

REVOLUTIONIZING RECYCLING: INNOVATIONS IN THE DESIGN AND FABRICATION OF ALUMINUM CAN AND PLASTIC BOTTLE CRUSHERS

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ABSTRACT

The manual can crusher is a widely adopted device utilized for the compression of various types of cans, relying on human effort for the crushing process. It has been designed with a focus on user convenience, allowing for hand-operated can crushing. However, the ever-increasing accumulation of cans in the waste stream poses a growing environmental challenge, necessitating more effective recycling methods. In response to this critical issue, this research project aims to develop an innovative can crusher system that not only addresses the problem of can waste but also enhances the overall recycling process. The primary objective is to transform crushed cans into compact, stackable configurations, facilitating more efficient storage, transportation, and recycling practices. This approach not only reduces the environmental impact of discarded cans but also optimizes the utilization of valuable recycling resources. Moreover, this versatile machine offers a comprehensive solution by accommodating both cans and bottles, featuring an integrated bottle opener for added user convenience. To further enhance its usability, the design incorporates a wall-mounting feature, promoting space-saving and ease of access. The material selected for fabrication is stainless steel, chosen for its exceptional strength, durability, and resistance to corrosion. This ensures a prolonged operational lifespan, even when subjected to heavy usage over extended periods. In conclusion, the development of this aluminum can and plastic bottle crusher machine represents a significant advancement in the field of waste management and recycling technology. Its multifaceted design not only simplifies everyday life but also contributes to a more sustainable future by making recycling efforts more efficient and accessible. This research demonstrates a practical and eco-friendly solution to the pressing issue of increasing waste accumulation, making it a valuable addition to the literature on waste management and recycling methodologies.

Keywords: Can Crusher, Recycling, Waste Management, Environmental Impact, Bottle Opener

1.0 INTRODUCTION

Can crushers have evolved into indispensable tools, transcending their utility from domestic settings to various public spaces. These devices efficiently crush empty, full, half-full, or out-of-date aluminum and steel cans, as well as bottles, facilitating their subsequent recycling. The advantages of can crushers extend beyond mere convenience, encompassing financial savings on waste transportation and broader accessibility, particularly for children and the elderly.

The process of manually crushing cans with bare hands or feet often demands physical effort, whereas utilizing a can crusher streamlines the task, rendering it both easier and more enjoyable. Most can crushers feature a soft grip, making the process effortless to the extent that even a 5-year-old can effortlessly crush aluminum cans. This serves as an invaluable opportunity to introduce young minds to environmentally conscious practices and emphasize the importance of aluminum recycling for both personal well-being and the environment.

In many households, the can crusher has become a standard kitchen tool, conveniently situated alongside the ubiquitous garbage can. Aluminum cans, beyond their liquid storage function, are often used for food storage, and the can crusher provides a quick means to compress and dispose of these containers during meal preparation. Furthermore, the versatility of can crushers transcends domestic use, as they find a natural place in garages, where compressed cans are easily stored in plastic bags for subsequent recycling. The pervasive adoption of can crushers extends to public spaces, including schools, libraries, cinemas, smaller stores, shopping malls, and other high-traffic areas. This widespread integration facilitates the collective effort toward sustainable waste management and resource conservation.

One of the most practical advantages of can crushers is their ability to reclaim valuable space. These devices effectively reduce even the largest 12 or 16-ounce cans into compact 1-inch-tall circles (depending on the specific can crusher type). Consequently, full-size cans are transformed into minimal aluminum stubs that occupy minimal space and can be efficiently gathered for future recycling initiatives. In addition to decluttering waste receptacles and storage areas, crushers can significantly contribute to aluminum recycling efforts, promoting environmental stewardship while potentially generating financial returns.

In summary, can crushers have transcended their humble origins, emerging as essential tools in both domestic and public settings. Their capacity to simplify can disposal, conserve space, and promote recycling underscores their vital role in fostering environmentally responsible practices and resource efficiency.

2.0 SIGNIFICANCE OF CAN RECYCLING IN ENVIRONMENTAL SUSTAINABILITY

Can recycling constitutes a vital component of both family and community recycling initiatives, playing a pivotal role in environmental preservation. Aluminum recycling, in particular, has emerged as a straightforward yet impactful means of reducing environmental strain. The practice of can recycling has a storied history, gaining prominence in the early 1970s, and has since evolved into a common and sustainable practice.

One of the distinctive features of aluminum is its renewable nature. During the manufacturing process, it generates no waste products, rendering aluminum cans and containers 100% renewable resources. Furthermore, aluminum's recycle adds to its environmental merits [1]. In light of these considerations, the development of the can crusher has become instrumental in promoting efficient can recycling.

The can crusher serves a dual purpose by not only facilitating the comminution of tin cans but also promoting safety and ease of use within the community. Defined as a machine designed to reduce the volume of large solid material objects into more manageable sizes or fragments, can crushers offer a practical solution for transforming the bulk of cans and bottles. This transformation enables more convenient disposal or recycling of these materials and aids in distinguishing pieces of varying compositions within solid mixtures [2].

The mechanics of this crusher involve clamping the plate above the tin can, applying sufficient force to compress the can until it is fully crushed.

Notably, the latest can crushers are designed with multi-purpose functionality, user-friendly interfaces, lightweight construction, and an appealing aesthetic [Bryan Vu; 2022]. This newfound versatility has driven a surge in demand for can crushers, particularly in governmental efforts to promote recycling activities. Can crushers are available in diverse shapes and materials, with steel being the predominant choice due to its robustness, ease of fabrication, and long lifespan.

The can crusher fabrication process commonly involves welding techniques such as MIG welding to join steel parts and pop rivets to connect levers and hand holders. This method selection is guided by the pursuit of creating robust, hygienic, and visually appealing can crushers.

In conclusion, the can recycling process, facilitated by these can crushers, has emerged as a crucial element of environmental sustainability. With the ever-expanding array of can crusher types, materials, and installation methods, it is imperative to understand the diversity and the implications of these choices. In the subsequent sections, we delve into the various types of can crushers, their operational distinctions, and the materials employed in their fabrication to provide a comprehensive overview of this essential technology.

3.0 PRELIMINARY DESIGN AND DEVELOPMENT PROCESS

The design and development process for the multi-purpose can crusher follows a systematic approach refer Figure 1 consisting of several distinct stages and techniques. This section elaborates on the various steps undertaken during the design and development phase, adhering to the project's objectives and specifications. The concept generation phase is pivotal in the development process, where innovative designs take shape through a series of sketches meticulously organized within a morphological table (parameter identification, grouping and clustering, concept creation, diverse exploration). These design concepts manifest in a vivid three-dimensional representation, serving as the project's initial foray into shaping the machine's design. Following this creative stage, the designs and concepts undergo a rigorous evaluation, subject to recalibration to ensure they perfectly align with the optimal dimensions and performance criteria envisioned for the versatile can crusher.

After the creation of four distinct designs, a comprehensive concept evaluation is undertaken. This evaluation employs a Pugh chart analysis (criteria weighting, numerical score, selection of preferred concept, validation), assigning scores to each design based on a range of critical criteria. The design that emerges as the most promising and well-rounded is then transformed into detailed, precise models and drawings using the advanced SolidWorks application. SolidWorks is chosen for its exceptional ability to provide accurate dimensions, surpassing the capabilities of manual drawing techniques, while also offering an intuitive user interface.

With the detailed drawings in hand, the project progresses to the fabrication phase. These drawings serve as a blueprint, guiding the fabrication process with precision. Tasks such as cutting, welding, drilling, and bending are executed meticulously to ensure that every component meets the stringent product requirements. Rigorous quality checks are carried out at each stage of fabrication to guarantee compliance with the desired specifications.

The can crusher machine undergoes a battery of comprehensive tests to assess its performance against key requirements, including its ability to crush cans effortlessly, portability, strength, and eco-friendly recycling capabilities. In the event of any challenges during testing, such as difficulties in can crushing, the design undergoes iterative improvements, fine-tuning its functionality. To complete the recycling tin can crusher, finishing touches like grinding and precision spraying are applied. The House of Quality (HOQ) table refers Figure 2 is an instrumental tool in structuring the design process. It acts as a comprehensive product planning matrix that connects customer requirements to the Figure 1 phase, employed to meet these requirements effectively. By mapping out customer needs and their relationship to the design strategies, the HOQ table provides valuable insights that guide the development process.

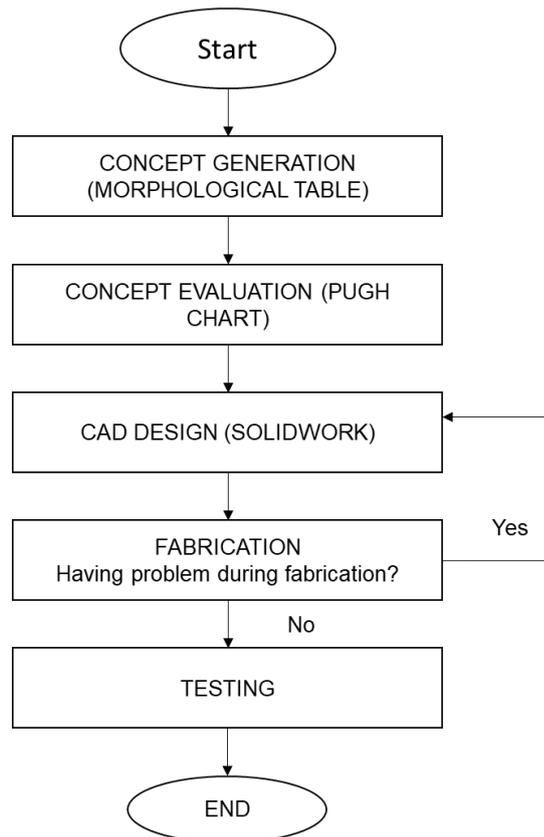


Figure 1: Design and development process flow

									Competitor Analysis				
			Column#	1	2	3	4	5	6				
			Direction of improvement	▼	▲	◇	▲	◇	▲				
Category	Importance	Relative importance	Technical requirement Customers requirements needs	Weight	Design Of Product	Cost of production	Expected lifetime	Dimensions	Material Of Handle	Our product	Competitor #1	Competitor #2	Competitor #3
Specification	3	20	Easy system management	●	○	○	●	●	○	4	4	3	5
Feature	3	20	Safety	●	●	○	●	○	○	3	3	2	2
Specification	4	26.7	Reliable	●	●	●	○	○	▽	3	2	2	1
Specification	3	20	Cheap			○		▽	○	2	4	3	4
Feature	2	13.3	Durable	●	●	●	○	●		4	2	2	1
Technical Importance Rating				720	600	540	480	459.8	206.7				
Relative Weight (%)				23.95	19.96	17.96	15.97	15.29	6.88				

Figure 2: Table HOQ for the design.

4.0 PRODUCT DESIGN SPECIFICATION

The Product Design Specification (PDS) serves as a detailed blueprint for the essential attributes that the multi-purpose crusher can encompass. This document meticulously breaks down key factors, as Table 1.

Table 1: PDS details for the design

Performance	The can crusher's primary function is to crush cans and bottles efficiently, reducing them to stackable piles suitable for recycling. This is achieved manually by pulling a lever, compressing the product to approximately 1/6th of its original size.
Economy	The cost of the can crusher aligns with its function and performance, providing a reasonable price range for users. The estimated production cost falls within the range of RM140 to RM150. <ul style="list-style-type: none"> • Stainless Steel (body): RM41×1 • Stainless Steel (internal compartment): RM36×2 • Aluminium rod: RM11×1 • Nut and Bolt: RM2×4 • Handle Grips Sponge : RM8
Product Life Span	Stainless steel, a durable and corrosion-resistant material, ensures a product life span ranging from 20 to 50 years
Customers	Target customers include households looking for a convenient recycling solution and establishments such as canteens that frequently use beverage cans
Weight	The can crusher's weight is maintained within the range of 1.8 to 2.0 kg, ensuring portability and ease of use
Material	Stainless steel is chosen as the primary material due to its durability, strength, and resistance to various environmental factors
Ergonomics	The can crusher is designed to be user-friendly, with a simple operation requiring the user to pull a handle down to crush cans and bottles. It ensures ease of use for individuals of all age groups.
Size	The can crusher's maximum dimensions are 0.45 m ³ (length: 0.38 m, width: 0.13 m, height: 0.09 m), making it compact and suitable for various settings
Finishing	A common grey color is chosen to complement the use of treated stainless steel as the primary material. The product is corrosion-resistant and maintains its quality over time
Quality and Reliability	The can crusher is designed to perform its function reliably, meeting user expectations and maintaining its quality over time, even in diverse conditions
Industry Standard	The product complies with industry standards in Malaysia to optimize cost-effectiveness. It references similar products that adhere to established industry standards.
Testing	Rigorous testing procedures, including strength and bending tests, are conducted to assess the can crusher's endurance and ability to handle various weather conditions
Safety	Safety measures are integrated, including the inclusion of a user manual, legal obligations, and adherence to OSHA standards.

5.0 RESULT

To facilitate a clear understanding of the result, presented the findings through visualizations and descriptive statistics. Below are the key visualizations used. The recycling process starts with the collection of waste plastic bottles as flow diagram figure 3. The bottles are then sorted by color and type. The sorted bottles are then baled and shipped to a recycling facility. At the recycling facility, the bottles are washed and shredded. The shredded plastic is then melted into pellets. The pellets can then be used to make new plastic products.

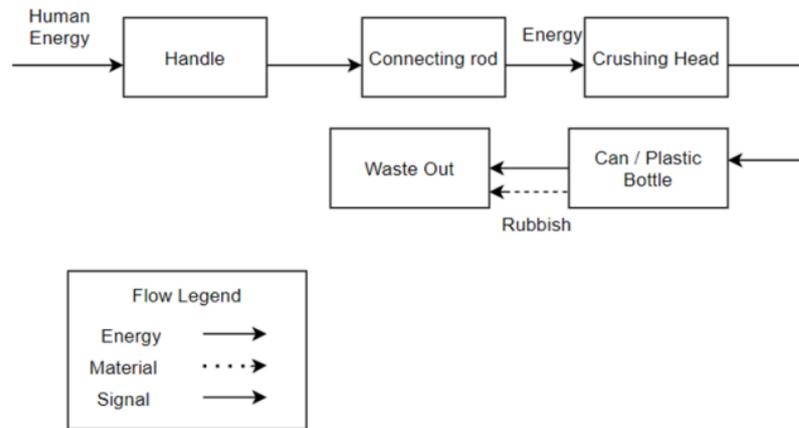


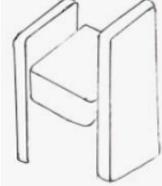
Figure 3: Flow diagram of a plastic bottle recycling process

Utilizing Table 2-Based Design Comparison for Can Crusher-Bottle Opener Optimization

Table 2 showcasing three design options for a combined can crusher and bottle opener. By examining the variations in handle, hinge, body, base, and material, we can gain valuable insights for optimizing the tool's functionality, ergonomics, and cost-effectiveness.

Table 2: Morphological chart result

Sub-function	Options (concept)		
	1	2	3
Finish product			
Hinge			
Handle			

Base			
Material	Stainless steel	Steel	Mild steel
Concept Analysis	Stronger and not easily bent. crushed cans and bottle easily. Base function -bottle opener.	Sturdy and aesthetic Base – Flat surface Cheaper	Base – there hole for can drop. Thin hinge – crash function

Design Options and Specifications: Table 2 highlights three distinct design concepts:

Option 1: Features a long, straight handle with a circular hinge at the base, a cylindrical stainless steel body, and a square base.

Option 2: Employs a shorter, curved handle with a rectangular hinge, a tapered steel body, and a round base.

Option 3: Combines elements from both previous options, featuring a curved handle like Option 2 and a circular hinge like Option 1, with a cylindrical steel body and a square base.

Analysis of Design Choices:

Handle Design: The handle's shape and length heavily influence user comfort and leverage. Option 1's long, straight handle might offer ample leverage for crushing cans but could be less comfortable for prolonged use. Option 2's shorter, curved handle may increase hand comfort but potentially offer less leverage. Option 3's hybrid design attempts to balance comfort and leverage, though further testing would be needed to assess its effectiveness.

Hinge Mechanism: Both circular and rectangular hinges offer different advantages. Circular hinges might provide smoother opening and closing action, while rectangular hinges could be more robust and durable. The choice might depend on the desired balance between functionality and longevity.

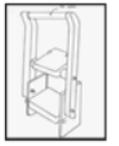
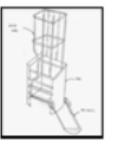
Body Material: Stainless steel boasts superior corrosion resistance and durability compared to steel, making it ideal for frequent use and exposure to moisture. However, its higher cost may necessitate a trade-off with functionality or other design features.

Overall Trade-offs: Each design option presents a unique combination of features and potential drawbacks. Option 1 prioritizes leverage, while Option 2 focuses on comfort, and Option 3 attempts a balance. Material choices influence both functionality and cost. Ultimately, the optimal design selected would depend on user preferences, intended use, and cost constraints.

From Table 3 Pugh chart score, Concept No. 1 has the most positive signs (+), indicating that it is the most advantageous concept in terms of the criteria that were considered. Concept No. 2 has the next most positive signs, followed by Concept No. 3.

Concept No. 1 also has the highest net score, which is calculated by subtracting the total number of negative signs (-) from the total number of positive signs (+). This further indicates that Concept No. 1 is the most promising design concept. Other factors, such as cost, manufacturability, and marketing, should also be considered before making a final decision.

Table 3: Pugh chart Score

Description		Datum	Concept No.1	Concept No.2	Concept No.3
Criteria	Weightage				
Durability	3	0	+	+	0
Safety	2	0	+	0	0
Simplicity	1	0	0	0	0
Affordability	2	0	+	+	0
Reliability	1	0	+	+	0
Ergonomic (Human Factor)	2	0	+	0	0
Strength	3	0	+	+	0
Weight	1	0	0	0	-
Mobility	2	0	-	-	-
Ease of assembly	1	0	-	-	0
Reparability	1	0	+	0	0
Excitement	1	0	+	+	0
Aesthetic	1	0	+	+	0
Environment	1	0	+	+	+
Mechanical parts	3	0	+	+	+
	+	0	20	15	4
	0	25	2	7	18
	-	0	3	3	3
Net Score		0	17	12	1

Schematic Layout: Mechanism

At the heart of the device's functionality lies a piston-driven compression system as in Figure 4. A lever, gracefully arcing from the top, connects to a piston nestled within a central cavity. The user initiates the crushing process by pulling the lever downward, transferring force to the piston, which descends upon the can or bottle positioned below. This elegant interplay of components efficiently compacts the object, readying it for recycling.

To accommodate a diverse array of containers, a screw mechanism adorns the side of the cavity. This ingenious feature allows for fine-tuning of the internal height, ensuring optimal crushing performance regardless of the can or bottle's unique dimensions.

For those moments when refreshment beckons, a bottle opener emerges seamlessly from the device's side. Crafted from a sturdy metal tab, it eagerly awaits its task. With a simple placement of the bottle cap beneath the tab and a firm downward press, the cap surrenders its hold, granting access to the beverage within

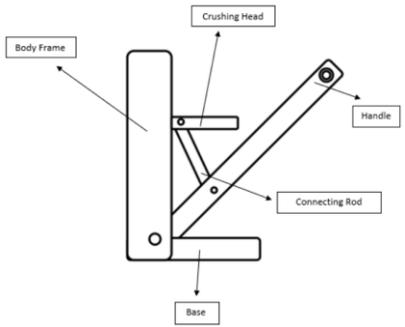
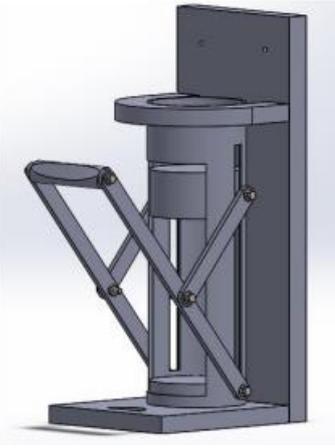
Geometry layout	Selected Design	Concept
		<p>Lever-operated crushing: The design utilizes a long lever mechanism to compress cans and bottles efficiently. By pulling down the lever, the user applies force to a piston that pushes against the can or bottle placed in the central cavity.</p> <p>Combined functionality: The single lever mechanism caters to both can crushing and bottle opening. A separate bottle opener protrudes from the side of the device, accessible when not in use for crushing.</p> <p>Compact and portable: The overall size appears suitable for countertop use or wall mounting. Its sleek and simple design blends well with various kitchen decors</p>

Figure 4: Final design and its concept

Table 4 Failure Mode and Effects Analysis (FMEA) is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures, in order to identify the parts of the process that are most in need of change. In the context the design, focusing on the piston system and connecting rod, FMEA provides valuable insights into potential failure modes, their effects, causes, and current mitigation strategies.

Piston System:

The primary function of the piston in this design is to crush cans and bottles. However, the FMEA identifies several failure modes. One significant failure mode is the piston breaking, which can lead to three critical effects: exposure of sharp edges, piston collapse, and potential user injury. The severity of these outcomes is rated as 7 on a scale, reflecting substantial concern. The potential causes of the piston breaking include high tolerance in the connecting rod and the loosening of screws. To mitigate these risks, the current preventive activities include ensuring low tolerance in the connecting rod design and conducting stress analysis. The occurrence of these failure modes is relatively low, as indicated by a low occurrence rating. Detection activities involve load testing, which has been effective, as demonstrated by a low detection rating and a resultant Risk Priority Number (RPN) of 21, indicating a moderate risk level.

Connecting Rod:

The connecting rod's function is to enable smooth movement, but it faces the risk of rough movement, making it challenging to flip inward/outward easily. The severity of this issue is rated as 8, indicating a high level of concern. The potential causes include corrosion of metal parts and the absence of a bearing between rotating parts. The current preventive measures involve using appropriately sized bearings to handle the expected load. Despite these measures, the occurrence rating is moderately high, suggesting a recurring issue. The detection method involves testing on a prototype, which seems somewhat effective, given the detection rating of 2 and an RPN of 96. This higher RPN signals a more significant risk compared to the piston system and warrants closer attention.

Overall, the FMEA analysis for this can crusher and bottle opener product highlight the importance of material selection, particularly in choosing corrosion-resistant and durable components. The analysis also underscores the need for robust preventive measures. While current strategies like low tolerance design, stress analysis, and the use of appropriate bearings are in place, the analysis suggests that there is room for improvement in both preventive and detection activities.

Table 4: FMEA for final design

No	System/Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Cause of the Failure Mode	Current Preventive Activities	Occurrence	Current Detection Activities	Detection	RPN
1	Piston to crush the cans and bottle	Piston breaks	a) Sharp edges exposed b) Piston collapse c) User injured	7	1) Connecting rod have high tolerance 2) Screw loosens	1) Make low tolerance 2) Stress analysis	3	Load test	1	21
2	Connecting Rod	Rough movement of connecting rod	Connecting rod not able to be flipped inward/outward easily	8	1) Corrosion of metal parts 2) No bearing between rotating parts	1) Use appropriate size of bearing according to the expected load for hanger rod	6	Testing on prototype	2	96

6.0 CONCLUSION

This project, centered on the design and fabrication of an aluminum can and plastic bottle crusher, marks a significant stride in recycling and waste management techniques. The machine is engineered to transform empty cans and bottles into neatly stackable piles, thereby enhancing the efficiency of recycling processes and conserving space in waste disposal areas. Key to its design is the minimal power and effort required for operation, making it user-friendly and environmentally responsible. Additionally, this project serves as a practical application of theoretical knowledge in mechanical engineering design, integrating advanced technology to create a product that is both innovative and functional. The success of this project not only lies in its immediate utility but also in its contribution to sustainable practices and the advancement of engineering design principles.

7.0 RECOMMENDATIONS

To further enhance the functionality and efficiency of the aluminum can and plastic bottle crusher;

Material Strength Adaptation: The current design effectively crushes low-strength aluminum cans. To broaden its utility, the machine should be modified to handle medium strength materials. This would allow for a wider range of recyclable materials to be processed, increasing the machine's versatility and usefulness in recycling efforts.

Automation Enhancement: Transitioning to an automatic operation system will elevate the machine's robustness and efficiency. An automated system can ensure consistent performance, reduce manual labor, and potentially increase the speed of the crushing process. This enhancement aligns with the trend of automation in modern machinery, offering a more user-friendly and efficient recycling solution.

Pneumatic Equipment Integration: Incorporating pneumatic equipment could significantly improve the machine's precision and output quality. Pneumatic systems, known for their reliability and efficiency, can provide consistent force and speed in the crushing process, leading to more uniform results. This addition would also align the machine with contemporary engineering practices, making it more appealing and functional in a broader range of settings.

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