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Optimization of a Non-Contact Air Conveyor: An Experimental Study

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Abstract

In today's dynamic industrial landscape, the demand for efficient, flexible, and safe material handling solutions is paramount. Traditional conveyor systems, while effective, often face limitations in adaptability and cleanliness, particularly in environments requiring strict hygiene standards or the handling of delicate goods. This study introduces a novel contactless conveyor system that uses a special aerodynamic traction mechanism to move flat materials—such as boxes, papers, and food items—without coming into interaction with one another. To facilitate fluid and contact-free posture, the technology makes use of a pneumatic cushion and regulated aeration. To guarantee correct representation, a thorough model of the system is created and parameters are identified. This research lays the groundwork for future exploration, positioning the contactless air conveyor as a transformative solution in modern material transport, with a rise time of 1.91 seconds for lighter objects and 3.46 seconds for heavier objects.

Keywords
Industry, Robust, Contaminants, Risetime, Contactless.

1. Introduction

The non-contact air conveyor uses the force of regulated air flow to move materials and products in a gentle and effective manner. This technology reduces friction and permits contactless object transfer by suspending loads on an air cushion. Comparing this novel technology to conventional belt-driven conveyors, the former offers improved safety, adaptability, and energy economy. In contrast to conventional conveyors that depend on mechanical touch, the NCACS levitates flat planar objects along the intended path by means of a network of finely regulated air streams. Reduced maintenance expenses and an extended operating lifespan result from this frictionless transport mechanism's reduction of wear and tear on the conveyor system and the transported goods. The NCACS is distinguished by its capacity to move cargo at fast speeds without sacrificing security. The system may achieve quick acceleration and deceleration by utilizing pneumatic technology, which allows for quick throughput and reduces bottlenecks in production or distribution processes. A cleaner and more hygienic working environment is promoted by the NCACS's non-contact nature, which reduces the buildup of dust, dirt, and other impurities on the conveyor surface. This capability is especially helpful in sectors like food processing, pharmaceuticals, and electronics manufacturing that have strict cleaning regulations.

Moreover, dry forces are eliminated. As a result, we are able to increase transportation speed without causing any harm to the goods. The Non-Contact Air Conveyor System's (NCACS) modular architecture makes it simple to integrate into current industrial or logistics infrastructures and enables smooth scalability and customization to satisfy particular application requirements. Furthermore, the experimental findings regarding the distribution of film pressure and flow rate characteristics are presented. Rated voltage: between 220 and 240 volts; frequency: 55 Hz 600W of rated input power Speeds without load: 13000 RPM, load: 12500 RPM.

Figure 1. Experimental setup of an Air Conveyor

We suggested a contactless air conveyor in this study for moving planners or flats. Instead of orifices, the conveyor uses aligned porous material as restrictors. Numerical simulations are performed and a theoretical model is developed. Furthermore, experimental findings on glass deformation, bearing force and stiffness, film pressure distribution, and flow rate characteristics are presented.

Noncontact conveying system

Figure 1 shows the picture and structure of the non-contact air conveyor. The porous pads allow air to enter beneath the glass sheet, creating an air film that provides support. The conveyor has 91 square units and measures 126500 mm square. A porous pad is inserted into a circular recess in each unit. The porous pad is 550 mm in length and 5 mm in diameter. The conveyor surface is a little higher than the porous surface. To exhaust to the atmosphere, grooves that are 150 µm deep and 5 mm wide are positioned in between the units. Additionally, 4mm-diameter holes are positioned where the grooves meet. The glass sheet can be pulled closer to the conveyors by connecting the exhaust holes to the atmosphere or the vacuum generators. To achieve a reasonably even pressure distribution, the outer units on the conveyor's edge are made to be marginally broader than the inner ones

1.1 Objectives

i. To learn about the underlying technology for material handling without physical contact and to look into the concepts of contactless air conveyor systems.
ii. To evaluate the efficiency of contactless air conveyors in moving items or objects by examining important factors such airflow velocity, pressure, and air cushioning effects.
iii. To investigate how various object attributes (size, weight, and form) affect contactless air conveyor systems' handling capacity and pinpoint any potential restrictions or difficulties.
iv. To investigate possible industrial uses for contactless air conveyor systems, which can provide notable advantages in terms of automation, speed, accuracy, and cleanliness.
v. To offer suggestions for improving contactless air conveyor systems' construction, use, and upkeep in order to boost productivity, effectiveness, and safety in industrial environments
vi. . To make recommendations for enhancing the design, operation, and maintenance of contactless air conveyor systems in order to increase industrial settings' efficiency, safety, and productivity

2. Literature Review

Contactless transportation and placement of clean or fragile items, including silicon wafers, glass sheets, solar cells, or flat meals, are necessary for many businesses. Because mechanical contact is avoided, it is possible to handle delicate, freshly painted, hot, sensitive, or micron-sized structural components. It is completely possible to prevent contamination from and of the end-effectors. When handling food or producing semiconductors, this can be crucial. Moreover, precise positioning or high velocity motions are made possible by the cancellation of dry friction forces. Numerous handling techniques have been put forth to prevent interaction between feeding devices and work parts. These techniques usually use aerodynamic, magnetic, electrostatic, and near-field levitation (Delettre et al.2010). The lifting force is dependent on the characteristics of the material, and both magnetic and electric levitation are limited to conductive materials. Pneumatic levitation techniques use air flow to provide force on a workpiece. Because air flow is magnetically free and causes little stress, pneumatic techniques can be applied to any material, whether it is an insulator or conductor, magnetic or non-magnetic, stiff or non-rigid. Levitation, the sample is held beneath the cup-shaped air nozzle that serves as the manipulator's end-effector (IEEE 2015). To create contactless manipulators, researchers have tried a range of air-jet methods. Gas flow provides a lift force in aerodynamic levitation. The air cushion and Bernoulli levitation are two possible methods. Bernoulli. Practical uses of Bernoulli levitation include "pick-and-place" wafers (Laurent et al. 2011) and flat soft meals (Bader and Rahimifard 2020). The sample is supported on a plate with numerous tiny holes punched in it during air cushion levitation. Through these perforations, pressurized air rises, creating an air cushion that balances the component's weight. This is the idea behind well-known air hockey tables. Two concepts—suction and an angled air jet—have been put forth to move the thing that is levitating on the table.

An air hockey table is used by Luntz and Moon. (Delettre et al. 2012), (Delettre et al. 2012), along with a few flow sinks (suction points) above the table. A steady flow pattern is produced in their direction by the sinks. Any rectangular object can be moved to a predicted orientation and position with this sensor-free positioning surface. The identical concept was established by (Ku et al. Corke and Hutchinson 2001), however they moved the object from one sink to another using closed-loop control. A 4 mm 4mmarray of 100 capillary glass tubes makes up the apparatus. For supplying either positive or negative pressure, each tube has a two-position valve and a pressure sensor. The object's normal velocity is 8 mm's 1. In addition to the air cushion, many devices provide a traction force using arrays of slanted air-jets. Wafer and glass transportation systems are two examples of devices whose geometry is intended to provide a reliable transport system without closed-loop control (Delettre et al. 2011, Siegel 2014, Staples et al. 2006). On the other side, 1,152 independently controlled and directed air-jets in a 12 in. 12 in. array are used by the Xerox PARK paper handling system Reed and Miles, 2004, (Yim et al. 2000) to raise paper sheets. Every jet's flow is managed by a separate MEMS-like valve. To sense and regulate the position of the paper, 32,000 optical sensors, or photodiodes, are incorporated between actuators.

The paper is located within a narrow opening where two arrays of 578 valves are positioned in opposition to each other as part of the levitation-transport system. The device has shown trajectory tracking with a typical velocity of around 30 mm's 1 and closed-loop positioning accuracy of 0.05 mm. A wafer transport approach based on the viscous traction principle was put up by (Rij et al. Li et al. 2014). The purpose of the gadget is to create a horizontal airflow beneath the wafer. The paper handling system is then comparable to the principle. MEMS actuator arrays have been used to create a few active surfaces on a nearly tiny size. Because of integrated electrostatic valves, the surface of (Fukuda Zhou et al., 2005) can generate inclined air jets. A flat piece of plastic was successfully moved in their experiments at a velocity of about 4.5 mm-1. In this research, a novel traction theory is used to present a mechanism that can move an object on an air hockey table. The system doesn't use a suction nozzle or an angled air jet. Strong vertical air jets create an airflow that moves the object indirectly. An air hockey table's particular orifices are the source of these powerful jets.

The structure of this document is as follows: In the first section, the experimental apparatus known as the induced air flow surface is described along with a qualitative explanation of the working principles. The control signal nature selection is shown in the second section. The system's identification is covered in the third section, and the device's closed-loop control is covered in the fourth. The initial experimental data, their analysis, and some discussions are presented in the last section. Innovative product transport techniques have been the subject of research at Delft University of Technology, including the utilization of arrays of actuator cells to generate horizontal airflow beneath things. An important advancement is an air actuator, which creates a thin layer of compressed air beneath a substrate to enable precise direction and floating of an object.

In 2008, Jacolin Van Rij of the University of Groningen conducted research on this contactless air transport system, examining its mathematical modeling and working principles. Later developments came from scholars like Van Ostayen and Jasper Wesselingh, who looked more closely at the theoretical underpinnings of this technology. To improve contactless manipulation, a variety of air jet techniques have been attempted, most notably the two main aerodynamic levitation techniques of air cushion and Bernoulli levitation. The object is suspended beneath a cup-shaped air nozzle that creates a lift force in Bernoulli levitation, demonstrating the adaptability of air-based transport systems in industrial settings. Bernoulli levitation, which successfully uses aerodynamic principles to handle fragile goods without contact, has useful applications in the accurate pick-and-place of wafers and flat food products. By placing an object on a perforated plate, on the other hand, pressurized air rushes upward through tiny holes to create an air cushion that balances the weight of the component. This technique is known as air cushion levitation. This idea is similar to how well-known air hockey tables work, which let the puck glide with ease.

By adding flow sinks above the air hockey table, researchers Lunt and Moon have developed this idea further. This improves the system's manipulation and transport capabilities by establishing a steady airflow pattern. They demonstrate the possibility of more regulated and effective handling of different objects in industrial settings by fusing these cutting-edge technologies. This collection of studies highlights the developments in contactless transportation systems and emphasizes how applicable and relevant they are to a variety of businesses.Additional research has examined how these systems might be incorporated into automated production processes, emphasizing the efficiency improvements brought about by less wear and friction on mechanical parts. Notably, (Shimizu et al. 2013) showed how air-bearing technology may be used in high-precision assembly lines to greatly improve accuracy and throughput. Furthermore, (Wang et al. 2017) looked at the scalability of air-based transportation systems, highlighting how versatile they are for a range of industrial settings, including food processing and electronics.
According to (Chen et al. 2020), who suggest adaptive control systems for optimizing object transport based on real-time feedback, the possibility of coupling air levitation with machine learning algorithms has also been studied. This combination of cutting-edge technology suggests that contactless transportation systems will eventually be able to adapt to changing circumstances on their own, expanding their usefulness even more.

3. Methods

3.1 Theoretical Analysis

The underside of the prototype is a one-way air supply. Here, the object can move because the material is a translucent acrylic sheet (3 mm). The sheet, which has holes punched at predetermined intervals, serves as the conveyor's top surface. This is securely affixed to the two-layered hardwood sheet. A wooden groove makes up the second layer. This layer has six grooves in total. There is a tunnel in the middle of the last layer, which is fastened to the second layer's wooden frame. This opening serves as a conduit for airflow to the upper surface that will come into touch with the goods. The concurrent air flow creates a thin layer of air. To move the objects, a high-power blower is linked to the route to create compressed air. The supporting structure that holds the entire system or its components in place follows next. The sturdy wooden structure that makes up this supporting frame has joints and bolts. The CACS has a very distinctive design, and certain requirements have been upheld.

Throughout the procedure, the materials should flow continuously and without interruption
The materials utilized in its construction are reasonably priced.
Railings are put in place to stop objects from falling
To prevent mistakes, materials are assembled correctly.

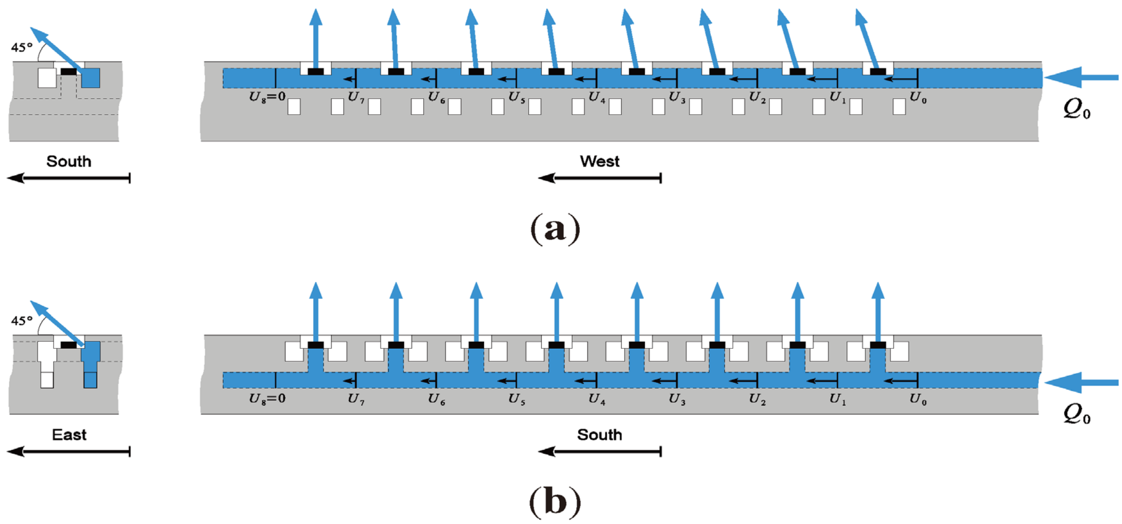

Figure 2**.** Illustration of the influence of the momentum given to geometry of nozzles. (**a**) Generation of jets towards south; (**b**) Generation of jets towards east.

3.2 Required Components

A number of essential parts make up the Non-Contact Air Conveyor System (NCACS), which enables the frictionless movement of goods through the use of pneumatic technology. The primary elements are as follows:

Air Supply Unit: For applications that need steady airflow, including air cushion transport systems and pneumatic conveying, an air supply unit with a centrifugal blower is perfect since it can deliver large amounts of air at comparatively low pressures.

Sealing Materials: For the NCACS to reduce air loss, it must be air sealed and leak-proof. Sealing materials include rubber and foam strips

Air Ducts: The conveyor surface must receive the air flow directly. Air flow is directed via a PVC or wooden duct. The surface needs to be polished or smooth.

Conveyor Surface: The conveyed items are supported and guided by the stable platform that the conveyor surface offers. It may include characteristics like smooth surfaces, guiding rails, and changeable portions to fit various object types and transportation needs. It is made to withstand the airflow produced by the air jets.

Nuts and Joints: Nuts and bolts should be used to secure the conveyor's components to one another. for ensuring structural integrity and performance by offering a dependable and safe connection between components.

Power Supply: To power the NCACS's control system and other electrical components, a dependable power source is necessary. To guarantee continuous operation, this may need electrical wiring, circuit breakers, power distribution units, and backup power systems.

Safety Features: Safety features are incorporated into the NCACS to prevent accidents and protect personnel and equipment. These may include emergency stop buttons, safety interlocks, protective enclosures to alert operators of potential hazards.

3.3 Experimental Setup

Figure 3. Overview of the entire Contactless Conveyor system.

3.4 Working principle

Using pneumatic technology to generate an air cushion that suspends and moves objects without making physical touch with a conveyor surface is the foundation of a Contactless Air Conveyor System (CACS). The working principle is explained in full below:

- Activation of Air Jet: A network of air jets placed along the conveyor line is activated by the system. To create regulated air streams, the air jet is positioned carefully.
- Air Cushion Generation: Pressurized air streams are released as the air jets are turned on, and they are aimed at the conveyor surface. The object is raised off the surface by the cushion of air created beneath it by the interaction of these air streams with the ambient air.
- Loading Area Preparation: At this stage, make sure the loading area has enough room for moving objects, is properly aligned, has guardrails and barriers, and has unobstructed access for equipment and operators.
- Object Levitation: The object is effectively suspended above the conveyor surface by the air cushion that is created, preventing any physical contact between the object and the conveyor. Smooth movement along the conveyor path is made possible by this frictionless transport mechanism, which also reduces the possibility of object damage.
- Transportation: The conveyor system moves the item along the intended path while it is levitating on the air cushion. The conveyor path's layout and the airflow from the air jets are adjusted to manage the movement's speed and direction.
- Object Release**:** The airflow from the air jets is changed or stopped once the object reaches its destination or the end of the conveyor line, allowing it to softly land on the receiving surface. As an alternative, the object could be released at the specified area using additional devices like robotic arms or pneumatic gates.
- Repeat Process: In order to maintain a steady flow of items along the conveyor system, the system constantly looks for new objects to transport and repeats the procedure as necessary.
- Report and Feedback: Last but not least are operational statistics, maintenance, follow-up, and safety performances. Methods of collecting, action planning, and analysis are also essential to the entire process.

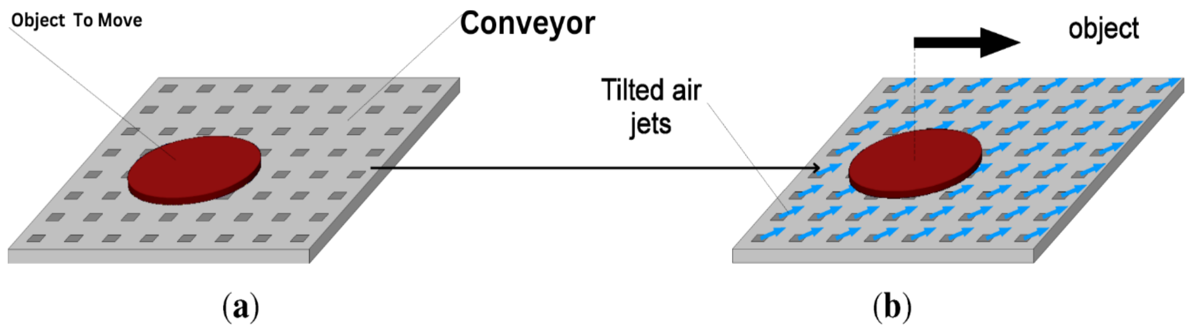

Figure 4. Basic working principal of Contactless Conveyor system.

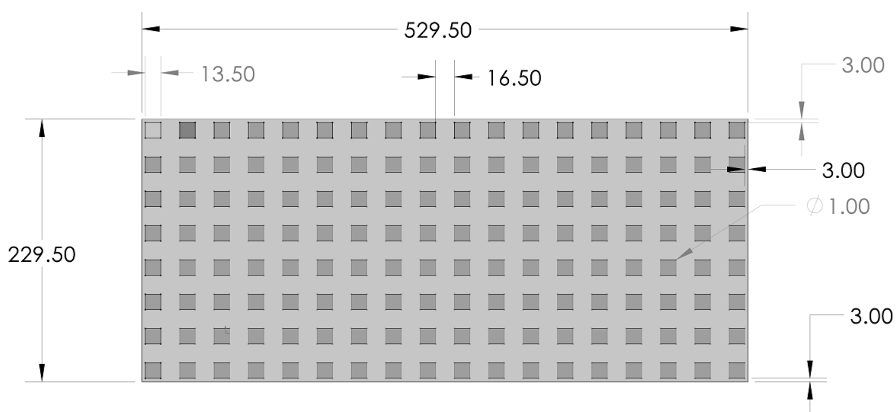

Figure 5. Dimensions and image of the proposed noncontact conveying system.

3.3 Flow chart

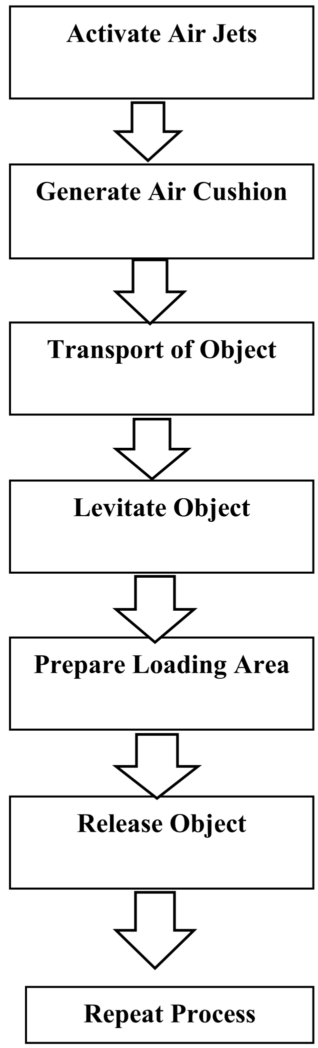

Figure 6. Flowchart of a Noncontact Air Conveyor

The following actions have been carried out in figure 6.

- Turn on Air Jets: This turns on the air jets, which starts the airflow required for the next steps.
- Produce Air Cushion: To assist the levitation operation, the active air jets produce an air cushion beneath the object.
- Transport Object (Transportation Phase): Using the air flow and cushion, the object is moved or transported from one place to another after being supported by it.
- Levitate Object: As the object is moved, the air cushion efficiently raises it so that it floats above the ground.
- Set Up the Loading Area: The loading area is set up for the subsequent item to be handled in parallel, or after the object has been transferred. This stage guarantees that the subsequent item may be transported on the air cushion.
- Release Object: After the object has arrived at the intended spot, it is taken off the air cushion and set down on the assigned surface.
- Repeat procedure: The system is prepared to begin the procedure over after the object has been released. Air jets are turned on, the next object is introduced into the system, and so on.

- Reports and Feedback: During the procedure, reports are produced about how the air jets, air cushion, object transport, and levitation are working. Reports for maintenance or operational analysis can be produced using this data, which can also be used to track system performance.

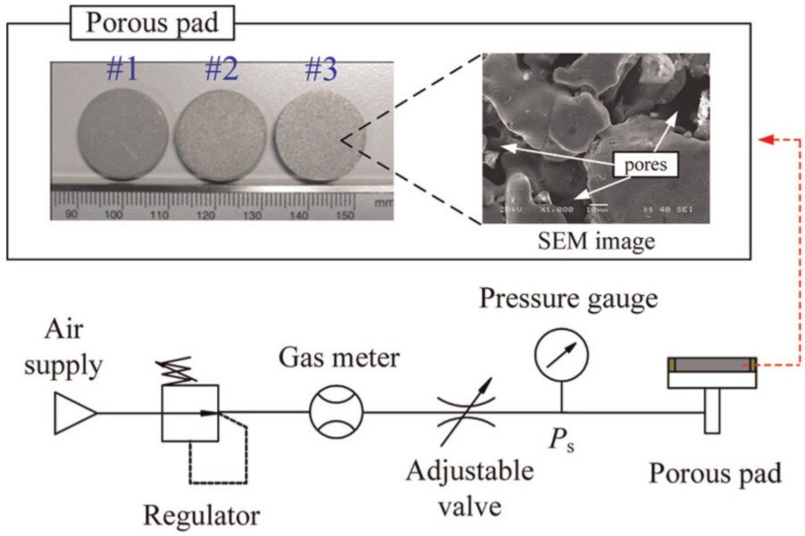

Figure 7. Schematic of the experimental setup for flow measurement.

4. Data Collection

Table 1. Data Table 1

Object	**1**	**2**
Mass(g)	110	154
Risetime(s)	1.91(smooth surface) 2.27(rough surface)	3.26(smooth surface) 3.46(rough surface)
Amplitude(mm)	335	335
Overshoot	10%	14.4%
Floatation Error	0.14%	0.34%

Table 2. Data Table **2**

Conveyor Area(**mm²**)	1265
Number of Cells	78
Gap Thickness(mm)	1.5
Pocket Depth (mm)	4

5. Results and Discussion

5.1 Numerical Results

The weight of the load and the size of the float pad are used to determine the pressure needed for an air float conveyor.

$$p = \frac{w}{A}$$
$$p = \frac{0.11}{0.03815}$$

The flow rate should be high enough to maintain air cushion under the object. The flow rate Q can be calculated by using this formula:

$$Q = A \times V$$
$$Q = 0.03815 \times 46.2$$
$$Q = 1.76 \quad \text{m}^3/\text{s}$$

Δp Equation:

$$\Delta p = f \times \frac{L}{D} \times \rho \times \frac{v^2}{2}$$
$$= \pm 499333 \quad \text{Pa}$$

Under table pressure:

$$P = \frac{\sqrt{volumetric\ flow\ rate}}{\sqrt{flow\ factor}}$$
$$P = \frac{\sqrt{2.166}}{\sqrt{66.91}}$$
$$P = 0.1797 \text{ Pa}$$

Shear Stress:

$$\tau = \frac{F}{A}$$
$$\tau = \frac{0.210}{0.03815}$$
$$\tau = 5.56\ N/m^2$$

5.2 Graphical Results

Graph 1: Gap thickness vs Flow rate.

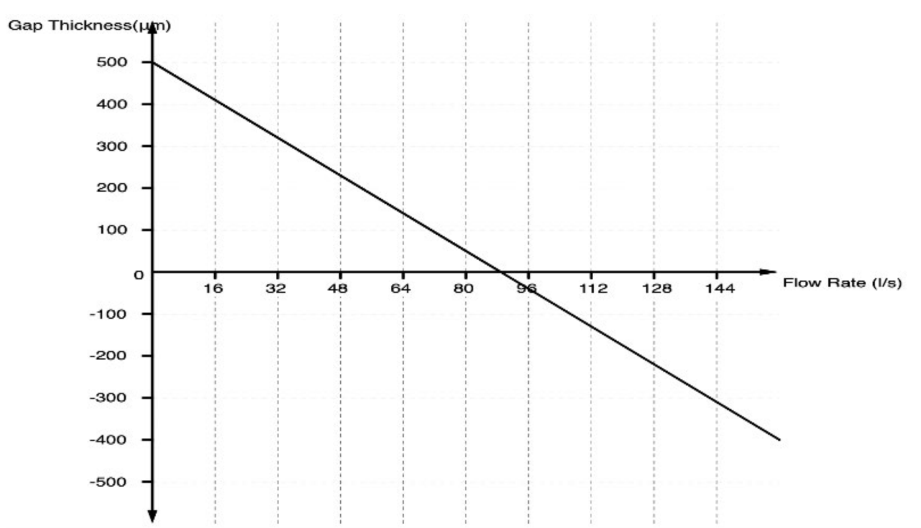

Figure 8. Gap thickness vs Flow rate

Units such as cubic meters per second (m^3/s) or liters per minute (L/min) could be used to measure the X-axis (flow rate). Millimeters (mm) or micrometers (μ-m) are used to measure the Y-axis (Gap Thickness). The relationship may be nonlinear in general. Gap thickness may decrease or remain relatively constant (in certain systems) when flow rate rises.

Graph 2: Acceleration vs Time graph.

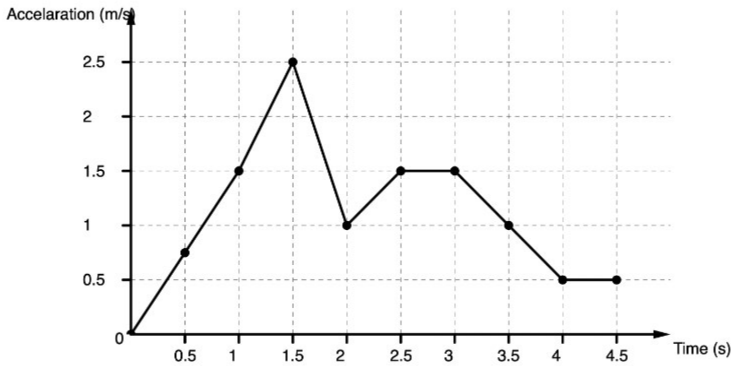

Figure 9. Acceleration vs Time graph.

Time is measured on the X-axis in seconds (s), and acceleration is measured on the Y-axis in meters per second squared (m/s2). Depending on how the object moves, the graph can take on different shapes. Acceleration increases with time on an upward-sloping line and decreases with a downward-sloping line. A straight line with constant acceleration indicates that the item is at rest.

Graph 3: Displacement vs Time

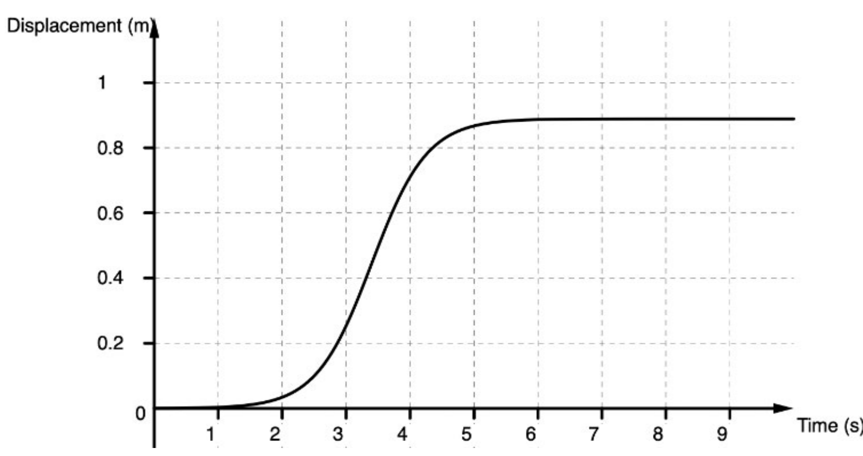

Figure 10. Displacement vs Time

Time is represented by the horizontal X-axis (often in seconds). The vertical Y-axis shows displacement, which is often expressed in meters. Uniform motion is indicated by a straight line. Speed is represented by the slope. A higher speed corresponds to a steeper slope. The speed change (acceleration or deceleration) is shown by a curved line. The curve's steepness indicates how rapidly the displacement is moving. When an item is at rest, its displacement remains constant over time, as indicated by a horizontal line.

Risk validation

ho : Increasing the conveyors air flow will not lead to anticipate an improvement in the conveyor performance.

$\therefore \quad ho = \quad 0$

ha : Increasing the conveyors air flow will lead to anticipate an improvement in the conveyor performance.

$\therefore \ ha = 1$

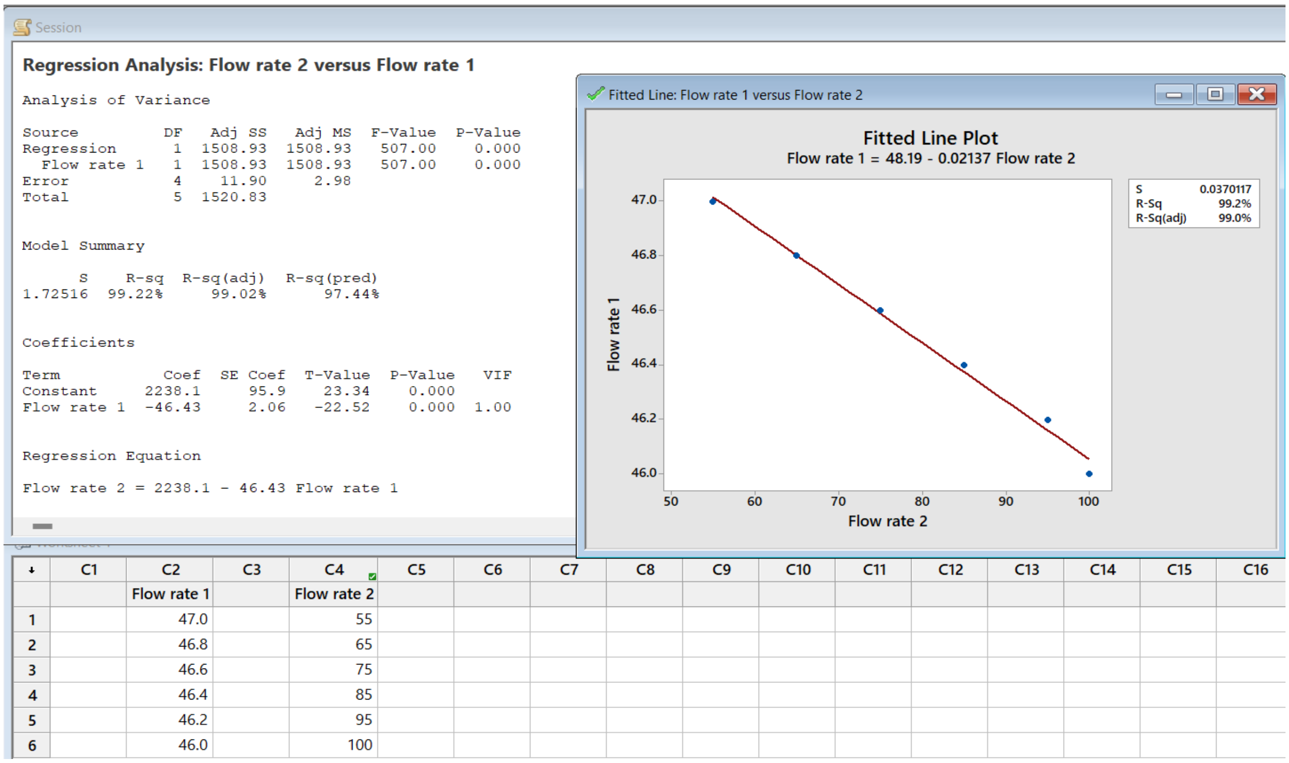

Figure 11. Regression Analysis

Regression Analysis Results

Strong statistical significance and predictive ability are displayed by the regression model:

F-Value = 507.00: A high F-value suggests that the independent variables account for a significant amount of the variation in the dependent variable and that the model is statistically significant. P-Value = 0.00: This indicates that the model's findings are extremely significant and that the observed correlations are not the result of chance. R-Squared (Predicted) = 97.224%: This indicates outstanding predictive accuracy, as the model accounts for 97.224% of the variance in the dependent variable. Adjusted R-Squared = 99.024%: This result indicates that the model is well-defined and that the predictors provide a significant contribution to the explanatory power of the model. A low standard error (S-Value) of 1.5672 signifies that the model's predictions are accurate and deviate little from the actual value.

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5.3 Proposed Improvements

Limitations

1. Limited capacity to load.
2. Needs for the Air Supply.
3. Environmental Factor Sensitivity.
4. Control system complexity.
5.Cost Considerations.
6. Limitations of Application.
7. The necessity for a larger dust collection system

Future scopes

For the future of material handling and maintaining items to move from one location to another, the Non-Contact Air Conveyor System (NCACS) has a lot of potential. Future advancements in pneumatic engineering and technology could increase the NCACS's load capability. The efficient and reliable transportation of bigger and bulkier things may be made possible by research efforts aimed at enhancing airflow dynamics, raising air pressure, and optimizing air cushion stability. Developments in energy-efficient compressor technology and optimization methods may help the NCACS use less energy while still operating at peak efficiency. Sustainability and cost-effectiveness of the system could be further improved by adding regenerative braking devices or incorporating renewable energy sources like solar or wind power into the air supply infrastructure. Exciting prospects for increasing automation and optimizing material handling procedures arise from the NCACS's integration with robotic systems or autonomous guided vehicles (AGVs). The NCACS and collaborative robots with sensors and AI algorithms might work together smoothly to load, move, and unload cargo on their own, increasing operational flexibility and efficiency.

The NCACS may optimize airflow patterns, anticipate maintenance requirements based on real-time sensor data, and dynamically adjust to changing operating circumstances by utilizing artificial intelligence (AI) algorithms and machine learning techniques. Higher levels of efficiency, dependability, and predictive maintenance capabilities might be attained by the NCACS through ongoing learning from operational data and performance feedback. This would result in less downtime and better system performance overall. Beyond the typical planar movement, future generations of the NCACS might investigate the idea of transporting items in other dimensions. The system might enable vertical stacking, tilting, or turning of delivered goods by integrating adjustable air jets and advanced control algorithms. This would enable more complex material handling jobs and increase the NCACS's versatility in a variety of applications. The Contactless Air Conveyor System (NCACS) may find uses outside of its current range as the technology develops and becomes more affordable. When transferring sensitive or valuable goods, components, and assemblies, industries like healthcare, automotive, aerospace, and e-commerce could profit from the NCACS's cleanliness, accuracy, and efficiency. The agriculture industry can also benefit from contactless air conveyors. The NCACS can be used for delicate fruit collection and gentle harvesting.

6. Conclusion

In summary, the Contactless Air Conveyor System (NCACS) offers a revolutionary approach to the transportation of items, with numerous benefits that meet the changing demands and difficulties of contemporary material handling procedures. The NCACS transforms efficiency, productivity, and safety in a variety of industrial sectors by enabling the frictionless, accurate, and hygienic transportation of commodities and planar objects through the creative application of pneumatic technology. The non-contact shipping method used by the NCACS reduces wear and tear and enhances product quality by removing the possibility of damage to fragile items. When combined with sophisticated sensor technology and exact control algorithms, this frictionless operation guarantees precise alignment and positioning of transported objects, enabling high-precision movement with little deviation. Additionally, the NCACS has major advantages in terms of cleanliness and hygiene since it reduces physical contact with the conveyor surface, which lessens the buildup of dust, debris, and pollutants.

This function is especially helpful in sectors like food processing, pharmaceuticals, and electronics production where hygienic conditions are crucial and cleanliness standards are very high. Because of its modular design and configurable features, the NCACS provides flexibility, adaptability, and scalability in addition to its operating advantages. Because of its adaptability to diverse kinds of goods, transportation needs, and operating environments, it can be seamlessly integrated into existing infrastructure and used in a variety of industries. The contactless air conveyor system

(NCACS) offers a wide range of uses that can increase productivity, safety, and efficiency, from manufacturing and auto assembly lines to food processing plants and storage activities. The NCACS is able to improve product quality, reduce downtime, and streamline material handling procedures. The NCACS is well-positioned to play a key role in influencing the direction of goods movement, spurring innovation, and providing real advantages to sectors throughout the globe as businesses work to streamline their material handling operations and adjust to shifting market needs.

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References

Bader, F., & Rahimifard, S. , A methodology for the selection of industrial robots in food handling. *Innovative Food Science and Emerging Technologies, 64,2020*. https://doi.org/10.1016/j.ifset.2020.102379

Corke, P. I., & Hutchinson, S. A. , A new partitioned approach to image-based visual servo control. *IEEE Transactions on Robotics and Automation, 17*(4),2001. https://doi.org/10.1109/70.954764

Delettre, A., Laurent, G. J., Haddab, Y., & Le Fort-Piat, N. , Robust control of a planar manipulator for flexible and contactless handling. *Mechatronics, 22*(5),2012. https://doi.org/10.1016/j.mechatronics.2012.05.003

Delettre, A., Laurent, G. J., Le Fort-Piat, N., & Varnier, C. (2012). 3-DOF potential air flow manipulation by inverse modeling control. *IEEE International Conference on Automation Science and Engineering*. https://doi.org/10.1109/CoASE.2012.6386380

Delettre, A., Laurent, G. J., & Le Fort-Piat, N. (2010). A new contactless conveyor system for handling clean and delicate products using induced air flows. *IEEE/RSJ International Conference on Intelligent Robots and Systems*. https://doi.org/10.1109/IROS.2010.5652194

Delettre, A., Laurent, G. J., & Le Fort-Piat, N. (2011). 2-DOF contactless distributed manipulation using superposition of induced air flows. *IEEE International Conference on Intelligent Robots and Systems*. https://doi.org/10.1109/IROS.2011.6048251

IEEE. (2015). *Proceedings of the 12th International Conference on Ubiquitous Intelligence and Computing, Autonomic and Trusted Computing, and Scalable Computing and Communications*. https://doi.org/10.1109/UIC-ATC-ScalCom.2015

Laurent, G. J., Delettre, A., & Le Fort-Piat, N. , A new aerodynamic-traction principle for handling products on an air cushion. *IEEE Transactions on Robotics, 27*(2),2011. https://doi.org/10.1109/TRO.2011.2109211

Li, Y., Xiao, S., Xi, L., & Wu, Z. , Design, modeling, control, and experiment for a 2-DOF compliant micro-motion stage. *International Journal of Precision Engineering and Manufacturing, 15*(4),2014. https://doi.org/10.1007/s12541-014-0394-x

Reed, J. N., & Miles, S. J. , High-speed conveyor junction based on an air-jet flotation technique. *Mechatronics, 14*(6),2004. https://doi.org/10.1016/j.mechatronics.2004.01.005

Siegel, R. A. (2014). Stimuli sensitive polymers and self-regulated drug delivery systems: A very partial review. *Journal of Controlled Release, 190*, 157–167,2014. https://doi.org/10.1016/j.jconrel.2014.06.035

Staples, M., Daniel, K., Cima, M. J., & Langer, R. , Application of micro- and nano-electromechanical devices to drug delivery. *Pharmaceutical Research, 23*(5), 847–863,2006. https://doi.org/10.1007/s11095-006-9906-4

Yim, M., Reich, J., & Berlin, A. A. (2000). Two approaches to distributed manipulation. In *Distributed Manipulation* (pp. 237–254). https://doi.org/10.1007/978-1-4615-4545-3_12

Zhou, L., Chapuis, Y. A., Fukuta, Y., Mita, Y., Braun, F., & Fujita, H. (2005). Architecture and implementation of distributed control system for MEMS-based intelligent motion surface. *IEEE International Symposium on Industrial Electronics*. https://doi.org/10.1109/ISIE.2005.1529067

Biographies

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Hrittik Mural has made notable contributions to industrial and system engineering through various projects and research. His work includes analyzing casting defects in gas burners using the Taguchi method, and he is preparing a review paper on advancements in wearable sensor technologies. He successfully integrated Six Sigma with Total Quality Management (TQM) to improve quality and reduce waste in the beverage industry, and utilized Multi-Criteria Decision-Making (MCDM) techniques to address supply chain disruptions in the steel and rolling industries in Bangladesh. His undergraduate thesis focused on real-time Bangla sign language detection using Long Short-Term Memory (LSTM) networks, achieving 96% accuracy. Mural has also designed and fabricated several innovative systems, including a pulley-based horizontal belt grinding machine, a contactless air conveyor, a smart door lock using

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Adri Dash, a Bangladeshi Industrial and Production Engineer, is a lecturer at the Bangladesh Army University of Science and Technology (BAUST) in Saidpur. He holds a Bachelor of Science in Industrial & Production Engineering from Rajshahi University of Engineering & Technology (RUET) and has expertise in supply chain management, quality control, lean manufacturing, sustainability, and automation. Adri has held teaching and research positions at the National Institute of Textile Engineering and Research (NITER) and the Bangladesh Industrial Technical Assistance Centre (BITAC). His research focuses on innovative applications in supply chain management and sustainable manufacturing, with notable publications on multi-objective job-shop scheduling and supply chain resilience in Bangladeshi industries. His project portfolio includes designing safety and automation devices like automatic hand sanitizers and gas leakage detectors. Adri has been an active member of professional and academic societies, earning awards like Student of the Year and multiple scholarships.

Hridoy Debanath, is an engineering student of Bangladesh Army University of Science and Technology, Department of Industrial and Production Engineering. He has an interest in photography, designing, and volunteering. Also, he is the Director of Social Media of the IEOM Society Student Chapter, Assistant General Secretary of the Career Society of BAUST, Assistant Treasurer of BAUST Photographic Eye, and Secretary Media & Marketing of IPE Club BAUST.

Md. Abdul Fahad is a student at the Bangladesh Army University of Science and Technology, currently pursuing studies in Industrial and Production Engineering. Based in Savar, Dhaka, he is passionate about supply chain management and ensuring quality in various systems. Fahad is also an IEOM-certified professional, showcasing his commitment to excellence in industrial engineering.