Properties of hybrid composites using coral reefs waste and coconut fiber

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Abstract. The use of engineering materials in the construction of cars, boats and other are still dominated by metal materials. However, lately metal material has begun to decrease and replaced with non-metallic materials such as composites. The advantages of composite materials compared to metals are good mechanical properties, corrosion resistance, and lower density. The fibers that are often used as reinforcement are synthetic fibers such as glass fiber, carbon, and graphite. This synthetic fiber has advantages in mechanical properties but the price is expensive and not environmentally friendly. Recently the use of composites tends to change from synthetic fiber composites to natural fiber composites because the composite waste of natural fibers is easily decomposed after unused. The problems that are often found from composite materials is broken caused by brittle nature and low tensile strength. One technique that often used to improve the ability of composite materials is the hybridization method, which is the process of combining two or more fibers in a composite. The aims of this study were to obtain baseline data for further development of applied research, in particular, the mechanical properties of hybrid composites that will be utilized as materials for automotive components. This study used unsaturated polyester as the matrix, methyl ethyl ketone peroxide as a hardener, with the fibers derived from coral reefs and coconut fiber as reinforcement. The composites were produced with press hand lay-up techniques, with the fraction of the Acropora weight in the composite keep constant of 30%, but particulate grain size varied 40, 100, and 200 mesh, while the coconut fiber was designed with weight variations of 5%, 10%, and 15%. The results showed that hybrid composites of Acropora mesh 100 with fiber fraction 15% had the highest tensile strength of 25.35 MPa and flexural strength of about 72.04 MPa.

1. Introduction
The selection of engineering materials is an important step in designing machine components. Materials with different properties require different manufacturing processes, but still, the main consideration is that materials must have sufficient strength for construction. Engineering materials that are widely used in manufacturing and construction are still dominated by metal materials. But lately, the use of metal materials has begun to diminish and is replaced with non-metallic materials such as composites. Composite is a material formed from a combination of two or more elements through an inhomogeneous mixture, where the mechanical properties of the constituent elements are different. The advantages of composite materials, when compared with metal materials, are having good mechanical properties,
corrosion resistance, and lower density. In general, fibers that are often used as fillers are synthetic fibers (minerals) such as glass fiber, carbon, and graphite. This synthetic fiber has advantages in mechanical properties but the price is expensive and not environmentally friendly, this encourages researchers to use natural fibers.

The use of composites currently tends to change from composites reinforced by synthetic fibers to composites reinforced by natural fibers. This is because composites with synthetic fibers such as glass fibers are not environmentally friendly, causing the problem of glass fiber waste, which cannot be decomposed naturally [1]. Composites produced from natural fibers are often referred to as biocomposites. Composites with natural fibers have the advantage of being environmentally friendly, cheap, and available in the form of plants and in the form of waste as a by-product. Natural fiber can be cultivated so that its availability can be guaranteed to be sustainable. Another advantage compared to synthetic fiber is its lighter weight, can be treated naturally and does not cause skin irritation [2].

Composites have rigid and brittle properties, where these properties are very dangerous especially for engine components that underwent impact loads and dynamic loads. Rigid and brittle properties of composites can be reduced by hybridization to improve the weakness of composite materials. The types of fibers from hybrid composites can be inorganic-inorganic, inorganic-organic, organic-organic and organic-metal or inorganic-metals, which are bound by matrices both thermosetting and thermoplastic. Hybrid biocomposites can be made by combining two natural fibers in a matrix, with the aim of increasing the mechanical properties of natural fibers. Natural fibers can be in the form of particulates or long fibers. In general, particulate fibers are not very effective in improving fracture resistance but can increase composite stiffness. Particulates improve performance at high temperatures, reduce friction, increase tensile strength and impact resistance, improve machinability, and increase surface hardness [3].

The mechanical properties of natural fibers can be enhanced by chemical treatments such as with solutions of NaOH, KMnO4, silane, and peroxide [4]. Alkaline treatment improves the fusion or binding process between matrix and fiber. Insufficient binding to the interface results in poor mechanical properties. Mwaikambo and Ansell [5] reported that alkaline NaOH treatment with concentrations between 4-6% produced the maximum stiffness and stress on hemp fibers. Soaking time for 2 hours in the treatment of oil palm fiber with 5% NaOH produced the highest tensile strength [1]. The length and diameter of the fiber also affect the mechanical strength of the composite. The highest tensile strength in banana/phenol fiber composites was obtained at 30 mm banana fiber length [6].

Some natural fibers such as sisal, kenaf, hemp, coir, pineapple, banana, hemp, and bamboo have been developed as reinforcement to make composites [7, 8, 9]. Kenaf fiber composites with thermoplastic and thermostet matrices have been used for vehicle interior panels, seat backs, headliners, dashboards, bumpers, and other interior parts [10, 11]. Bamboo fiber composites can be used as an alternative material to replace glass fibers in the skin of a ship [12]. Pineapple fiber and palm fiber have been developed as composites instead of wood so that it can reduce tree cutting and the impact of global warming [13]. House buildings such as doors, windows, walls, ceiling, and roofs have also used natural fiber composites [14, 15]. Meanwhile, Irawan et al. [16] utilizing hemp fiber composites as an alternative material for making prosthesis socket replacing glass fiber composites because glass fibers are not good for health. The polyester composite of coco fiber has the highest tensile strength at 30% fiber volume fraction [17]. In the particulate form of seashell fibers (Andara granosa) in epoxy composites produces the highest tensile strength in 30% fiber weight fraction [18]. The tensile strength of polypropylene / CaCO3 composites increases by decreasing particulate size [19].

Based on these conditions, the mechanical properties of Acropora coral reef waste fiber hybrid biocomposite material combined with coconut fiber and polyester matrix as a binder were investigated. The selection of natural fiber types of coral reef waste is due to its abundant availability which until now has not been utilized. Acropora type coral reefs have a density of $1.89 \pm 0.16$ g / cm3 in bulk, and $2.64 \pm 0.02$ g / cm3 in the treated state [20]. Likewise, the selection of coco fiber because it is abundantly available which is currently only used as firewood for cooking. The urgency of this research is to find a solution to get new materials that are environmentally friendly but have enough mechanical properties.
that are suitable for use as engineering materials. The aim of the study was to obtain scientific data to support the development of further applied research, specifically the mechanical properties of hybrid biocomposites reinforced by the particulate waste of Acropora coral and coconut fiber.

2. Experimental Method
Coral reef waste was obtained from the North coast of Nusa Penida Island, Klungkung Regency which is scattered mixed with sand along the coast. The types of coral reefs used were included in the Family Acroporidae, Genus Acropora, where the most waste was found from Acropora Cervicornis and Acropora Acuminate Species. The scattered coral reefs were collected, the sorting was done to select one type of coral reef namely Acropora, then it was pulverized and sieved as shown in Fig. 1. Sieving using mesh sizes of 40, 100 and 200.

Coconut coir has a length of up to 20 cm. In its use coco fiber is cut to a certain length. The length of banana fiber 30 mm produced the highest tensile strength in banana/phenol fiber composites [6]. After separated coconut fiber cannot be used directly as reinforcement, because of certain substances such as wax coating and others in the fiber that must be removed first through alkaline treatment, NaOH and others that can affect strength and power tie between matrix and fiber. Fig. 2 shows coco fiber which has undergone 5% NaOH treatment for 2 hours. Coconut fiber fibers that have been treated are then cut to a length of 30 mm.
When making composites, coco fiber was randomly distributed. Acropora particulates were mixed with Yukalac 157 BQTN of the saturated polyester matrix, then stirred using a mixer until smooth, and add 1% (v/v) hardener methyl ethyl ketone peroxide (MEKPO) to accelerate the hardening process in the composite. Then the manufacturing process is carried out by hand lay-up techniques.

3. Results and Discussion

Hybrid biocomposites with Acropora particulate reinforcement and coconut coir fiber are successfully produced. The Acropora particulate weight fraction in the composite was made at 30% for all composite products, but the grain size was varied according to 40, 100 and 200 mesh sizes. While the weight of coconut coir fibers in composites varied by 5%, 10%, and 15%.

3.1. Tensile Strength

The highest tensile stress occurs in the particulate size of Acropora mesh 100, with a fraction coconut fiber weigh 15% of about 25.35 MPa. Likewise, the highest tensile strain occurs at the same composition with a value of 2.93%. Meanwhile, the highest elasticity modulus occurs in mesh 40 size with a fraction of coconut fiber weight 15% of 1.45 GPa. Composite tensile test characteristics were presented in Table 1 and graphically were shown in Fig. 3.

From the graph Fig. 3 can be seen the overall trend of the curve. In the fraction of 0% fiber weight, it means that the composite was made with pure polyester without Acropora particulate and without coconut fiber, the tensile strength is 16.9 MPa.

| Mesh size | Fiber weight fraction (%) | Tensile strength (MPa) | Strain (%) | Modulus elasticity (GPa) |
|-----------|---------------------------|------------------------|------------|-------------------------|
| Polyester | 0                         | 16,90                  | 1,30       | 1,32                    |
|           | 5                         | 14,96                  | 1,37       | 1,09                    |
| 40        | 10                        | 17,51                  | 1,83       | 0,96                    |

Table 1. Tensile properties of hybrid composite
The tensile strength of the composite decreased in the 5% fiber fraction weight for all particulate sizes with a strength of about 14.5 MPa. Then it increased in the 10% fiber weight fraction where the mesh size of 100 mesh and 200 mesh has the same strength of about 20 MPa. Furthermore, the curve underwent the highest increase when the hybrid biocomposite was made with a composition of 15% fiber weight and mesh 100-grain size, where the highest tensile stress was 25.35 MPa, and tensile strain 2.93%.

**Fig. 3.** The tensile strength of the hybrid composite

### 3.2. Flexural Strength

The highest flexural stress and modulus of elasticity occurred in the particulate size of Acropora mesh 100 with a weight fraction of coconut fiber 15% where a flexural strength of 72.04 MPa, and a modulus of elasticity of 2.277 GPa. Conversely, the highest flexural strain occurred in mesh size 40 and fiber weight fraction of 10% was 4.27%. Flexural characteristics of the hybrid composite were presented in Table 2 and graphically were shown in Fig 4.

| Mesh size | Fiber weight fraction (%) | Flexural strength (MPa) | Strain (%) | Modulus elasticity (GPa) |
|-----------|---------------------------|-------------------------|------------|-------------------------|
| Polyester | 0   | 75,910 | 6,590 | 1,61 |
|-----------|-----|--------|-------|------|
| 40        | 5   | 62,123 | 3,880 | 1,606|
|           | 10  | 70,632 | 4,271 | 1,650|
|           | 15  | 42,523 | 2,448 | 1,731|
| 100       | 5   | 53,563 | 2,995 | 1,778|
|           | 10  | 49,149 | 2,604 | 1,887|
|           | 15  | 72,041 | 3,359 | 2,277|
| 200       | 5   | 59,222 | 3,464 | 1,711|
|           | 10  | 54,932 | 2,786 | 1,973|
|           | 15  | 68,008 | 4,115 | 1,754|

Figure 4. Flexural Strength of hybrid composite

Through the graph Fig. 4 can be seen an overall trend of the curve. In the fraction of 0% fiber weight, it means that the composite was made with pure polyester without Acropora particulate and without coconut fiber, the flexural strength of 75.91 MPa was obtained. The flexural strength of the composite decreased in the 5% fiber fraction weight for all particulate sizes with a strength of about 55 MPa. Then fiber fraction weight 10% the flexural strength still decreased for 100 and 200 mesh, and slightly increased at 40 mesh. The highest flexural strength occurs at 100 mesh particulate size and 15% weight fraction which was 72.04 MPa.

4. Conclusion
Hybrid biocomposites reinforced with particulate Acropora and coconut fiber were successfully produced. Hybrid biocomposites with particulate size mesh 100 and weight fraction of coconut fiber 15%, has the highest mechanical properties, the namely tensile strength of 25.35 MPa, and flexural strength of 72.04 MPa.
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