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AMC Brake Pad Engineering: The Role of Reinforcement, Silica Sand, and Boiler Fly Ash on Friction Coefficient and Density

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ABSTRACT

Innovations in making non-asbestos brake linings are increasingly being developed, asbestos materials which are less friendly to the environment and health are the main factors. This research utilizes recycled aluminum as a matrix and boiler fly-ash and silica sand as reinforcement. The aim of this research process is to determine the differences in variations in hot compaction pressure and powder volume percentage on shrinkage values and friction coefficients. The method used is the powder metallurgy method which includes mechanical alloying, hot compaction pressing and sintering. Mechanical Alloying is carried out using a ball mill machine with Ball Parameter-weight of Ratio (BPR) parameters of 10:1, rotational speed of 90 rpm, holding time of 6 hours with variations in the matrix percentage of 86%, 90%, 94% and the results of the mechanical alloying will be weighed in variations, namely 25 gr, 35 gr, and 45 gr. ASTM B962-17 density test and ASTM G99-05 coefficient of friction or wear test. The results obtained were the highest density value of 2.055 gr/cm3 with a reinforcement percentage of 94% compaction of 5600 Psi. The lowest density value is 1.848 gr/cm3 with a reinforcement percentage of 86% compaction of 5600 Psi. The friction coefficient test value is 0.147 gr with a reinforcement percentage of 86%, the powder weight is 45 gr. The lowest value of the friction coefficient test was 0.020 gr using a reinforcement percentage of 94% and a powder weight of 35 gr.

Keywords: *Brakes-pads; Powder-Metallurgy ; Aluminium-Matrix-Composite.*

1. INTRODUCTION

The use of asbestos materials poses significant health hazards, as individuals exposed to asbestos fibers in the air can experience respiratory issues and face an increased risk of mortality. Consequently, 67 countries have banned asbestos due to its environmentally harmful properties and associated health risks [1].

Brake pads are commonly made from an alloy that includes asbestos as the primary component, along with various other materials such as friction additives, resins, and fillers [2]. However, alternative materials for brake pads are available, including non-asbestos options like aluminum. Aluminum is frequently used due to its low density, relatively low melting point, corrosion resistance, and good elasticity[3].

Aluminum Matrix Composite (AMC) brake pads are a type of non-asbestos brake pad, where aluminum serves as the main matrix material, constituting over 70% of the total composite. This material is being widely developed because aluminum is abundant in the Earth's crust and ranks as the third most abundant element, following oxygen and silicon [3].

Silica sand is a natural mineral composed of silicon dioxide, with the molecular formula SiO_2 [5]. This material is derived from minerals or metals containing silica and is frequently utilized in powder metallurgy. Silica sand can yield a variety of chemical products with different compositions, including 0.25% loss on ignition (LOI), 0.389% iron oxide (Fe_2O_3), 0.054% aluminum oxide (Al_2O_3), 0.079% titanium dioxide (TiO_2), and 98.75% silicon dioxide (SiO_2) [6].

In Indonesia, the total area of oil palm plantations spans approximately 14.966 million hectares, producing around 9.375 million tons of palm fruit shell waste annually [7]. This waste, along with palm fiber, is often repurposed by factories as fuel to generate steam [8]. The byproduct of this combustion process is known as fly ash (specifically boiler fly ash), which possesses desirable characteristics such as fine particles and low porosity [9].

In the context of this research, the matrix investigated by the researchers consists of aluminum reinforced with silica sand and boiler fly ash. The researchers performed ASTM G99 tests [10] to evaluate the friction coefficient using a pin-on-disk apparatus, as well as ASTM B962-17 tests to determine density[11]. Through this study, the aim is to develop sustainable and innovative solutions.

2. METHODOLOGY

2.1 Materials

The metal matrix powder utilized in this study was recycled aluminum, with a D50 particle size of 282.53 μm, as measured by a Particle Size Analyzer. Chemical composition testing conducted at the Metal Laboratory, Polman Ceper revealed that this powder consists of 83.4% aluminum (Al), 10.09% silicon (Si), and 2.6% copper (Cu), with the presence of iron oxide (FeO2). For reinforcement, this study employed silica sand obtained from tin tailing waste and boiler fly ash derived from palm oil waste, sourced from PT. Tata Hamparan Eka Persada in Bangka Regency. Figure 1 illustrates the results from the Aluminum Particle Size Analyzer.

2.2 Tools and method

The tools utilized in this study include a ball mill machine, which is designed to mix aluminum powder, silica sand, tin tailings, and boiler fly ash. This machine can also crush the materials into finer particles. For this study, the matrix and reinforcement were mixed using a mechanical blending process for 6 hours at a designated speed of 90 RPM. It was observed that the longer the grinding time, the more uniform the particle size produced [12]. Inside the ball mill, steel balls are used, maintaining a Ball Powder Weight Ratio (BPR) of 10:1. Figure 2 provides an image of the ball mill machine employed in this study [13]

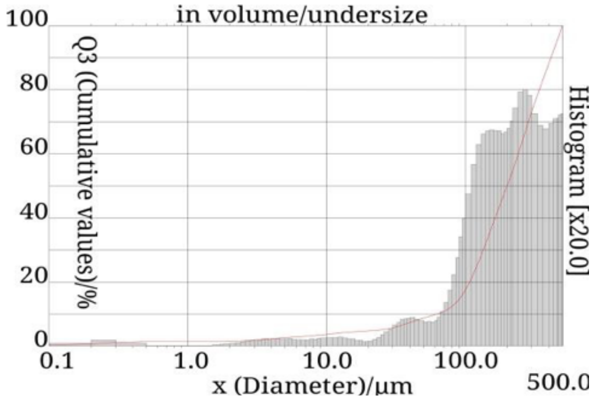

Figure 1. Graph of aluminum particle size analyzer

Figure 2. Ball mill machine

In this study, a hydraulic press was utilized to consolidate a composite material made from an aluminum powder matrix and reinforcement, which consisted of silica sand and boiler fly ash. The mixing process for this composite had already been completed prior to using the hydraulic press.

The hydraulic press is capable of exerting pressure in both upward and downward directions. It is equipped with a pressure gauge that can measure pressures of 6000 psi, 5600 psi, and 5200 psi. Additionally, this research tool is combined with a heater (thermocouple) that heats the powder during the printing process.

Figure 3. Hydraulic press machine

The sample mold used has an outer diameter of 50 mm and an inner diameter of 20 mm. The procedure for the initial printing process involves placing the mold onto the hydraulic press. The mechanically combined powder is then inserted into the mold and leveled to match the inner diameter of the mold. Next, the mold is heated using a thermocouple to a temperature of 400 °C. Following this, two-way pressure is applied for a waiting time of 10 minutes. Figure 3 illustrates the hydraulic press tool used in this study.

Oven heat treatment is utilized to facilitate the sintering process on specimens that have undergone heat compaction. Sintering involves forming bonds between individual powder particles, a process often referred to as interlocking. In this study, the heat treatment occurs at a temperature of 600 °C, with a holding time of 10 minutes. After this duration, the specimens are allowed to cool to room temperature. Figure 4 illustrates the oven used for this process.

Figure 4. Electrical oven

3. RESULTS AND DISCUSSION

The molds used for the tests are tubular and ring-shaped, with an inner diameter of 50 mm and an outer diameter of 20 mm. A total of 27 samples were produced for the shrinkage test and nine samples for the friction coefficient test, as illustrated in Figure 5, which displays the shape of the brake pad specimen mold [13].

Figure 5. Mold for AMC brake pads

3.1 Results of mechanical alloying

A composite mixture was created using a powder that consists of aluminum as the binder (matrix) and silica sand along with boiler fly ash as reinforcement. This mixture underwent mechanical alloying for 6 hours with a ball-to-powder ratio (BPR) of 10:1, resulting in powder particles that are smaller than the original size.

According to the results from a Particle Size Analyzer test conducted at the Laboratory of the Faculty of Mathematics and Natural Sciences at Brawijaya University in Malang, the following results were observed based on different percentages of matrix (binder) and reinforcement:

1. With a composition of 94% binder and 6% reinforcement, the average particle size (D50) was measured to be 120.41 µm (see Figure 6).
2. For a mixture containing 90% binder and 10% reinforcement, the average particle size (D50) was found to be 118.37 µm (see Figure 7).
3. Lastly, a composition of 86% binder and 14% reinforcement yielded an average particle size (D50) of 111.67 µm (see Figure 8).

These findings indicate that increasing the percentage of reinforcement leads to a decrease in the average particle size of the composite mixture.

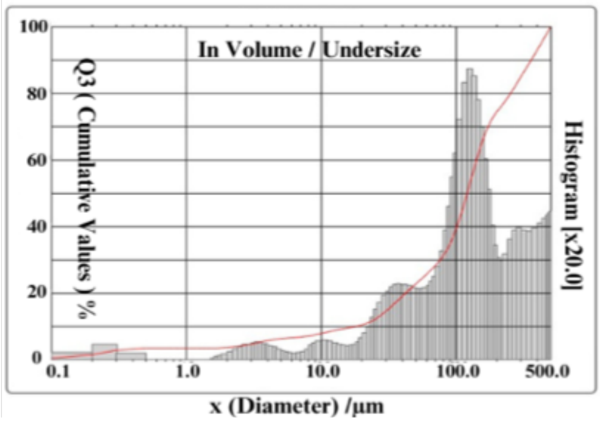

Figure 6. Particle size analyzer showing a 6% concentration with a D50:120.41 µm

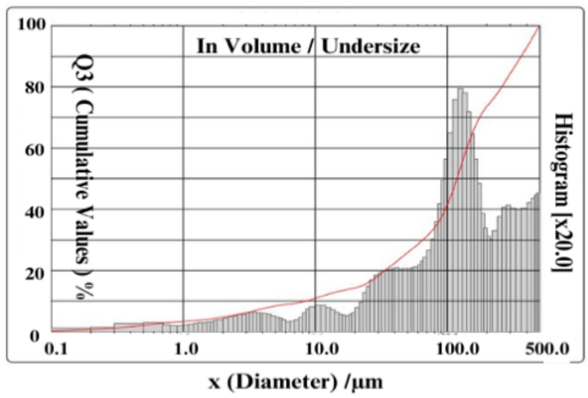

Figure 7. Particle size analyzer showing a 10% concentration with a D50:118.37 µm

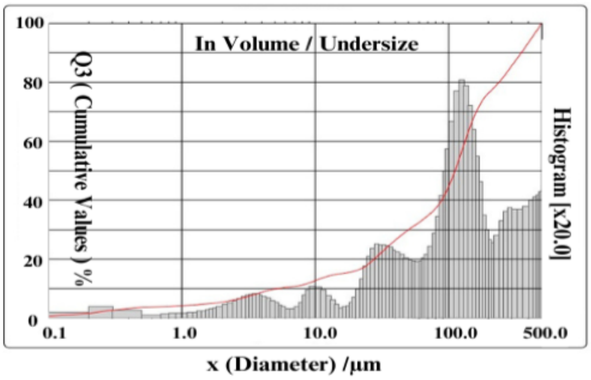

Figure 8. Particle size analyzer showing a 14% concentration with a D50:111.67 µm

The brake pad mold has an outer diameter of 50 mm and an inner diameter of 20 mm. The thickness of the specimen varies based on the percentage of powder used during molding, with amounts of 25 g, 35 g, and 45 g. This process is conducted under a compaction pressure of 5200 psi, as illustrated in Figure 9.

Figure 9. Sample of AMC brake pads

3.2 Density and friction coefficient testing

The purpose of this test is to determine the differences in density and friction coefficient values in AMC brake pad composite samples that are reinforced with boiler fly ash and silica sand. These values will be influenced by variations in the volume of powder and the percentage of reinforcement used.

3.2.1 Density testing

Once the AMC brake pad samples have completed the sintering treatment process at a temperature of 600 °C, with a waiting time of approximately 10 minutes, each sample is labeled. The density testing process begins by measuring the weight of the sample in dry conditions. Next, the sample is weighed in wet conditions by submerging it in distilled water. After both measurements are obtained, the composite density (ρ_m) is calculated using Archimedes' Law, as shown in Equation (1) below. This applies to both dry and wet AMC brake pad samples. In this equation, ρ_m represents the actual density (grams/cm^3), m_s is the mass of the dry sample (grams), mg is the mass of the wet sample suspended in water (grams), and ρH_2O is the density of water, which is 1 gram/cm^3.

$$\rho_m = \frac{m_s}{m_s - m_g} pH_2O \ldots\ldots\ldots\ldots [1]$$

Based on Figure 10, the density test value graph using the ASTM B962-17 standard approach and the Archimedes' Law principle shows that the AMC brake pad specimen with the highest density was obtained at the reinforcing composition in the form of silica sand and Boiler-Fly-Ash of 6%, with two-way hot compaction pressure of 5200 Psi at a temperature of 300ºC, resulting in a density of 2.256 g/cm^3.

Figure 10. Graph of density test results

The lowest density, measured at 1.848 g/cm^3, was observed in the specimen with 14% reinforcement, which was processed using a two-way hot compaction pressure of 5600 psi at a temperature of 300 °C. This variation in density is impacted by both the percentage of reinforcement and the level of hot compaction pressure. Specifically, as the reinforcement percentage increases, the bond between the powder particles in the AMC brake pad specimen decreases, leading to a lower density. Conversely, a lower hot compaction pressure tends to result in a higher density value.

3.2.2 Friction coefficient testing

The procedure for testing the friction coefficient involves the use of a specialized testing tool, as illustrated in Figure 11. The test parameters for the sample include a constant load of 2 kg, a rotational speed of 65 rpm, and a waiting time of 4 minutes. A total of nine samples were tested, with variations in powder compositions of 25 g, 35 g, and 45 g, as well as variations in the percentage of reinforcement at 86%, 90%, and 94%. The compaction pressure was set at 5200 psi. The friction coefficient is calculated using Equation (2).

$$W = \Delta V = \frac{V_i - V_f}{t} \dots \dots \dots [2]$$

Where W is the wear rate in gr/minute, V_i is the initial mass of the specimen in gr, V_f is the final mass after the test in gr, t is = Test duration (minutes), and ΔV is the scratch loss mass in gr.

Figure 11. Machine for friction coefficient testing

Figure 12 below presents the results from the friction coefficient test data, which were calculated using a specific formula. The calculation procedure involves subtracting the final volume of the specimen from its initial volume after the test, and then dividing that difference by the test duration of 4 minutes.

Table 1 shows that the highest friction coefficient value corresponds to a binder percentage of 86% and a powder weight of 45 grams, resulting in a wasted volume scratch of 0.147 grams. In contrast, the lowest value occurs at a binder percentage of 94% and a powder weight of 35 grams, leading to a wasted volume scratch of just 0.020 grams.

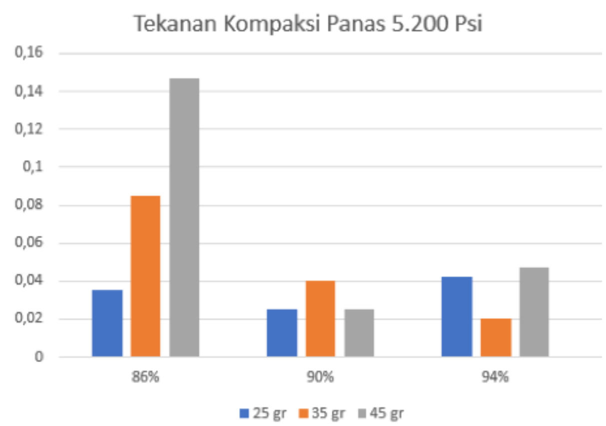

Figure 12. Graph of results from the friction coefficient test

4. CONCLUSION

The analysis of the Archimedes Theory density value data reveals that the brake pad specimen with the highest density value has a binder percentage of 94%, a hot compaction pressure of 5200 psi, and a temperature of 300 °C, resulting in a density of 2.256 g/cm^3. Conversely, the specimen with the lowest density value, which has a binder percentage of 86%, a hot compaction pressure of 5600 psi, and a temperature of 300 °C, yielded a density of 1.848 g/cm^3.

According to Figure 12, the highest friction coefficient test result is associated with a binder percentage of 86% and a powder weight of 45 g, which produced a wasted volume of 0.147 g from scratches. In contrast, the lowest value for the friction coefficient test corresponds to a binder percentage of 94% and a powder weight of 35 g, resulting in a wasted volume of only 0.020 g from scratches.

In conclusion, a smaller binder volume leads to a greater volume of wasted material on the test specimen due to friction, as observed in the friction coefficient test using a powder weight of 45 g and a binder percentage of 86% made from recycled aluminum. Conversely, a higher binder percentage corresponds to a greater volume of wasted material, as seen in the friction coefficient test with a powder weight of 35 g and a binder percentage of 94% of recycled aluminum.

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REFERENCES

1. I. B. A. NETWORK. 67 Negara telah melarang asbes, Indonesia Kapan?. 2022. [Online]. Available: https://inaban.org/67-negara-telah-melarang-asbes-indonesia-kapan/
2. Suhardiman and Syaputra M. Analisa Keausan Kampas Rem Non Asbes Terbuat Dari Komposit Polimer Serbuk Padi dan Tempurung Kelapa. Jurnal Invotek Polbeng. 2017; 07(2): 210–4.
3. Rismiani M. Ketahanan Korosi Sistem Lapisan Al dan Nicrsi dengan Metode Thermal Spray. Repository.Uinjkt.Ac.Id, 2020.
4. Irwansyah R, Rodika R, Wanto A, Wahyudi M, Wiryono S. Pengaruh Pemadatan Dua-arah Penekanan Terhadap Densitas dan Kekerasan AMC diperkuat Serbuk Silikon Dioksida. Infotekmesin. 2023; 14(2): 265–72.

doi: 10.35970/infotekmesin.v14i2.1902.

5. Sukanto S, Soenoko R, Suprapto W, Irawan Y.S. Characterization of aluminium matrix composite of Al-ZnSiFeCuMg alloy reinforced with silica sand tailings particles. Journal of Mechanical Engineering Science. 2020; 14(3): 7094–108. doi: 10.15282/jmes.14.3.2020.11.0556.
6. Sukarman N, Gani RA. Lahan Bekas Tambang Timah di Pulau Bangka dan Belitung, Indonesia dan Kesesuaiannya untuk Komoditas Pertanian (Ex-mining land in Bangka and Belitung Islands, Indonesia and their suitability for agricultural commodities). Jurnal Tanah dan Iklim. 2020; 41(2): 101. doi: 10.21082/jti.v41n2.2017.101-114.
7. Grand Riset Sawit, "No Title," Badan Pengelola Dana Perkebunan Kelapa Sawit.
8. Oktavianty H. Sintesis Zeolit X dari Fly Ash Boiler Pabrik Kelapa Sawit sebagai Adsorben Pemurnian Biodiesel. Sang Pencerah Jurnal Ilmiah Universitas Muhammadiyah Buton. 2022; 8(2): 430–43. doi: 10.35326/pencerah.v8i2.1938.
9. Simanjorang BP, Abda S, Isranuri I, Syam B, Sabri M. Pembuatan dan analisa sifat mekanik komposit dengan penguat abu (fly ash) cangkang sawit untuk bahan kampas rem sepeda motor. Dinamis. 2017; 5(1): 42–50. doi: 10.32734/dinamis.v5i1.7041.
10. ASTM International. ASTM G-99. 2016; 05(2016): 5-10. doi: 10.1520/G0099-17.Copyright.
11. ASTM-C127. Standard Test Methods for iTeh Standards iTeh Standards or to indicate the Preview. 2015; I: 1–4. doi: 10.1520/B0962-17.2.
12. Soenoko R. The effect of milling time on the alumina phase transformation in the amcs powder metallurgy reinforced by silica-sand-tailings. 2022; 1: 103–17. doi: 10.21303/2461-4262.2022.001906
13. Asep M. Pembuatan Komposit Matrik Aluminium Diperkuat Pasir Silika Tailing Timah. Skripsi Politeknik Manufaktur Negeri Bangka Belitung. 2022.