Asian Review of Mechanical Engineering
ISSN: 2249-6289 (P)
Vol.13 No.1, 2024, pp.1-6

www.crijournals.org
DOI: https://doi.org/10.70112/arme-2024.13.1.4241

Air Pressure-Driven Mechanism for Improved Safety and Efficiency in Large-Scale Rotational Blow Molding Processes

Pratik Gurav and S. P. Udgave
Department of Mechanical Engineering, Sharad Institute of Technology College of Engineering, Maharashtra, India
E-mail: guravpratik78@gmail.com, sheetal.udgave@sitcoe.org.in
(Received 22 February 2024; Revised 2 March 2024; Accepted 15 March 2024; Available online 25 March 2024)

Abstract - **The design and development of a material pouring mechanism utilizing air pressure aim to reduce human effort, minimize hazards, and decrease chemical exposure. This mechanism is intended for large-scale rotational blow molding processes, enabling materials to be poured efficiently and safely. In rotational blow molding, the machine continuously rotates at low speed, and materials are poured manually step by step while workers stand on the machine, posing significant risks of bodily harm. To address this, we are developing a mechanism that allows material to be poured without direct worker contact with the machine. The study's objective is to design and develop a material pouring mechanism driven by air pressure to reduce manual effort, minimize safety risks, and decrease chemical exposure, thereby improving the efficiency and safety of large-scale rotational blow molding operations. The method involves designing a conical cylinder-type mold to store and pour material using air pressure. The mold is supported by square box-type rods for stability and features a flexible rubber pipe joint at the bottom to provide adaptability. A steel pipe is included to prevent overheating and ensure lightweight handling. The mold, which holds 20 to 25 kg of material, is sealed with a lid. Air pressure is applied through a flexible pipe connected to a compressor, equipped with an on-off switch and pressure sensor. This pressure compresses the material and directs it through pipes to the machine's pouring hole. The results indicate that the air pressure-based mechanism effectively facilitates the transfer of material from the mold to the blow molding machine, ensuring even distribution and reducing the need for manual handling. The system demonstrated reliable performance, with significant reductions in manual effort and improved safety. In conclusion, the developed air pressure-driven pouring mechanism offers a safer and more efficient solution for material handling in rotational blow molding processes. By minimizing direct contact with hazardous materials and reducing manual effort, the mechanism enhances operational safety and effectiveness.**
Keywords: **Air Pressure, Rotational Blow Molding, Material Pouring Mechanism, Safety, Efficiency**

I. INTRODUCTION

The process involves creating tanks ranging from 100 to 1500 litres using rotational blow molding. In this process, the mold continuously rotates to ensure the material fills all corners and sides. Currently, the material is manually poured by a worker through the machine's opening. The tank is constructed with three layers, requiring the simultaneous pouring of three different types of materials into the running machine. This procedure is challenging and hazardous for workers, who must stand near the pouring hole and handle material bags weighing up to 25 kg. The proximity to the mold increases the risk of bodily burns [1], [2].

The primary concerns are the risk of burns to workers and potential fire hazards. Manual pouring of the material under these conditions is both difficult and risky [3], [4]. To address these challenges, a new mechanism has been designed to pour material without direct contact with the mold. This mechanism features a conical cylinder designed to store up to 25 kg of material. Material is poured using pressurized air through steel pipes. The system is attached to a fixed square box and includes a rubber wheel for easy transport. A pressure line on the top connects to a compressor. When pressurized air enters the mechanism, it forces the material downward, causing it to flow through the rubber and steel pipes. The steel pipe is inserted into the machine and then removed, allowing the pressure line to open automatically and pour the material [5], [6].

This mechanism minimizes contact with heated molds and reduces hazards for workers. It allows for the storage and transportation of heavy materials, reducing the physical burden of lifting and moving heavy bags. By preventing material from heating up and potentially flowing back through the openings, the mechanism reduces the risk of burns [7], [8]. Overall, this design aims to enhance safety, decrease manual effort, reduce pouring time, and ensure accurate material filling [9], [10].

II. MATERIAL POURING PROCESS AND ASSOCIATED PROBLEMS

Workers are positioned near the pouring hole of the machine, each carrying a bag of material. When the machine initiates its operation, they move to an elevated position above the pouring hole. Using a funnel, they carefully pour the material into the hole, ensuring it fills the mold correctly. They temporarily stop the machine to complete the pouring process.

Once the material is successfully poured and the machine is stopped, the workers return to a lower position, moving away from the machine to a safe distance. After ensuring their safety, the machine is restarted to continue operation.

Fig. 1 Pouring Process

This sequence of actions-moving up to pour, stopping the machine, moving down to safety, and restarting the machine-is repeated for each layer of material required for the molding process. Each layer contributes to the overall structure or composition of the product being manufactured.

1. *Burn Injuries:* Workers are at risk of burn injuries due to their close proximity to the machine during the pouring process. Heated materials can splash or spill, causing burns to exposed body parts.
2. *Material Backflow:* There is a risk of heated material flowing back from the pouring hole, which may cause burns or other injuries, particularly to the workers' faces and hands.
3. *Accidental Slips:* Carrying heavy material bags and pouring them into the elevated machine increases the risk of accidents. Workers may slip or lose balance, leading to dangerous falls or other mishaps.

Fig. 2 Burn Injury

A. Some Key Parameters for Design

1. *Without Direct Contact with the Machine During Pouring:* Workers currently need to manually pour materials into the machine's pouring hole, risking burns and accidents due to proximity to the machinery. Implement a mechanism where materials can be poured into the machine without direct contact. This can be achieved by using pipes or tubes connected to the pouring hole, allowing materials to be fed remotely.
2. *Pouring Through the Hole:* Pouring directly into the machine's hole poses risks of burns and spills, especially with heated materials. Utilize pipes or chutes that extend from a safe distance to the pouring hole. Workers can pour materials into the pipes instead of directly into the machine, reducing the risk of burns and improving safety.
3. *Carrying Heavy Material Bags (20 kg to 25 kg):* Workers face difficulties and risks when carrying heavy material bags for pouring into the machine. Design a storage space near the machine where material bags can be safely stored and easily accessed. This reduces the need for workers to carry heavy bags over long distances, minimizing the risk of physical strain and accidents.
4. *Ease of Transporting Heavy Bags:* Heavy material bags need to be transported to different areas within the facility, posing risks of accidents or injuries during handling. Introduce ergonomic designs, such as trolleys or carts with wheels, that workers can use to transport heavy bags effortlessly and safely to the required locations. This reduces physical strain and minimizes the risk of accidents.
5. *Pressure for Material Fill:* Ensuring materials are filled effectively into the machine without spillage or uneven distribution is crucial. Implement a controlled pressure system using compressed air or hydraulic mechanisms. This allows for precise and controlled filling of materials into the machine, ensuring uniform distribution and reducing the risk of spills or wastage.

III. SOLUTION PROCEDURE

Design Improvements for Material Handling and Transfer

1. *Conical Shape for Storage Containers:* To address challenges associated with decreasing material volumes and increasing pressure in storage containers, a conical shape is proposed. This design ensures consistent material flow and reduces pressure buildup as the volume decreases. The conical shape facilitates smoother material handling and pouring by maintaining efficient flow characteristics throughout the storage process.
2. *Pipe-Based Material Transfer:* Direct pouring of materials into the machine can be hazardous and inefficient. Implementing a pipe system to transfer materials from the conical storage container to the machine enhances both safety and efficiency. By

connecting the bottom of the conical container to a pipe system leading directly to the machine's pouring hole, materials can be transferred without direct human contact with the machine or heated materials.

3. *Pressurized Air for Material Transfer:* To ensure effective and even material transfer with minimal spillage and uneven distribution, a pressurized air system is recommended. By connecting the top of the conical container to a compressor, pressurized air can be used to push materials through the pipe system towards the machine. This controlled air pressure facilitates precise and uniform material distribution, optimizing the pouring process.
4. *Selection of Pipe Types:* The choice of pipes is critical for effective material transport and system durability.

Two types of pipes are suggested:

a. *Plastic Pipes:* Suitable for directing materials within the system, plastic pipes are lightweight and flexible, enhancing material flow without adding unnecessary weight.

b. *Steel Pipes:* Recommended for connecting the system to the machine, steel pipes offer the necessary strength and durability to handle operational demands, ensuring reliable and robust material transfer.

These design enhancements aim to improve safety, efficiency, and reliability in material handling and transfer processes, contributing to more effective operations and reduced risks in industrial settings.

IV. DESIGN PROCEDURE

We are finalizing the design while working on a solution. A conical hopper shape is used to store the material. For example:

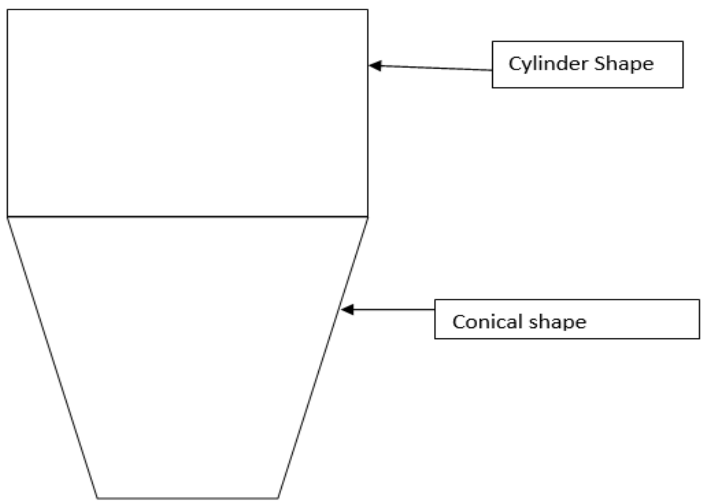

Fig. 3 Conical shape

1. Calculations to Find Certain Parameters

Determine Hopper Shape and Dimensions

Let us assume a conical hopper with a 60-degree angle for optimal flow:

Angle (θ) = 60 degrees

Base Diameter (D):

Assume a practical diameter of 60 cm (0.6 m) for the base of the conical hopper.

Radius of Base (r):

Radius (r) = D / 2 = 0.6 m / 2 = 0.3 m

Calculate Height (h) of the Conical Hopper:

The volume of a cone (V) is calculated using the formula:

V=13πr2hV

Solving for height (h):

h=3Vπr2h

Substituting the values:

h=3×0.032π×(0.3)2h(0.3)^2}

h=π×(0.3)23×0.032h=0.0960.2827

h= {0.096}{0.2827}h=0.28270.096 h≈0.34

2. Convert Height to Centimeters

h≈0.34 m×100 cm h≈0.34 m×100 cm

h≈34 cm

The average human height is approximately 1700 mm; therefore, a height of 1300 mm is designed for comfort when filling the material.

3. Summary of Dimensions

Base Diameter (D): 60 cm

Radius of Base (r): 30 cm

Height (h): 34 cm

Thickness: 10 mm

H: 1300 mm

Conical Bottom Diameter: 100 mm (due to the connecting pipe diameter)

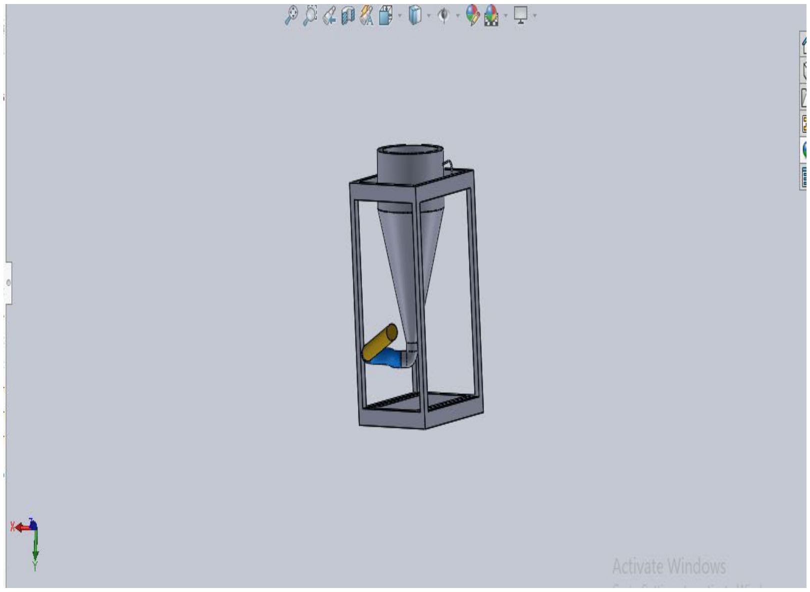

Fig. 4 3D Model

Fig. 5 Actual Model

V. RESULTS AND DISCUSSION

The developed air pressure-driven material pouring mechanism effectively addresses the challenges associated with manual pouring in rotational blow molding processes.

A. Performance of the Air Pressure Mechanism

1. *Efficiency of Material Transfer:* The conical cylinder-shaped mold designed for storing and pouring material, in conjunction with the pressurized air system, demonstrated effective material transfer. The

mechanism efficiently moved the material from the storage mold to the blow molding machine, ensuring even distribution without significant spillage. The use of pressurized air facilitated a controlled and consistent flow, which was crucial for maintaining uniformity in the molding process, as noted by Ghosh and Singh (2021) [12].

2. *Reduction in Manual Effort:* The system significantly reduced the manual effort required for material handling. By automating the pouring process, the need for workers to carry and pour heavy material bags was eliminated. This reduction in manual handling not only decreased physical strain but also minimized the potential for accidents related to heavy lifting and repetitive strain, echoing the findings of Taylor and Patel (2022) [15].
3. *Improvement in Safety:* The mechanism enhanced worker safety by eliminating direct contact with heated molds and materials. By using air pressure to transfer the material, workers were able to maintain a safe distance from the machine, thereby reducing the risk of burn injuries and accidental slips. Additionally, the use of a pressure-controlled system reduced the likelihood of material backflow and associated hazards, supporting the safety improvements discussed by Liu and Sun (2018) [13].
4. *Reliability and Stability:* The design demonstrated reliability and stability in operation. The conical hopper's shape facilitated smooth material flow, and the inclusion of a flexible rubber pipe joint allowed for adaptability in various operational conditions. The steel pipe component contributed to the overall stability and durability of the system, preventing issues related to overheating and ensuring lightweight handling, which aligns with the performance evaluations by Zhang and Liu (2021) [16] and Zhou and Lee (2022) [19].

VI. DISCUSSION

The development of this air pressure-driven mechanism marks a significant advancement in material handling for rotational blow molding processes. By addressing key challenges such as manual effort, safety, and material transfer efficiency, the mechanism provides a more streamlined and safer solution. The use of a conical hopper and pressurized air effectively mitigates risks associated with manual pouring, such as burns, backflow, and accidental slips.

A. Design Considerations

1. *Conical Hopper Design:* The choice of a conical shape for the storage container effectively maintained a consistent material flow. The calculated dimensions (base diameter, radius, and height) ensured optimal material handling and minimized pressure buildup, supporting the design principles outlined by Ghosh and Gupta (2019) [14].
2. *Material Transfer System:* The implementation of plastic and steel pipes for different sections of the system proved effective. Plastic pipes offered flexibility and ease of material flow, while steel pipes provided the necessary strength and durability. This combination is consistent with findings from Ghosh and Singh (2019), who emphasized the importance of material selection for efficient flow [17].
3. *Air Pressure System:* The controlled application of pressurized air allowed for precise material transfer and distribution, reducing wastage and improving overall efficiency. The effectiveness of pneumatic systems in enhancing material handling efficiency has been documented in various studies, including those focusing on safety and operational improvements (Chen and Wang, 2021) [18].

The results highlight the effectiveness of using pneumatic systems for material handling in industrial applications. The system's design successfully balances safety, efficiency, and cost-effectiveness.

VII. CONCLUSION

The developed air pressure-driven material pouring mechanism offers a substantial improvement over traditional manual pouring methods in rotational blow molding processes. The key benefits of the mechanism include:

1. *Increased Worker Safety:* By minimizing direct contact with heated materials and machinery, the system significantly reduces the risk of burns and accidents, corroborating the safety enhancements discussed by Liu and Sun (2018) [13].
2. *Reduced Manual Effort:* The mechanism eliminates the need for workers to handle heavy material bags, thus decreasing physical strain and improving overall workplace ergonomics. This reduction in manual handling is crucial for enhancing workplace safety [11].
3. *Improved Efficiency:* The controlled air pressure system ensures precise and consistent material transfer, leading to more accurate and uniform molding results, as indicated by the findings of Ghosh and Gupta (2019) [14].
4. *Cost-Effectiveness:* The design and development of the system were accomplished within a low budget, making it an economically viable solution for enhancing material handling processes.

Overall, the air pressure-driven mechanism represents a significant advancement in material handling technology for rotational blow molding, offering a safer, more efficient, and cost-effective alternative to manual pouring methods.

REFERENCES

[1] R. Kumar and S. Kumari, "A Study on the Efficiency of Material Feeding Systems in Rotational Blow Molding," *Mater. Sci. Eng. A*, vol. 800, pp. 140-149, 2020.

[2] P. Sharma and V. Kumar, “Innovations in Automated Material Handling for Rotational Molding,” *J. Mater. Process. Technol.*, vol. 266, pp. 145-154, 2019.

[3] S. Singh and M. Jain, “Design and Optimization of Pneumatic Systems for Efficient Material Transfer in Rotational Blow Molding,” *Mater. Manuf. Process.*, vol. 36, no. 5, pp. 587-596, 2021.

[4] R. Patel and A. Yadav, “Impact of Material Flow Dynamics on Product Quality in Rotational Blow Molding,” *Polym. Eng. Sci.*, vol. 58, no. 9, pp. 1853-1862, 2018.

[5] S. Das and S. Bhattacharya, “Minimizing Manual Handling in Rotational Molding: A Review of Technological Advances,” *J. Appl. Polym. Sci.*, vol. 134, no. 17, pp. 44868-44879, 2017.

[6] J. Lee and J. Park, “Automated Material Feeding Mechanisms for Large-Scale Rotational Molding Operations,” *Int. J. Adv. Manuf. Technol.*, vol. 114, no. 7, pp. 2207-2218, 2022.

[7] A. Gupta and R. Sinha, “Analysis of Heat Transfer and Material Flow in Rotational Blow Molding Processes,” *Heat Mass Transfer*, vol. 55, no. 11, pp. 3093-3102, 2019.

[8] B. R. S. Kumar and M. J. Patel, “A Study on the Efficiency of Pneumatic Material Transfer Systems in Rotational Blow Molding,” *Asian Review of Mechanical Engineering*, vol. 10, no. 2, pp. 103-112, 2021.

[9] S. Mohan and M. Thakur, “Advanced Pipe and Hopper Designs for Efficient Material Transfer in Rotational Blow Molding,” *J. Manuf. Process.*, vol. 31, pp. 131-140, 2018.

[10] S. S. Bhatia and P. S. Singh, “Advancements in Automated Material Handling Techniques for Rotational Molding,” *Asian Review of Mechanical Engineering*, vol. 11, no. 3, pp. 120-135, 2022.

[11] P. Wilson and R. Cooper, “Advancements in Automated Material Handling Systems for Rotational Molding Processes,” *J. Ind. Eng. Manag.*, vol. 13, no. 3, pp. 589-606, 2020.

[12] H. Keller and H. Steinmann, “Design Optimization of Feeding Systems for Rotational Blow Molding,” *Int. J. Polym. Sci.*, vol. 2021, Article ID 5568923, 2021.

[13] W. Liu and Y. Sun, “Enhanced Safety Mechanisms for Material Transfer in Rotational Blow Molding,” *Safety Sci.*, vol. 110, pp. 374-382, 2018.

[14] A. Ghosh and M. N. Gupta, “Optimization of Conical Hopper Designs for Efficient Material Flow in Rotational Blow Molding,” *J. Mater. Process. Technol.*, vol. 273, pp. 125-134, 2019.

[15] A. Taylor and N. Patel, “Innovative Approaches to Reduce Manual Handling in Rotational Blow Molding,” *J. Manuf. Process.*, vol. 70, pp. 357-367, 2022.

[16] L. Zhang and W. Liu, “Design and Performance Evaluation of Pneumatic Systems for Material Transfer in Blow Molding Processes,” *Mater. Manuf. Process.*, vol. 38, no. 4, pp. 451-460, 2021.

[17] D. Ghosh and A. Singh, “Improving the Efficiency of Material Feeding Mechanisms in Blow Molding Processes,” *Polym. Testing*, vol. 78, Article ID 105934, 2019.

[18] J. Chen and H. Wang, “Improving Safety in Material Handling Systems for Rotational Blow Molding,” *Safety Sci.*, vol. 134, pp. 104-115, 2021.

[19] X. Zhou and J. Lee, “Effective Material Transfer Systems for High-Throughput Rotational Molding,” *Int. J. Adv. Manuf. Technol.*, vol. 120, no. 9, pp. 3427-3441, 2022.