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Chemical Composition Characterization of Recycled Aluminum as a Basis for Evaluating Ship Propeller Materials

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Abstract: *Chemical composition provides essential information for evaluating recycled aluminum intended for cast components. This study identifies the elemental composition of a recycled aluminum sample associated with ship propeller research and examines the limitations of using these results for material evaluation. A descriptive analysis was conducted using a chemical composition certificate and its supporting measurement records issued by PT Guna Sukses Inti. The documentation contains one sample code and three readings obtained using a Hitachi FM Expert instrument. The analysis covered elemental composition, variation among readings, and interpretation supported by relevant literature. The certificate summary reports 84.90 wt.% Al, 11.00 wt.% Si, 2.12 wt.% Fe, 1,440 wt.% Zn, 0.184 wt.% Mn, and 0.076 wt.% Mg. These results indicate an aluminum–silicon-based composition containing iron and zinc that warrants further evaluation. The Mn-to-Fe mass ratio calculated from the certificate summary is approximately 0.087. Document examination also identified a copper result reported as >0.0010 wt.%, a difference between the stated aluminum average and the arithmetic mean of the displayed readings, and a testing standard whose applicability requires clarification. The composition data provides a preliminary basis for sample characterization but does not establish a specific alloy grade, mechanical properties, or operational suitability for ship propellers.*

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Introduction

The use of recycled aluminum offers the opportunity to reuse materials that have reached the end of their useful life. However, the recycling process also faces composition control issues. Remelting does not, by itself, produce a material with the same purity or characteristics as primary aluminum. Lu et al. [1] addressed these limitations in their research on the development of a process for refining scrap aluminum. This suggests that the evaluation of recycled materials should begin with information about their constituents.

In cast aluminum alloys, silicon is an element related to solidification behavior and filling ability during casting. Patarić et al. [2] showed that changes in silicon content in Al–Si–Mg alloys affect the solidification range and molten metal feeding mechanism. Therefore, silicon content needs to be considered when discussing the characteristics of a casting material.

Other elements can also affect material properties. Research by Mikolajčík et al. [3] showed that variations in Fe and Mn in AlSi7Mg0.6 alloys are related to changes in intermetallic phase morphology and fatigue behavior. This relationship depends on the material conditions and loading, so the results of composition testing need to be read together with information on microstructure and mechanical properties.

In ship propeller material research, compositional analysis is useful for identifying the material used before further evaluation. This information helps determine which elements to monitor, select additional tests, and avoid assigning alloy classes without sufficient basis. However, composition results do not directly indicate the material's ability to withstand loads during use.

This study utilizes the chemical composition test results of a single recycled aluminum sample recorded in a ship propeller research document. The discussion focuses on elemental content, variation in readings, and the limits of data interpretation. Within this scope, this study aims to provide a preliminary characterization of the material that can serve as a basis for subsequent microstructural examination and mechanical property testing.

Research Methods

Types of Research and Data Sources

This research is a descriptive study of laboratory test results. The data source is the Chemical Composition Test Certificate Number 2026.LAB.US.VIII.0109 and its attachments, issued by the Testing and Calibration Laboratory of PT Guna Sukses Inti [4]. The document records the receipt of samples, testing, and issuance of the certificate on August 18, 2026.

The sample has the code “METAL,” with the material class “RECYCLE” and the material identity aluminum. The test appendix presents three readings for that sample code. These three readings are treated as readings on a single sample identity, not as three independent research samples.

The document does not provide details regarding the sampling locations on the product, the specimen dimensions, or the position of each reading. Therefore, the analysis is limited to the information contained in the report.

Testing Information

The instrument listed in the certificate is the Hitachi FM Expert. According to the manufacturer, the FM Expert is an optical emission spectrometer for metal analysis [5]. The instrument type identification is used to explain the general principles of the test, while the

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specific operational parameters follow the information available in the laboratory documentation.

The certificate lists the traceability to the BAM-M324 standard, the test temperature is (21 ± 0.98) °C, and the relative humidity is (46 ± 2.5)%. The elemental composition is reported in percent by weight.

The standard listed on the certificate is JIS G 1253:2013. The official Japanese Standards Association document indicates that the standard addresses spark discharge emission spectrometry analysis for iron and steel [6]. Its inclusion in aluminum testing needs to be clarified with the laboratory.

As a scope comparison, ASTM E1251 addresses the analysis of aluminum and its alloys using spark atomic emission spectrometry [7]. The mention of this standard is for comparative information and does not imply that the testing of samples in the study was carried out according to ASTM E1251.

Data Processing

The analysis was performed by copying the composition values from the certificate summary, examining the three readings in the appendix, and calculating the relevant derived quantities. The arithmetic mean of the readings was calculated using the equation:

$$\bar{x} = \frac{x_1 + x_2 + x_3}{3}$$

with x as the average and x1, x2, and x3 as the displayed reading values.

The mass ratio of Mn to Fe is calculated using the equation:

$$R_{\mathrm{Mn/Fe}} = \frac{C_{\mathrm{Mn}}}{C_{\mathrm{Fe}}}$$

with CMn and CFe being the levels of each element in weight percent.

Values marked with a "<" or ">" are retained as reported. They are not reset to zero or considered the exact concentration. Differences between the calculated values and those listed on the certificate are explained separately, without changing the official laboratory results.

Results and Discussion

Chemical Composition of Recycled Aluminum Samples

A summary of the test results is shown in Table 1. The numbers follow the values on the certificate summary sheet, including the number of decimal places. The Cu notation follows the appendix for clearer reading.

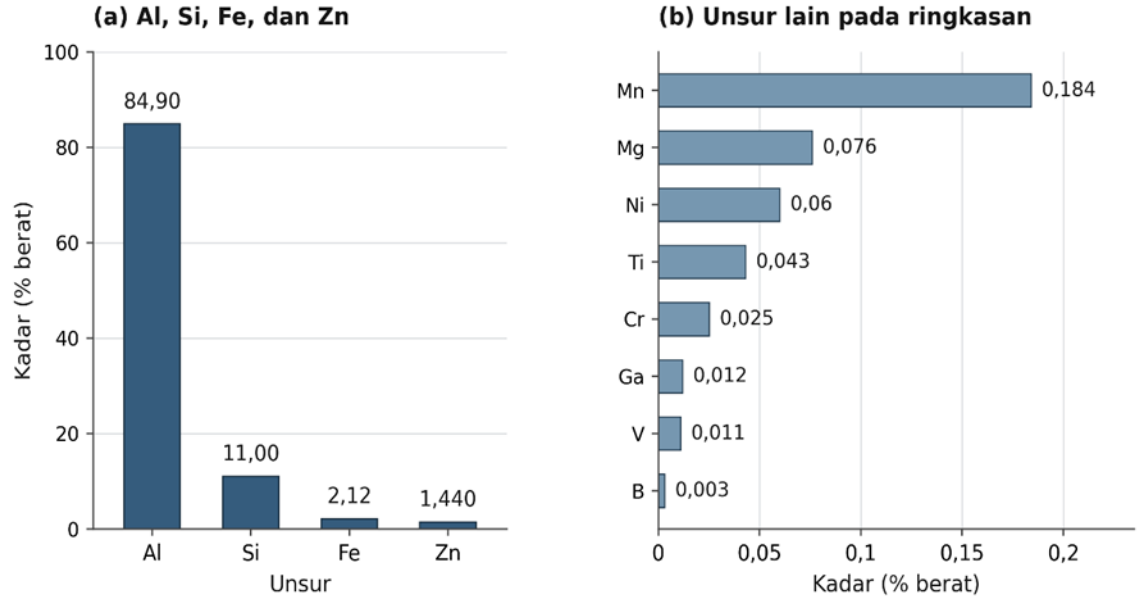
Table 1. Chemical Composition in the Certificate Summary

No.	Element	Symbol	Content (% weight)
1	Aluminum	Al	84.90
2	Silicon	Si	11.00
3	Iron	Fe	2.12
4	Zinc	Zn	1,440
5	Manganese	M N	0.184
6	Magnesium	Mg	0.076
7	Nickel	This	0.06
8	Titanium	Ti	0.043
9	Chromium	Cr	0.025
10	Gallium	No	0.012

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11	Vanadium	V	0.011
12	Boron	B	0.003
13	Zirconium	Zr	0.00
14	Copper	Cu	>0.0010

Source: certificate and attachment of PT Guna Sukses Inti test results [4].



Source: certificate and attachment of PT Guna Sukses Inti test results [4].

Aluminum is the element with the largest content in the test results summary. Silicon has the next largest numerical value, at 11.00% by weight. This composition provides the basis for describing the sample as an aluminum–silicon-based material. The term is used as a compositional description, not as a standard alloy class designation.

Iron and zinc were reported at 2.12% and 1.440% by weight, respectively. The presence of these two elements is crucial to the sample's characterization because it demonstrates that the material discussion is not limited to aluminum and silicon.

The difference in the number of decimal places between the summary and the appendix is noteworthy. For example, Mg is listed as 0.076% in the summary and 0.0756% in the appendix average line. Zr is listed as 0.00% in the summary, while the appendix lists it as 0.0026%. Therefore, a Zr value of 0.00% in the summary should not be interpreted as the absence of the element.

The appendix also contains other elements not shown in the main summary, including Pb at 0.0604%, Sb at 0.0943%, and Mo at 0.0141% in the average row. These values are part of the sample composition information, but their effect on material properties was not specifically tested in this study.

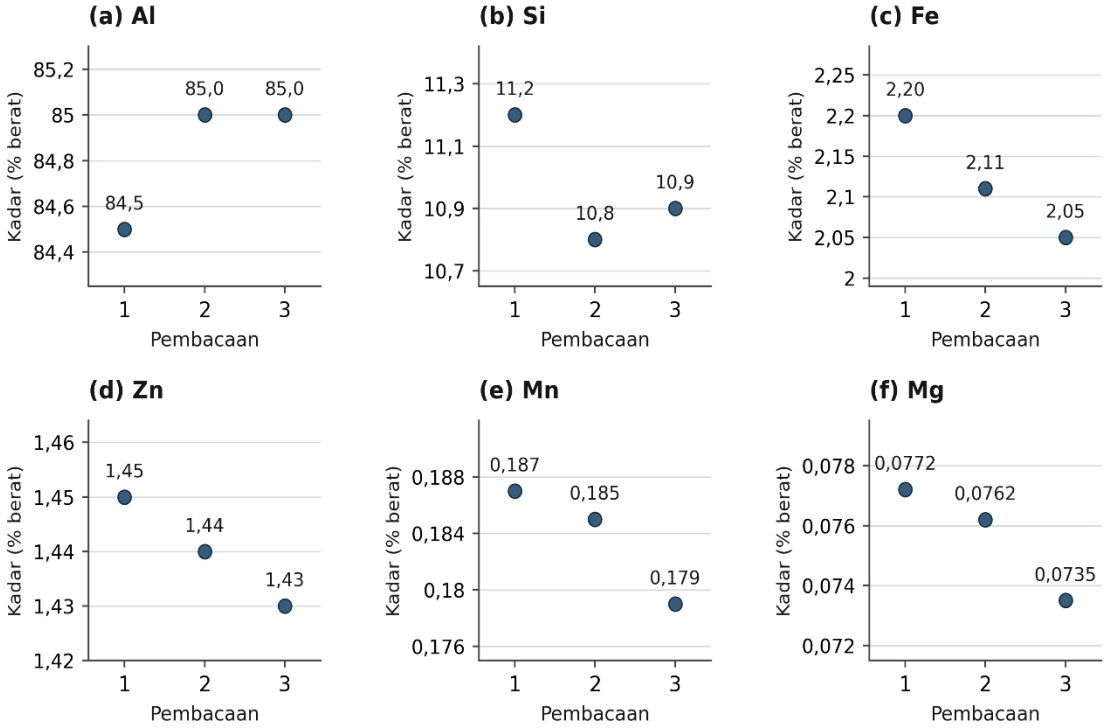
Variation in Reading Results

Three readings for some elements are shown in Table 2.

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Table 2. Results of Reading Several Elements in the Test Appendix

Element	Reading 1 (% weight)	Reading 2 (% weight)	Reading 3 (% weight)
Al	84.5	85.0	85.0
Si	11.2	10.8	10.9
Fe	2.20	2.11	2.05
Zn	1.45	1.44	1.43
M N	0.187	0.185	0.179
Mg	0.0772	0.0762	0.0735



Source: attachment of PT Guna Sukses Inti test results [4].

Si content ranges from 10.8–11.2%, while Fe content ranges from 2.05–2.20%. Zn content ranges from 1.43–1.45%. Mn content ranges from 0.179–0.187%, while Mg content ranges from 0.0735–0.0772%.

The range represents the variation in the numbers across the three available readings. This information is insufficient to determine whether the variation stems from material irregularities, surface conditions, or measurement factors. Determining the cause requires information regarding the preparation procedure, reading positions, and evaluation of instrument performance.

For the Al element, there is a difference between the calculated results based on the displayed figures and the averages listed in the report. Calculations from three readings yield the following results:

$$\bar{x}_{\mathrm{Al}} = \frac{84{,}5 + 85{,}0 + 85{,}0}{3} = 84{,}83\%$$

The result is approximately 84.83%, while the report lists 84.9% in the appendix and

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84.90% in the certificate summary. The reason for the discrepancy cannot be determined from the documents. The possibility of using internal figures with higher precision or discrepancies in recording needs to be confirmed with the laboratory.

In this study, the 84.90% value remains the value reported on the certificate. The 84.83% result is presented as a recalculation of the apparent reading. This separation ensures that the author's processing results are not considered official corrections to the certificate.

Interpretation of Silicon Content

The Si content of 11.00% indicates that silicon is an important component in the sample composition. The research of Patarić et al. [2] on Al–Si–Mg alloys showed that increasing silicon can narrow the freezing range and improve the feedability during solidification. These findings provide a basis for considering the role of Si in the discussion of casting materials.

However, this study did not include fluidity testing, cooling curve analysis, or shrinkage defect measurements. Therefore, the Si content of the samples cannot be used to determine whether the molten metal has properly filled the mold or produced a defect-free product.

The composition also does not yet indicate the shape and distribution of silicon within the microstructure. Metallographic examination is necessary to determine the true nature of the structure. Interpretation at this stage is limited to the presence of silicon as one of the main measurable elements.

Iron Content and Its Comparison with Manganese

Based on the certificate summary, the Fe content is 2.12%, while the Mn content is 0.184%. The mass ratio of the two elements is calculated as follows:

$$R_{\mathrm{Mn/Fe}} = \frac{0{,}184}{2{,}12} \approx 0{,}0868 \approx 0{,}087$$

This ratio indicates that the Mn content is approximately 8.68% of the Fe content. This value represents a comparison between the elemental levels and not the percentage of Mn content in the overall material.

Mikolajčík et al. [3] observed that the addition of Mn to AlSi7Mg0.6 alloys can change the amount and size of the Fe-containing plate-like or needle-like phases. The same study also showed that the response to fatigue loading was not uniform across test conditions. These results support the need to evaluate Fe and Mn together with the microstructural characteristics and loading conditions.

In the samples studied, the Mn/Fe ratio can be used as information for designing further investigations. This ratio cannot yet be used as a basis for stating that the influence of Fe has been controlled or that a specific intermetallic phase has formed. Phase identification requires appropriate observation and analysis.

A Fe content of 2.12% also does not directly influence hardness, tensile strength, or impact toughness. The relationship between composition and mechanical properties must be demonstrated through testing on the same material.

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Copper Information Limitations and Alloy Grade Determination

The Cu content in the appendix is written as >0.0010%. Literally, this notation indicates a value greater than 0.0010%, but does not provide a precise concentration.

Therefore, the Cu data cannot be rewritten as 0.0010%, considered zero, or stated as below the detection limit. This notation is also insufficient to conclude that Cu is an extremely low-level element. Certainty regarding the number and its sign must be obtained from the laboratory.

This condition is one of the limitations in determining alloy grade. Class identification requires adequate comparison of the composition to the applicable standard requirements. The closeness of the concentration of a single element, such as Si, is not sufficient to determine that a sample belongs to a particular grade.

On this basis, the material is referred to in the study as recycled aluminum with an Al–Si-based composition. No alloy class or statement of conformity to specific product specifications is made.

Implications for Ship Propeller Material Evaluation

Test results provide initial information regarding the materials used in ship propeller research. The content of Al, Si, Fe, Zn, and associated elements can serve as a basis for determining the focus of subsequent investigations. However, evaluating propeller materials requires evidence that extends beyond chemical composition.

Mikolajčík et al.'s [8] research discussed the influence of Fe and Mn on the phase morphology and corrosion resistance of secondary aluminum alloys. These findings demonstrate that corrosion evaluation needs to consider the composition and structure of the material. Research results on other alloys cannot be directly transferred to the corrosion resistance values of the samples studied.

To further assess the sample, microstructural examination can be directed at the distribution of silicon, Fe-containing phases, and the presence of pores. Mechanical testing is then required to determine the material's hardness, strength, and load-bearing capacity. Corrosion evaluation and repeated loading also need to be tailored to the intended use conditions of the propeller.

The available data does not yet allow for a comparison of the effects of sand molds and metal molds. The report contains a single sample code "METAL" without any paired composition data representing other mold conditions. The code is also not used as sole evidence regarding the sample manufacturing process.

Within these limitations, the contribution of this study lies in presenting a composition profile and determining the need for further evaluation. The results do not yet constitute a basis for declaring that the material meets the operational requirements for a ship propeller.

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Conclusion

Based on the review of the certificate and test result attachments, the following conclusions

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were obtained.

1. The certificate summary reports a composition of 84.90% Al; 11.00% Si; 2.12% Fe; 1.440% Zn; 0.184% Mn; and 0.076% Mg by weight. This composition supports the description of the sample as Al–Si-based recycled aluminum, without specifying a specific alloy grade.
2. The Mn-to-Fe mass ratio, according to the certificate summary, is approximately 0.087. This value can provide supporting information for microstructural examination, but does not yet provide evidence of the intermetallic phase form or the material's mechanical properties.
3. The document review identified three issues requiring clarification, namely the reporting of Cu as >0.0010%, the discrepancy between the listed average Al and the calculated readings, and the conformity to the JIS G 1253:2013 standard for aluminum testing.
4. ResultsChemical composition provides the initial basis for sample characterization. Determining suitability as a ship propeller material requires additional testing of the microstructure, mechanical properties, corrosion, and relevant loading conditions.

Suggestion

The next step is to request clarification from the laboratory regarding the Cu content, the basis for calculating the average Al, and the testing standards used. If necessary, the clarification results should be documented in an official document or revised certificate so that the identity and testing basis can be traced.

Further research should utilize independent samples from multiple product sections or multiple castings. Sampling should include information on location, process conditions, and preparation procedures. This allows for a more representative evaluation of compositional variations.

Further compositional examination needs to be linked to metallographic results and material property testing. If the goal of the study is to compare printing media, each printing condition needs to have clear sample data and an adequate number of repetitions.

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