Design of a Rotary-Based Feeding System for Improving the Performance of Eddy Current Separator

Moh Khairul Imam Assidiqqi
Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia

Dhelika, Radon
Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia

https://doi.org/10.5109/7172312

出版情報：Evergreen. 11 (1), pp.493-500, 2024-03. 九州大学グリーンテクノロジー研究教育センター
バージョン：

EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 11, Issue 01, pp493-500, March 2024

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Moh Khairul Imam Assidiqqi[1], Radon Dhelika[2*]
[1,2]Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia, 16424

*Author to whom correspondence should be addressed:
E-mail: radon@eng.ui.ac.id

(Received October 22, 2023; Revised February 10, 2024; Accepted March 06, 2024).

Abstract: The performance of an Eddy Current Separator (ECS) plays a crucial role in efficiently separating non-ferrous metals from solid waste streams. This paper presents a novel approach for enhancing the performance of an ECS through the design of a rotary-based feeding system. The proposed system aims to optimize the feeding process by ensuring non-overlapping, consistent and controlled flow of material to the separator, thereby improving separation rate and overall efficiency. The design incorporates a rotary mechanism that facilitates a smooth and continuous material flow, minimizing disruptions and maximizing the effectiveness of the separation process. Experimental results demonstrate the superiority of the rotary-based feeding system. The results demonstrate the advantages of a rotary based system, showing a lower amount of material overlap and a better success rate of eddy current separation with an average value of 93.5%. More notably, the system achieved an 89% success rate for aluminum and an 98% success rate for copper. The findings of this study provide valuable insights into the design considerations for improving the performance of eddy current separators and offer practical solutions for enhancing metal recovery in recycling applications.

Keywords: electronic waste; eddy current separator; novel rotary feeder design; improving separation rate

1. Introduction

Electrical and electronic equipment (EEE) has become an integral part of our daily lives, enabling a large proportion of the global population to enjoy a better standard of living[1]. The high use of electrical and electronic equipment (EEE) causes a reduction in the service life of these devices due to rapid changes in capabilities and features, thereby speeding up the process of creating and storing electronic waste[2]. Current Waste electrical and electronic equipment (WEEE) production, consumption and disposal practices have reached unsustainable levels. As a result, there is an urgent need for effective strategies to address this growing problem[3].

WEEE, also commonly referred as electronic waste (e-waste) can be defined as electrical or electronic equipment which constitutes waste, including all components, sub-assemblies and consumables that form part of the product upon disposal[4]. EEE becomes waste electronics after being discarded by the owner as having no purpose for reuse[1].

The E-waste Statistics Guidelines on Classification Reporting and Indicators – Second Edition[5] classifies WEEE into 54 different products which are categorized into six sections, namely:

1) Temperature exchange equipment
2) Screens and monitors
3) Lamps
4) Large equipment
5) Small equipment
6) Small IT and Telecommunication equipment

To date, the predominant method of disposing of various waste, including electronic waste, has been the conventional practice of depositing it in landfills[6]. Electronic equipment is particularly noteworthy, given its composition of 69 different material elements, encompassing both valuable metals and critical, as well as non-critical raw materials. These materials hold significant potential for recycling, serving as a valuable source of secondary raw materials[3]. This is also in line with similar recycling approaches commonly undertaken for other types of solid waste (e.g. plastic waste, biomass, and MSW) to promote sustainability[7-9]. A recent study has underscored the economic significance of this recycling potential by estimating the total value of raw materials extracted from electronic waste in 2016 to be a staggering 55 billion euros[10]. This emphasizes the lucrative prospects that maximizes electronic waste's role within the concept of circular economy.

The formal WEEE recycling process, as delineated by Jafar[11), comprises seven essential stages:

1) E-Waste Acceptance and Collection: The initial phase involves the collection and acceptance of e-waste from various sources.
2) Disassembly: In this stage, the collected electronic waste is meticulously disassembled, breaking down devices into their constituent parts.
3) Crushing and Shredding: Following disassembly, the electronic waste undergoes a process of crushing and shredding, reducing materials to manageable sizes.
4) Separation of Materials: This critical stage involves the separation of different materials, isolating valuable components from the waste stream.
5) Melting and Molding: Certain materials, once separated, are subjected to melting and molding procedures, readying them for reuse.
6) Manufacturing of New Electronic Devices: Recycled materials are then employed in the manufacturing of new electronic devices, promoting sustainability and resource conservation.
7) Electronic Waste: The final stage signifies the responsible handling of any residual waste and by-products of the recycling process, closing the loop of the electronic waste recycling journey.

To separate materials, the use of ECS is increasingly recognized for its ability to selectively recover high-value non-ferrous metals12). The performance of ECS plays an important role in achieving efficient separation of these metals from the solid waste stream. In general, ECS consists of a magnetic drum. The magnetic drum always consists of magnetic poles placed in N–S–N configuration. Changes in the magnetic field will be influenced by the rotation of the magnetic drum13,14). Eddy Current Force (ECF) is the force produced by the ECS15). This force is a combination of electric and magnetic forces on particles due to electromagnetic fields16).

However, one crucial factor that significantly impacts the efficiency of the separation process is the materials feeding. Since the separation rate of the ECS is very prone to the geometrical aspects of the specimens, there is a need to eliminate material overlap and to maintain a uniform material distribution, as well as to ensure a consistent and controlled flow of material to the ECS17), which all correspond to the functions of the feeding system.

This paper presents a novel approach aimed at enhancing the performance of ECS by introducing a rotary-based feeding system. The concept of the rotary-based feeding system draws inspiration from the widely used rotary airlock feeder model, which functions as a sluice gate. The incorporation of a rotary mechanism allows for a steady and continuous flow of material18). By minimizing disturbances during the material feed, this system could potentially enhance the effectiveness of the separation process. The controlled and uniform material distribution enables the ECS to operate at maximum efficiency, resulting in improved metal recovery rates and higher levels of purity.

Therefore, the objective of this research is to design and develop a rotary-based feeding system for the ECS. Subsequently, a validation of the effectiveness of the system is carried out by experimentally comparing its performance with conventional feeding methods.

2. Literature Review

In selecting a suitable feeder system and design for the ECS, a comprehensive analysis is essential to identify a feeder that offers adjustable output and feeding rates. The industrial sector commonly utilizes various types of feeders with such capabilities, including:

1) Vibratory Feeder: A vibrating feeder consists of a tray that vibrates, utilizing vibration to move and transport materials along a predetermined path. It is widely used for the transport of granular and particulate material in various manufacturing industries19,20).
2) Screw Feeder: Screw feeders use an auger or screw mechanism to transport materials along a tube or trough. The feed rate can be precisely controlled by adjusting the rotational speed of the screw. They are commonly used for handling powders, granules, and bulk solids21,22).
3) Rotary Feeder: Rotary airlock feeders, also known as rotary valves, are employed to discharge bulk solid materials such as powders, granules, and pellets from a hopper. They use a rotating mechanism to discharge a measured amount of material at a controlled rate. It is widely used in the processing of non-staple food products, metal smelting, and terminal transportation because of its convenient control23,24).
4) Weight Belt Feeders: Weigh Belt Feeders combine the functionality of a belt conveyor with weighing capabilities. The material to be fed is stored in a hopper, then transported on a belt, and its weight is continuously monitored to adjust the feed rate. These feeders are commonly used in applications where accurate feeding and precise weight control are crucial. They can handle large volumes of bulk material with varying flow characteristics25,26).

Each of these feeder types offers distinct advantages and features, and the selection should be based on specific application requirements and the desired level of control over the feeding process. Detail comparison of the feeders, in terms of the advantages and disadvantages are provided in Table 1.

Table 1. Comparison of various feeders

Feeder Type	**Advantages**	**Disadvantages**
Vibratory Feeder	• Provide precise control over the feed rate, ensuring a consistent flow • Accommodate a wide range of materials, from fine powders to large particles. • Can handle high-capacity feeding requirement • Can be customized with various bowl sizes and track configurations to meet specific application needs.	• Material discharged from the feeder randomly and uniformly[27] • Vibratory feeders may require additional mechanism or controls to regulate the vibration amplitude and frequency accurately. • Some materials may be prone to sticking or bridging, leading to feed interruptions or inconsistent flow.
Screw Feeder	• Offer precise and adjustable feed rates, making them suitable for applications requiring a constant and uniform feed[28]. • Can handle materials with various flow characteristics. • Provide excellent accuracy and control over the feeding process. • Can be customized with different screw configurations to suit specific material requirements[28].	• Certain materials, such as cohesive or sticky substances, may cause clogging or erratic feeding. • Screw feeders may have limitations in handling abrasive or large-sized particles.
Rotary Feeder	• Offer a constant and non-overlapping feed, ensuring a uniform material flow. • Can handle materials with varying flow characteristics, including powders, granules, and solids • Provide reliable and accurate feeding control[18]. • Can be customized with different valve designs and rotor configurations to suit specific application needs.	• Rotary feeders may have limitations in handling material with high abrasiveness or poor flow properties. • The rotary mechanism requires periodic maintenance and cleaning prevent material buildup or jamming.
Weigh Belt Feeder	• Provide precise and continuous weight-based control over the feed rate, ensuring a constant and uniform flow. • Offer high accuracy and repeatability in material feeding. • Can handle a wide range of materials, including fine powders and coarse aggregates. • Suitable for applications that require accurate dosage or blending of materials.	• Weigh belt feeders may require additional space due to their conveyor structure. • Fine or dusty materials may require special precautions to prevent material leakage or airborne dust.

Among various types of feeders listed, we argue that the most suitable choice for the application of ECS is a rotary feeder capable of delivering a consistent, uniform, and non-overlapping feed. However, to achieve enhanced feeding results, modifications are required to tailor the rotary feeder to the specific demands of an ECS designed to handle WEEE with an average size ranging from 2 to 4 inches.

3. Design of The Rotary-Based Feeding System

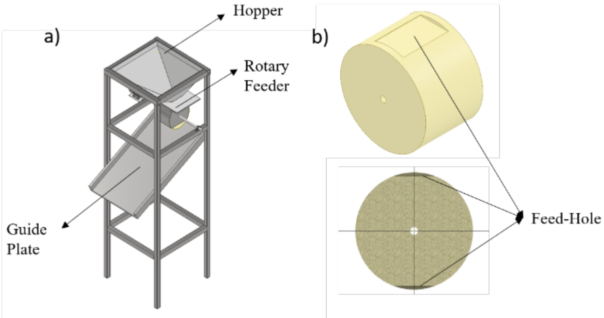

Fig. 1: a) Overall feeder design, b) Rotary drum design details

The proposed design of the rotary-based feeder comprises several essential components. Firstly, the feeder frame acts as a supportive structure for the feeder assembly. Additionally, a hopper is incorporated to facilitate the material feed-in process. The key component of the design is the rotary feeder, which utilizes a motor to adjust the feed rate. Lastly, a guide plate is included to direct the material flow into the ECS effectively. The overall feeder design is depicted in Fig. 1.a.

The rotary feeder component itself consists of a housing, a rotary drum, and a shaft responsible for rotating the drum. The rotary drum is specifically designed with two holes, each sized to accommodate the average dimensions of WEEE particles. The visual representation of the rotary drum design is shown in Fig. 1.b.

The rotary feeder operates in a simple manner. Specimens are initially introduced through the hopper and subsequently directed towards the rotary feeder. As the rotary drum continues to rotate, the specimens enter the feed-hole in the drum. Upon reaching a 180-degree rotation, the specimens gently descend from the drum. Exiting the rotary drum, the specimens transition into the conveyor system through the assistance of the guide plate.

4. Material & Experimental Setup

Two non-ferrous materials were used in this experiment: aluminum and copper plates. The materials were in the shape of squares measuring 4x4 cm with a thickness of 1 mm. Table 2 provides detailed properties of these materials for reference.

Table 2. Non-Ferrous Material Properties

Non-Ferrous Material	**Electrical Conductivity**	**Density (g/cm3)**	**Conductivity/Density**
Copper	64.1	8.96	7.15
Aluminum	40.8	2.7	15.11

For the feeder system, a rotary drum rotational speed of 5 s/rev was employed. To achieve this, a motor with a speed of 12 rpm was utilized. All experiments were conducted using a typical ECS with a belt-driven rotary drum configuration[16]. The ECS was manufactured in-house in the Laboratory of Mechanical Design, Universitas Indonesia (out of the scope of this article). The rotary drum consisting of 16 permanent magnets is placed underneath the conveyor belt with a distance of 7.5 mm. The operational parameters of the ECS are as follows: the speed of magnet roller/rotary drum is 2490 rpm, the speed of the belt is 10 cm/s.

In general, when other operational conditions of the ECS are kept constant, it has been understood that the Eddy Current Force that repels the specimens are proportional to some material properties as shown in Equation (1)

$$F \propto \frac{\sigma}{\rho} \tag{1}$$

where σ is the electrical conductivity whereas ρ is the density. Therefore, from Table 2, we may anticipate that the forces exerted on aluminum specimens may be larger than that of copper by almost two times, which also contribute to the difference in distances. This is reflected by the placement of container boxes which are placed at distances of 41.25 cm and 30.15 cm at the end of the conveyor belt for the collection of aluminum and copper specimens, respectively. These precise values of the distances were determined by trial and error, ensuring optimal separation efficiency.

The experiment was conducted in three stages. The first stage was aimed to compare the success rate of the ECS for overlapping and non-overlapping specimens. In the second stage, the feeder system was assessed to determine the quantity of specimens resulting from feeding that did not overlap. Finally, the third stage focused on determining the success rate of the ECS for specimens which were fed using the rotary feeder. In the first stage of the experiment, we conducted a comparative analysis of the success rates between overlapping and non-overlapping specimens. To establish the overlapping condition, two pieces of specimens were stacked together, with identical materials combined and mixed. This process was replicated five times, and each iteration included 20 specimens (10 aluminum and 10 copper). The success rate of the ECS was determined by counting the number of specimens that correctly entered the designated container box. The experimental setup for the first stage is shown in Fig. 2, depicting the arrangement and configuration employed for this phase of the experiment.

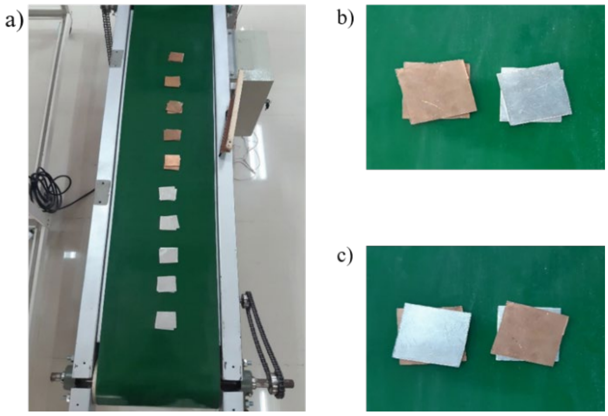

Fig. 2: a) Setup for the first stage of the experiment b) Two overlapping identical specimens, c) Two overlapping mixed specimens

In the second stage, we conducted experiments to evaluate the success rate of the feeders in achieving non-overlapping feeding results. The experiment was repeated five times, where 20 pieces of specimens (including 10 aluminum and 10 copper) were simultaneously placed into the hopper. Following the passage through the rotary feeder, the number of specimens that did not overlap was carefully counted and recorded. This allowed us to assess the effectiveness of the developed feeder system in ensuring the requirement of non-overlapping feeding of the materials. The experimental setup for the second stage is shown in Fig. 3.a)**.**

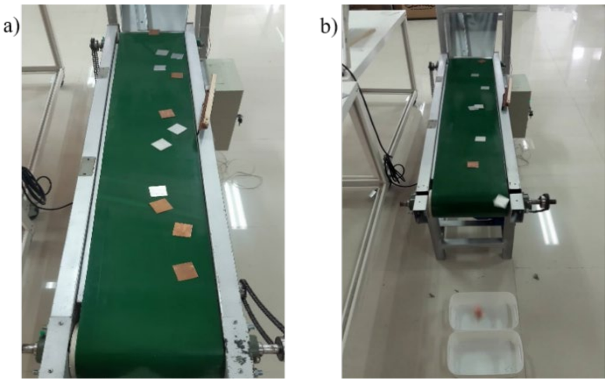

Fig. 3: a) Rotary feeding specimen result b) Third stage experiment setup

In the third stage, we conducted an experiment to assess the separation success rate of the ECS based on the feeding results from the rotary feeder. Similar to the previous experiments, we performed five trials using 20 pieces of specimens (comprising 10 aluminum and 10 copper samples). After being fed by the rotary feeder, the specimens proceeded to the separation process through the ECS. The success rate was determined by counting the number of specimens that correctly entered the designated container box. The experimental setup for the third stage is shown in Fig. 3.b)

5. Results & Discussion

The design of the proposed rotary feeder, as shown previously in Fig. 1 was then manufactured in-house in the Laboratory of Mechanical Design, Universitas Indonesia. Hollow iron of square cross-section with a dimension of 40 x 40 mm were selected as the material for the base frame. Additionally, a steel plate with a thickness of 1.2 mm was used for the manufacturing of the hopper part. The plate was cut and bent accordingly using a roll-bending machine before being welded into the final shape. The rotary drum was also manufactured; a nylon with a cylindrical shape was selected because it is light and wear-resistant which makes it a good option. Finally, after all parts were manufactured, they were assembled, and the motor drive system which consists of induction motor OTG Series 4TG 70W and sprocket were also installed. The final result of the rotary feeder is as shown in Fig. 4.

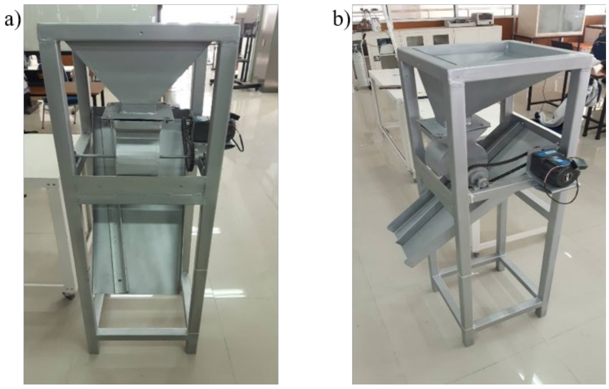

Fig. 4: a) Front view, and b) Isometric view of the overall rotary feeder system, consisting of hopper, rotary feeder, guide plate, and motor drive system

The results of the three-stage experiments are shown in Fig. 5. Fig. 5.a) depicts the result of stage one, i.e. comparative analysis of success rates among three scenarios: non-overlapping specimens, two overlapping specimens of identical materials, and two overlapping specimens of mixed materials. The graph evidently shows the varying success rates of ECS separation for different scenarios. Notably, when handling non-overlapping specimens, the ECS achieves a 100% success rate in the separation process, signifying the condition of non-overlapping specimens as the necessary condition to meet in ECS to achieve a high separation rate. The data is in contrast with the case of overlapping specimens, i.e. wherein copper maintains a 100% success rate, but aluminum saw a drop to 74% which made the average rate to drop to 87%. Finally, in the case of overlapping mixed materials, the separation rate for aluminum drops to 0%, while copper still maintains a 100% success rate. These results can be attributed to the accumulation of mass when both aluminum and copper overlap, causing aluminum specimens to inadvertently enter the copper container box during the separation process.

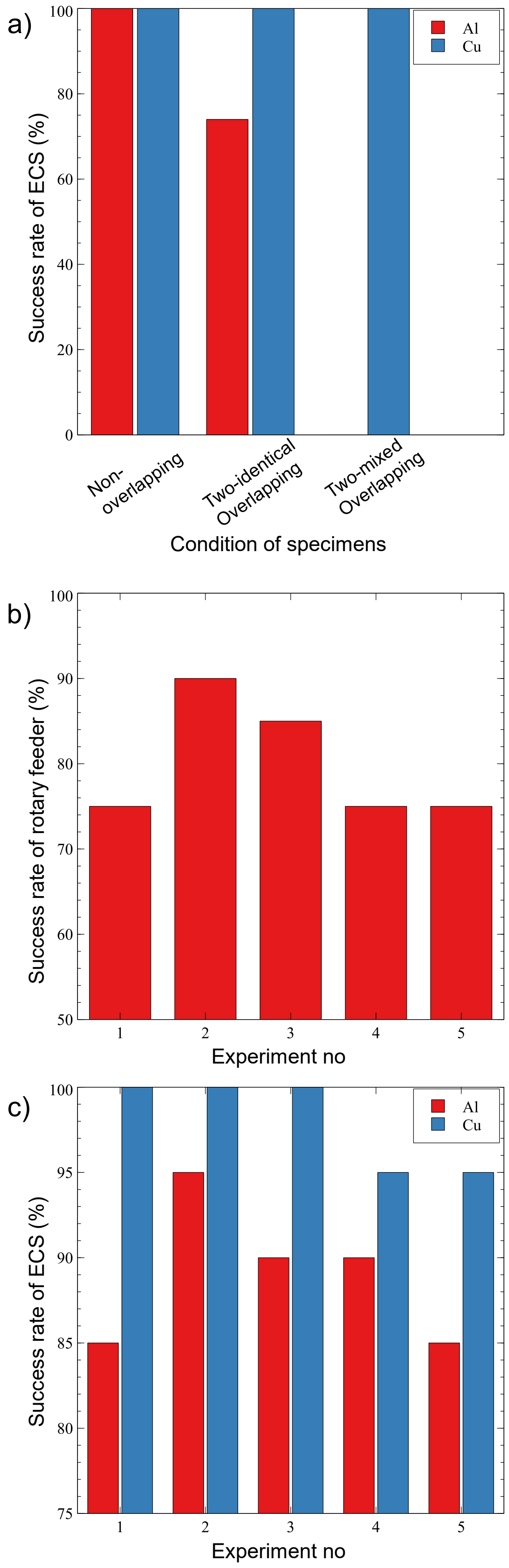

Fig. 5: a) Stage one experimental result, b) Stage two experimental result, c) Stage three experimental result

Next, the second stage experiment assessing the performance of the rotary feeder is shown in Fig. 5.b). The graph reveals that the average success rate of the rotary feeder for establishing a non-overlapping condition at the output is approximately 80%, with slight variations ranging from 75% to 90%. The primary factor contributing to the success rate not reaching 100% is the limited efficacy of the brush component within the rotary feeder in firmly holding the specimen, which occasionally results in specimens descending from the drum in pair, instead of one by one as originally intended by the design. In the future, an improvement in the design is required to further optimize the discharging mechanism of the specimen from the drum.

Finally, Fig. 5.c) shows a graph presenting the experimental results of the stage three experiment. The graph illustrates the separation success rate of the ECS when specimens were fed by the rotary feeder. Based on the results of five experiments conducted, the average success rate of the ECS is quite promising at 93.5%. On average, the ECS achieved a success rate of 89% for specimens made of aluminum and an impressive 98% for copper. These values demonstrate that the proposed rotary feeder design effectively delivers constant and non-overlapping feeding results, resulting in a commendable ECS success rate.

6. Conclusion

This paper has presented an approach to enhance the efficiency of ECS, a critical component in the recycling process of WEEE. The novel rotary-based feeding system introduced in this research offers a promising solution to enhance the ECS's performance. By drawing inspiration from the well-established concept of rotary airlock feeders, this system ensures a steady and continuous flow of material, minimizing disturbances and enabling the ECS to operate at maximum efficiency. Our experimental results have demonstrated the effectiveness of this rotary-based feeding system. The ECS's success rate in separating materials fed by this system shows promising results, with an average success rate of 93.5%. Notably, the system achieved an 89% success rate for aluminum and an outstanding 98% success rate for copper. These results emphasize the potential of the proposed the rotary-based feeding system to help improve the separation rate of ECS in the recycling process of WEEE. Future works entail improvement in the design, especially in the discharging mechanism of the specimen from the rotary drum.

Acknowledgement

This research was funded by Research Grant “Penelitian Dasar Unggulan Perguruan Tinggi” by The Ministry of Education and Culture (Kementerian Pendidikan dan Kebudayaan) fiscal year 2022 (contract

no: NKB-856/UN2.RST/HKP.05.00/2022).

References

1) Initiative, T. S. (2014). Solving-the-E-waste-Problem. The Step Initiative. Retrieved from https://api.globalewaste.org/publications/file/203/Solving-the-E-waste-Problem-StEP-Initiative-Annual-Report-2013-14.pdf
2) Mostafa, T. M., & Sarhan, D. S. (2018). Economic Feasibility Study of E-Waste Recycling Facility in Egypt. Evergreen, 05. doi:https://doi.org/10.5109/1936214
3) Forti V., Balde C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam
4) Union, E. (2012). DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Retrieved from eur-lex.europa.eu: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0019
5) Forti V., Baldé C.P., Kuehr R. (2018). E-waste Statistics: Guidelines on Classifications, Reporting and Indicators, second edition. United Nations University, ViE – SCYCLE, Bonn, Germany.
6) Zhumadilova, A., & Zhigitova, S. (2023). Features of Modern Areas of Solid Waste Disposal. Evergreen, 10(2), 640-648(2023). doi.org/10.5109/6792809
7) Syafrudin, M.A. Budihardjo, N. Yuliastuti, and B.S. Ramadan, "Assessment of greenhouse gases emission from integrated solid waste management in semarang city, central java, indonesia," Evergreen, 8 (1) 23–35 (2021). doi:10.5109/4372257.
8) Kurnianto, I. R., Setiawan, A. G., Surjosatyo, A., Dafiqurrohman, H., & Dhelika, R. (2022). Design and implementation of a real-time monitoring system based on internet of things in a 10-kW downdraft gasifier. Evergreen, 9(1) 145-149 (2021). doi.org/10.5109/4774230
9) Sunaryo, S., & Aidane, M. A. (2022). Development Strategy of Eco Ship Recycling Industrial Park. Evergreen, 9(2) 524-530 (2022). doi.org/10.5109/4794183
10) Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.
11) Jafar, R. (2021, October 14). HOUSEHOLD ELECTRONIC WASTE IN INDONESIA. Retrieved from sipsn.menlhk.go.id: https://sipsn.menlhk.go.id/download/ewaste2021/NED_Presentation_EwasteRJ.pdf
12) Zhang, S., Forssberg, E., Arvidson, B., & Moss, W. (1999). Separation mechanisms and criteria of a rotating eddy-current separator operation. Resources, Conservation and Recycling, 215-232. doi:https://doi.org/10.1016/S0921-3449(98)00051-2.
13) Peterson, W. (2003). Numerical solution of eddy current problems in ferromagnetic bodies travelling in a transverse magnetic field. International Journal for Numerical Methods in Engineering, 58(12). doi:https://doi.org/10.1002/nme.812
14) Rolicz, P. (2009). Eddy currents generated in a system of two cylindrical conductors by a transverse alternating magnetic field. Electric Power Systems Research, 79(2). doi:https://doi.org/10.1016/j.epsr.2008.06.016
15) Jujun, R., Yiming, Q., & Zhenming, X. (2014). Environment-friendly technology for recovering nonferrous metals. Resources, Conservation and Recycling. doi:http://dx.doi.org/10.1016/j.resconrec.2014.03.017
16) Smith, Y. R., R, J., Nagel, & Rajamani, R. (2019). Eddy current separation for recovery of non-ferrous metallic particles. A comprehensive review. Minerals Engineering. doi:10.1016/j.mineng.2018.12.025
17) Jia, Y., Liu, J., Zhang, H., Zeng, J., & Jiang, M. (2021, October). A Review on Application of Eddy Current Separation for the Recycling of Scraped Vehicles. In International Workshop of Advanced Manufacturing and Automation (pp. 141-147). Singapore: Springer Singapore
18) Karwat, B., Rubacha, P., & Stańczyk, E. (2022). NUMERICAL SIMULATIONS OF THE EXPLOITATION PARAMETERS. Management Systems in Production Engineering. doi:DOI 10.2478/mspe-2022-0044
19) Main applications and uses of Vibrating Feeders. (n.d.). Retrieved from Rollier.com: https://rollier.com/main-applications-and-uses-of-vibrating-feeders/
20) Ribic, A. I., & Despotovic, Ž. V. (2009). High-Performance Feedback Control of Electromagnetic Vibratory Feeder. TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 57. doi:10.1109/TIE.2009.2037677
21) Types of Screw Feeders. (n.d.). Retrieved from kwsmfg.com: https://www.kwsmfg.com/engineering-guides/screw-conveyor/types-of-screw-feeders/
22) Minglani, D., Sharma, A., Pandey, H., Dayal, R., Joshi, J. B., & Subramaniam, S. (2020). A review of granular flow in screw feeders and conveyors. Powder Technology.

doi:https://doi.org/10.1016/j.powtec.2020.02.066

23) Rotary Airlock Feeder. (n.d.). Retrieved from schenckprocess.com: https://www.schenckprocess.com/glossary/rotary-airlock-feeder
24) Dong, F., & Li, Y. (2020). Parameter Simulation and Analysis of Rotary. Materials Science and Engineering, 772. doi:10.1088/1757-899X/772/1/012105
25) Smart Weigh Belt Feeders SWB. (n.d.). Retrieved from coperion: https://www.coperion.com/en/products-services/process-equipment/feeders/smart-weigh-belt-feeders-swb#:~:text=Weigh%20Belt%20Feeders%20are%20relatively,feeder%2C%20batcher%2C%20or%20meter.
26) Hopkins, M. (n.d.). Loss in weight feeder systems. Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/002029400603900801
27) Chandravanshi, M., & Mukhopadhyay, A. (n.d.). Dynamic analysis of vibratory feeder and their effect on feed particle speed on conveying surface. doi:https://doi.org/10.1016/j.measurement.2017.01.031
28) Yu, Y. (n.d.). Theoretical Modelling and Experimental Investigation of The Performance of Screw Feeders. Retrieved from https://ro.uow.edu.au/cgi/viewcontent.cgi?article=2601&context=theses