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Sikahyflex-Epoxy Mixed Adhesive's Effect on the Aluminum-Composite Joint's Shear Tensile Strength for the Automotive Industry

(Pengaruh Mixed Adhesive Sikahyflex-Epoksi Terhadap Kekuatan Tarik Geser Sambungan Aluminium-Komposit Untuk Industri Otomotif)

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ABSTRACT

The automotive industry sector encounters challenges in the construction of connections between different materials. Hence, a breakthrough is needed in the automotive industry in manufacturing connections between different wall panel materials. Mixed adhesive materials for different materials are required and represent an innovation in the manufacturing process for joints of different materials due to the need for stiff and slightly ductile adhesives. This research aims to analyze the effect of using a sikahyflex-epoxy mixture adhesive in aluminum-composite joints on the shear tensile strength of the joints for the automotive industry. This research serves as an innovation in dissimilar material connection systems by developing the use of mixed adhesives and cocofiber aluminum-composite adherend materials with environmentally friendly and corrosion-resistant properties. The research material used aluminum 5083-cocofiber composite. The adherend surface was roughened employing sandpaper of #60, #80, and #150. The adhesive used the addition of sikahyflex adhesive to the epoxy adhesive with additional variations of 10%, 20%, 30%, and 40% sikahyflex. Connections between different materials with the single lap joint type refer to ASTM D1002. The roughness test results yielded the best roughness grade #150 on the surface of the aluminum adherend and coco fiber composite. The shear tensile test results by adding 40% sikahyflex adhesive, 0.4 mm adhesive thickness, and #150 sandpapering resulted in a 20% increase in shear tensile strength in the single lap joint of 2.51 N/mm^2. The surface roughness enhanced the adhesive bond strength between mechanical interlocking adhesives and adherend. Meanwhile, the failure modes observed in macro observations included thin-layer cohesive failure, cohesive failure, two-stage failure, and stock-break failure modes. The SEM observation revealed that in the initial propagation of microcracking and voids, which mark the initial onset of adhesive failure, tearing took place, leading to a failure mode in the aluminum-composite coco fiber single overlap joint.

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1. INTRODUCTION

Connections can be established between both metallic and non-metallic materials. Metal joining is commonly achieved through the utilization of welding and riveting systems. Presently, the automotive industry sector is facing challenges concerning the joining construction of diverse materials in the structure and interior walls. The process of joining distinct aluminum-composite materials can be done using the adhesive bonding method [1]. In various industries, particularly the automotive sector, it is imperative to minimize fuel consumption. This requires vehicles to be light in weight by reducing their constituent mass. One possible answer to the problem of reducing vehicle weight is to select materials that are both lightweight and resistant to environmental corrosion [2]. Reduction necessitates the utilization of different materials and a robust connection mechanism. Connections can be made between metal-metal, metal-non-metal, and non-metal-non-metal through several methods of rivet connection, welding [3], and adhesive bonding [4]. Connections are extensively employed in the automotive industry, such as in the transportation of cars, motorbikes, trains, ships, and other industries.

The new innovative connection method for different metal and non-metal materials can be performed using the adhesive bounding method. The advantages of connections using adhesive-bounding encompass simple design, cheapness, lack of machining, corrosion resistance, light [5], and environmental resistance [6]. Joints using adhesive can be utilized for construction manufacturing on interior wall panels in the automotive industry. Apart from adding aesthetics by using different materials, the connection results are neater, stronger, and more environmentally resistant. Mixed adhesives with a type of adhesive that has stiff/brittle properties can use an epoxy type of adhesive. For adhesives with ductile properties, Sika-type modified polymer adhesives can be used to glue glass, metal, and non-metal materials.

Specifically, aluminum has corrosion-resistant and light properties with a density of 2.70 g/cm3. This material is widely used in the manufacturing industry because of its better weight-strength ratio than steel material [7]. Aluminum alloys are increasingly developing and innovating with the addition of alloying elements, such as silicon, magnesium, copper, and others.

Additionally, composites made from natural fibers have great potential in reducing the use of pollutants/synthetic materials, such as glass fiber or carbon. Composite materials consist of at least two materials that act as reinforcement, namely fiber and binder, namely matrix (resin/polymer material) [8]. Also, coconut fiber has great potential for use in composites made from natural fibers. The fiber volume fraction in the coconut fiber reinforces composite of 20% increased by 13.6% with a composite bending strength of 41.6 N/mm2 and is directly proportional to the composite impact toughness of 0.017 J/mm2. The failure mode for coconut coir fiber composites is fiber pull out [9] because it is unable to withstand bending loads [10].

A single aluminum-aluminum overlap connection with a mixture of silyl-modified polymer adhesive and epoxy with a percentage of 25% can increase the shear tensile strength of 15.32 MPa. Apart from being influenced by the addition of a small amount of ductile adhesive, which increases shear tensile strength, this is also influenced by treating the roughness of the aluminum adherend surface with sandpapering #150 and chromic-sulphuric acid (CSA). The roughness treatment causes irregularities in the adherend surface. It produces the effect of increasing even and strong mechanical interlocking between the aluminum adherend and the modified epoxy-polymer silyl mixture adhesive. Regarding the failure mode, a mixed adhesive failure mode occurred [11].

The type of damage mode in a single lap joint (SLJ) refers to the ASTM D5573-99 standard [12]. Figure 1 depicts the types of connection failure modes, including stock-break failure mode, fiber-tear failure mode, light-tear failure mode, cohesive failure mode, adhesive failure mode, thin layer cohesive failure mode, and two-stage failure mode [13]

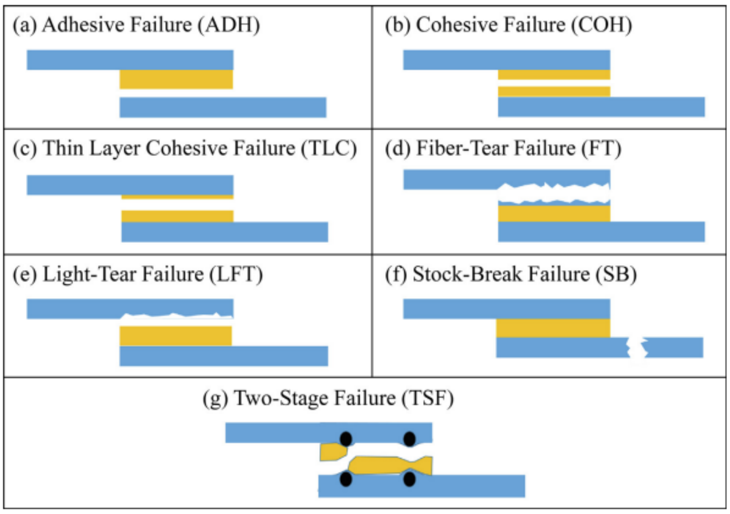


Figure 1. Adhesive Joint Failure Modes [13]

The type of damage mode in a single lap joint (SLJ) refers to the ASTM D5573-99 standard [12]. Figure 1 depicts the types of connection failure modes, including stock-break failure mode, fiber-tear failure mode, light-tear failure mode, cohesive failure mode, adhesive failure mode, thin layer cohesive failure mode, and two-stage failure mode [13].

The adhesive for the joints of different aluminum-coconut fiber composite materials uses a mixed adhesive with the addition of rubber latex to the epoxy adhesive. Treatment of the surface roughness of the aluminum-coco fiber/coconut fiber composite connection material using sandpapering grade 150 provides a surface morphology that forms incisions through macro-observations, thus providing a surface roughness effect on the adherend surface. Small and even incisions will increase the shear tensile strength due to increased bonding power between the adherend and adhesive. A mixed adhesive will be used with the addition of a small amount of 10% rubber latex adhesive in the epoxy adhesive type. This influences the ductile properties of the epoxy adhesive type and increases the shear tensile strength of 1.91 MPa [4].

On the basis of the description of previous studies, research is needed to analyze the effect of the sikahyflex mixed adhesive on the shear tensile strength of aluminum-composite joints for transportation wall panels. For that reason, the research innovated the use of adhesive with a sikahyflex-epoxy mixed adhesive with ductile and brittle properties. Adherent material from coconut fiber waste, which has local wisdom value and is abundant in Klirong, Kebumen, was used. Connecting different materials will provide innovations in the use of interior design on the walls of transportation modes, such as cars or trains.

2. RESEARCH METHODS

The joint adherend material used dissimilar materials, namely aluminum 5083 and coconut fiber composite (coco fiber). The adherend material was cut to a size of 101×25.4×3 mm. Coco fiber-reinforced composites employed a fiber volume fraction of 30% and unsaturated polyester resin matrix binding material (hardener 1-2%) [4]. The surface of the coco fiber aluminum-composite adherend was treated with roughness sandpapering grades #60, #80, and #150 and cleaned using acetone. The adhesive material used was sikahyflex-110 type and epoxy adhesive types A and B. The ratio of Epoxy resin adhesive A and Hardener B was 1:1. The mixed adhesive utilized variations in the addition of sikahyflex-110 of 10%, 20%, 30%, and 40%. The thickness of the mixed adhesive was 0.4 mm. The adhesive was mixed using a mixer for 6-7 minutes at a speed of 60 rpm. Single lap joint specimens were made with a pressure of 0.1 MPa for 24 hours. Post-curing of the connection was carried out before being tested in tensile shear for 100 minutes at a temperature of 100°C [11].

Surface roughness testing was carried out at the Universitas Sebelas Maret production laboratory utilizing a surface roughness tool on aluminum and composite surfaces [14]. The roughness testing procedure was conducted on the adherend surface, which had been given sandpaper surface roughness and cleaned with acetone. The roughness test results appeared on the tool monitor digitally, and what was used was the Ra value. For testing, data were collected for each sample six times. The shear tensile test or single lap shear test was performed using a Universal Testing Machine (UTM) tensile test tool with reference to the ASTM D1002 testing standard, which was carried out at the Sanata Dharma Materials Laboratory. The tensile shear testing procedure was done by clamping the specimen in a clamp with the specimen in a vertical position. The load/tensile load and shear tension speed were set by the UTM machine via the layer monitor. Test results came out in the form of graphs and tables. Each variation was tested with six test samples, which were subjected to shear tensile testing, and the test result data were averaged. While macro morphology observations were carried out at the Metal Processing & Technology laboratory at Universitas Sebelas Maret, a Scanning Electron Microscope (SEM) was performed at the materials laboratory at Universitas Muhammadiyah Surakarta. The SEM testing procedure involved preparing the part to be tested and cutting it to an area of 10 x 10 mm with a thickness of 3 mm. Observations were made through magnification of the morphology, which is expected to be visible by setting the magnification and shifting the observation point. Macro and SEM photo observations were only taken as samples to determine the fracture morphology that occurred after the shear tensile test was carried out on the single lap joint. The single lap joint type aluminum 5083-coco fiber composite is illustrated in Figure 2, whereas the research flow diagram is shown in Figure 3.

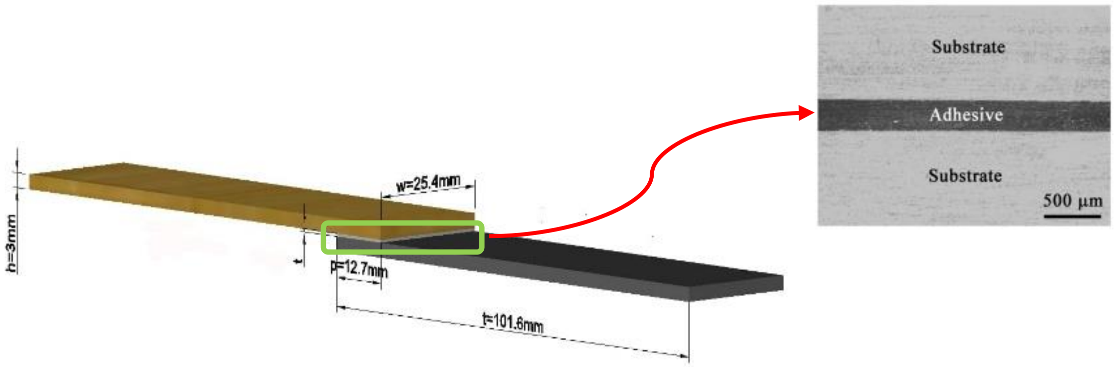


Figure 2. Single Lap Joint Type Connection

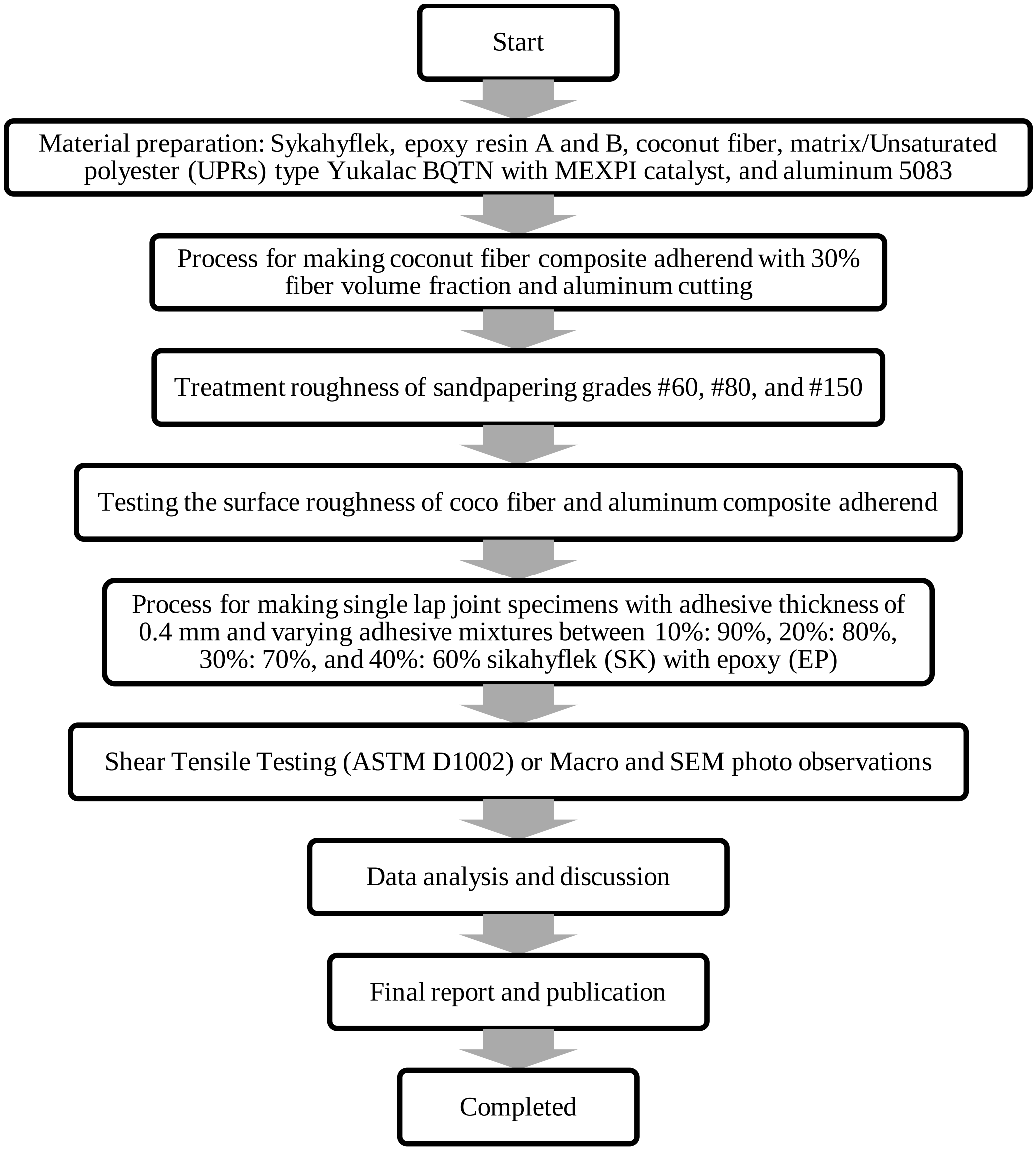


Figure 3. Research Flow Diagram

The research applied the basic principles of Safety, Health, Work Security, and the Environment (K3L) during the research process in the laboratory, both in making test specimens and testing specimens. K3L complied with using gloves, goggles, a wear pack, safety shoes, and a helmet. Gloves functioned to protect hands from chemical solutions or from the production process of cutting materials. Glasses were to protect the eyes from chemical splashes or dust in the environment. Wearpack served to protect the body from metal debris, dust, and chemical solutions. Safety shoes were used to protect feet from impacts and falls of metal materials or chemicals during specimen manufacturing and testing. The function of a helmet was to protect the head from impacts or hard foreign objects such as metal that can fall on the head during work and testing of specimens. K3L applied in the implementation of research is depicted in Figure 4.

a) Plate cutting b) Shear tensile testing c) Macro observations

Figure 4. Application of K3L in Research

3. RESULTS AND DISCUSSION

Testing the surface roughness of adherend dissimilar materials produced different roughness values in three variations of sandpapering grades #60, #80, and #150. The roughness test results (Ra) on aluminum adherend materials and coco fiber composites experienced a decrease in the roughness value with the addition of the grade value from sandpapering. The sandpapering treatment yielded the best roughness value at grade #150, with a roughness value on the aluminum material surface of 2.57 µm and the coco fiber composite surface of 5.14 µm. This was influenced by the irregularity of the resulting porosity and sandpapering scratches on the surface of the adherend, which has the effect of making it easier to increase mechanical interlocking between the adherend and mixed adhesive, thereby increasing the mechanical strength of the single overlap joint [11]. The results of the roughness test values are portrayed in Figure 5.

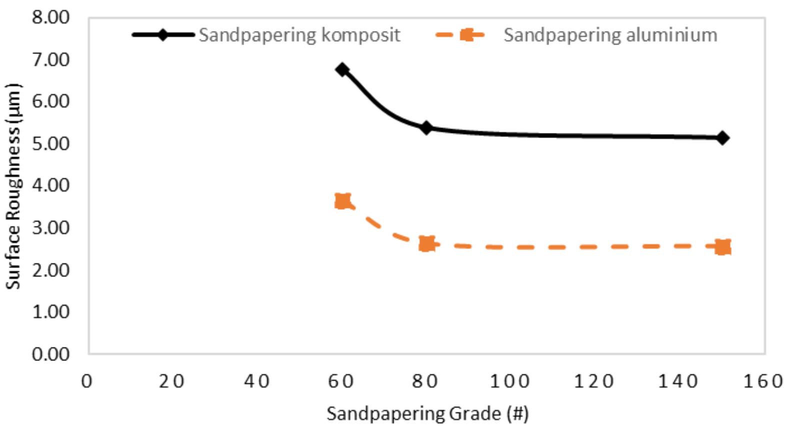


Figure 5. Surface Roughness Adherend Results

The results of the shear tensile test on aluminum joints with coco fiber composite using the sikahyflex (SK) - Epoxy (EP) mixed adhesive are shown in Figure 6. The shear tensile strength value with surface roughness treatment of grade #150 sandpapering adherend produced the highest shear tensile strength value along with the addition of sikahyflex 40% mixed adhesive on the epoxy adhesive of 2.51 N/mm^2. The effect of even and smooth irregularities on the adherend surface could increase the shear tensile strength. Apart from that, the addition of sikahyflex adhesive material, which is ductile to epoxy adhesive which is brittle [15], can have an increasing effect on variations in adhesive addition of 10% to 40% addition, resulting in a quite large increase in shear tensile strength of 20%. The epoxy adhesive has an important role in cohesion because of its strength and stiffness properties. The research results of mixed adhesives with the addition of sikahyflex to epoxy can be applied to construction or connections in transportation modes such as the interior walls of cars or trains. The results of neat and simple connections with strong shear tensile strength can be applied. Apart from that, the joint has the advantage of being water resistant and has brittle and ductile properties. If damage occurs, the joint will not break directly because of the role of the ductile adhesive, in this case, sikahyflex.

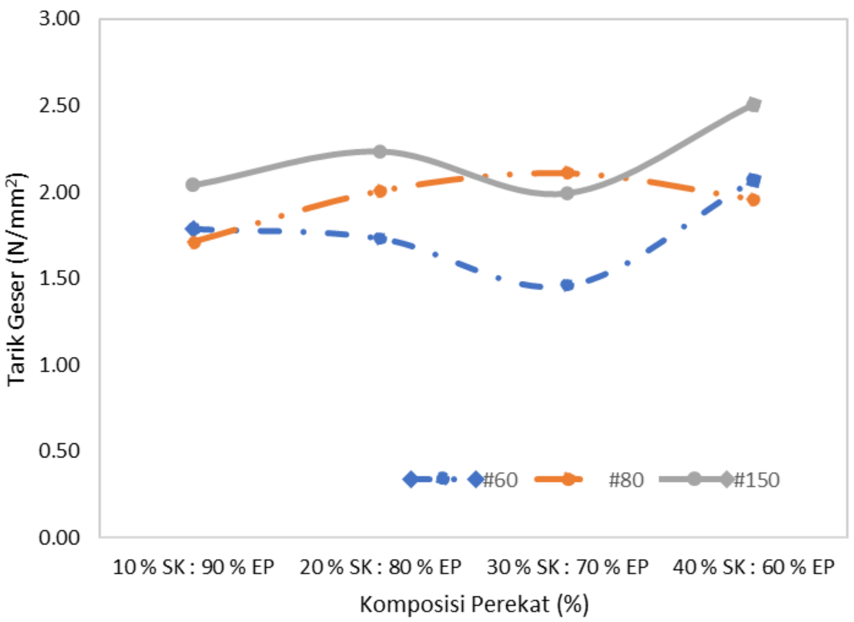
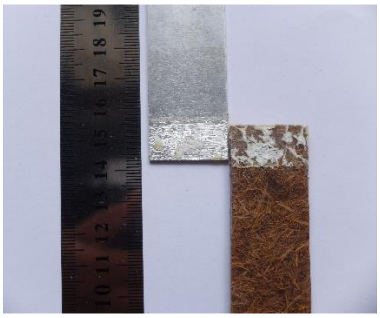
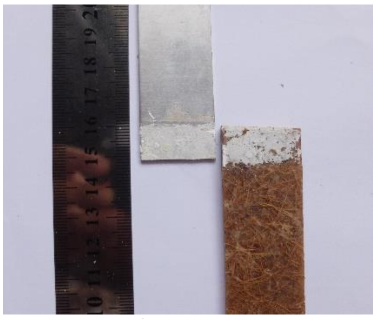


Figure 6. Shear Tensile Test Results of Single Lap Joint Aluminum-Coco Fiber Composite

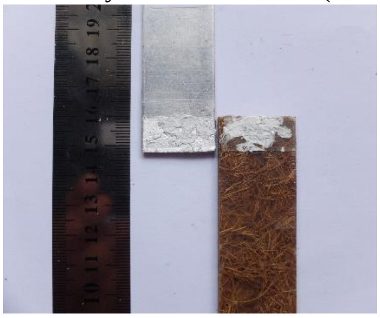
Single lap joints experienced several failure modes, as shown in Figure 7. Failure modes occurred in single lap joints of aluminum with coco fiber composite, including Figure 7. (a) thin layer cohesive failure (TLC), Figure 7. (b) cohesive failure (COH), Figure 7. (c) two-stage failure (TSF), and Figure 7. (d) stock-break failure mode (SB), [13] and fiber pull out [10]. Based on macro-observations, the sikahyflex-epoxy mixture adhesive could be used on the interior walls of cars or trains. The adhesive could bond to two different materials, and failure occurred at the joint, namely the adhesive tears, because it could not withstand the shear tensile load.



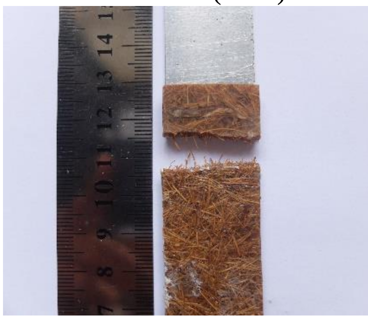
a. Thin layer cohesive failure (TLC)



b. Cohesive failure (COH)



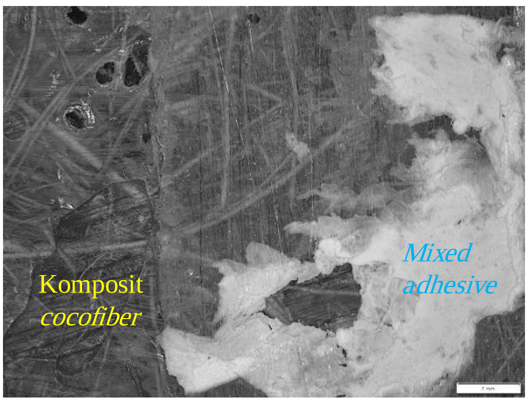
c. Two-stage failure (TSF)



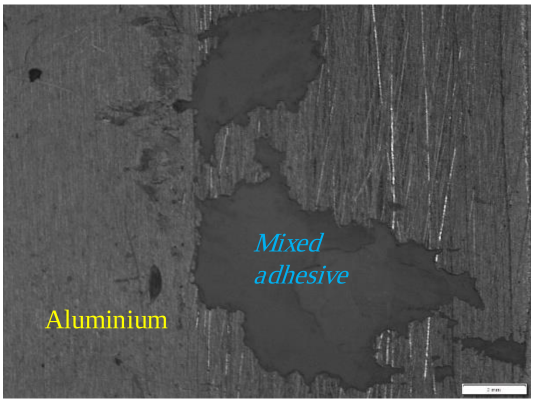
d. Stock-break failure (SB)

Figure 7. Failure Modes in Aluminum-Composite Coco Fiber Joints

Macro observations revealed that the adherend and mixed adhesive failed to tear the adhesive on one side of the adherend surface. Besides, it was seen that the sikahyflex mixed adhesive with epoxy had been mixed on the surface of the adherend, causing a cohesive failure mode [13]. Observations of the mixed adhesive sticking to the adherend surface are shown in Figure 8.a. adhesive on the surface of the coco fiber composite and Figure 8.b. adhesive on aluminum surfaces.



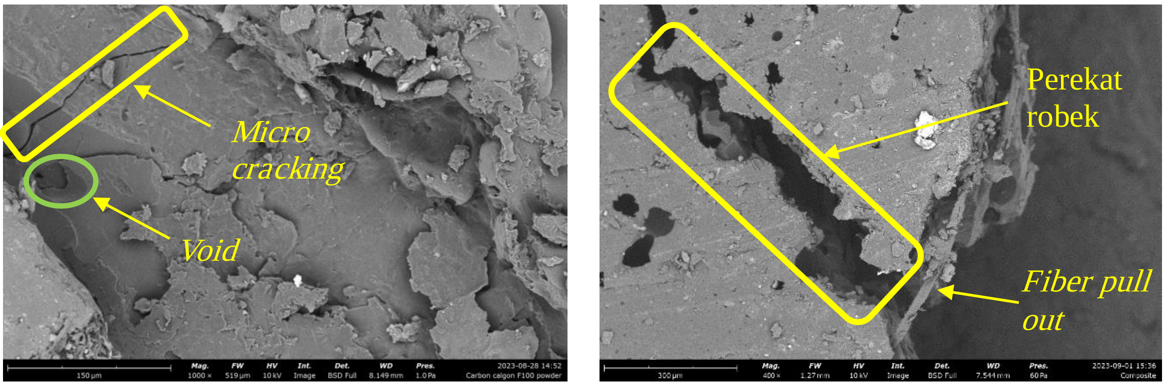
a) Adhesive to aluminum surfaces



b) Adhesive on the surface of the coco fiber composite

Figure 8. Results of Adhesive Macro-Observations

The results of Scanning Electron Microscope (SEM) morphological observations are illustrated in Figure 9.a. on aluminum adherend surfaces and 9.b. on the composite adherend surface. The mixed adhesive was seen cracking due to shear tensile loads during shear tensile testing of aluminum-coco fiber composite overlay joints. The adhesive could not withstand the load, and initial micro-cracking propagation occurred [15], and adhesive tear failure took place. For the adhesive on the surface of the aluminum adherend and cocofiber composite, sikahyflex could be seen mixed with epoxy, which indicates that the sikahyflex adhesive is white and the epoxy adhesive is gray. The adhesive could be mixed evenly, thereby increasing the shear tensile strength of the joint with the support of strong mechanical interlocking interactions and strong adhesion between the adhesive and adherend due to #150 sandpapering treatment on the adherend surface [16]. In mixed adhesives, voids occurred, which could potentially cause the adhesive to crack initially and cause a tearing joint failure mode. Another phenomenon took place when fiber pull-out occurred in the coco fiber composite adherend, which is attracted by the mixed adhesive [17].



a) Aluminum b) Composite

Figure 9. SEM Morphology Results of Mixed Adhesive

4. CONCLUSION

The mixed adhesive on single lap joints treated with sandpapering surface roughness with scratch irregularities at grade #150 provided an increase in bonding strength between the aluminum-coco fiber composite adherend and the sikahyflek-epoxy mixed adhesive by 20%, with a shear tensile strength of 2.51 N/mm2. Shear tensile strength with the addition of 40% sikahyflex adhesive to the epoxy adhesive increased adhesive bonding due to mechanical interlocking between the adherend and the adhesive.

The failure modes included thin-layer cohesive failure, cohesive failure, two-stage failure, and stock-break failure mode. The morphology of macro and SEM observations showed that the sikahyflex adhesive and epoxy were mixed evenly, there was microcraking, which caused the adhesive not to be able to withstand the shear tensile load, and adhesive failure occurred, or the adherend broke/stock break failure mode occurred, resulting in fiber pull out.

Based on the research results, a solution for connecting different materials could be used, and a mixed adhesive with stiff (epoxy) and slightly ductile (sikahyflex) properties has the potential for joining interior walls in a mode of transportation such as a car or train. Roughness treatment will increase the bond strength between two adherends of different materials being joined and enhance mechanical interlocking by providing surface roughness.

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