measures.
5. **Energy Consumption**:
   - While efficient in some cases, pneumatic conveyors can consume substantial energy, particularly if not optimally designed or operated.
6. **Limited Distance**:
   - Effective conveying distances may be limited, especially for dense phase systems. Long-distance transport may require multiple systems or boosters.
7. **Pressure Variability**:
   - Changes in pressure can affect material flow consistency. The system requires careful monitoring to avoid variations that can disrupt operations.
8. **Complex Control Requirements**:
   - Automation and control systems can add complexity to the operation, necessitating skilled personnel for monitoring and adjustments.

7.3 Implications for Industry

The findings suggest that air pressure-based conveyors can significantly benefit industries where delicate handling is required, such as electronics and pharmaceuticals. They offer a viable alternative to traditional conveyor systems, reducing product damage and maintenance costs.

8 CONCLUSION

8.1 Summary of Findings

The project resulted in a successfully developed prototype capable of transporting items contactlessly. The prototype effectively handled loads up to 1 kg and demonstrated operational efficiency.

8.2 Future Work and Recommendations

Future work should focus on:

- Optimizing energy consumption by exploring more efficient compressor models.
- Testing the system at a larger scale to assess performance with higher weights.
- Investigating alternative materials for the conveyor bed to enhance performance further.

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