ISSN 2087-3336 (Print) | 2721-4729 (Online)
TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika
Vol. 13, No. 1, 2026, page. 162-169
http://jurnal.sttmcileungsi.ac.id/index.php/tekno
DOI: 10.37373

Crusher machine design for plastic bottle cap waste recycling process to support sustainability

Herry Syaifullah, Indra Setiawan*, Albertus Aan Dian Nugroho, Dinda Lutfiah, Dwima Septiar Priambada, Arka Baswara Bimo Sakti

*Astra polytechnic, Jl Gaharu Lippo Cikarang, Bekasi Indonesia

*Correspondence Email: indra.setiawan@polytechnic.astra.ac.id

Submitted: 09/08/2025 Revised: 15/11/2025 Accepted: 07/12/2025

Abstract

The problem of plastic waste in Indonesia is becoming increasingly urgent every day due to the increase in plastic consumption. The increasing number of plastic bottle caps will have a negative impact on the environment. This problem can be overcome by converting this waste into economically valuable products. One effective solution is recycling, but the current obstacle is the lack of effective tools to optimally crush plastic bottle cap waste. Therefore, it is necessary to design and manufacture a special crusher machine to process plastic bottle cap waste. This study aims to develop a crusher machine specifically designed to process plastic bottle cap waste to support sustainable recycling. . The purpose of this research is to develop innovative technology for crushing plastic bottle cap waste. The method used in this research is the CDIO approach, the research includes stages of problem identification, machine design, prototype fabrication, and performance testing. Several improvements were implemented, including blade geometry modification, addition of a secondary shaft, gear reducer ratio adjustment, and frame redesign for safety enhancement. Test results show that the prototype effectively crushes various types of plastic caps, with improved cutting speed after modifying the gear reducer from 1:30 to 1:20 and adding forked blades. This development supports the recycling industry by providing a more efficient and reliable plastic crushing process. The purpose of this research is to develop innovative technology for crushing plastic bottle cap waste. The method used in this research is the CDIO (Conceive, Design, Implement, Operate) approach, starting from problem identification, design, prototyping, and performance testing. Several innovations were made, such as modifying the shape and thickness of the cutting blade, adding a shaft, changing the gear reducer ratio, and improving the frame design to increase safety and efficiency. The test results showed that the machine can crush various types of plastic, such as bottles and gallon caps, effectively. Changing the gear reducer ratio from 1:30 to 1:20 increased the rotation speed, while modifying the blade to form a branch accelerated the crushing process. This research is important to meet the needs of the industry that continues to grow along with technological advances, so that the process of recycling plastic bottle cap waste can run more efficiently.

Keywords: Waste recycling; manufacturing; crusher machine; sustainable; plastic bottle caps

1. Introduction

Plastic consumption in everyday life has increased along with industrial development and modern lifestyles. Data from the Indonesian Plastics Industry Association (INAPLAS) and the Central Statistics Agency (BPS) shows that plastic waste in Indonesia reaches 64 million tons per year [1]. The high rate of plastic consumption, not matched by the implementation of an efficient waste management system, has led to the accumulation of plastic waste, which in turn negatively impacts environmental sustainability and ecosystem balance [2]. This increase has resulted in the accumulation of plastic waste, particularly plastic bottle cap waste, which is difficult to decompose and pollutes the environment [3].

The amount of plastic bottle cap waste has increased significantly. The increasing amount of plastic bottle cap waste has a significant impact on the surrounding environment [4]. Plastic bottle cap waste is considered non-organic waste, which is a type of waste that is difficult to decompose [5]. This shows that if plastic bottle cap waste is not promptly managed, the earth will become a home for trash and useless items.

The lack of innovation in converting used goods into value-added and economical products has resulted in a continuous increase in the volume of plastic waste. Suboptimal management of recycled plastic waste leads to environmental pollution and resource waste [6]. Plastic waste management should be carried out by applying the 4R principles: Reduce, Reuse, Recycle, and Replace (substitute environmentally friendly materials) [7]. One current effort is the process of shredding plastic to process it into new raw materials. One effective solution is to develop creativity in processing waste into crafts that are not only functional but also have aesthetic and commercial value [8]. However, before it can be transformed into value-added products, plastic bottle cap waste requires an effective destruction process. The destruction process of plastic bottle cap waste requires the support of tools capable of supporting this process. Therefore, this research focuses on the design and manufacture of a special crusher machine to support the processing of plastic bottle cap waste. A plastic crusher machine is a plastic shredding tool designed to cut plastic material into small pieces, making it easier to process for recycling [9]. The crusher machine works by utilizing the cutting and frictional force of a rotating blade (cutter) against a spacer (dummy cutter). This crusher machine prototype is designed to crush plastic bottle cap waste into small fragments ready for recycling, thus not only reducing the volume of plastic waste but also increasing the efficiency of its management and the economic value of recycled materials. The urgency of this research arises along with industrial developments that require new technologies to ensure the plastic waste recycling process runs optimally and sustainably. The purpose of this research is to develop innovative technology for crushing plastic bottle cap waste.

2. Method

This research uses design techniques [10], [11], [12]. This research adopted the Conceive-Design-Implement-Operate (CDIO) approach, which systematically applies scientific principles to design and test a plastic crusher machine [13]. CDIO is a learning approach that focuses on mastering basic engineering knowledge and applying it to real-world situations to develop a system or product [14]. Through the CDIO method, the team can manage the project comprehensively, from idea formulation to finding solutions to address the problems encountered [15].

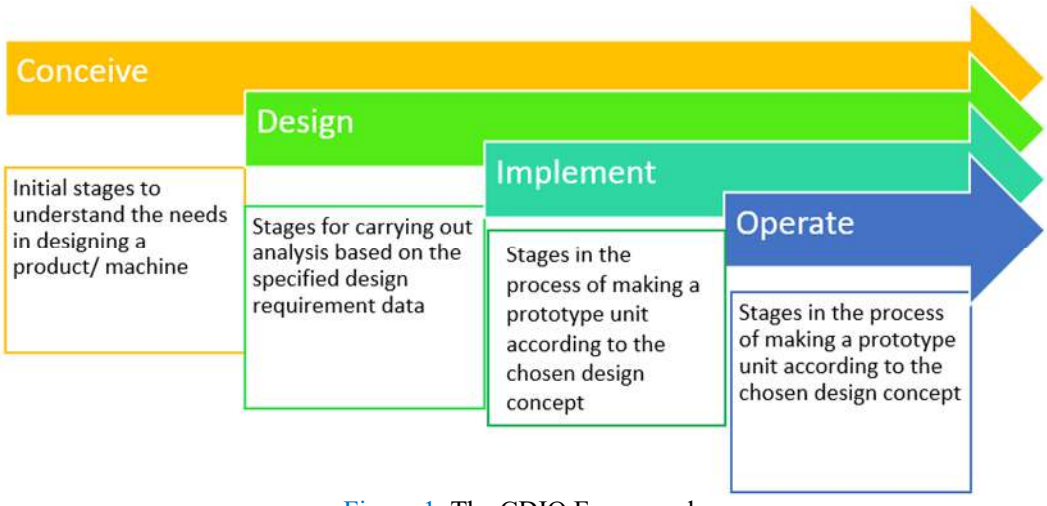

Figure 1. The CDIO Framework

The conceive stage involves identifying the problem of plastic waste accumulation and formulating a crushing solution to facilitate recycling. In the design stage, a machine assembly model is created with the main components being a forked cutting blade and a gear reducer. In the implement stage, the

prototype is then implemented and tested using various types of plastic (bottles, gallon caps, plastic bags), with evaluation of crushing effectiveness and blade speed optimization. The operate stage includes quality control, automated process monitoring, and routine maintenance (motor lubrication and component inspection) to ensure continuous performance [16], [17]. All tests were conducted at the Astra Polytechnic Laboratory, with plastic flake size (targeting <5 mm) and output consistency serving as the key performance benchmarks. All tests were conducted at the Astra Polytechnic Laboratory with plastic flake size (<5 mm) and output consistency as benchmarks.

This study used two data collection techniques: observation to assess the actual conditions of the plastic bottle cap waste processing process, thus identifying the need for designing an integrated crusher machine, and focus group discussions to discuss the design and implementation of the machine [18], [19], [20]. This study followed a systematic methodology divided into eight main stages as shown in

3. Result and Discussion

3.1 Conceive

The urgent need for research is to address the growing needs of the industry, driven by the emergence of new technologies, enabling the smooth running of plastic bottle cap waste recycling. The machine design aims to achieve a compatible design that meets these needs. Focused group discussions with stakeholders are necessary to obtain concrete information. The proposed machine design aims for optimal capacity. The proposed machine design has a capacity of 1.32 kg/minute, or 78 kg/hour, or 630 kg/day, with an optimal level of 100%. At 60%, that's approximately 378 kg/8 hours (per day).

3.2 Design

To address these issues, a breakthrough in the form of a plastic bottle cap crusher is needed. Using simple technology, this crusher can be designed to help increase the productivity and quality of recycled plastic bottle cap waste. The project to develop a crusher for recycling plastic bottle cap waste has been successfully implemented through various stages, from design to testing. The following is the design of the plastic bottle cap crusher, shown in Figure 2.

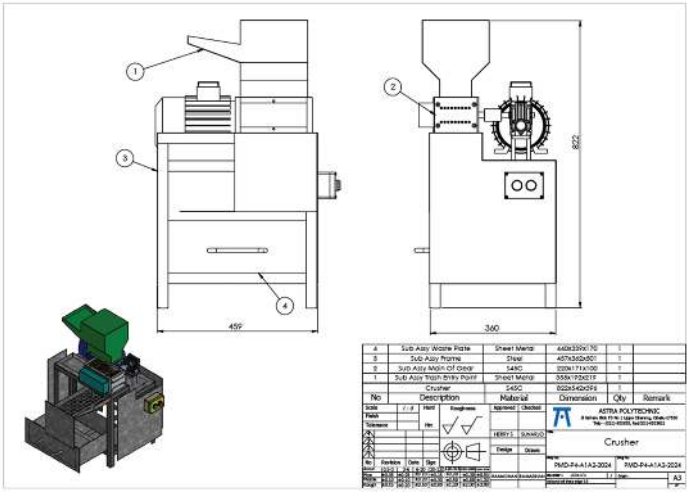

Figure 2. Full assembly crusher machine concept design

The resulting crusher machine consists of several main components, namely:

1. Trash Entry Point: Where the plastic bottle cap waste is inserted.
2. Main Gear: The cutting part consisting of the cutter and dummy cutter.
3. Frame: The machine frame is made of L-shaped steel.
4. Waste Plate: Where the plastic scraps exit.

The part materials used include:

1. Sheet Metal: To make the frame cover, waste plate, and trash entry point
2. S45C Steel: To make the main gear parts
3. L-Shaped Steel: To make the frame

3.3 Implement

Meanwhile, The shredding process takes place systematically through the following stages:

Raw Material Preparation: The plastic waste to be processed first undergoes a sorting and cleaning process to separate non-plastic materials such as paper, metal, or other debris. The remaining plastic waste consists only of plastic bottle caps.

Figure 3. Plastic bottle cap waste

Figure 3 displays the collected plastic bottle cap waste before the crushing process, showcasing the variety of colors and sizes. This visual underscores the initial state of the raw material, which is often heterogeneous and requires a robust machine design to handle different cap dimensions and plastic polymer types effectively. Feeding Process (Material Input): The operator feeds the processed plastic waste through a Trash Entry Point (input funnel), which is designed at a specific angle to ensure smooth material flow.

Figure 4. Process of feeding plastic bottle cap waste to the trash entry point

Figure 4 illustrates the manual feeding operation where an operator directs the prepared plastic bottle caps into the machine's hopper. The design of the trash entry point, with its specific geometry and safety groove (as improved in the design phase), is crucial for guiding the material smoothly into the cutting chamber while minimizing the risk of jamming and enhancing operator safety.

Cutting Mechanism: This machine is equipped with a powerful cutting blade, which functions to shred the plastic into small pieces of a uniform size. This plastic shredding process allows initially large and difficult-to-manage plastic waste to be converted into smaller pieces ready for further recycling. The motor drives the rotating cutter, which shreds the plastic bottle cap waste into small pieces.

Figure 5. Machine motor

Figure 5 shows the electric motor that serves as the prime mover for the crusher machine. This motor provides the necessary torque and rotational power, which is transmitted through the gear reducer to the cutting shafts. The selection of an appropriately powered motor is fundamental to ensuring the machine can handle the mechanical stress of crushing hard plastic caps consistently.

Figure 6. Machine cutter

Figure 6 provides a close-up view of the central cutting mechanism, featuring the dual-shaft assembly with the spiral-patterned, forked blades. This design innovation is critical for creating a shearing and tearing action, effectively grabbing, cutting, and reducing the bottle caps into small flakes. The spiral arrangement ensures continuous material feed and prevents clogging. Filtering System: The cut material passes through a predetermined mesh screen, which controls the output size.

Figure 7. Plastic bottle cap waste filtering process after cutting

Figure 7 captures the output of the crushing process, where the shredded plastic flakes are collected after passing through a mesh screen. This screening stage is essential for controlling the final particle size distribution. The resulting uniform flakes, as shown, are ideal for subsequent recycling steps like washing, melting, and molding into new products, ensuring quality and consistency in the recycled material.

Output: The resulting plastic scraps can be used for various purposes. Used plastic bottle caps can be transformed into attractive, creative craft products with high sales value (Supriyatin et al., 2024b). For example, shredded plastic waste can be melted and molded into new products, such as tables, chairs, accessories, and other items with higher sales value. This crusher machine is expected to reduce plastic accumulation and increase the effectiveness of the recycling process, as well as transform used plastic into useful and economically valuable products.

3.4. Operate

This Test results showed that the machine was capable of crushing plastic bottle caps into small, uniform-sized pieces. However, during observations, our team identified several aspects that needed improvement, including:

Cutter Design: On the previous machine, the 10 mm thick, box-shaped cutter resulted in suboptimal cutting results. In this project, the cutter was improved by reducing the thickness to 5 mm and adding prongs to the blade to increase sharpness. As a result, cutting efficiency significantly increased.

Cutter Pattern and Shaft Addition: The old machine only used one shaft, concentrating the workload on one side of the gearbox. To address this, a second shaft was added and the cutter pattern was arranged in a spiral pattern. This change reduced plastic accumulation and distributed the load more evenly.

Machine Frame: The old design of the trash entry point appeared unsafe and could potentially injure the face. This was due to the lack of a groove at the trash entry point. Therefore, improvements were made by adding a groove at the trash entry point for greater safety when inserting plastic bottle caps.

Using a Gear Reducer with a 1:20 Ratio: Changing the gear reducer from a 1:30 to a 1:20 ratio results in faster cutter rotation, making the plastic shredding process more efficient. However, care must be taken not to insert too many bottle caps at once to avoid overloading the motor.

Test results showed that the machine successfully crushed plastic bottle caps into small and uniform pieces. Several improvements were implemented to enhance performance. First, reducing the blade thickness to 5 mm and adding forked prongs increased cutting sharpness, resulting in smoother material flow and faster crushing time (improvement ±25–30%). Second, the addition of a second shaft and spiral blade pattern distributed torque more evenly, reducing motor load and preventing material clogging. Third, redesigning the trash entry point significantly increased operator safety by minimizing the risk of accidental contact with rotating parts. Lastly, the installation of a 1:20 gear reducer increased cutter rotational speed, improving shredding efficiency, although operators must regulate feeding rate to avoid overload.

Impact on research outcomes:

These improvements demonstrated that the redesigned prototype not only increased productivity but also addressed weaknesses found in earlier designs. The enhanced blade geometry contributed to finer and more consistent output size, supporting better-quality recycled material. The new shaft configuration also improved machine durability by reducing concentrated stress on the gearbox. In addition, the improved frame layout ensured safer operation, which is crucial for user acceptance in industrial applications. Overall, the design modifications significantly increased process efficiency and machine reliability while supporting sustainable recycling practices.

4. Conclusion

This study successfully designed, built, and tested a crusher machine specifically for plastic bottle cap waste. The application of the CDIO approach facilitated a systematic development process, leading to several key design improvements: a forked blade, a dual-shaft spiral cutter arrangement, an enhanced safety frame, and an optimized gear reducer ratio. These modifications collectively resulted in a machine that processes plastic bottle caps with significantly improved efficiency, safety, and reliability. The results of this study indicate that the developed machine is capable of processing plastic with good efficiency. However, several improvements have been made, such as modifications to the design of the blade, shaft, gear reducer, and machine frame to improve performance and safety factors. The presence of this crusher is expected to not only reduce the volume of plastic waste but also be able to produce recycled materials with economic value while supporting sustainable waste management practices. This crusher machine not only reduces plastic waste but also produces recycled raw materials with economic value. The resulting plastic flakes can be used to make new products such as tables, chairs, or accessories, thus supporting the concept of sustainability. Through regular maintenance, this machine is expected to operate optimally in the long term and provide real benefits to society and environmental sustainability.

Acknowledgment

The author would like to thank the BOPTN Research and Community Service for the 2025 fiscal year for supporting the funding of this research grant.

Reference

[1] F. Zainuddin, "Peran Produsen dalam Mengurangi Sampah Plastik," *Bahtera Inov.*, vol. 7, no. 2, pp. 56–64, 2023, doi: 10.31629/bi.v7i2.6659. https://doi.org/10.31629/bi.v7i2.6659

[2] A. Z. Majida, A. Muzaki, K. Karomah, and M. Awaliyah, "Pemanfaatan Sampah Plastik dengan Metode Ecobrick Sebagai Upaya Mengurangi Limbah Plastik," *Profetik J. Pengabdi. Masy.*, vol. 1, no. 01, pp. 49–62, 2023, doi: 10.62490/profetik.v1i01.340. https://doi.org/10.62490/profetik.v1i01.340

[3] R. Fadhilah *et al.*, "Transforming Plastic Bottle Cap Waste into Creative Bags for Economic Independence and," *J. Abdi Insa.*, vol. 12, no. 4, pp. 1521–1529, 2025, doi: 10.29303/abdiinsani.v12i4.2372. https://doi.org/10.29303/abdiinsani.v12i4.2372

[4] T. Supriyatin, A. Nurazhimah Arfa, and V. Islamay Hartono, "Pemanfaatan Limbah Tutup Botol Plastik Menjadi Kerajinan Tangan Yang Bernilai Estetika Dan Ekonomi," *J. Pengabdi. Pendidik. Masy.*, vol. 5, no. 2, pp. 282–288, 2024, doi: 10.52060/jppm.v5i2.2418. https://doi.org/10.52060/jppm.v5i2.2418

[5] Ni Wayan Sri Suliartini *et al.*, "Pengolahan Sampah Anorganik Melalui Ecobrick Sebagai Upaya Mengurangi Limbah Plastik," *J. Pengabdi. Magister Pendidik. IPA*, vol. 5, no. 2, pp. 209–213, 2022, doi: 10.29303/jpmpi.v5i2.1741. https://doi.org/10.29303/jpmpi.v5i2.1741

[6] F. Husna, Windu Fajar Arum, Evi Aryanti, and Islamul Hadi, "Optimalisasi Pengelolaan Sampah dan Daur Ulang untuk Mengurangi Emisi Gas Rumah Kaca Di Perkotaan," *Lambda J. Ilm. Pendidik. MIPA dan Apl.*, vol. 5, no. 1, pp. 9–24, 2025, doi: 10.58218/lambda.v5i1.1029. https://doi.org/10.58218/lambda.v5i1.1029

[7] H. Hendra, S. Al Qiram, S. Susilo, K. Nugraha, Hernadewita, and F. Hardian, "Analisa Tegangan pada Desain Empat Mata Potong untuk Mesin Pencacah Plastik Menggunakan Metode Elemen Hingga," *J. Tek. Mesin*, vol. 5, no. April, pp. 52–69, 2019, doi: 10.30630/jtm.16.2.1245. https://doi.org/10.30630/jtm.16.2.1245

[8] N. W. Rustiarini, I. M. Legawa, Y. Adnyana, and T. D. Setyono, "Pengolahan Sampah Plastik Menjadi Kerajinan Tangan Bernilai Ekonomi," *JURPIKAT (Jurnal Pengabdi. Kpd. Masyarakat)*, vol. 2, no. 2, pp. 10–21, 2021, doi: 10.37339/jurpikat.v2i2.502. https://doi.org/10.37339/jurpikat.v2i2.502

[9] L. K. Ncube, A. U. Ude, E. N. Ogunmuyiwa, R. Zulkifli, and I. N. Beas, "An overview of plasticwaste generation and management in food packaging industries," *Recycling*, vol. 6, no. 1, pp. 1–25, 2021, doi: 10.3390/recycling6010012. https://doi.org/10.3390/recycling6010012

[10] V. Dixit, S. Karvate, M. Shinde, U. Pandhare, and A. Shinde, "Review on Design and Fabrication of Can Crushing Machine," *Int. J. Innov. Eng. Res. Technol.*, no. 978, pp. 1–6, 2021, [Online]. Available: https://repo.ijiert.org/index.php/ijiert/article/view/1925

[11] K. Govindan, A. Rajeev, S. S. Padhi, and R. K. Pati, "Supply chain sustainability and performance of firms: A meta-analysis of the literature," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 137, no. March, p. 101923, 2020, doi: 10.1016/j.tre.2020.101923. https://doi.org/10.1016/j.tre.2020.101923

[12] S. A. Belayneh, P. H. Qi, P. D. Xianhui, and M. Manufacturing, "Design and Manufacture of block crusher Machine," *Global*, vol. 10, no. 7, pp. 2614–2621, 2022.

[13] CDIO, "CDIO Standards 3.0." Accessed: Mar. 18, 2025. [Online]. Available: http://www.cdio.org/content/cdiostandards-30

[14] F.- Fadillah, R. Zelmiyanti, D. Irianto, and S. Riadi, "CDIO Framework: A Solution of The Project-Based Learning Problem in Accounting Study Program," *J. Appl. Manag. Account.*, vol. 8, no. 1, pp. 146–155, 2024, doi: 10.30871/jama.v8i1.7379. https://doi.org/10.30871/jama.v8i1.7379

[15] J. Power, D. Tanner, A. Ryan, and B. Devitt, "Developing CDIO practitioners: A systematic

approach to standard 10," *Procedia Manuf.*, vol. 38, no. 2019, pp. 680–685, 2019, doi: 10.1016/j.promfg.2020.01.087. https://doi.org/10.1016/j.promfg.2020.01.087

[16] H. Syaifullah, I. Setiawan, A. A. Dian, M. Chorda, and R. Budi, "Pembuatan Trailer Jetski Menggunakan Metode Reverse Engineering dan Conceive Design Implement Operate," *J. Penelit. dan Apl. Sist. dan Tek. Ind.*, vol. 18, no. 2, pp. 194–202, 2024, doi: 10.22441/pasti.2024.v18i2.005. https://doi.org/10.22441/pasti.2024.v18i2.005

[17] A. Rokhmah, H. Putra, and F. E. Gunawan, "Penerapan quality control circle untuk meningkatkan yield produksi dengan mengurangi scrap di recoiling line," *TEKNOSAINS J. Sains, Teknol. dan Inform.*, vol. 10, no. 2, pp. 244–253, 2023, doi: 10.37373/tekno.v10i2.536. https://doi.org/10.37373/tekno.v10i2.536

[18] D. Panutan, M. Ma, A. Wijianto, and R. Novison, "Design and simulation of a fan-shaped banana cutting machine," JTTM J. Terap. Tek. Mesin, vol. 6, no. 1, pp. 101–108, 2025, doi: 10.37373/jttm.v6i1.1518. https://doi.org/10.37373/jttm.v6i1.1518

[19] P. A. Nugroho, S. Subekti, and A. Iswahyudi, "Design of organic fertilizer pellet machine with a capacity of 170 . 90 Kg / Hour using verein deutcher ingenieure 2222 method," JTTM J. Terap. Tek. Mesin, vol. 4, no. 2, pp. 163–171, 2023, doi: 10.37373/jttm.v4i2.575. https://doi.org/10.37373/jttm.v4i2.575

[20] A. Dharmanto, A. H. Muzakki, H. Sholih, and A. Domodite, "Analysis of the strength of the frame construction on the nyamplung bean peeling machine using the finite element method," Teknol. Pangan Media Inf. dan Komun. Ilm. Teknol. Pertan., vol. 12, no. 1, pp. 1–7, 2025, doi: 10.37373/tekno.v12i1.1027. https://doi.org/10.37373/tekno.v12i1.1027