Performance Test of Input Mechanisms on Cardboard Folding Machine System

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Abstract

The packaging industry has experienced significant global growth, driven by increasing demand for cardboard packaging and the rising volume of packaging waste. This growth highlights the industry's need to enhance efficiency and effectiveness in production processes. Manual handling of cardboard sheets for folding and stacking is time-consuming, necessitating the development of automated solutions. This study introduces the cardboard folding machine, designed and fabricated by mechanical engineering students at UPN Veteran Jakarta. The machine comprises three main mechanisms: the input mechanism, the conveyor for folding cardboard sheets, and the output mechanism. To optimize production, performance testing is conducted to identify the most efficient speed settings to achieve maximum cardboard folding output. This testing also aims to promote the machine as a practical tool for potential users in the packaging industry. Previous research has explored various mechanisms for handling cardboard, including friction systems, slider systems, and vacuum systems. Each approach offers distinct advantages and challenges. By addressing these issues, the cardboard folding machine aims to improve production reliability in alignment with the needs of potential users. The results of this study delineate the advantages and disadvantages inherent to both friction and slider mechanisms. These results can be utilized to tailor the mechanisms according to the preferences of prospective users.

Keywords: Cardboard Folding Machine; Performance Test; Input Mechanism; Efficiency

Abstrak

Industri pengemasan telah mengalami pertumbuhan global yang signifikan, didorong oleh meningkatnya permintaan terhadap kemasan kardus dan volume limbah kemasan yang terus meningkat. Pertumbuhan ini menyoroti kebutuhan industri untuk meningkatkan efisiensi dan efektivitas dalam proses produksinya. Penanganan manual lembaran kardus untuk pelipatan dan penumpukan memerlukan waktu yang lama, sehingga memerlukan pengembangan lebih lanjut. Studi ini memperkenalkan mesin pelipat kardus, yang dirancang dan diproduksi oleh mahasiswa teknik mesin di UPN Veteran Jakarta. Mesin ini terdiri dari tiga mekanisme utama: mekanisme input, konveyor untuk melipat lembaran kardus, dan mekanisme output. Untuk mengoptimalkan produksi, dilakukan pengujian performa untuk mengidentifikasi pengaturan kecepatan yang paling efisien guna mencapai output lipatan kardus yang maksimal. Pengujian ini juga bertujuan untuk mempromosikan mesin sebagai alat praktis bagi pengguna potensial di industri pengemasan. Penelitian sebelumnya telah mengeksplorasi berbagai mekanisme penanganan kardus termasuk mekanisme gesekan, mekanisme penggeser, dan mekanisme vakum. Setiap pendekatan menawarkan keuntungan dan tantangan tersendiri. Dengan mengatasi isu-isu ini, mesin pelipat kardus bertujuan untuk meningkatkan keandalan produksi sesuai dengan kebutuhan pengguna potensial. Temuan dari studi ini menjelaskan kelebihan dan kekurangan yang terdapat pada mekanisme gesekan dan slider. Temuan ini dapat digunakan untuk menyesuaikan mekanisme tersebut sesuai dengan preferensi calon pengguna.

Kata kunci: *Mesin Pelipat Kardus; Uji Performa; Mekanisme Input; Efisiensi*

1. Introduction

The packaging industry is one of the global industrial sectors that has experienced significant growth in recent years [1]. This is supported by the increasing amount of packaging waste, particularly cardboard packaging [2]. This increase serves as an indicator of rising market demand due to the growing number of consumers requiring cardboard packaging [3]. Therefore, the packaging industry sector is beginning to prioritize efficiency and effectiveness in every production process [4]**.** By prioritizing these two aspects, it will have an impact on the increased customer satisfaction due to the services provided and creating new and loyal industrial customers in this packaging sector [5-7] . Overall, the combination of prioritizing efficiency and effectiveness of packaging industry for continued growth and success in meeting the evolving needs of consumers and industries alike [8].

One of the processes in the packaging unit involves cardboard sheets that will go through the gluing process and be stacked to be ready for distribution [9]. This process will take a long time when done manually using labor. Hence, a system that can increase production, be efficient, effective, and easy to maintain is needed. This system is called the box folding machine [10]. This system requires a mechanism that can feed cardboard sheets one by one into the folding conveyor to be distributed. Therefore, an input mechanism is designed for this system to be integrated into the cardboard folding machine's folding conveyor. This innovation reduces the need for manual intervention and increases overall production efficiency. Additionally, the input mechanism is designed to be easily maintainable, with accessible components and straightforward troubleshooting procedures to minimize downtime and ensure continuous operation. Cardboard input mechanisms commonly utilize friction and slider systems. These mechanisms are intended to handle products with flat surfaces, especially paper, cardboard, or multi-page printed materials**.** As mentioned by Maximilian Helmstidter in his patent on the friction mechanism, a friction bar with rollers is ideal for handling thin materials like paper or cardboard. In this setup, the material moves slowly through the space between the rollers [11].

The author conducted a study on previous research with a similar concept. As done by Dwikky Eryawan Saputra and Arifin Nurusyamsi both studies examine similar equipment but feature distinct innovations. Dwikky's research emphasizes the use of an aluminum friction feeder, which is more affordable and easier to source, and includes a multi-size acrylic support due to its elastic nature. Additionally, a motor is utilized to power the prototype belt conveyor that transports the cardboard to the folding machine. However, this study encountered problems with the friction feeder, such as slippage that damaged the cardboard. To resolve this, the research introduced a smooth rubber component to reduce friction, which led to a production capacity with a failure rate of about 33% based on testing 40 cartons. Meanwhile, Arifin's research aims to address issues found in previous studies. Although using the same material, this study encountered problems with the PLC system due to the distance between the limit switch and the belt conveyor being too great, causing the tested cardboard to get stuck on the belt conveyor before reaching the desired limit [12-13]. In the study conducted by Thivanka Kasun Gunawardena, the roller mechanism was chosen because it is suitable for the test material, which is glossy paper. For the paper folding process, the researcher used a roller mechanism due to its high folding speed and simple design. However, the study does not include information on the production capacity achieved, as it only discusses simulations based on the design [14]. The research conducted by Prahadid Blya Narafuadi employs a vacuum feeder mechanism similar to the loading and unloading process at ports. The vacuum process was chosen to move cabinets from pallets and place them onto a conveyor. Subsequently, the cabinets are fed into the glue spreader via a roller conveyor mechanism. Since this equipment is intended for industrial use, a discussion was held between the user and the researcher. For the conveyor, a roller conveyor was selected with a 1 HP electric motor and a speed of 1450 RPM. The speed of the roller conveyor was targeted to match the speed of the glue spreader roller, which is 0.3 m/s (linear). Additionally, the vacuum components included two types of actuators: vertical and horizontal. The vertical actuator lifts the cabinets from the pallets, while the horizontal actuator moves the lifted cabinets to the conveyor. In selecting the vertical actuator, the stroke length impacts the height of the vacuum mechanism frame. If the height is too great, maintenance can become challenging. To prevent the frame from being excessively high, an air cylinder type vertical actuator was chosen. Based on time simulations and testing, the production capacity of the feeder is estimated to decrease from 1627 cabinets per day to 1342 cabinets per day [15].

The box folding machine system has been designed and fabricated previously by mechanical engineering students at UPN Veteran Jakarta, and this system is called the cardboard folding machine. This system consists of three mechanisms: the input mechanism, the conveyor for folding cardboard sheets, and the output mechanism. However, the production process of this system needs to be tested first through performance testing aimed at finding the best number of folded cardboard productions at certain speed variations. This testing is also conducted because the cardboard folding machine system serves as a form of promoting the fabricated tool, a result of the student's work, to be offered to potential users in the packaging business. This not only ensures that the machine meets the demands of potential users but also highlights the innovative capabilities and practical skills of the students involved in the project. Ultimately, this will create a cardboard folding machine that can provide significant benefits to businesses in the packaging industry. This initiative demonstrates the practical application of engineering education and the student's ability to contribute to real-world industrial solutions.

2. Research Materials and Methods

During the performance testing conducted on the cardboard sheet input mechanism, the focus was to find the best speed values, cardboard folds output, and the potential user produced by each mechanism. To obtain these values, the testing was carried out with 3 speed variations; 60 rpm, 80 rpm, and 100 rpm. Additionally, the duration for each speed variation was tested, ranging from 1 minute to 5 minutes. The performance test was conducted on 2 out of the 3 mechanisms available in one work cycle as shown in Figure 1. The output mechanism was not used in this test because it only functions as a container for the cardboard output from the folding machine conveyor.

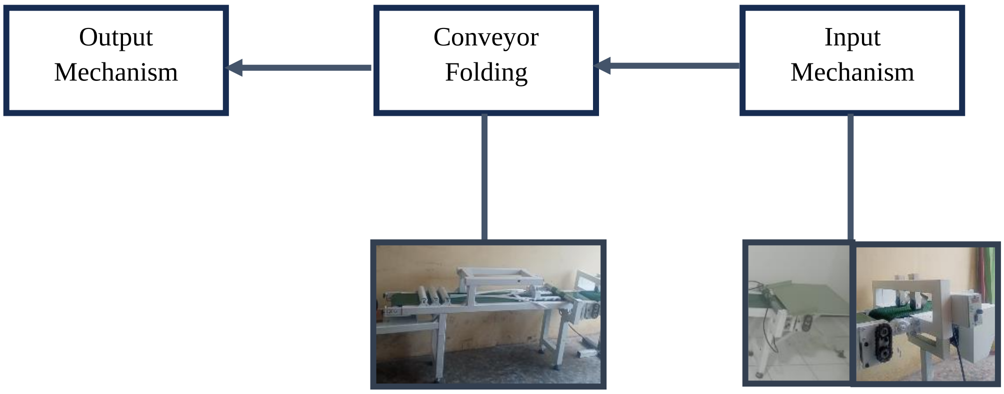


Figure 1. Cardboard Folding Machine Work Cycle

The cardboard sheets used in the test measured (10x10x10)cm with a thickness of approximately ±3 mm and were made of cardboard as shown in Figure 2. There were 2 variations of the cardboard sheet input mechanism: the slider mechanism and the friction mechanism.

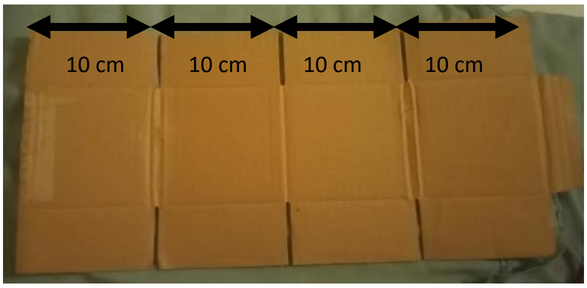
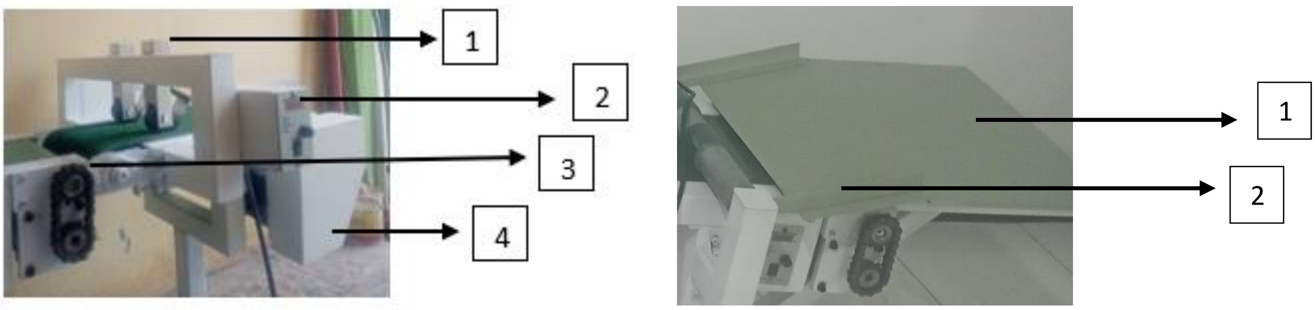


Figure 2. Cardboard Sheet Size

The friction mechanism referred as V1, can be seen in Figure 3a. The friction mechanism comprises 4 main components with their respective functions: 1. Friction Mechanism, which functions to separate the stack of cardboard sheets that will be fed to the conveyor folding machine one by one for folding, 2. Motor Controller, which regulates the speed, 3. Friction Conveyor, which serves as the driving medium for the stack of cardboard sheets, and 4. Motor Driver.

Similarly to the friction mechanism, the slider mechanism referred as V2, can be seen in Figure 3b. The slider mechanism has 2 main components with their respective functions: the Slider Mechanism, which functions as the distributor of cardboard sheets provided by the operator to be fed to the conveyor folding machine, and the collect point, which serves as the place for the stack of cardboard sheets that will be fed one by one through the slider mechanism. The testing data obtained will be presented through a graph that provides answers to the results and conclusions sought.



(a) (b)

Figure 3. (a) Friction Mechanism (V1), (b) Slider Mechanism (V2)

3. Results and Discussions

Based on the performance tests conducted with variations in speed and time, data on the number of cardboard folds in the input slider mechanism and friction can be presented in Table 1. Data in the table has previously been processed using Microsoft Excel.

Table 1. Performance Test Results

Number of Cardboard Folds (pcs)		
Time (sec)	60 RPM	
	V1	V2
60	16	10
120	30	22
180	43	30
240	62	40
300	77	51
	80 RPM	
60	20	12
120	39	25
180	55	34
240	80	47
300	92	58
	100 RPM	
60	30	16
120	54	32
180	88	51
240	102	68
300	117	87

Table 1 shows the results of tests conducted with variations in the conveyor motor rotation speed, controlled through a motor controller with variations of 60 rpm, 80 rpm, and 100 rpm. This testing started at 60 seconds and its multiples up to 300 seconds, measured with a stopwatch. Based on the data from the table, each can be explained one by one through graphs referencing the speed variations below.

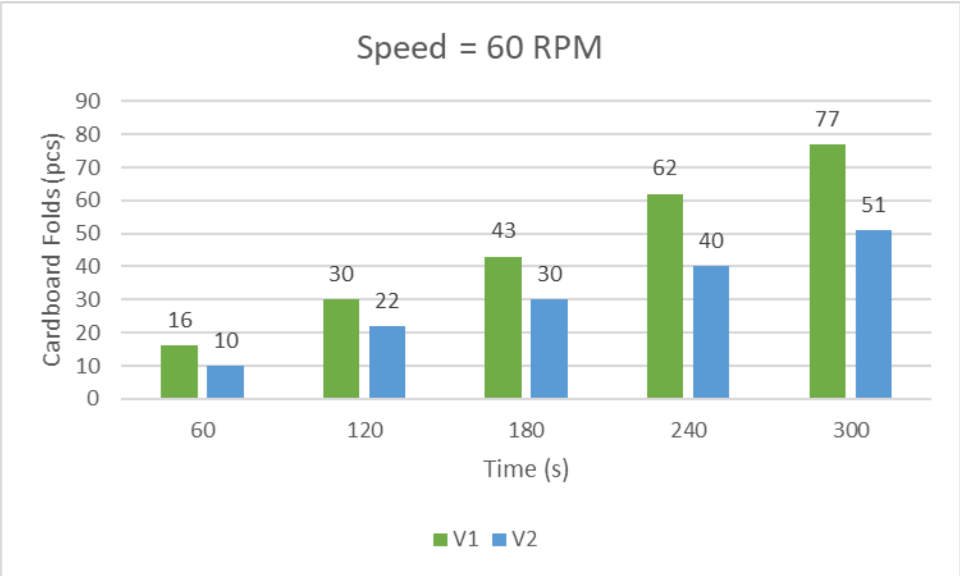


Figure 4. Cardboard Folding Result at 60 RPM

Based on Figure 4 when the conveyor motor speed is set to 60 rpm, the friction mechanism in a 60-second variation folds 16 cardboard. This value is higher compared to the slider mechanism, which only folds 10 pieces of cardboard. This is because the initial point of inserting the cardboard sheets can enter through the gap between the friction mechanism, unlike the initial point of the slider mechanism, which requires control from the operator, so the initial point of the cardboard sheets that enter must be continuously monitored by the operator. At this speed, the difference in time intervals between the number of input cardboard sheets in this process is quite significant, with an average time interval of about 3.9 seconds for the friction mechanism, and 5.8 seconds for the slider mechanism.

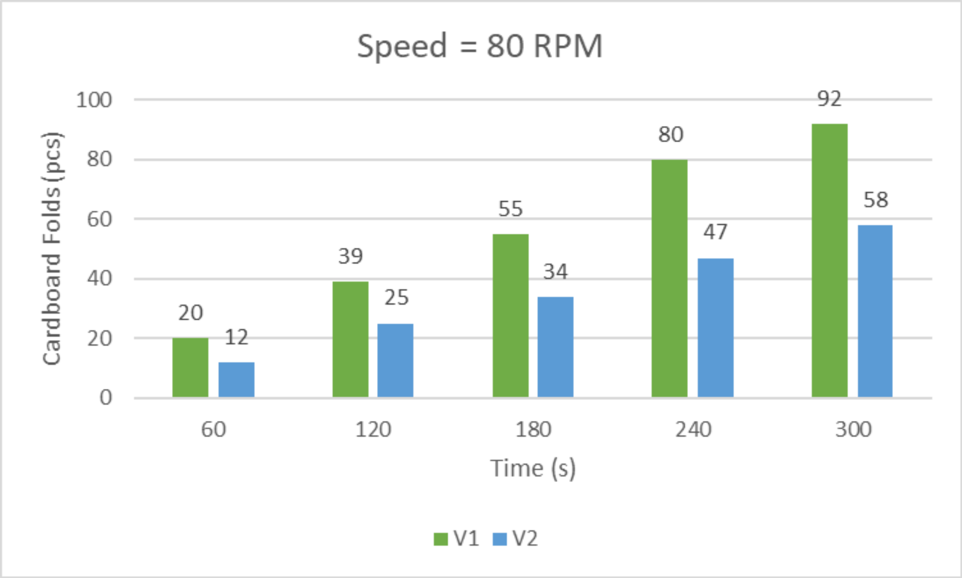


Figure 5. Cardboard Folding Result at 80 RPM

Based on Figure 5 similarly to the previous speed variations, at a speed of 80 rpm, the friction mechanism has a higher initial insertion point for cardboard, with a difference of 8 sheets of cardboard compared to the slider mechanism. However, the friction mechanism experiences a decrease in the production of cardboard sheets between the time ranges of 120 to 180 seconds and 240 to 300 seconds. This occurs because the stack of cardboard needs to be refilled by the operator when it reaches the maximum stack capacity of 40 sheets and its multiples, as illustrated in Figure 6. At this speed, the average interval time between cardboard folds is closer compared to the 60 rpm variation for both the slider and friction mechanisms. This results in better production efficiency of cardboard folding at 80 rpm compared to the previous variations.

Figure 6. Cardboard Stack Limit

Based on Figure 7, at a conveyor motor speed variation of 100 rpm, it can be observed that the slider mechanism shows a more regular increase in the number of folded cardboard production. Although it is less efficient compared to the friction mechanism, the cardboard folding activity can be monitored comprehensively by the operator, reducing the likelihood of bottlenecks or obstructions in each process.

In contrast, while the friction mechanism produces almost twice as many units as the slider mechanism, it encounters bottlenecks, usually happens due to constraints on resources such as the technology used or the workforce, which limit the capacity of the production system [16-17]. When the speed variation reaches 180 to 240 seconds and

240 to 300 seconds. This leads to a queue of cardboard sheets waiting to be folded. This issue arises because the length of the folding conveyor is not suitable for handling a large volume of production at one time. Consequently, within this time range, the number of folded cardboard does not reach the expected amount, increasing by only 14-15 units. This bottleneck can be seen in Figures 8a and 8b.

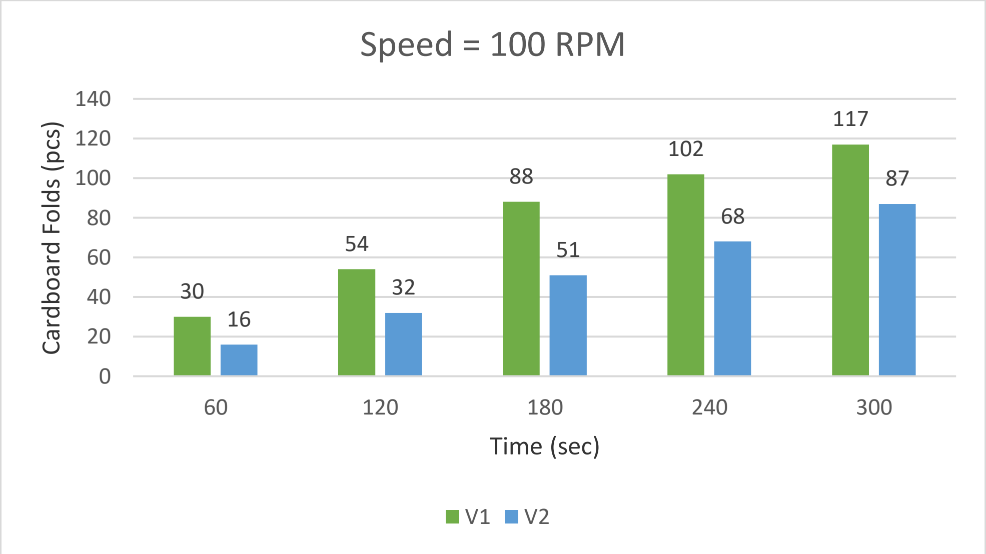


Figure 7. Cardboard Folding Result at 100 RPM

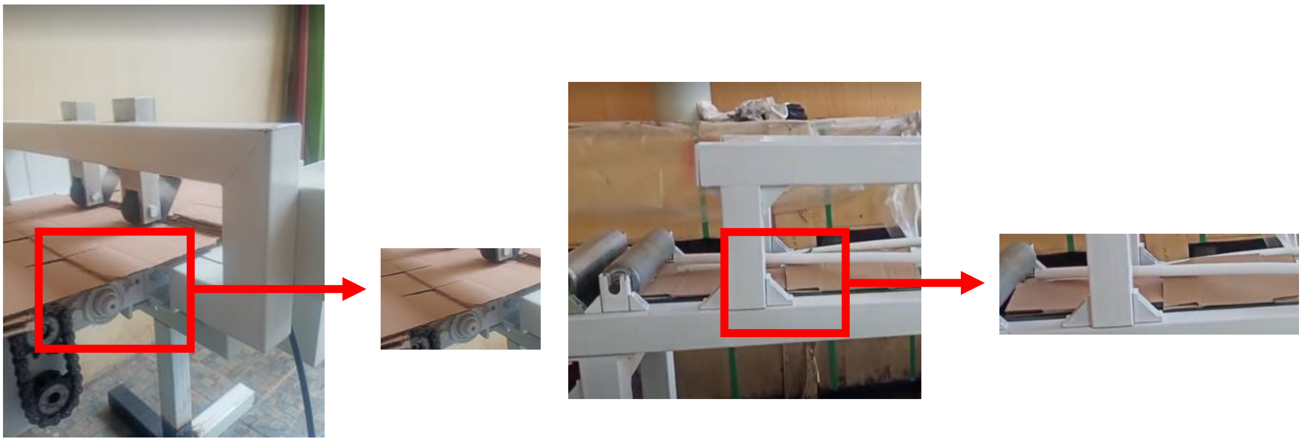


Figure 8. (a) Bottleneck in Friction Mechanism, (b) Bottleneck in Folding Conveyor

4. Conclusion

Based on performance testing of the input mechanism of the cardboard folding machine, it can be concluded that there are both advantages and disadvantages to the slider mechanism and the friction mechanism. The friction mechanism is suitable for potential users who want to achieve efficiency in production time for their operations. However, it is important to note that a speed of 80 RPM is considered more appropriate for this system because it offers better production efficiency compared to the slider mechanism and does not create bottlenecks that could impede the production process. The slider mechanism is suitable for potential users who want their production process to be thoroughly controlled and to reduce potential obstacles during the folding process. Therefore, with the assistance of an operator, this mechanism is expected to minimize any bottlenecks or other issues. For the slider mechanism, a speed of 100 RPM is considered appropriate because it results in a higher production rate compared to other speed variations without internal system constraints. Furthermore, further research is needed to explore variables that could provide additional variations in this study, and further development of the tool's design is also required to obtain the best version of the cardboard folding machine.

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References

[1] D. Feber, O. Lindqvist, D. Nordigården, And, and M. Seidner, “2022 and beyond for the packaging industry’s CEOs: The priorities for resilience,” *Mc Kinsey and Company*, Australia, pp. 2–3, Mar. 2022.

[2] A. Vuk, I. Szucs, and A. Bauerné Gáthy, “Packaging waste and recycle in EU,” *Int. Rev. Appl. Sci. Eng.*, vol. 14, no. 3, pp. 402–412, 2023, doi: 10.1556/1848.2023.00615.

[3] C. M. Val, “Trends in Packaging.,” *Int. J. Microcircuits Electron. Packag.*, vol. 7, no. 2, pp. 21–34, 2022.

[4] F. N. Azizah and D. N. Rinaldi, “Effort to Improve Overall Equipment Effectiveness Performance with Six Big Losses Analysis in the Packaging Industry PT BMJ,” *IJIEM - Indones. J. Ind. Eng. Manag.*, vol. 3, no. 1, p. 26, 2022, doi: 10.22441/ijiem.v3i1.13508.

[5] A. Taufik, S. Santoso, M. I. Fahmi, F. Restuanto, and S. Yamin, “The Role of Service and Product Quality on Customer Loyalty,” *J. Consum. Sci.*, vol. 7, no. 1, pp. 68–82, 2022, doi: 10.29244/jcs.7.1.68-82.

[6] M. I. N. Maya Sari, Muhammad Andi Prayogi, Jufrizen Jufrizen, “Membangun Loyalitas Pelanggan Berbasis E-Service Quality Dengan Mediasi Kepuasan Pelanggan (Studi pada Transportasi Online Grab-Car di Kota Medan),” *J. Manajemen, Strateg. Bisnis dan Kewirausahaan*, vol. 14, no. 2, pp. 218–235, 2020, doi: doi: https://doi.org/10.24843/MATRIK:J MBK.2020.v14.i02.p07.

[7] BELLA BELLINDA, E. DOLOROSA, and D. KURNIATI, “Kepuasan Dan Loyalitas Pelanggan Aming Coffee: Experiential Marketing,” *J. Bisnis dan Akunt.*, vol. 22, no. 2, pp. 335–346, 2020, doi: 10.34208/jba.v22i2.760.

[8] S. F. Yeo, Y. H. Khoo, C. L. Tan, and K. B. Lim, “Product packaging: Impact on customers’ purchase intention,” *Int. J. Bus. Soc.*, vol. 21, no. 2, pp. 857–864, 2020.

[9] M. Bhoir, N. Bharti, S. Ghosalkar, and V. Rathour, “AUTOMATED BOX FOLDING MACHINE,” *Int. J. Creat. Res. Thoughts*, vol. 6, no. 2, pp. 377–386, 2018.

[10] Y. Wang and R. B. Stone, “Box Folding Machine Design by Using Product Design Method Functional Based Model,” *J. Phys. Conf. Ser.*, vol. 1852, no. 4, 2021, doi: 10.1088/1742-6596/1852/4/042017.

[11] H. Maximilian, “Friction Feeder For Paper Sheets,” 5,244,197, 1993.

[12] A. Nurusyami, “Perencanaan Ulang Stapler Dan Penekuk Karton,” UII, 2019.

[13] D. E. Saputra, “Rancang Bangun Feeder Untuk Pengembangan Pelipat Otomatis Kotak Karton Untuk Makanan,” UII, 2017.

[14] T. K. Gunawardena, P. R. Dadigamuwa, and B. G. D. A. Madhusanka, “Low Cost Automated Machine for Paper Gathering and Folding,” *Eur. J. Adv. Eng. Technol.*, vol. 2, no. February 2015, pp. 40–43, 2015, [Online]. Available: https://www.researchgate.net/publication/283980969.

[15] P. B. Narafuadi, “Perancangan Mesin Pengumpan dengan Menggunakan Mekanisme Vakum di PT. Yamaha Indonesia,” 2018, [Online]. Available: https://dspace.uii.ac.id/handle/123456789/7626.

[16] W. Urban and P. Rogowska, “The Case Study of Bottlenecks Identification for Practical Implementation to the Theory of Constraints,” *Multidiscip. Asp. Prod. Eng.*, vol. 1, no. 1, pp. 399–405, 2018, doi: 10.2478/mape-2018-0051.

[17] A. Koliński, A. and Tomkowiak, “Using the analysis of bottlenecks in production management.,” *Gospod. Mater. i Logistyka*, vol. 9, pp. 16–21, 2010.