Bearing design on rubber shredder machine

Bima Aprilasho[1], Hammar Ilham Akbar[2]*, Ganjar Pramudi[2], Dian Arum Cahyaningtyas Wibowo[2]

[1]Department of Mechanical Engineering, Vocational School, Universitas Sebelas Maret, Surakarta, Indonesia

[2]Department of Manufacturing Engineering Technology, Vocational School, Universitas Sebelas Maret, Surakarta, Indonesia

*Corresponding author, email: hammar_ilham@staff.uns.ac.id

Article history
Submitted: 20 October 2025
Revised: 20 November 2025
Accepted: 25 December 2025
Published: 30 December 2025

Keywords
Bearing
Shredder Machine
Waste Tires

Abstract
The rapid development in the automotive industry has driven mass production and the abundance of various important components needed in vehicle manufacturing. One of the main components in the vehicle is tires. Tires that are no longer used will become waste and will create a nest of disease. Therefore, a machine is needed that can process used tire waste before being recycled. The tire rubber shredder machine is a machine used to shred tire rubber into smaller sizes and can be recycled into new products. This final project aims to design a tire rubber shredder machine using a 2 HP motor power with a rotational speed of 1400 rpm and a 1:20 gear box, so that it has an output speed of 70 rpm. The selection of bearings is very important to support the work of the machine. The bearings used in the tire rubber shredder machine are single row deep grove ball bearings with a type of bearing number 206 which has an inner diameter of 30 mm. The service life of the bearing can reach 5 years and 11 months.

1. Introduction

In 2022, Statistics Indonesia (BPS) recorded that all provinces in Java ranked at the top as regions with the highest number of motorized vehicles in Indonesia. Central Java Province was among the top, with a total of 17,637,791 motorcycles [1]. The rapid growth of the automotive industry has led to the mass and abundant production of essential components required in vehicle manufacturing. One of the crucial components in vehicles is the tire [2].

The continuous increase in tire production each year, in line with the growth of the automotive industry and domestic market demand, has led to a rise in the volume of used tire waste, which has the potential to pollute the environment [3]. Used tires are categorized as post-consumer materials commonly found in many regions; however, they cannot be reused or decomposed in the soil, making them hazardous to the environment [4]. Currently, tire waste is generally managed by piling it up in landfills without further processing, a method considered ineffective and posing new environmental problems such as land scarcity, disease outbreaks due to mosquito breeding, and environmental pollution [5]. Although there are reuse efforts such as retreading, or vulcanization, this method is typically limited to only 2–3 times before the tires once again become waste [6].

Used rubber tires need to be recycled through a shredding or crushing process to make them easier to reprocess [7]. However, this process faces technical challenges because tires are designed with a strong, elastic, and tough structure made from a blend of rubber reinforced with steel wire and nylon fibers, making them difficult to break down using conventional machines [8]. Therefore, industrial shredders with high-capacity cutting systems and large torque are required to efficiently cut through fibers, steel wires, and rubber[9]. The proper use of shredders makes the process more effective, increases productivity, and allows used tires to be processed into valuable products such as household goods [7] [10]. Additionally, the shredding process becomes more time-efficient, producing results in a shorter period, with the shredded rubber usable in applications such as asphalt mixtures to improve asphalt quality [11].

In addition to high torque and power, the selection of the electric motor shaft size is also an important factor to consider, as the shaft must withstand significant torsional loads from the process of shredding hard materials such as rubber and steel wire contained in tires [12]. Likewise, the bearings must be robust enough to allow the shaft and other machine components to function properly. If the bearings do not perform well, the overall system performance will decrease or fail to operate as intended [13]. Therefore, the shredder machine to be developed will utilize high power and torque to shred used tire waste, along with the appropriate selection of bearings [14]. As a result, used tire waste will be reduced and recycled into products that generate new economic value and have a high market potential [15] [16].

© 2025 The Author(s)
This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 3110-1577

2. Method

2.1. Design Stages

The bearing design process for a rubber shredding machine consists of several stages, as illustrated in Figure 1.

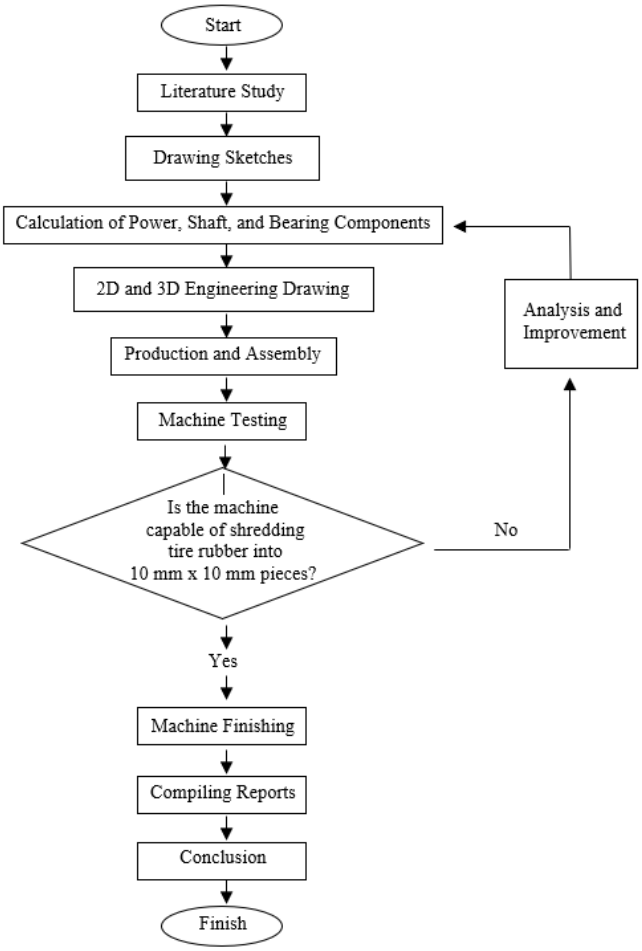


Figure 1. Flow Diagram Design Process

a. Literature Review

This stage aims to gather as much field information as possible regarding the conditions and specification requirements that must be met by the tire rubber shredding machine. This includes identifying the components of existing rubber shredder machines, as well as the advantages and weaknesses of current tire shredders. The information is then used to formulate solutions to the identified problems. Based on the conclusions drawn, detailed specifications are developed for the tire shredding machine to be designed.

b. Drawing Sketches

The design phase of the tire rubber shredding machine begins with field data collection and literature review to identify specifications, analyze components, and understand the strengths and weaknesses of similar existing machines. This information is used to formulate solutions and define clear technical specifications. An initial design sketch is then created as a reference for technical calculations, which is further developed into a 3D model using SolidWorks to enable detailed visualization, conflict analysis, and performance simulation before proceeding to the manufacturing stage.

c. Calculation of Power, Shaft, and Bearing Components

After creating the sketches and gathering theoretical data from literature studies, power calculation is a crucial step in designing a tire rubber shredding machine. It ensures the machine's ability to shred effectively, assists in selecting the appropriate motor and reducer, prevents component failure, and optimizes the overall design and efficiency [17]. Essentially, this calculation validates the design to ensure the machine operates effectively and safely.

d. 2D and 3D Engineering Drawing

After obtaining specific references from the initial sketches and conducting in-depth calculations for the tire rubber shredding machine, the next step is to create 2D drawings and a 3D model. The 2D drawings, serving as detailed working drawings, will include precise dimensions and component specifications, acting as the main guide for the production team in manufacturing and raw material procurement. Simultaneously, a comprehensive 3D model will be developed to realistically visualize the entire machine, allowing for conflict detection between components, performance simulation, and easier assembly. The main goal of these two stages is to ensure that the entire manufacturing process of the rubber shredder machine runs smoothly, efficiently, and accurately, while also being well-documented for future reference.

e. Production and Assembly

The production process planning for the tire rubber shredding machine aims to minimize the risk of errors that may occur during the sequential manufacturing stages. This ensures that the work proceeds optimally without unnecessary material waste.

f. Machine Testing

Once the machine has been completed, it proceeds to the testing phase to determine whether the rubber shredding machine is feasible and meets the initial design specifications. Therefore, testing is conducted.

g. Analysis and Improvements

The data obtained from the testing results are used as a reference to analyze the feasibility of the machine, whether it is ready for use or requires prior improvements due to issues that deviate from the design, causing the machine to operate suboptimally.

h. Machine Finishing

The engine finishing process is carried out after the testing and repair process. This process includes sanding, filling, painting the engine frame, and installing instruction labels and safety warnings. Finishing also ensures that all components are properly installed, and that the lubrication system and electrical connections are functioning optimally.

i. Report Preparation

Once the product is complete and there are no further errors, the report can be prepared. The report is prepared based on the established systematics. The finished report is submitted to the supervisor for printing and revision. Once there are no further revisions, the report is ready to be printed and archived.

3. Results and Discussion

3.1. Motor Power Calculatin

Calculations and analysis on power are carried out to determine how much power will be used, so that the tire rubber shredder machine can function properly as designed [18]. Power calculations can be found using the following data, rubber shear stress of 3 MPa, rubber width and thickness measuring 100 mm x 10 mm. To find the power of the machine that will be used to shred used tire rubber, is presented in Figure 2.

Parameter	Equation	Data	Result
Cutting Force (F)	$F = \tau_r \times A$	$\tau_r = 3\ Mpa$ $A = 1000\ mm^2$	3000 N

Figure 2. Cutting Force Calculation

Torque calculation using a shredder blade radius of 60 mm (machine specification), and power with an assumed blade rotational speed of 70 rpm [19]. can be found in Figure 3.

Parameter	Equation	Data	Result
Torque (T)	$T = F \times r$	$F = 3000\ N$ $r = 60\ mm$	$180 \times 10^3\ Nmm$
Power (P)	$P = \frac{T \times 2\,\pi\, N}{60}$	$T = 180 \times 10^3\ Nmm$ $N = 70\ rpm$	1300 $Watt$

Figure 3. Torque and Motor Power Calculation

From the calculation results, the required machine power is 1.3 kW or 1.8 HP. Through a survey of available motors on the market, a motor with a power of 1.5 kW or 2 HP at a rotational speed of 1400 rpm was selected. Transmitted through a gearbox with a 1:20 ratio, the resulting output speed is 70 rpm.

Before calculating the motor torque, the actual power output of the motor gearbox must be determined. Given that the motor efficiency is 90%, the calculation of actual power is shown in Figure 4.

Parameter	Equation	Data	Result
True Power (P_{true})	$P_{true} = P \times \eta$	$P = 1500\ Watt$ $\eta = 90\ \%$	$1350\ Watt$

Figure 4. Actual Motor Power Calculation

The result indicates the actual power output of the motor gearbox is 1350 watts.

3.2. Motor Drive Shaft Calculation

To find the diameter of the drive motor shaft, you must first know the torque calculation based on the drive motor specifications. Torque can be found using the following equation on Figure 5.

Parameter	Equation	Data	Result
Torque (T)	$T = \frac{P\ x\ 60}{2\pi\ x\ N}$	P = 1500 Watt N = 70 rpm	$204{,}6\ x\ 10^3\ Nmm$
Minimum Motor Shaft Diameter (d)	$T = \frac{\pi}{16}\ x\ \tau_s\ x\ d^3$	$T = 204{,}6\ x\ 10^3\ Nmm$ $\tau_s = 42\ MPa$	$29{,}1\ mm$

Figure 5. Minimum Motor Shaft Diameter

The calculation above yields a minimum motor shaft diameter of 29.1 mm. This means that a drive shaft with a diameter of 32 mm still meets the standard and is safe for use [20].

3.3. Structural Statics on the Chopper Knife Shaft

Structural statics is used to determine the magnitude of the load received by the bearing on the shaft as a support. Before determining the load received by the bearing, first find the force that occurs on the blade and clutch, with the following known data, torque (T) = 204.6 Nm, arm length (L arm) = 0.08 m, rubber load force (F load) = 29.4 N, blade force (F blade) = 249.9 N. The following are the forces that occur on the blade and clutch on Figure 6.

Parameter	Equation	Data	Result
F1	$F1 = \frac{T}{L\ arm}$	$T = 204{,}6\ x\ 10^3\ Nmm$ $L\ arm = 0{,}08\ m$	$2557{,}5\ N$
F2	$F2 = Fload + Fblade$	$Fload = 29{,}4\ N$ $Fblade = 249{,}9\ N$	$279{,}3\ N$

Figure 6. Blade Load and Clutch Load

After the load is known then look for the reaction at the support which can be seen in Figure 7.

Parameter	Equation	Data	Result
Reaction at Point D (RDV)	$\sum M_B = 0$ $R_{DV}\ (0{,}32) - F_2(0{,}16) + F_1(0{,}08) = 0$	$F1 = 2557{,}5\ N$ $F2 = 279{,}3\ N$	- $500\ N$
Reaction at Point B (RBV)	$\sum Fy = 0$ $R_{total} = F_{total}$	$F1 = 2557{,}5\ N$ $F2 = 279{,}3\ N$	$3336{,}8\ N$
Determine the axial load	$R_{DH} = Cos\ 30°\ x\ R_{DV}$	$R_{DV} = 500\ N$	$433{,}01\ N$

Figure 7. Reaction at Support

After performing the calculations, the forces on the shaft have been identified.

3.4. Bearing Design

In designing a tire shredder with a blade shaft rotation of 70 rpm, the bearing is expected to be able to support the load and withstand the load that occurs on the shredder blade shaft. Bearing calculations are used to determine the design of a machine within the required limits of several parameters, can be seen at Figure 8.

Parameter	Equation	Data	Result
Dynamic equivalent load (W)	$W = X \,.\, V \,.\, W_R + Y \,.\, W_A$	$X = 0{,}56$ $V = 1$ $W_R = 3336{,}8\ N$ $Y = 1$ $W_A = 433{,}01\ N$	$2301{,}61\ N$
Rating Life (L)	$L = 60 \,.\, n \,.\, L_H$	$n = 70\ rpm$ $L_H = 20.000$	$84\ x\ 10^6\ rev$
Dynamic load (C)	$C = W\left(\frac{L}{10^6}\right)^{1/k}$	$W = 2301{,}61\ N$ $L = 84\ x\ 10^6\ rev$ $k = 3$	$10079{,}9\ N$

Figure 8. Bearing Design

The results of the above calculations obtained a large dynamic load value of the bearing of 10,079.9 N. Based on table 2.6, the dynamic load capacity is greater than the dynamic load of the bearing, with a dynamic load capacity of 15,000 N and a dynamic load of 10,079.9 N, then the bearing design is SAFE and meets the requirements for a service life of LH = 20,000 hours. Therefore, a single row deep groove ball bearing with bearing code 206 is required. Next, a bearing life calculation is required which can be seen in the calculation below on Figure 9.

Parameter	Equation	Data	Result
Bearing Reliability (L_n)	$L_n = a1 \,.\, a2 \,.\, a3 \,.\, L_H$	$a1 = 0{,}62\ (95\%)$ $a2 = 1$ $a3 = 1$ $L_H = 20.000$	$12.400\ Hours$
Bearing Life (L_b)	$L_b = \frac{L_n}{8\ jam\ .\ 260\ hari}$	$L_n = 12.400\ Hours$	$5{,}9\ Year$

Figure 9. Condition of Bearing Age

From the results of the design calculation of the replacement period/bearing life above with the reliability factor used being 95%, the value of the material used and the work factor value used being 1 in accordance with normal working conditions, the bearing life is 5.9 years or 5 years and 11 months with the maximum operating time of the tire rubber shredder machine for 8 hours per day and working for 5 days in 1 week.

3.5. Results

Testing was conducted to evaluate the performance of the rubber shredder machine after it was designed and assembled. The testing was carried out in two phases: no-load testing and load testing [21]. The purpose was to verify whether the entire transmission system, including the motor, coupling, shaft, and shredding components, operated correctly and whether the design was safe and in accordance with technical standards.

3.5.1. No-Load Testing

No-load testing was conducted to ensure that all machine components could rotate smoothly without excessive vibration, abnormal friction, or unusual noise that might indicate assembly errors or design flaws. During this test, the machine was operated without inserting any rubber waste material, as shown in Figure 10.



Figure 10. No-Load Testing

The test results indicated that the transmission system functioned properly without any signs of mechanical defects or assembly faults. The shaft rotation remained consistent at 70 rpm (the result of gearbox reduction), and the bushed-pin flexible flange coupling effectively dampened minor vibrations that occurred during startup.

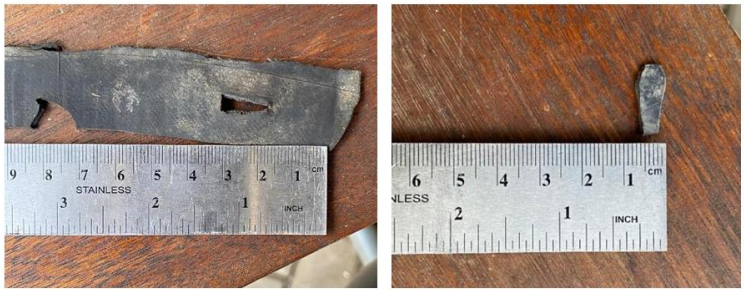
3.5.2. Load Testing

Following the successful no-load testing, load testing was conducted using tire rubber waste samples inserted into the shredder chamber to evaluate the machine's ability to cut and shred hard materials. This test is illustrated in Figure 11.



Figure 11. Load Testing

The results showed that the machine operated stably for 10 minutes of continuous use, producing rubber shreds with dimensions of approximately 10 mm x 10 mm. No damage was found on the coupling pins, nor was there significant wear on the bushings. The maximum torque, as calculated theoretically, was successfully transmitted without slippage or component deformation. The shredding results are shown in Figure 12, with (a) displaying the rubber before shredding and (b) showing the rubber after being processed. This test also confirmed that the use of a flexible coupling effectively reduced the impact of vibrations caused by the irregular shape of the rubber material [22].



(a) (b)

Figure 12. Shredding Result

3.6. Machine Specifications

Based on the mechanical calculations and test results, the rubber shredder machine achieved technical specifications that match real-world field conditions. The technical specifications of the rubber shredder machine are listed in Table 1.

Table 1. Specifications of Rubber Shredder Machine

Specification	Details
Drive System	Motor Gearbox 1:20
Power	2 HP ~ 1.5 kW
Motor Speed	1400 rpm
Output Speed	70 rpm
Torque	184.2×10^3 Nmm
Transmission	FCL Coupling
Machine Dimensions	980 mm × 460 mm × 910 mm
Shredder Type	Single Shaft
Shaft Diameter	32 mm
Number of Fixed Blades	25 pieces
Number of Rotary Blades	25 pieces
Rotary Blade Diameter	120 mm
Max Rubber Input Size	10 mm × 100 mm × 20 mm
Mesh Size	Ø 10 mm
Machine Weight	24 kg
Operating Time Limit	8 hours/day

4. Conclusion

Based on the results of the design and testing of the rubber crushing machine, the following conclusions were obtained.

a. The load that can be supported by the bearing on the tire rubber shredder machine is 10.079,9 N.

b. The type of bearing suitable for use in a tire rubber shredder machine with a rotational speed of 70 rpm on the shredder shaft is a single row deep groove ball bearing with bearing code 206 and the bearing life that can last on a tire rubber shredder machine that operates 5 days a week with 8 hours per day is 5.9 years. Which means the bearing can last for 5 years and 11 months.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

No funding support was received.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analysed during the current study are available from the corresponding author on reasonable request.

References

[1] J. Putri and F. Bioresita, "Pengamatan Persebaran Konsentrasi Polutan Udara Terhadap Jumlah Kendaraan Bermotor Menggunakan Citra Landstat 8 di Provinsi Jawa Tengah Tahun 2019-2022," *J. Geod. dan Geomatika*, vol. 07, no. 02, 2024.

[2] N. K. S. Deviyani and I. W. Mudra, "Teori Dekonstruksi dalam mengintepretasi limbah ban kendaraan bertransformasi menjadi produk kursi sebagai makna baru," *Prod. J. Desain Prod. (Pengetahuan dan Peranc. Produk)*, vol. 7, no. 1, pp. 45–52, 2024, doi: 10.24821/productum.v7i1.4928.

[3] D. H. Setiaji, S. Riyanto, and D. Novianto, "Pengaruh Limbah Ban Karet Sebagai Substitusi Pasir Terhadap Kuat Tekan Dan Modulus Elastisitas Beton," *J. JOS-MRK*, vol. 2, no. 2, pp. 175–181, 2021, doi: 10.55404/jos-mrk.2021.02.02.175-181.

[4] N. Martina, M. F. R. Hasan, and Y. Setiawan, "Pengaruh Serbuk Ban Bekas Sebagai Campuran Agregat Halus Pada Campuran Aspal Porous," *Wahana Tek. Sipil J. Pengemb. Tek. Sipil*, vol. 24, no. 2, p. 144, 2019, doi: 10.32497/wahanats.v24i2.1731.

[5] M. Nasra, S. Raharjo, and F. Goembira, "PEMANFAATAN LIMBAH BAN BEKAS ALAT BERAT MENJADI BAHAN BAKAR CAIR (BBC) MELALUI PROSES PIROLISIS," *Syntax Lit. J. Ilm. Indones.*, vol. 7, no. 5, pp. 167–186, 2022.

[6] A. E. E. Putra, M. Rahman, and A. Y. Aminy, "Produksi Bahan Bakar Ramah Lingkungan Melalui Proses Pirolisis Limbah Ban," *J. Penelit. Enj.*, vol. 20, no. 2, pp. 26–31, 2016, [Online]. Available: http://download.garuda.kemdikbud.go.id/article.php?article=1121503&val=16833&title=Produksi Bahan Bakar Ramah Lingkungan Melalui Proses Pirolisis Limbah Ban

[7] E. B. Santoso, A. Syaichu, and A. Sukarsono, "Perencanaan Dan Analisis Pembuatan Mesin Penyayat Ban Bekas," *J. Mech. Manuf. Technol.*, vol. 6, no. 1, pp. 10–16, 2025, doi: 10.35891/jmmt.v6i1.6108.

[8] S. Layuk, "Sistem Shredder Terhadap Limbah Karet Ban Motor Bekas," Universitas Fajar, 2021.

[9] H. Irawan, A. K. Alkhakim, and S. B. Sasongko, "Analisis Kekuatan Rangka Pada Desain Mesin Pencacah Ban Multifungsi dengan menggunakan Metode Finete Element Analysis," no. Senastitan V, 2025.

[10] Triadi N, Martana B, and Pradana S, "Perancangan Mesin Pencacah Plastik Tipe Shredder dan Alat Pemotong Tipe Reel," *J. Rekayasa Mesin*, vol. 15, no. 2, pp. 144–153, 2020, [Online]. Available: https://jurnal.polines.ac.id/index.php/rekayasa

[11] G. G. Y. Riruma, Hamkah, and P. T. Istia, "Pengaruh Penambahan Karet Ban Bekas Terhadap Sifat Marshall Campuran Aspal AC-WC," *J. Simetrik*, vol. 13, no. 2, pp. 757–764, 2023.

[12] M. T. Qurohman, S. A. Romadhon, and W. J. Usman, "Efektivitas Putaran Terhadap Hasil Cacah Pada Mesin Shredder Plastik," *Nozzle J. Mech. Eng.*, vol. 9, no. 1, pp. 10–14, 2020, doi: 10.30591/nozzle.v9i1.2254.

[13] M. F. Ilhamsyah, "Perancangan Sistem Transmisi Pada Mesin Pencacah Limbah Plastik Tipe Shredder," *Gorontalo J. Infrastruct. Sci. Eng.*, vol. 3, no. 2, p. 14, 2020, doi: 10.32662/gojise.v3i2.1212.

[14] R. Muhfidin, S. N. Sari, and R. Prastowo, "Analisis Kapasitas Mesin Pencacah Limbah Plastik dan Tekstil Menggunakan Unit Penghancur (Shredder)," *G-Tech J. Teknol. Terap.*, vol. 8, no. 3, pp. 1474–1483, 2024, doi: 10.33379/gtech.v8i3.4400.

[15] B. D. Kurniawan and B. Tristiyono, "Studi Kebutuhan Desain Berdasarkan Riset Konsumen pada Produk Tas Sekolah Siswa SMA dalam Rangka Menentukan Design Requirement and Objective (DR&O)," *J. Sains dan Seni ITS*, vol. 8, no. 1, pp. 34–39, 2019, doi: 10.12962/j23373520.v8i1.41961.

[16] M. Nurtanto, S. Nurhaji, S. Deni Ramdani, J. Pendidikan Kwarganegaraan, U. Sultan Ageng Tirtayasa, and J. Pendidikan Teknik Mesin, "Pemberdayaan Ekonomi Kreatif Karang Taruna Melalui Kerajinan Dari Limbah Ban Bekas (Upcycling)," *J. Widya Laksana*, vol. 6, no. 2, pp. 90–99, 2017, [Online]. Available: http://elangjalanan.net

[17] & A. Munawir, Turmizi, "Analisa Kegagalan Poros Pompa Sentrifugal Ebara Type 56-GA 4002 A Melalui Evaliasi Pola Patahan Serta Pengujian Kekerasan dan Metalografi," *Mesin Sains Terap.*, vol. 3, no. 2, pp. 81–87, 2019.

[18] A. Supriyanto and Y. Y. Kristiawan, "Pemanfaatan Limbah Ban Bekas Sebagai Bahan Bakar Altenatif dengan Metode Pirolisis," *J. Tek. Atw*, pp. 35–40, 2017.

[19] A. Nurhasan and A. S. Darmawan, "Perancangan Bushed Pin Coupling pada Motor Listrik Siemens dengan Daya 40 kW dan Putaran Motor 1000 rpm dengan Menggunakan Metode Elemen Hingga," 2020, [Online]. Available: https://eprints.ums.ac.id/id/eprint/81494%0Ahttps://eprints.ums.ac.id/81494/11/Naskah Publikasi.pdf

[20] V. Van Harling and H. Apasi, "Perancangan Poros Dan Bearing Pada Mesin Perajang Singkong," *Soscied*, vol. 1, no. 2, pp. 42–48, 2018, doi: 10.32531/jsoscied.v1i2.164.

[21] Y. S. Handayani, J. Haidi, and A. Mardian, "Analisis Sistem Kelistrikan pada Beban Motor Mesin Pencacah Sampah Plastik," *J. List. Instrumentasi dan Elektron. Terap.*, vol. 2, no. 1, pp. 3–7, 2021, doi: 10.22146/juliet.v2i1.61278.

[22] L. Puspitasari, "Analisa Performance Ban Pada Unit Produksi Overburden Hd-785 Terhadap Produktivitas Tambang Batubara," *Kurvatek*, vol. 5, no. 1, pp. 69–79, 2020, doi: 10.33579/krvtk.v5i1.1775.