Effect of Travel Speed on Aluminium Composite CNT (Al+CNT) Layer with Friction Surfacing Process Using a Drilling-Milling Machine and Wear Resistance of Al+CNT Coating

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Abstract. This study presents an experimental investigation on the wear resistance properties of Al6061cor and mixed (Al 6061 +1%CNT) cor. CNT is important in improving the quality of the coating due to the extraordinary mechanical and physical properties of the CNT, namely exceptional high strength to weight ratio, high aspect ratio, and high fracture strain and high flexibility. The layer is obtained from the friction surfacing process , utilizing the friction that occurs between the surface / substrate with the consumable rod. Consumable rods are Al6061cor and mixture (Al6061 + 1% CNT) in the casting process with a diameter of 16 mm length 125 mm. Consumable Rods with constant pressure and constant rotation with speeds up to 3000 rpm move around the substrate with a table speed that varies 3.5, 4.2, and 5 cm / minute. The coating results are then analyzed to determine wear resistance according to ASTM G99-04 abrasive methods with variations in wear time for each specimen. Wear resistance of Al6061cor and (Al6061 + 1% CNT) cast layers with varying table speeds obtained the best results at speeds of 3.5 cm / min with thickness of 0.23 mm, width of 1.6 mm for Al6061cor layers and thickness of 0.25 mm, width of 1.8 mm for layers (Al6061 + 1% CNT) cast. Pengujian wear show that the wear rate increases with the length of time used in the process of wear. The highest wear rate value contained in the Al layer type 6061 cast in each variation of the time used . The wear rate (Al 6061 + 1% CNT) cast is lower than the wear rate in the Al 6061 cast.

1. Introduction

Wear and tear occurs when two objects its wear her greater in softer materials. Factors that affect wear are speed, pressure, surface roughness and hardness of the material [1]. It has been observed that shear or abrasive characteristics of materials are very important in tribological systems such as pistons [2]. One way to reduce the wear and tear on the material value of al the method of liquid such as stir casting and compocasting , approaching the size of the final result, it is easier to control the matrix structure and manufacturing costs relatif cheaper [3]. In this study using the *stir casting* method in the casting or composite process. One type of composite based on its matrix is, *metal matricx composites* (MMCs) with high specific strength and stiffness, as well as resistance to *creep* and wear. MMCs are designed to combine the positive characteristics of metal, such as high toughness, ductility, and Young's modulus were high [4].

In this study the authors use aluminum 6061 as a matrix material, this is because aluminum has a light mass and has advantages in strength, wear resistance, stiffness, and good dimensional stability [5]. The addition of reinforcement in the form of carbon nanotubes (CNT) can improve the mechanical properties of composites as reinforced Al 6061- composites [6] due to the extraordinary mechanical and physical properties of CNT, namely exceptional *high strength* to weight ratio, high aspect ratio, and *high fracture strains* and high flexibility. CNT can conduct heat and also has better electrical properties compared to copper [7]. The aim of the research group is to produce composites with mechanical properties higher [8], this researchs associated with Al-CNT composites which will be used as a coating material (*coating*) of materials using *friction surfacing* . Lots of research on *friction surfacing* , but many of them are not quality. The one that caused it to happen is the absence of a process or method for improving the quality and sensitivity of the process parameters that exist [9]. Based on the description above, the writer is interested in examining the coating with Al-CNT material with the friction surfacing process method using a Dilling-milling machine , one of the parameters to be analyzed is the effect of travel speed on the quality of the coating wear.

2. Materials and Methods

2.1. Research materials

2.1.1. Aluminium 6061. To function as a material to be melted , this material was chosen because the compound is not only for house hold appliances, but also used for industrial, construction, and so on [10].

2.1.2. Carbon Nanotube Powder. Functioning as a material used for mixing aluminum (Al) that has been melted.

Figure 1. Aluminium 6061.

Figure 2. Carbon nanotube.

2.1.3. ST37 Steel Plate. Used as a specimen to be coated in the friction surfacing process.

2.1.4. Grit Sandpaper 250-7000. Used to smooth the surface of the workpiece / specimen.

Figure 3. ST37 Steel Plate. **Figure 4.** Grit Sandpaper.

2.1.5. Green stone. Used in the specimen polishing process.

2.1.6. Keller Reagent Etching Liquid. The composition of the Keller Reagent etching fluid consists of 25 ml of distilled water, 5 ml of HF, 7.5 ml of HCL, and 12.5 ml of HNO3.

Figure 5. Green stone. **Figure 6.** Keller Reagent Etching Liquid.

2.1.7. Argon gas. Serves as a protective gas to minimize porosity that occurs when molten aluminum 6061 becomes solid. Porosity occurs because air bubbles are trapped in molten aluminum, resulting in a decrease in the strength of aluminum.

2.1.8. LPG gas cylinders. Serves as a fuel source to raise the temperature of the furnace. This will later melt aluminum 6061 and carbon nanotubes.

Figure 7. Argon gas. **Figure 8.** LPG gas cylinders.

2.2. Research methods

2.2.1. Study of literature. This data collection method is the first step of research by collecting information related to research material. Several journals and theses are used as references and then understood.

2.2.2. Preparation of Equipment and Materials. The material that has been prepared is measured its mass in advance by using milligrams between Aluminum and CNT. The instrument used is examined before entering the casting stage.

2.2.3. Casting. The stages that need to be carried out in the metal casting process are as follows :

- Prepare the Fireplace, Ensure the place and furnace are clean, and check the availability of argon and gas in the ignition process.
- Smelting Material, a composite is a structural material consisting of two or more combined elements, which are combined at a macroscopic level and do not dissolve from one another [11]. Aluminum 6061 is first put into the furnace and awaited until the material melts at a temperature of 700^0C. Next, the Stir Casting process is carried out, ie slowly pouring CNT powder into aluminum 6061 which has melted except Rod Al6061 cast without the need to pour CNT powder, for casting alloys, the naming system is somewhat different. Here the first digit identifies the group, the next two digits identify the alloy and the last digit which is preceded by a decimal refers to the product form for example, 0 for cast results and 1 for ingots [12]. Stirring and giving Argon is needed at this stage, in order to reduce the occurrence of material defects.
- The pouring, the surface of molten aluminum will reduce water vapor in the atmosphere [13]. Liquid aluminum is poured into the mold in this case, the use of a furnace clamp and gloves is very necessary so that it is easy to pour into the mold. The mold required must be made based on the capacity of the furnace and research needs.
- Print Check, At this stage, specimens that have been cooled are removed from the mold. The next few steps are cutting excess metal, cleaning the surface, inspecting the product, adjusting the size to the machining process.

2.2.4. Friction surfacing process. At this stage the cast AL6061 and Al + CNT composites that have been casted will serve as a coating material (Steel) which will be a test specimen with constant rotation and pressure. Stages of the process of friction surfacing, namely:

- Prepare Rod Al6061cor and Al + CNT that have been casted and have passed the machining process with the specified form and standard. Prepare a steel plate that has been polished and cut according to the specified size.
- Ensure the Drilling-Millig machine that will be used for the friction surfacing process is functioning properly and is connected to electricity. Furthermore, installing rods and steel plates on the machine. After the rod and plate are installed make sure the table has been locked to the y-axis direction so that it does not move during the friction surfacing process, then perform the friction surfacing process with the planned travel speed variation. In the friction surfacing process preheating is done before the table is moved. The initial heating in the friction surfacing process is done by using the friction pressure and rotation generated by the engine against the rod and the coating. Preheating is done until the temperature reaches 130 ° C. After reaching this temperature, the table is moved according to the planned travel speed variations. After the table is moved it will produce a layer on a steel plate. The temperature reaches 240 ° C in the friction surfacing process. After the friction process has been completed, make sure the engine has been cut off from electricity. Take a steel plate that has been coated and cut in accordance with the standards of testing to be carried out.

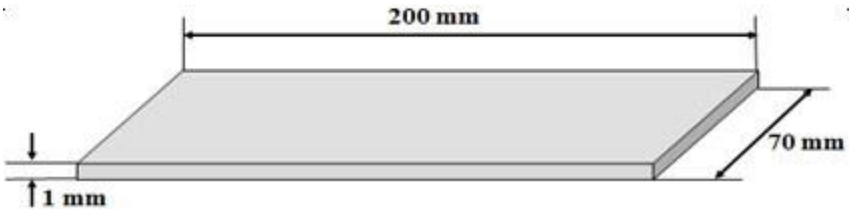

Figure 9. Steel plate specimens.

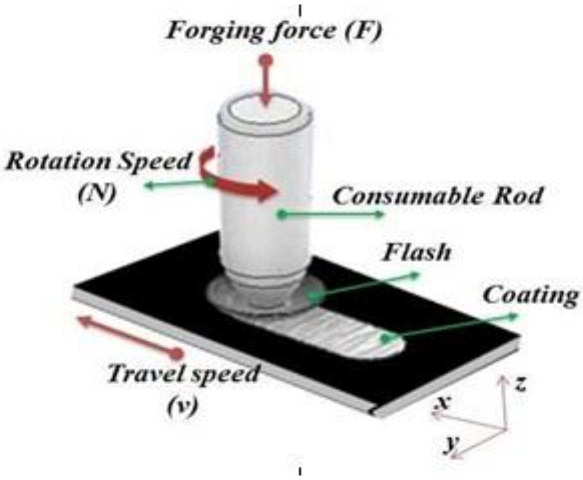

Figure 10. The process of friction surfacing or can be called a thermomechanical process is a process in which there are two treatments on a material. The thermomechanical process is used for the coating process which aims to provide a layer that has a good microstructure [14].

2.2.5. Analysis. Friction Surfacing process specimens are then tested on Bending Machines, Hardness Machines, and Wear Test Equipment.

2.2.6. Observation. Data retrieval is then observed directly and carried out data analysis.

3. Results and Discussion

3.1. Coating quality

Testing the quality of layers is one way to determine the feasibility, dimensions or physical and mechanical properties of the coating results in this study. Checking the quality of the coating is done by comparing the physical or mechanical properties of the planned travel speed variations namely, 3.5, 4.2 and 5 cm / min. In this study the method used to see the quality of the layer is twofold, by measuring directly from each specimen results of friction surfacing with different travel speed rates and bending tests. Measurement of Layer Thickness and Width, Layer quality can be said to be good or feasible if the minimum width of the resulting friction surfacing layer is equal to the width of the rod which is 16 mm.

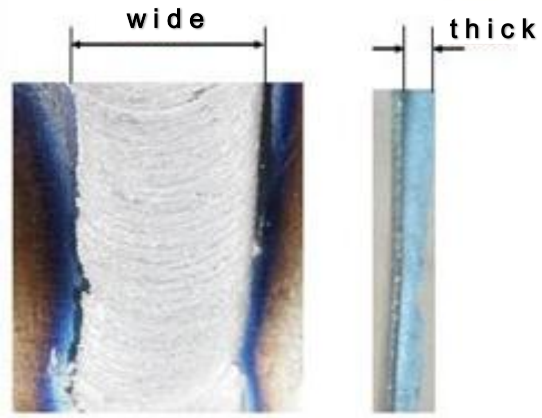

Figure 11. Friction surfacing layer.

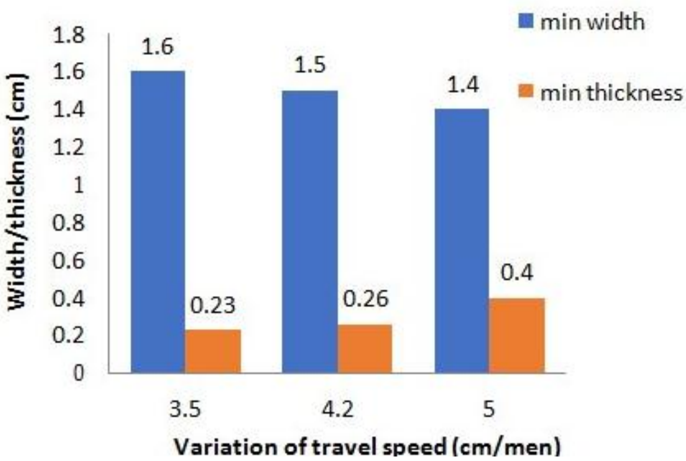

Figure 12. Comparison of the width and thickness of the layer against variations in the rate of travel speed resulting from the friction surfacing process.

From Figure 11. above it can be seen that the results obtained after measuring thickness and layer width, at a travel speed rate of 3.5 cm / min with a minimum thickness of 0.23 cm and a minimum width of 1.6 cm, for a travel speed rate of 4.2 cm / min with a minimum thickness of 0.26 cm and minimum width of 1.5 cm while for the travel speed rate of 5 cm / minute with a minimum thickness of 0.4 cm and a minimum width of 1.4 cm. The results of maximum thickness measurements have also been obtained after taking measurements. The value obtained at the travel speed rate of 3.5 cm / minute with a maximum thickness of 0.25 cm and a maximum width of 1.8 cm, for the travel speed rate of 4.2 cm / minute with a maximum thickness of 0.29 cm and a maximum width of 1.7 cm while for the travel speed rate of 5 cm / minute with a maximum thickness of 0.45 cm and a maximum width of 1.5 cm. The measurement results show that the thinner the layer, the greater the value or measurement of the layer width. This happens because the flash phenomenon tends to lead outward and wider to form a thin and wide layer. For the results of a thick layer will produce a smaller layer width. This is because there is a flash phenomenon that tends to accumulate and only a few point out, resulting in a thicker layer and a smaller layer width.

3.2. Bending Test

Bending testing in this study aims to determine the quality of adhesive and the value of force (N) when testing bending of each variation of the travel speed rate. The force (N) value in the bending test can be seen in Figure 13. Figure 13, shows the force value (N) for each variation of the different travel speed rates through bending testing. At the travel speed rate of 3.5 cm / men the force value is up to 185,841 N, at the travel speed rate of 4.2 cm / men the force value is 174.28 N and at the travel speed rate of 5 cm / men the force value is 156,491 N. Increasing the force value (N) of the steel plate (without layers) for the travel speed rate of 3.5 cm / men increased to 71.51 N, the travel speed rate of 4.2 cm / men increased to 59.94 N and at the travel speed rate of 5 cm / men increased to 42.16 N. The value of the increase in testing for each variation of travel rate speed indicates the influence of the coating on the coated plate. It can be seen that from the measurement results of each variation of the travel speed rate affects the quality of the adhesive or bending test results. The test results show that the thicker a layer, the value of force (N) decreases this is influenced by poor adhesion strength. The highest force (N) value is found in specimens with a layer thickness of 0.23 cm at a travel speed of 3.5 cm / men. Bending test results show the value of force (N) is inversely proportional to the speed of travel speed.

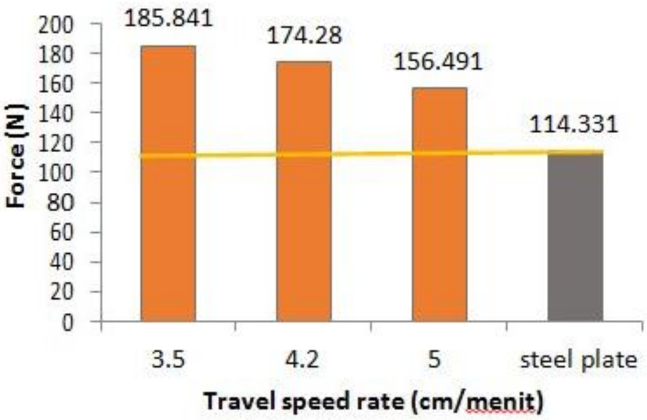

Figure 13. Relationship between force (N) values and variations in travel speed rate.

3.3. Hardness Test

Hardness testing aims to compare the hardness value of 6061 series aluminum specimens that have been casted with the addition of CNT and without the addition of CNT. This hardness test was conducted at the Laboratory of Physical Metallurgy of the Department of Mechanical Engineering at UNHAS, using the Rockwell method. In the hardness test there are 3 types of test specimens, namely the rod hardness test before friction, the rod hardness test after friction and the hardness test of the friction surfacing layer. The data on the results of rod and layer hardness testing can be seen in Figure 14 :

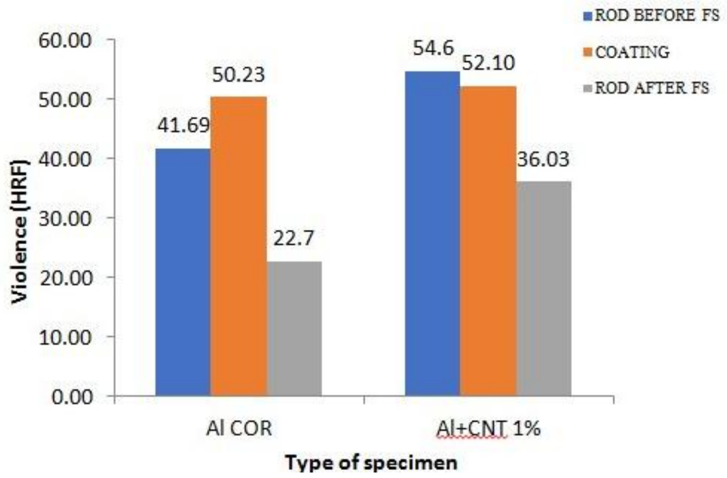

Figure 14. Hardness value of layers, rods before and after the friction surfacing process.

In Figure 14, shows the comparison of the average value between the test results of the coating and rod hardness before and after going through the friction surfacing process. From Figure 4.8 it can be seen that there is a significant change in the value of hardness in the rod specimen before and after undergoing the friction surfacing process. The price of violence on the rod is, for Al6061cor with 41.69 HRF hardness and Al + CNT 1% with 54.6 HRF hardness. The price of Al violence containing CNT is higher than Al without CNT. This is because the addition of CNTs can increase the strength and hardness of a composite compared to a pure matrix. Since its discovery in 1991, carbon nanotubes (CNT) have made a promising reinforcement for nano composites, due to the extraordinary mechanical and physical properties of nanotubes [2]. Rod hardness test results decreased after passing the friction surfacing process clearly seen in Figure 4.8. This is due to the effect of heat during the friction surfacing process to temperatures of 200-250 ° C and rotation which causes the grain structure in the composite material to enlarge and be arranged randomly. In addition, the specimen rod also goes through an air-cooling process that requires a long time to cool, so the grains in the rod get enlarged resulting in decreased hardness. Figure 4.8 also shows the difference in mean hardness in the Al6061cor layer, and Al + CNT 1%. On Al cast the price of violence is 50.23 HRF, and on Al + CNT 1% 52.1 HRF. The value of hardness produced in the friction surfacing layer shows that there is an increase in the hardness value of Rod for Al cor. Increased hardness value up to 8.54 HRF. While in the Al + CNT layer 1% actually experienced a decrease in the price of violence by 2.5 HRF.

3.4. Wear Test
Generally wear is classified into adhesive wear, abrasive wear, corrosive wear and surface fatigue [15]. In this study, wear testing has been carried out with the ASTM G99-04 standard abrasive method with variations in wear time for each specimen. The test was carried out with a load weight of 255 gr with a disk rotational speed of 1.5 rev / sec. Wear time used is 10 s, 40 s and 80 s, respectively. The value of the wear rate that occurs in the layer can be seen in the following figure 15 :

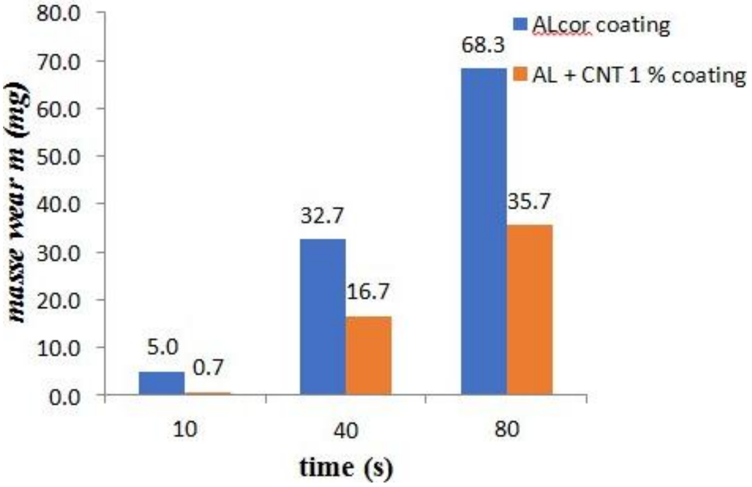

Figure 15. Comparison of wear mass with time.

Figure 15 shows a comparison graph between the mass of the wear (mg) and the time (s) or the length of time for each type of coating. The graph shows the value of the wear mass increases with the length of time the wear is done. This is due to friction between the specimens with the disk that is getting longer. The comparison between the wear mass in the Al cor layer with the Al + CNT layer 1% is clearly seen in Figure 4.9 above. The value of the mass of wear for each time variation in the Al cast layer respectively is 5, 32.7 and 68.3 (mg). As for the value of wear mass in the Al + CNT layer 1% in a row is 0.7, 16.7 and 35.7 (mg). It is seen that the highest wear mass value is in the Al cast layer type for each given time variation. This is because the mass wear value is influenced by several factors including the violence factor. A low hardness value will produce mass or a high wear rate. The hardness value of Al cor layer is lower than the hardness value at Al + CNT layer 1%, so the wear mass value at Al cor layer is higher than the wear mass value at Al + CNT layer 1%.

4. Conclusion

The highest adhesion quality or force value in the bending test is at a travel speed rate of 3.5 cm / min which results in the thinnest layer for three variations of the travel speed rate used. The results of wear testing show that the wear rate increases with the length of time used in the wear process. The highest wear rate is found in the Al6061cor layer type at each time variation used. The Al + CNT wear rate is 1% lower than the wear rate in the Al cast layer.

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