PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

THESIS

MUHAMMAD YUNUS FADILAH

20210110052

MECHANICAL ENGINEERING STUDY PROGRAM

FACULTY OF ENGINEERING, COMPUTER AND DESIGN

NUSA PUTRA UNIVERSITY

SUKABUMI

2025

PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

THESIS

Submitted to Fulfill One of the Requirements in Pursuing Bachelor Degree in Mechanical Engineering

MUHAMMAD YUNUS FADILAH

20210110052

MECHANICAL ENGINEERING STUDY PROGRAM

FACULTY OF ENGINEERING, COMPUTER AND DESIGN

NUSA PUTRA UNIVERSITY

SUKABUMI

2025

AUTHOR'S STATEMENT

JUDGE : PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

NAME : MUHAMMAD YUNUS FADILAH

NIM 20210110052

"I declare and take responsibility that this thesis is my own work except for excerpts and summaries, each of which I have explained the source. If at a later time there are other parties who claim that this thesis is their work, accompanied by sufficient evidence, then I am willing to cancel my bachelor's degree in mechanical engineering along with all the rights and obligations attached to the degree."

Sukabumi 19 September 2025

MUHAMMAD YUNUS FADILAH
AUTHOR

THESIS APPROVAL

TITLE : PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

NAME : MUHAMMAD YUNUS FADILAH

NIM 20210110052

This thesis has been checked and approved

Sukabumi 19 September 2025

Head of Mechanical Engineering S1 Study Program	Supervisor
Lazuardi Akmal Islami M, Si	Lazuardi Akmal Islami M, Si
NIDN. 0415039402	NIDN. 0415039402

THESIS ATTESTATION

TITLE : PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

NAME : MUHAMMAD YUNUS FADILAH

NIM 20210110052

This thesis has been examined and defended before the board of examiners at the thesis session on August 29, 2025 in our opinion, this thesis is adequate in terms of quality for the purpose of conferring a bachelor's degree.

Sukabumi 19 September, 2025

Supervisor	Chief Examiner
Lazuardi Akmal Islami M, Si	Prof. Dr. Sivakumar N S, B.E., M.E., Ph.D
NIDN. 0415039402	NIP: 0120240039

Head of Mechanical Engineering S1 Study Program	Dean of Faculty of Engineering, Computer and Design (FECD))
Lazuardi Akmal Islami M, Si	Ir. Paikun, S.T., M.T., IPM., ASEAN Eng.
NIDN. 0415039402	NIDN 0402037401

MOTTO

If at that time in nature my spirit refused to be born into the world, maybe I would not feel 1% of the grace that God sent down to this earth

Jika pada saat di alam ruh ku menolak untuk dilahirkan ke dunia, mungkin aku tidak akan merasakan 1% rahmat yang tuhan turunkan ke bumi ini

"Muhammad Yunus Fadilah"

Seien Sie Teil der Veränderung, die Sie in dieser Welt sehen möchten

Jadilah bagian dari perubahan yang ingin kamu saksikan di dunia ini

"Adolf Hitler"

I dedicate this thesis to my parents,

my lecturers, and my teachers.

ABSTRACT

The use of aluminum as a transportation component has been widely used because it is light, easy to shape and resistant to corrosion in dry environments. Aluminum Scrap is used material or aluminum waste that can be recycled and reused in the production process. In previous research, the aluminum scrap casting process was carried out in the shape of a propeller but there was porosity. So a surface coating process with anodization is required. The propeller used was cut to a size of ± 2 cm x 2.5 cm x 0.5 cm for hardness testing based on ASTM E92 and wear with a size of ± 6 cm x 3 cm x 1 cm based on ASTM G 99 and the anodization process with 22 ml sulfuric acid solution and 178 ml distilled water with time variations of 30, 45 and 60 minutes. This research aims to find out how the variation in anodization time for propellers made from aluminum scrap affects the hardness and wear and tear. The results of hardness testing using the Vickers test on the surface of aluminum scrap after anodizing had the highest hardness of 96.52 HV, with a time of 60 minutes. Meanwhile, the untreated one had a hardness of 81.68 HV, while for wear, after being tested, the sample that was most resistant to wear was the one without treatment with an average trace width of 2.19 mm and specific abrasion of 1.75 ($10^{-6}mm^3/\ mm$).The anodized sample that was most resistant to wear was treated with a 60 minute treatment time with an average trace width of 2.27 mm and a specific abrasion of 1.94 ($10^{-6}mm^3/\ mm$), When observed under the SEM at magnifications ranging from 50X to 2000X, the anodized layer was not yet fully formed. Both a barrier layer and a porous layer were formed after 60 minutes.

Keywords: aluminum scrap, Anodization, hardness, wear, propeller.

PREFACE

All praise to Allah SWT who always gives his grace and guidance to all of us. Sholawat and salam are always poured out to the king of nature, namely the prophet Muhamad SAW. With the grace of Allah SWT, the author can complete this thesis entitled " PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP " smoothly and as expected. In the process of completing this final project, many parties have helped me, both materially, morally, spiritually and mentally. For that, on this occasion the author expresses his deepest gratitude and respect to:

1. Family, Both of my parents my Mother ”Heni” and my father “H.Ece Burhanudin” who have provided support in terms of material and prayers, my brother “Agung Rudiasyah, Laili Masruroh” and my sister “Citra Nurkarimah” who always accompany me in joy and sorrow.
2. Dr. H Kurniawan, S.T., M.Si., M.M as the Rector of Nusa Putra University.
3. Lazuardi Akmal Islami, M.Si. as the Head of the Mechanical Engineering study program at Nusa Putra University, as well as the supervisor who has provided guidance and support so that the author can complete this thesis.
4. Prof. Dr. Sivakumar N S, B.E., M.E., Ph.D and Mr. Zaid Sulaiman S.T., M.T. As examiners who have provided input for the research that has been done.
5. All teaching staff in the Mechanical Engineering Study Program. Nusa Putra University who always provide input and advice and also invaluable knowledge.
6. Tribal Chief "Irul Irawadi" as head of class TM21A, friend of the writer who is always together in this long research which starts in August 2023.
7. Friends of the Mechanical Engineering class of 2021 who always remind and support the continuity of the author's research, Thank you to senior “Nur M. Fathurrahman S.T” class of 2018 who has started this research on aluminum scrap so that we can continue it.junior "Rifani Putri Nayla and Paulus Dara Bani" class of 2022 who have been involved and continuing this research.

Finally, I would like to apologize if there are any shortcomings in the writing and results of our research. Hopefully this thesis can provide benefits and inspiration for interested readers. Thank you for the attention and support you have provided. Hopefully we can continue to contribute to society and science.

Sukabumi 19 September 2025

Writer

FINAL PROJECT PUBLICATION APPROVAL PAGE FOR ACADEMIC PURPOSES

As an academic community member of NUSA PUTRA UNIVERSITY, I, the undersigned below:

Name	: Muhammad Yunus Fadilah
NIM	: 20210110052
Study Program	: Menchanical Engineering :
Type of work	Final Project /Thesis

For the development of science, agree to grant Nusa Putra University a **Non-exclusive Royalty-Free Right** on my scientific work entitled:

PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP

along with existing devices (if needed). With this Non-exclusive Royalty Free Right, Nusa Putra University has the right to store, transfer media/format, manage in the form of a database (data base), maintain, and publish my final project as long as I keep my name as the author/creator and as the copyright owner.

Thus I make this statement truthfully.

Made in : Sukabumi

On the date of : 19 September, 2025

That State

(Muhammad Yunus Fadilah)

TABLE OF CONTENT

IMAGE LIST

TABLE LIST

CHAPTER I
INTRODUCTION

1.1 Introduction

Aluminum material is one of the metals that is often used in the industrial world with various advantages, including resistance to rust, light weight, good electrical conductivity, and easy to recycle [1]. The use of this material is widely used as a transportation component with its advantages which are easy to shape, lightweight and corrosion resistant. Aluminum is also divided into several types of aluminum, one of which is aluminum scrap. Aluminum Scrap is used material or used aluminum waste then reprocessed for production. aluminum management is very important in the context of sustainability and resource management. Research has been conducted on the manufacture of a boat propeller-shaped aluminum scrap casting method using sand casting [2]. The Propeller is an object that produces thrust by rotating, which is found on ships, planes and so on [3].

In this scrap aluminum casting process, the effect of mold temperature on the microstructure of cast aluminum from scrap also shows a temperature of 550° C which has a morphology with the least pores. This is due to the temperature difference between the mold and the low melted aluminum which makes the solidification process take a long time [4]. Although many studies have been conducted on the effect of scrap aluminum casting temperature, there are still few that examine its impact on mechanical properties such as hardness and wear. In addition, this research also focuses on the use of aluminum in corrosive seawater environments. It is known that high salinity in such environments can cause localized corrosion of aluminum, especially in the form of pitting, which is often triggered by the presence of intermetallic phases in aluminum alloys [5]. Due to the disadvantages of aluminum, such as low hardness and dull surface, a surface coating process is required. Surface treatment is carried out to improve the mechanical and physical properties of aluminum, including increasing hardness, wear resistance, and corrosion resistance [6]. One of these surface treatments is anodizing.

Anodizing is an electrolysis coating process that aims to turn the surface of

aluminum into aluminum oxide (Al_2O_3) Based on this definition, the main principle of this process is electrolysis, which is a chemical reaction that occurs due to the flow of electric current, in the electrolysis process, the key components needed are electrodes and electrolytes. The electrode consists of two poles, the cathode acts as a negative pole and serves as a conductor for the workpiece. and the anode acts as a positive pole and is the workpiece to be coated. [7].

Research has been conducted by Diki Adita et al, in this study concluded that the greater the current density used in the anodization process, the thicker the layer formed. This process is proven to significantly increase the surface hardness of Aluminum Alloy 6061 material. Based on existing data, the hardness increased from 107.03 HVN to 301.03 HVN within 30 minutes with a current density of 2.8/Adm^2 [8]. Research conducted by Bambang Wahyu Sidharta in this study concluded that the best wear test value was obtained from the material anodizing process using an electrolyte of 15% vol.H_2SO_4 (Sulfuric Acid) 6% wt. $C_{(2)}$ $H_{(2)}$ $O_{(4)}$ (Oxalic Acid) decrease in the value of specific wear (Ws) on aluminum alloy material occurs after the process for 7 minutes. 3.04 x $10^{-4}mm^2$ /kg before anodizing to 7.15 x10^{-4} mm^2 /kg after anodizing process for 7 minutes, the specific wear value (Ws) of aluminum alloy material decreased. This indicates that the material becomes more wear-resistant compared to the condition without anodizing process [9].

Therefore, after reviewing the background above, research was conducted on the PERFOMANCE ANALYSIS OF ANODIZING PARAMETER VARIATIONS ON THE HARDNESS AND WEAR RESISTANCE OF PROPELLERS MANUFACTURED FROM ALUMINIUM ALLOY SCRAP, [10], [11], [12]to find out whether variations in anodizing time on scrap aluminum can improve mechanical properties, especially hardness and wear.

1.2 Problem Formulation

Based on the existing background, this research faces several problems which are then formulated as follows:

1. How does variation in anodization time for propellers made from aluminum scrap affect hardness?
2. How does variation in anodization time for propellers made from aluminum scrap affect wear?
3. How does variation in anodization time for propellers made from aluminum scrap affect the surface morphology of the material?

1.3 Research Objectives

Based on the purpose of the research, the formulation of this problem is:

1. To find out how the variation in anodization time for propellers made from aluminum scrap affects hardness.
2. To find out how the variation in anodization time for propellers made from aluminum scrap affects wear.
3. To find out how the variation in anodization time for propellers made from aluminum scrap affects the surface morphology of the material.

1.4 Problem Limitation

In order for this discussion to run as expected and not expand, this research includes problem limitations including:

1. The sample used is Aluminum Scrap material.
2. Material coating using anodization method with Hard Anodizing coating type.
3. The anodizing time uses variations of 30, 45 and 60 minutes.
4. Hardness tests were conducted using the Vickers method, which refers to the ASTM E92 standard.
5. Wear test was conducted by pin-on-disk method, which refers to ASTM G99 standard.
6. Morphology test on the surface of the sample material after anodizing using SEM.

1.5 Benefits Of Research

The benefits of activities for the author for carrying out this research include:

1. Being an experience for the author in soft skills and hard skills regarding the anodization process and the hardness and wear testing process.
2. The application after this research can be applied in propellers, especially with aluminum scrap material.
3. The results of this study can be used as a reference for making or developing variations in current and anodization time that are similar.

BAB V
CONCLUSION

1.1 Conclusion

Therefore on this study the test results and data analysis in this study that has been done, it can be concluded that:

1. Vickers ASTM E92 test results shows that increasing varying anodization time on aluminum scrap increases surface hardness. Sample (D) without treatment had an average of 81.86 HV, sample (A) at 30 minutes reached 92.14 HV, sample (B) at 45 minutes was 93.82 HV, and the highest was sample (C) at 60 minutes with a value of 96.52 HV.
2. The wear test results showed that sample (D) without treatment had the improved wear resistance significantly, with an average gap width of 2.19 mm. For the anodized samples, the average gap widths were 2.51 mm for sample (A, 30 minutes), 2.50 mm for sample (B, 45 minutes), and 2.27 mm for sample (C, 60 minutes). From these results, it can be understood that the smaller the gap width value, the better the wear resistance of the material.
3. SEM analysis revealed that anodization affected the surface morphology. Sample (D) without treatment showed no layer formation, while sample (A, 30 minutes) exhibited an initial barrier layer with visible gaps. In sample (B, 45 minutes), the gaps became narrower, resulting in a denser layer. Meanwhile, sample (C, 60 minutes) displayed a more clearly barrier layer along with the early growth of a porous layer, although the pore structure can be improved by further research by varying anodization parameter.

1.2 Suggestion

1. Extend the anodizing duration to more than one hour to produce a thicker, stronger, and more uniform oxide layer.
2. Apply X-Ray Diffraction (XRD) testing to identify the crystal phases and oxide composition after anodizing.
3. Perform more comprehensive surface preparation to achieve a smooth, defect-free, and uniform anodizing result.
4. Use cross-sectional Scanning Electron Microscope (SEM) analysis to examine the thickness and uniformity of the oxide layer in detail.

LITERATURE

[1] A. M. Koten, D. G. H. Adoe, J. U. Jasron, And J. T. Mesin, "Pengaruh Variasi Tegangan Dan Waktu Terhadap Kekerasan Lapisan Nikel Dengan Metode Electroplating Pada Coran Aluminium Scrap," 2016, [Online]. Available: Http://Ejournal-Fst-Unc.Com/Index.Php/Ljtmu

[2] S. Widyastuti And M. S. Si, "Analisis Pengaruh Variasi Beda Potensial Terhadap Ukuran Pori Dan Struktur Permukaan Anodic Aluminium Oxide (Aao) Dengan Metode Mild Anodizing," 2020.

[3] A. H. Staf, P. Program, S. Teknika, A. Maritim, And N. Cilacap, "Analisa Pengebab Keausan Poros Baling Baling Kapal," 2019.

[4] M. R. F. Putra, W. Suprapto, And A. A. Sonief, "Pengaruh Kecepatan Pengadukan Proses Rheocasting Terhadap Struktur Mikro Dan Fluiditas Paduan Al-Cu," *Jurnal Rekayasa Mesin*, Vol. 10, No. 3, Pp. 257–263, 2019, Doi: 10.21776/Ub.Jrm.2019.010.03.6.

[5] L. Allen, A. Gill, A. Smith, D. Hill, P. Z. Moghadam, And J. Cordiner, "Development Of A Machine Learning Framework To Determine Optimal Alloy Composition Based On Steel Hardenability Prediction," *Digital Chemical Engineering*, Vol. 9, No. May, P. 100118, 2023, Doi: 10.1016/J.Dche.2023.100118.

[6] S. U. Mariam, A. Ibrahim, Y. Yuniati, And N. Nazirudin, "Pengaruh Variasi Rapat Arus Hard Anodizing Terhadap Laju Korosi Pada Aluminium 6061," *Jurnal Mesin Sains Terapan*, Vol. 4, No. 2, P. 99, 2020, Doi: 10.30811/Jmst.V4i2.2014.

[7] S. U. Mariam, A. Ibrahim, Y. Yuniati, And N. Nazirudin, "Pengaruh Variasi Rapat Arus Hard Anodizing Terhadap Laju Korosi Pada Aluminium 6061," *Jurnal Mesin Sains Terapan*, Vol. 4, No. 2, P. 99, 2020, Doi: 10.30811/Jmst.V4i2.2014.

[8] D. Aditya, R. Usman, And Yuniati, "Pengaruh Variasi Arus Dan Waktu Pada Anodisasi Type," Vol. 3, No. 2, 2019.

[9] A. Wisnujati And F. Yudhanto, "Karakterisasi Lapisan Oksida Hasil Anodizing Pada Aluminium Dengan Variabel Waktu Pencelupan," *Jurnal Rekayasa Mesin*, Vol. 14, No. 2, Pp. 525–536, Aug. 2023, Doi: 10.21776/Jrm.V14i2.1309.

[10] W. Elbar And K. Tampubolon, "Pengaruh Campuran Silikon Pada Aluminium Terhadap Kekerasan Dan Tingkat Keausannya," *Jmemme*, Vol. 4, No. 2, 2020, Doi: 10.31289/Jmemme.V4i2.4070.

[11] B. Aviriano, "Pengaruh Konsentrasi Asam Dan Waktu Proses Anodizing Terhadap Sifat Mekanik Dan Fisik Oksida Aluminium," 2007.

[12] St. ,Mt. ,Ph. D. I Dewa Gede Ary Subagia, *Modul Praktikum Metalurgi*. 2015.

[13] I. Pratama And A. Zay, "Daur Ulang Scrap Aluminium Sebagai Solusi Alternatif Untuk Mengurangi Ketergantungan Aluminium Impor Di Indonesia," 2014. Doi: 10.13140/2.1.3237.6006.

[14] I. Pratama And A. Zay, "Daur Ulang Scrap Aluminium Sebagai Solusi Alternatif Untuk Mengurangi Ketergantungan Aluminium Impor Di Indonesia," 2014, Doi: 10.13140/2.1.3237.6006.

[15] Woodhead, "Disposal And Recycling Of Aerospace Materials," In *Introduction To Aerospace Materials*, Elsevier, 2012, Pp. 558–568. Doi: 10.1533/9780857095152.558.

[16] M. Kamau Njuguna, "Influence Of Modifiers And Heat Treatment On The Fatigue Life And Mechanical Properties Of Recycled Cast Aluminium Alloys," 2007.

[17] P. J. Blau *Et Al.*, *Metals Handbook Desk Edition 2nd Edition By J. R. Davis, Asm International Handbook Committee*. 1998.

[18] Nur M. Fathurrahman, "Analisis Sifat Korosi Hasil Cor Terhadap Temperatur," 2023.

[19] D. Aditya, R. Usman, And Yuniati, "Pengaruh Variasi Arus Dan Waktu Pada Anodisasi Type," Vol. 3, No. 2, 2019.

[20] Muhamad Rizky Firdaus, "Pengujian Anodizing Dan Elektroplating," 2014.

[21] Muhammad Rozihan Anwar, “Pengaruh Penempaan Dan Heat Treatment Pada Pembuatan Perkakas Logam Berbahan Pegas Daun Mobil Terhadap Kekerasan Mikro Vickers, Kekuatan Impak Dan Struktur Mikro,” 2017.

[22] Anang Dwi Apriambudi, “Pengaruh Variasi Waktu Dan Konsentrasi Larutan Terhadap Kekerasan Lapisan Nikel Electroplating Pada Baja Karbon Rendah,” 2019.

[23] A. Wisnujati And F. Yudhanto, “Karakterisasi Lapisan Oksida Hasil Anodizing Pada Aluminium Dengan Variabel Waktu Pencelupan,” *Jurnal Rekayasa Mesin*, Vol. 14, No. 2, Pp. 525–536, Aug. 2023, Doi: 10.21776/Jrm.V14i2.1309.

[24] J. , Y. Dalis Ikbal1, “Pengaruh Variasi Kuat Arus, Waktu Dan Pewarnaan Terhadap Kekerasan Permukaan Pada Proses Anodisasi Aluminium 1100,” *Jurnal Mesin Sains Terapan* , Vol. Vol.2, No. No.2, 2018.

[25] Muhtar Ngarifin, “Optimasi Sifat Mekanik Aluminium Seri 6061 Dengan Perlakuan Anodizing,” 2022.

[26] M. Nofri, “Analisis Perubahan Sifat Mekanik Al 6063 Setelah Dilakukan Heat Treatment Pada Temperatur Tetap Dengan Waktu Tahan Yang Bervariasi,” 2020.

[27]. Bambang Wahyu Sidhartab Soekrisnoa, “Optimalisasi Temperatur Hard Anodizing Terhadap Ketahanan Aus, Kekerasan Serta Ketebalan Lapisan Oksida Aluminium Paduan,” 2012.

[28] J. S. Bale, R. N. Selan, D. G. Adoe, And Dan Daniel Situmorang, “The Application Of Vdi 2221 Method On Embodiment Design Of Pin On Disk Wear Test,” 2018.

[29] I. Isranuri, W. Aditya, K. Kunci, A.-S. Alloy, And L. Keausan, “Analisa Pengaruh Beban Terhadap Laju Keausan Al-Si Alloy Dengan Metode Pin On Disk Test,” *Jurnal Dinamis*, Vol. Ii, No. 10, 2012.

[30] A. Ramadhan, “Analisis Perbandingan Tribometer Types Dengan Variasi Material-Review,” *Jurnal Rekayasa Mesin*, Vol. 6, No. 2, Pp. 101–105, 2015.

[31] Teknik Metalurgi Dan Material Logam, “Pengujian Keausan,” Jumat, 16 November 2018.

[32] S. Diajukan Untuk Memenuhi Salah Satu Syarat Mengikuti Ujian Seminar Skripsi Jurusan Fisika Pada Fakultas Sains Dan Teknologi Uin Alauddin Makassar Oleh, "Uji Karakteristik Nanopartikel Magnetit (Fe3o4) Menggunakan X-Ray Diffraction Dan Scanning Electron Microscopy," 2017.

[33] Lisa Marlisa Syam, "Uji Karakteristik Nanopartikel Magnetit (Fe3o4) Menggunakan X-Ray Diffraction Dan Scanning Electron Microscopy," 2017.

[34] A. Sujatno, R. Salam, And A. Dimyati Pusat Sains Dan Teknologi Bahan Maju, "Studi Scanning Electron Microscopy (Sem) Untuk Karakterisasi Proses Oxidasi Paduan Zirkonium," 2015.

[35] S. Sembodo And A. Anawati, "Combine Effect Of Temperature And Additive Ethylene Glycol On The Characteristics Of Anodic Film Formed On Aluminum Alloy Aa7075," In *Aip Conference Proceedings*, American Institute Of Physics Inc., Apr. 2020. Doi: 10.1063/5.0001486.

[36] A. Y. Prastya, "Pengaruh Variasi Arus Listrik Terhadap Sifat Fisik Dan Mekanik Hasil Proses Anodizing Pada Aluminium Seri 1xxx," 2021.

[37] A. Djafar Shieddique, J. Saputra Jimi, D. Ardi Rajab, M. Iqbal Zaelana, A. Abdullah, And D. Kurnia Santosa, "Peningkatan Nilai Kekerasan Dan Perubahan Morfologi Fasa Logam Aluminium Melalui Variasi Perubahan Kandungan Silikon Pada Paduan Al-Si-Cu-Fe Untuk Aplikasi Industri Pertahanan," 2020. [Online]. Available: Http://Ejournal2.Uika-Bogor.Ac.Id/Index.Php/Ame/Index

[38] B. Hidayanto, A. Wardoyo Dan Muhammad Wahyu Darojad, And N. Diterima, "Pengaruh Variasi Temperatur Tuang Pada Pengecoran Daur Ulang Al-Si Terhadap Struktur Mikro Dan Kekerasan Dengan Pola Lost Foam Informasi Artikel Abstrak," 2018. [Online]. Available: Http://Jurnal.Untirta.Ac.Id/Index.Php/Jwl

[39] Y. Cahyo Pamungkas And P. Trihutomo, "Identifikasi Tingkat Kekerasan Paduan Al-Si Yang Di-Quenching Dengan Variasi Media Pendingin Dan Waktu Pencelupan," 2016.

[40] F. Teddyan Syach, B. Junipiyoto, And G. Sakti, "Effect Of Anodizing On Mechanical Properties Of Aluminum Alloy 2024-T42."

[41] Pramuko Ilmu Purboputro, “Pengembangan Bahan Kampas Rem Sepeda Motor Dari Komposit Serat Bambu Terhadap Ketahanan Aus Pada Kondisi Kering Dan Basah,” 2016.

[42] Sulaksono Cahyo Prabowo, “Pengaruh Variasi Waktu Anodizing Terhadap Struktur Permukaan, Ketebalan Lapisan Oksida Dan Kekerasan Aluminium 1xxx,” 2021.

[43] I. Widyastuti, “Pertumbuhan Lapisan Oksida Terhadap Hasil Anodizing Aluminium,” 2011.

[44] H. Hidayat, “Optimasi Parameter Proses Anodisasi Aluminium 6061 Untuk Komponen Otomotif,” *Jurnal Penelitian Enjiniring*, Vol. 25, No. 2, Pp. 85–91, Jul. 2022, Doi: 10.25042/Jpe.112021.01.