EPI International Journal of Engineering
Volume 6, Number 1, February 2023, pp. 24-27
DOI: 10.25042/epi-ije.022023.04

pISSN 2615-5109
eISSN 2621-0541

The Effect of Hot Pressing on the Mechanical Properties of Metal Composites (Al/SiC) Results from Metallurgical Processes with Heating Temperature Variations in Bushing Making

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Abstract

The manufacture of Al/SiC alloy matrix composites has been widely carried out by researchers through powder metallurgy techniques. Bushings are slit cylindrical type bearings that serve to support the shaft. Bushings can be made by powder metallurgy, to get the perfect compaction process, compaction can be done by high temperature or Hot Pressing. A hot press will make the powder softer/plastic, making it easier during the perfect compaction process. For this reason, heating must be controlled in order to obtain a homogeneous product. Al/SiC metal matrix composites are alloyed materials of different types of materials, as matrices in this case are aluminum and as reinforcement are SiC particles (ceramics) made by powder metallurgy techniques. In this study, the Al/SiC composite composed of 70% Al - 30% SiC and Hot Pressing temperature variations of 100, 150 and 200°C with a pressure of 5000 kg and a holding time of 10 minutes. In the sintering process, the temperature used is 450, 500 and 550°C with a holding time of 2 hours. The results of this study show, in hardness testing it is known that the value of sample hardness increases as the temperature of Hot Pressing increases.

Keywords: Composite Al/SiC; hot pressing; temperatur sintering

1. INTRODUCTION

Powder metallurgy processes are relatively new and have several advantages compared to metal casting processes. However this process is not can completely replace the function of the casting process [1]. At this time, the development of metal matrix composite (MMC) technology is increasingly advanced along with the development of automotive industry technology. The use of steel as a raw material for automotive parts and components began to be replaced with composite materials which have good formability and corrosion resistance [2]. Currently the method that is developing in the manufacture of composites is powder metallurgy which is a fabrication technique that is very widely applied in various material technology innovations in the industrial world. The advantages of applying powder-based technology include being able to combine various material properties with different characteristics, so that they become new properties as planned. Metal matrix composites with aluminum matrix and powder-based SiC reinforcement, also known as Al/SiC isotropic composites, have wide applications and development. This composite has advantages especially in strength and resistance to wear [3].

The advantage of powder metallurgy is that the resulting product components can be used directly without the need for machining processes and can be produced on a small or mass scale. The type of composite that is widely developed by the automotive industry is a metal matrix composite (Metal Matrix Composite), namely an aluminum matrix composite (Aluminum Matrix Composite). Currently AMC is used in the automotive industry such as pistons, disk brakes, gears, and engine blocks. The 6061 aluminum matrix material with SiC ceramic reinforcement is a very suitable combination in improving mechanical performance and resistance to corrosive damage. In manufacturing that has different constituent material properties, the composite between materials must bond strongly, so it is necessary to add a wetting agent. One of the wetting agents is magnesium, the use of magnesium is done nto be a binder between the aluminum matrix and SiC reinforcement. There are various ways that can be done in improving the mechanical properties of aluminum, one way that can be used is by adding reinforcing materials, such as silicon carbide (SiC). The addition of SiC particle elements must be evenly distributed on all sides of the aluminum to be formed [4].

AMC (Aluminum Matrix Composites) is a type of metal composite material with aluminium as matrix and SiC powder as reinforcement [5]. MMCs can be produced using a wide variety of techniques. By changing

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manufacturing methods such as processing and finishing, as well as from the selection of the geometry of the reinforcing components, it is possible to obtain different characteristics despite the same composition and number of forming components [6]. Fabrication technology developed for produce metal matrix composites (MMCs) such as: liquid metallurgy, powder metallurgy, filament diffusion bonding and foils and vapor phase infiltration techniques [7].

Silicon carbide (SiC) is one of the fortifications, silicon carbide or often known (SiC) has high hardness, so it can work in the mechanical properties of the lattice during composite production. Al-SiC composites benefit in strength and fatigue protection. Also, by reinforcing the ceramic material it will provide expansion on the high temperature barrier and warm shock [8]**.** The structure of the dense arrangement between the atoms of Si and C can be considered in one period of the crystallographic structure of SiC. Polytypes in SiC are formed when differences form in crystallography [9]**.** The use of SiC has advanteges in terms of harness and high temperature resistivity [10].

Bushing (Fig. 1) serves to focus the loaded shaft, so that the rotation or reciprocating motion can take place smoothly and safely. Bushings are included in the classification of sliding bearings. What happens between the bearing surface and the focused surface is a sliding motion. The product made in this research is a cylindrical bushing. A good bushing is a bushing that has mechanical properties that are high strength and hardness but also high wear resistant. Bushings should have a homogen distribution of hardness because it is seen from its function to focus the loaded shaft so that the presence of loads and forces from various directions does not result in the material being damaged and easy to break. However, sometimes the bushing produced does not match what we want or in other words does not have good mechanical properties [2].

To get the perfect compaction process, the perfect compaction process can be done with high temperatures or known as Hot Presing. A hot press will make the powder softer/plastic, making it easier to solidify. For this reason, the influence of heating temperature can be controlled so that homogeneous products are obtained. Density is very influential on the strength of the product produced. From research that has been done by varying heating at the time of compaction with different temperatures, namely with room temperature, temperatures of 100, 200 and 300°C, higher temperatures are difficult to achieve due to limited tools [4]. The shape of powder particles depends on how they are made, they can be bulau, irregular, dendritic, flattened or sharp-angled. Fineness is closely related to grain size and is determined by sieving the powder with a standard sieve or by microscopic measurements. Standard mesh sieves of 36 to 850 µm are used to check the size and determine the particle size distribution within a given area [11].

Figure 1. Bushing

Fitria and Waziz in [12] examined the Al-9% Si alloy powder from the study. Preparation of specimens with compaction pressure variations of 300,400 and 500 MPa and sintered temperature variations of 450,500 and 500°C for 2 hours in an argon gas environment. The results showed that increasing the compaction pressure and sintered temperature would increase the hardness and density of the specimen.

Powder metallurgy is one of the production techniques using powder as the initial material before the formation process. This principle is to solidify the metal powder into the desired shape and then heat it below the melting temperature, so that the metal particles combine due to the mass transport mechanism due to the diffusion of atoms between particle surfaces [6]**.** The compaction process is a process of the formation metal from metal powder with a pressing mechanism after the metal powder is inserted into the mold. The compaction process is generally carried out with one-way and two-way emphasis. On a one-way press, the top press moves down. Whereas in two directions, the upper and lower press simultaneously press each other in opposite directions. The types and kinds of products produced by the powder metallurgy process are highly determined in the compaction process in forming powders with good strength. The powder compaction process includes the process of pressing a shape in a mold made of steel. The pressure exerted ranges from 20-1400 MPa [12].

Heating to temperatures below the melting point of the material is called sintering. Based on the bonding pattern that occurs in the compaction process, there are 2 phenomena that may occur during sintering, namely shrinkage and cracking where shrinkage occurs because during the sintering process the gas (lubricant) that is in porosity experiences degassing (gas release event during sintering) [13]. And if the sinter temperature continues to be increased, surface diffusion will occur between matrix particles and fillers which will eventually form a liquid bridge / necking (has a mixed phase between matrix and filler). This liquid bridge will cover porosity so that there is elimination of porosity (reduced number and size of porosity). While cracking (cracking) If the compaction forms a bond pattern between particles in the form of planes, causing gas trapping (gas / lubricant trapped in the material), then at the time of sintering the trapped gas has not had time to come out but the liquid bridge has occurred, so that the porosity path has been tightly closed. This trapped gas will push in all directions so that bloating occurs, so that the pressure in porosity is higher than the pressure outside. If the quality of particle surface bonding in the composite material is low, it will not be able to withstand greater pressure, causing [3].

By means of powder metallurgy processes materials will be obtained with properties suitable for a specific purpose to meet the increasing demands of modern technology. Beneficial or not, properties always change when there is a structural change in the material during the forming process. The structure in the material changes when there is deformation, therefore there is a change in the properties. Thermal processes also affect the internal structure of materials. The pre-formed material will have a set of strength, hardness, etc. properties selected to meet the design requirements [14].

2. Research Methods

2.1. Materials and tools

In this study, the material used was aluminum fine powder with purity above 90%. As a fiber-shaped reinforcing material, SiC is used as a mixing medium. The composition of the weight percent mixture of composite materials is Aluminum 70% and SiC 30%.

Mixing is the process of mixing materials so they can join being a uniform homogeneous substance and has excellent crrying capacity [8].

SiC reinforcement combined with powdered aluminum is mixed with a dry mixing process. The stirring process is carried out using a mixer, then the stirring process is carried out ±10 minutes until the fine powder and reinforcement are mixed homogeneously [15].

2.2. Hot pressing method

The pressing process is one way to solidify the powder into the shape of the material. The emphasis of the powder serves to consolidate the powder into the desired shape, obtaining precise dimensions as desired. In the pressing process, the friction force that occurs between the powder particles used and the mold wall particles can cause density differences in the center and edge areas of the mold. To avoid this, use lubricant. The lubricant used must have non-reactive properties to the powder used and have a low melting point, so that the lubricant can evaporate in the Hot Pressing process (Fig. 2).

Making test samples is done by pressing on the mold that has been provided using a hydraulic press. In the bushing manufacturing process, the required pressure compaction is 5000 kg, the pressing temperature variation (room temperature) 100°C, 150°C and 200°C heating and pressing using powder metallurgy hot pressing molding tools. The dimensions of the bushing size to be made are outer diameter D2 = 65 mm, inner diameter D1 = 50 mm and height (h) = 50 mm.

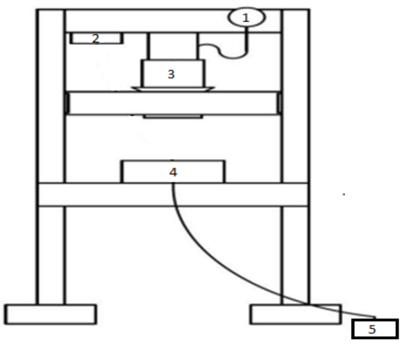

Figure 2. Illustration of hot pressing mechanism

Information :

1. *Pressure gauge*
2. *Display temperature*
3. *Suppression Load*
4. *Molds bushing*
5. *Thermo Regulator*

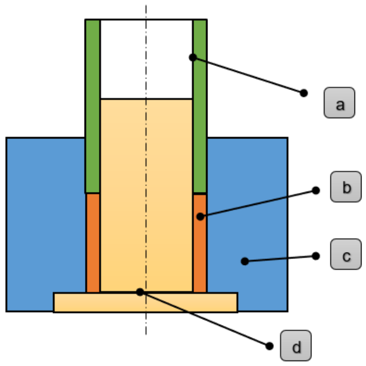

Figure 3. Mold bushing manufacturing process

Hot Pressing Equipment used as shown in Fig. 3. The mold is made of steel with heating around it. Press is carried out after the temperature is reached as desired.

2.3. Sintering process

After the specimen compaction process, the Sinter process was carried out with temperatures of 450,500 and 550°C for 2 hours (120 minutes). After the sintering process is complete, the specimen is removed from the kitchen by air cooling. Mechanical properties testing carried out includes hardness testing.

3. Experimental Setup and Results

From the tests that have been done, the value of Vickers acidity is found in Table 1-3, where each table has a different level of hardness in a different Hot Pressing process and different Sintering temperatures. In each part of the sample, three repetitions were made at different points on the hardness test surface. Hardness values are obtained by finding the average hardness value in each sample.

Table 1. Vickers hardness test values at sintered temperature 450^0 C with Hot Pressing temperature 100.150 and 200^0 C

Hot Pressing	28°	100°	150°	200°
Point 1	42.3	36.7	42.9	42.5
Point 2	38.4	28.8	37.2	30.9
Point 3	36.1	30.3	40.6	35.3
Average	38.9	31.9	40.2	36.2

Table 2. Vickers hardness test values at sintered temperature 500^0 C with Hot Pressing temperature 100.150 and 200^0 C

Hot Pressing	28°	100°	150°	200°
Point 1	40.4	52.4	51.8	41.5
Point 2	46.7	48.2	57.0	35.5
Point 3	38.5	41.5	61.3	34.2
Average	41.8	47.3	56.7	37.0

Table 3. Vickers hardness test values at sintered temperature 550^0 C with Hot Pressing temperature 100.150 and 200^0 C

Hot Pressing	28°	100°	150°	200°
Point 1	44.7	66.3	63.1	52.9
Point 2	37.9	51.2	61.9	58.7
Point 3	52.4	44.9	49.7	48.1
Average	45.0	54.1	58.2	53.2

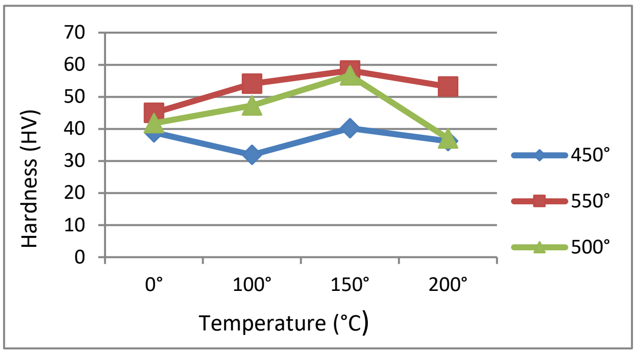

Figure 4. Graph of the average hardness values of Vickers at sintered temperatures of 450 ^{0} C, 500 ^{0} C and 550^0 C with Hot Pressing temperatures of 100,150 and 200^0 C

4. Result Discussions

Figure 4 shows that the value of Vickers hardness can be seen that the hardness of each specimen has a different tendency if associated with differences in each Hot Pressing treatment or Sintered temperature differences. In the graph, it can be seen that the value of Vickers tightness increases with every increase in temperature Hot pressing or increase in sinter temperature. This happens because the more the temperature increases, the sample will undergo the diffusion process of the Al matrix against the SiC reinforcement which is characterized by a change in shape after the sintering process, where seen in the Hot pressing process 1500 the highest value is found during the 550° C sintering process with a value of 58.2 kg / mm2. With increasing temperature, the Al and SiC grains will be more docked.

However, the Hot Pressing temperature of 200° C at each sintered temperature shows a decrease in the hardness value of Vickers. This is because it is possible that during the Hot Pressing process there is an expansion coefficient so that there is a crack between the surface bonds of the Al and SiC powder mixture. The bond of the Al/SiC composite is reduced (weakened), resulting in a weakened hardness value [3].

Conclusions

Based on the results of the study, it can be concluded that the Hot pressing process is very influential in making the Al/Si matrix, it can be seen from the increase in hardness value that occurs in hardness testing where the optimum temperature in the Hot Pressing process is found at a temperature of 150° C where the hardness value is constant at each sintered temperature. The higher the sintered temperature in making the Al/SiC matrix, the greater the ability of the sample to withstand external loads or mechanical forces. The effect of material composition and treatment temperature affects the characteristics of the composite.

Acknowledgements

Thank you to the Foundry Laboratory and Physical Metallurgical Laboratory of Mechanical Engineering Hasanuddin University Makassar, Head of the Foundry Laboratory and Physical Metallurgy Laboratory, Mechanical Engineering Staff of Hasanuddin University and people who have helped and supported.

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