EMITOR: Jurnal Teknik Elektro

Design and Development of Syringe Needle Destroyer Using Melting Method

Ade Firdaus*,[1], Nanda Ferdana[1], Samsul Mujakar[1], Hendrik Satrio[1], Zulhamidi[2]
[1]Departement of Medical Electronics Engineering – Akademi Teknik Elektromedik Andakara, [2]Badan Standar Nasional – Jakarta Bekasi, Indonesia
*Firdaus@atemandakara.ac.id

Abstract – *Syringe needles are among the most commonly used medical tools in healthcare facilities across Indonesia, contributing significantly to medical waste. Improper disposal of syringe waste poses risks of disease transmission and potential misuse. Presently, small-scale beauty clinics resort to third-party waste management services due to the lack of incinerators. This research aims to develop a device capable of melting used syringe needles to ensure safe waste processing for both humans and the environment. Additionally, the objective is to create a low-budget needle destroyer, making it accessible to other healthcare services. The melting method is employed for needle destruction, utilizing a transformer to generate electrical current and heat. This approach offers ease of use and eliminates air, noise, and metal dust pollution. Through experimentation with various syringe sizes (1 cc, 3 cc, 5 cc, and 10 cc), it was found that melting times sequentially increase with needle size: 4 seconds for 1 cc, 5 seconds for 3 cc, 6 seconds for 5 cc, and 8 seconds for 10 cc syringes. This research contributes to sustainable healthcare waste management practices, ensuring safer and more affordable solutions for healthcare facilities.*

Keywords – *Needle destroyer; Melting method; transformer; conductor; syringe sizes.*

I. Introduction

AFTER the Covid-19 pandemic, an amount of government and private sector entities turned their attention to ensuring the independence of the country's medical equipment. This in consequently caused the placement of more professional electromedical workers in a variety of healthcare facilities and equipment-related industries. wellness. This increase is consistent with data from the Ministry of Health about Indonesia's medical imaging equipment population, which is growing annually in terms of the total number of devices in each hospital [1, 2]. Healthcare facilities provide a range of services, from basic health promotion to advanced medical treatments. These services are offered by governments and communities, including cosmetic clinics that specialize in aesthetic treatments [3].

However, such activities generate various types of waste, including liquids, solids, and gases, which need proper disposal. Medical waste includes items like infectious materials, sharp objects, and pharmaceuticals. Improper disposal of these wastes poses risks, including injury and infection. Medical waste management is a critical issue due to its potential hazards to human health and the environment. This waste includes infectious materials, sharps, and pharmaceuticals [4, 5]. Improper disposal can lead to injuries, infections, and environmental contamination [6, 7]. Many countries struggle with proper collection, separation, and disposal of medical waste, with incineration being a common but polluting method [5]. In low- and middle-income countries, inadequate systems and resources often result in open burning, dumping, and even illegal trade of reused medical equipment [8, 9]. Challenges include financial constraints, lack of awareness, inadequate legislation, and insufficient specialized staff [10]. Improving medical waste management requires better awareness, education, and policy interventions to ensure safe and sustainable practices [6, 8].

For instance, needle stick injuries are common among healthcare workers in Indonesia, affecting a significant proportion of them. Regulations like those from the Occupational Safety and Health Administra-

The manuscript was received on March 6, 2024, revised on November 15, 2024, and published online on November 29, 2024. Emitor is a Journal of Electrical Engineering at Universitas Muhammadiyah Surakarta with ISSN (Print) 1411 – 8890 and ISSN (Online) 2541 – 4518, holding Sinta 3 accreditation. It is accessible at https://journals2.ums.ac.id/index.php/emitor/index.

tion (OSHA) aim to ensure the safety of workers handling hazardous substances.

Healthcare waste, if not managed properly, can spread harmful microorganisms and contribute to environmental pollution. It can spread harmful microorganisms, causing infections among healthcare workers, patients, and the public [11, 12]. Improper disposal can lead to contamination of soil, groundwater, and air, contributing to environmental pollution [13, 14]. Hazardous waste, comprising about 10-15% of total healthcare waste, requires special handling and disposal [11, 15]. Common disposal methods include incineration, autoclaving, and chemical treatments, each with its own benefits and limitations [15]. Many developing countries face challenges in implementing proper waste management practices due to lack of knowledge, resources, and enforcement of regulations [13, 16]. Effective healthcare waste management requires proper segregation, treatment, and disposal methods, as well as staff training and awareness [17, 18]. To address these issues, proper waste management practices are crucial, including safe disposal methods and adherence to safety protocols. This helps prevent injuries, infections, and environmental contamination associated with healthcare waste.

Previous research has explored various aspects of needle destroyers, indicating potential areas for further development. For instance, some studies have investigated the consequences of not utilizing needle destroyers, highlighting the importance of proper medical waste management [19]. Additionally, there are inquiries into the local components required for designing needle destroyers, emphasizing the need for tailored solutions to suit specific contexts [20]. Furthermore, research has delved into the application of needle destroyers in dental practice, showcasing their versatility in different healthcare settings [21]. However, the scope of medical equipment development extends beyond needle destroyers, with recent studies focusing on innovations such as the enhancement of weighing scales for improved accuracy and functionality [22]. Moreover, advancements in informatics have been observed, particularly in Picture Archiving and Communication Systems (PACS), which play a crucial role in medical imaging management [23]. Amid the COVID-19 pandemic, the emphasis on sterilizing living environments has become paramount, prompting research efforts towards developing effective sterilization methods and equipment [24].

This comprehensive review underscores the diverse avenues for research and development in the medical field, ranging from waste management to technological innovations aimed at enhancing healthcare delivery and safety. The studies highlight the complexity of healthcare operations and supply chains, emphasizing the need for improved safety and ergonomics [25]. Medical waste management emerges as a critical concern, with challenges in classification, disposal, and environmental impact [5, 26–28]. Technological advancements, including blockchain, AI, and EMRs, offer potential solutions for improving healthcare efficiency and patient care, despite introducing new challenges [29]. The impact of COVID-19 on medical waste production and management is noted, along with the need for sustainable practices aligned with SDGs [28]. The review also emphasizes the global disparities in healthcare waste disposal methods and their effects on public health [30].

This research aims to develop a needle destroyer that meets the specific needs of users. By addressing the requirements and preferences of end-users, the objective is to create a needle destroyer that is user-friendly, efficient, and effective in medical waste management. Through comprehensive analysis and feedback from potential users, the design and functionality of the needle destroyer will be tailored to ensure ease of operation and seamless integration into existing healthcare practices. By prioritizing user needs and preferences, the research endeavors to produce a needle destroyer that enhances safety, reduces environmental impact, and facilitates proper disposal of medical waste, ultimately contributing to improved healthcare standards and practices.

II. Research Methods

For the experimental setup of the needle destroyer using the melting method, we prepared the necessary equipment, including a high-temperature heater or burner capable of melting metal [31]. In this paper, we ensured that the used needle samples were free from toxic or infectious substances and thoroughly cleaned. Next, we arranged the experiment by placing the needle samples inside a closed chamber connected to the heating machine. In this study, controlled variables such as temperature, holding time, and cooling rate were adjusted to achieve optimal melting conditions. After the melting process, we allowed the samples to cool down and observed the results visually, while also measuring the temperature to ensure effectiveness. Throughout the experiment, we conducted visual observations and temperature measurements to monitor the melting process. After completion, we analyzed the data to assess the effectiveness and safety of the melting process. Overall, this experimental setup was designed to explore the potential use of the melting method for safely and efficiently destroying used needles.

i. Material and Tools

The materials used in this research serve different functions in electrical circuits. The power supply provides electricity to all components, ensuring they can work properly. A fuse acts as a safety device, protecting electronic components from damage by cutting off excess current flow. Limit switches control an object's performance by limiting its movement, usually operated manually. Transformers change the electrical characteristics of a circuit, mainly altering voltage levels. A diode bridge converts alternating current into direct current, allowing for smooth flow in one direction. Electrode contacts are metal parts used in burners during melting processes. These materials play essential roles in the study, contributing to its experimentation and outcomes.

ii. Experiment

In this research, experiments were conducted to explore the functionality and effectiveness of the materials mentioned. This research set up various electrical circuits incorporating each material, observing how they interacted and contributed to the overall performance. For instance, we tested the power supply's ability to deliver electricity to different components and assessed the fuse's protective capabilities by intentionally creating excessive current flow. Similarly, we examined the limit switch's role in controlling object movement and evaluated the transformer's ability to modify voltage levels accurately. Additionally, we analyzed the diode bridge's performance in converting alternating current to direct current and observed how electrode contacts functioned in the melting process. Through these experiments, we aimed to gain a deeper understanding of each material's function and their practical applications in electrical circuits.

iii. The Diagram of Block

Each component plays a specific role in the electrical circuit. The power supply supplies electrical energy to all components. The fuse protects electronic components from damage by cutting off excessive current flow. The limit switch controls and limits the performance of an object, usually operated manually. The transformer converts the electrical characteristics of a circuit, primarily altering voltage levels. The diode bridge converts alternating current to direct current. The electrode contact serves as a metal contact for the burner in the melting process.

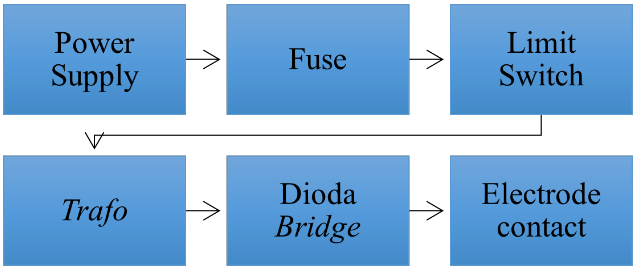

Figure 1: Block Diagram of the Needle Destroyer Setup

iv. The Flowchart

The flowchart in Figure 2 outlines the steps involved in operating the needle destroyer device. Firstly, when the circuit receives electrical voltage from the source, the on switch is pressed. This action triggers the indicator light to illuminate, indicating that the system is powered on. Subsequently, the safety system, including the fuse and circuit interlock, becomes active to ensure safe operation. Once ready, the waste container must be closed to enable device usage, as it is equipped with an interlock system. Then, the used needles are inserted into the crusher hole slowly for gradual destruction. After the needle destruction process is completed, the waste container at the bottom of the device is cleaned. Finally, the off switch is pressed, and the power cable is disconnected from the voltage source to conclude the operation.

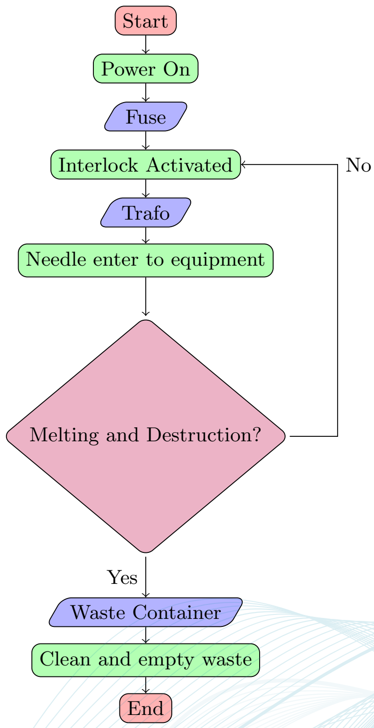

Figure 2: Flowchart of Needle Destroyer

v. The Analog Circuit

The wiring diagram in Figure 3 consists of several key components. Firstly, the 220V AC input serves as the voltage supply for the circuit. When the On switch is pressed, indicating that the circuit is activated, the indicator light illuminates. The current then passes through the fuse, and the interlock system becomes active, ensuring safety. Next, the transformer receives the current and redirects it to the diode to convert it into DC current. Once converted, the electrode contact generates heat from the transformer to melt the syringe needles. Overall, these components work together systematically to facilitate the safe and efficient operation of the needle destroyer device.

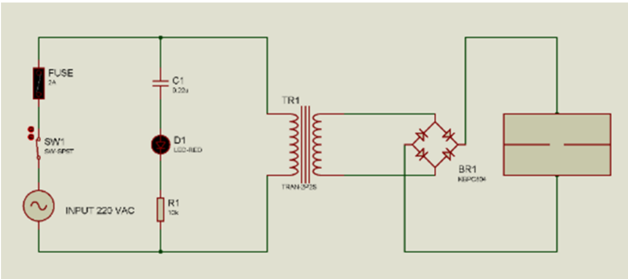

Figure 3: Wiring Diagram of the Needle Destroyer Circuit

Figure 4: Prototype of Needle Destroyer Design

III. Results and Discussion

i. Development of Needle Destroyer Model

In this study, the needle destroyer device is designed to efficiently crush metal syringe needles. With dimensions of 21 cm x 12 cm x 12 cm and a weight of 4 kg, it is compact and portable. Operating at 240 W with a frequency of 50-60 Hz and an input voltage of 220 V AC, it delivers an output voltage of 24 V DC. Equipped with a 2 A fuse and a 4 A diode bridge, the device ensures safety and reliable performance. Constructed with a 2 mm aluminum plate conductor and a 3 mm iron frame, it is durable and sturdy. Additionally, it features two 2 W lamps for illumination and a small container with dimensions of 8 cm x 4 cm x 3 cm for waste disposal. Overall, the device combines functionality, efficiency, and safety to effectively handle used syringe needles.

ii. Functional Testing

The functional testing of the device involves both electrical and physical evaluations to ensure its proper operation. Firstly, electrical testing determines the input voltage by connecting the power cable to a 220 V AC power source and pressing the on switch, confirming that the power indicator light illuminates. Secondly, the on/off switch is tested to ensure its functionality, showing that it operates properly. Thirdly, the indicator light is tested by pressing the on/off switch, demonstrating that it functions correctly by illuminating when the switch is on and turning off when the switch is off. Lastly, the fuse is tested by replacing it with a lower ampere rating, ensuring that it interrupts the circuit when required. Additionally, the device undergoes functional testing with various sizes of syringe needles to validate its performance. Overall, these tests confirm the device's functionality and suitability for crushing syringe needles effectively, as shown in Table 1.

Table 1: Timer Testing in Needle Destroyer Prototype

Volume of Needle	Melting Time (Second)		
	Test 1	Test 2	Test 3
1 cc	4	4	4
3 cc	5	5	5
5 cc	6	6	6
10 cc	8	8	8

During the functional testing of the device, experiments were conducted using various sizes of syringe needles to assess their melting times. The results obtained from the testing are presented in Table 1, indicating the melting times for each needle size across three trials. For 1 cc syringe needles, the melting time consistently averaged at 4 seconds across all trials. Similarly, 3 cc and 5 cc syringe needles exhibited consistent melting times of 5 seconds and 6 seconds, respectively. Larger 10 cc syringe needles showed slightly longer melting times, averaging at 8 seconds across all trials. These results demonstrate the device's ability to effectively melt syringe needles of different sizes within relatively consistent timeframes, validating its functionality and suitability for use in healthcare settings.

Table 2 provides an overview of the physical and functional aspects of the device. It assesses various components to ensure their proper operation. The table indicates whether each component is functioning well (”V”) or not (”Tidak”). The physical aspects include the body/cover, cable and flexibility, on/off switch, indicator light, fuse, conductor, and transformer. All components are marked as functioning well, indicating that the device is in good condition both physically and functionally. This monitoring sheet serves as a tool for evaluating and maintaining the device's performance over time, ensuring its continued effectiveness in crushing syringe needles.

Table 2: Functional Test in Needle Destroyer Prototype

Part Prototype	Visual		Function	
	Good	Bad	Good	Bad
Cover	✓		✓	
Cable	✓		✓	
power on/off	✓		✓	
Indikator lamp	✓		✓	
fuse	✓		✓	
Trafo	✓		✓	

IV. Conclusion

After designing and constructing the device, conducting several functional tests and trials, and analyzing the cost of materials used in terms of design and composition, several conclusions can be drawn: Analysis indicates that the length and diameter of syringe needles significantly affect the melting time, with longer and larger needles requiring more time for destruction, while smaller needles melt more quickly. The average melting times for different syringe sizes were found to be: 4 seconds for 1 cc, 5 seconds for 3 cc, 6 seconds for 5 cc, and 8 seconds for 10 cc syringes. The needle destroyer device using the melting method offers several advantages, including ease of use and minimal air, noise, and metal dust pollution. The author acknowledges that the scientific paper module still has room for improvement, suggesting the addition of features such as a syringe counter for better functionality. In terms of recommendations for future research and development, the author suggests: using a larger transformer for improved performance, utilizing lighter materials like acrylic or plastic for the body cover to enhance portability, and adding more attractive stickers or labels for better device identification and usability.

References

[1] A. Firdaus, “Analisa alat angiography menggunakan failure mode and effects analysis (fmea) berbasis fuzzy logic,” Master's thesis, Universitas Mercu Buana, Jakarta, 2022.

[2] A. Firdaus, N. Ferdana, Y. Helmy, and A. Ismanuri, “Innovative approaches in electromedical education: Designing low-cost x-ray stationary simulations using camera from concept to implementation,” *Journal of Medical Electronics*, vol. 1, no. 1, pp. 14–18, 2024.

[3] *Occupational Health and Safety Risk in Healthcare Sector*. Luxembourg: Europe Commission, 2010.

[4] Velivckovic.

[5] M. Attrah, A. Elmanadely, D. Akter, and E. R. Rene, “A Review on Medical Waste Management: Treatment, Recycling, and Disposal Options,” *Environments*, vol. 9, no. 11, p. 146, nov 21 2022. [Online]. Available: https://doi.org/10.3390/environments9110146

[6] I. M H, T. M C, P. Y P, and S. R H, “Pharmaceutical Waste Disposal Current Practices and Regulations: Review,” *INTERNATIONAL JOURNAL OF PHARMACEUTICAL QUALITY ASSURANCE*, vol. 14, no. 03, pp. 821–824, sep 25 2023. [Online]. Available: https://doi.org/10.25258/ijpqa.14.3.59

[7] P. K. and M. G. N., “Review ON: Waste MATERIAL MANAGEMENT IN PHARMACEUTICAL INDUSTRY Review Article,” 2012.

[8] E. Cook, A. Woolridge, P. Stapp, S. Edmondson, and C. A. Velis, “Medical and healthcare waste generation, storage, treatment and disposal: a systematic scoping review of risks to occupational and public health,” *Critical Reviews in Environmental Science and Technology*, vol. 53, no. 15, pp. 1452–1477, dec 5 2022. [Online]. Available: https://doi.org/10.1080/10643389.2022.2150495

[9] E. Cook, C. A. Velis, A. Woolridgeb, P. Stapp, and S. Edmondson, *Medical and healthcare waste generation, storage, treatment and disposal: A systematic review of risks to occupational and public health*. Open Engineering Inc, dec 5 2020. [Online]. Available: https://doi.org/10.2174/97898114765561200100014

[10] Y. B. Y., B. I. D., G. Tukur, G. B. A., and Abubakar, “Poor Medical Waste Management (MWM) Practices and Its Risks to Human Health and the Environment: A Literature Review,” 2013.

[11] E. Janik-Karpinska, R. Brancaleoni, M. Niemcewicz, W. Wojtas, M. Foco, M. Podogrocki, and M. Bijak, “Healthcare waste—a serious problem for global health,” *Healthcare*, vol. 11, no. 2, p. 242, jan 13 2023. [Online]. Available: https://doi.org/10.3390/healthcare11020242

[12] D. S. Khobragade, “Health care waste: Avoiding hazards to living and non living environment by efficient management,” *Fortune Journal of Health Sciences*, vol. 2, no. 2, 2019. [Online]. Available: https://doi.org/10.26502/fjhs007

[13] H. S., “Nanophotocatalysts — encyclopedia,” 2020.

[14] M. S., “Hospital waste management and environmental problems in india,” 2011.

[15] Q. G. Omo and N. E. Hassan, “Biomedical waste management and their effects on the environment: A review,” *World Journal of Advanced Engineering Technology and Sciences*, vol. 11, no. 1, pp. 086–095, jan 30 2024. [Online]. Available: https://doi.org/10.30574/wjaets.2024.11.1.0020

[16] N. Ngwuluka, N. Ochekpe, P. Odumosu, and J. Sa, “Waste management in healthcare establishments within jos metropolis, nigeria,” 2009. [Online]. Available: https://doi.org/10.4314/AJEST.V3I12.56295

[17] H. S. Bansod and P. Deshmukh, “Biomedical waste management and its importance: A systematic review,” *Cureus*, feb 3 2023. [Online]. Available: https://doi.org/10.7759/cureus.34589

[18] D. C. Husaini, V. Bernardez, N. Zetina, and D. D. Mphuthi, “Healthcare industry waste and public health: a systematic review,” *Arab Gulf Journal of Scientific Research*, dec 18 2023. [Online]. Available: https://doi.org/10.1108/agjsr-01-2023-0026

[19] S. M. Kim, T. Kim, H. J. Lee, S. Y. Cho, and W. C. Cha, “Effect of the automatic needle destroyer on healthcare providers’ work in an emergency department: A mixed-methods study,” *Health Informatics Research*, 2022.

[20] “Nepalese development project: Design of a local manufactured needle & syringe destroyer,” IFM Manufacturing Engineering Tripos, 2018.

[21] N. Sriram, D. Ganapathy, and V. Sivaswamy, “Awareness and practice in using needle destroyers in dental practice - a questionnaire-based study,” *EBSCO*, vol. 14, no. 6, 2020.

[22] A. Firdaus, N. Ferdana, R. Suhartina, and Y. Borhanudin, “An arduino-driven approach for weight and height measurement monitoring,” *Jurnal Teknik Elektro dan Komputer*, vol. 12, no. 2, pp. 121–126, 2023.

[23] A. Firdaus, “Studi implementasi metode queueing melalui teknologi medical imaging pada pacs (picture archiving and communication system),” *Jurnal Ilmu Teknik dan Komputer*, 2021.

[24] D. I. Z. R. S. A. P. M. N. Ferdana, “Uvc sterilization robot with remote wireless mode and autonomous,” *Sanitas*, vol. 13, pp. 68–80, 2022.

[25] S. G. Iyer, V. K. Pillai, and S. Mandal, “Research avenues in ensuring safety of healthcare operations: a perspective through logistics/supply chain, technology, quality and waste management,” *International Journal of Indian Culture and Business Management*, vol. 20, no. 2, p. 262, 2020. [Online]. Available: https://doi.org/10.1504/ijicbm.2020.10024643

[26] E. S. Windfeld and M. S.-L. Brooks, “Medical waste management – A review,” *Journal of Environmental Management*, vol. 163, pp. 98–108, 11 2015. [Online]. Available: https://doi.org/10.1016/j.jenvman.2015.08.013

[27] P. Yadav, “Environmental Biotechnology for Medical Waste Management: A Review of Current Practices and Future Directions,” *Annals of Advanced Biomedical Sciences*, vol. 6, no. 2, 2023. [Online]. Available: https://doi.org/10.23880/aabsc-16000214

[28] A. G. Olabi, N. Shehata, K. Obaideen, E. T. Sayed, M. Mahmoud, M. N. AlMallahi, and M. A. Abdelkareem, “Covid19: Medical Waste Management, Impact on Sustainable Development Goals, and Bibliometric Analysis,” *Chemical Engineering & Technology*, vol. 47, no. 1, pp. 4–19, 9 2023. [Online]. Available: https://doi.org/10.1002/ceat.202300046

[29] A. A. Alhur, “Impact of technological innovations on healthcare delivery: A literature review of efficiency, patient care, and operational challenges,” *World Journal of Biology Pharmacy and Health Sciences*, vol. 18, no. 2, pp. 216–219, may 30 2024. [Online]. Available: https://doi.org/10.30574/wjbphs.2024.18.2.0273

[30] C. Kenny and A. Priyadarshini, “Review of Current Healthcare Waste Management Methods and Their Effect on Global Health,” *Healthcare*, vol. 9, no. 3, p. 284, mar 5 2021. [Online]. Available: https://doi.org/10.3390/healthcare9030284

[31] “User manual needle of destroyer,” GIMA.