International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 2
ISSN: 2088-5334

Weight Fraction Effect of Sugar Palm Fiber as Polypropylene-Elastomer Matrix Reinforcement on Fire Resistance of Hybrid Composite

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Abstract— **Indonesia is one of the countries with abundant availability of palm fiber (Arenga pinnata), polypropylene (PP), elastomer. By utilizing these three types of materials, it is hoped that they can become new composite materials that have good physical properties and characteristics and are useful in engineering applications. PP and elastomer materials used in this study act as a composite matrix and are reinforced by palm fiber *(Arenga pinnata)*. Composites are generally a new material by combining two or more different materials to produce a new material with better properties than the constituent material itself. This study aims to determine the value of the fire resistance of PP composites and elastomers with sugar palm fiber *(Arenga pinnata)* reinforcement with various weight fractions of 20 % (80:20), 30 % (70:30), and 40 % (60:40). Based on the fire resistance test results of hybrid polypropylene and elastomeric composites with sugar palm fiber reinforcement *(Arenga pinnata)* showed that the composite with a fraction of 20 % (80:20) had the lowest linear combustion rate of 0.128 mm/minute. In comparison, the composite with a weight fraction of 40 % (60:40) obtained the highest linear combustion rate of 0.202 mm/minute. For the weight loss rate test, the composite with a weight fraction of 20 % (80:20) got the highest result of 0.759 gram/minute, while the composite with a weight fraction of 40 % (60:40) got the lowest weight loss rate of 0.480 gram/minute.**

Keywords— **Hybrid composites; weight fraction; polypropylene; elastomer; palm fiber; fire resistance.**

Manuscript received 24 Jul. 2021; revised 24 Sep. 2021; accepted 10 Nov. 2021. Date of publication 30 Apr. 2022.

I. INTRODUCTION

A type of commodity polymer that has various advantages and is also free to be modified with supporting techniques is called polypropylene (PP). PP polymer commodity is a polymer commodity that has the highest production rate of other types of polymers because it can have a good impact on various applications. PP has excellent durability, fire resistance, good tensile and impact strength, recyclability, good stiffness, balanced properties, reasonable price, has insufficient impact resistance properties for certain applications and low density. Polypropylene is also often used in structural applications, especially in the construction and automotive fields. By adding fiber reinforcement, the properties and characteristics of the material can be improved [1], [2]. In addition, in the global plastics market PP is the second most economical thermoplastic polymer after polyethylene, and can be applied in various engineering fields. Global PP production in 2018 was 55.9 million metric tons according to a new Research and Markets report, and by 2025 global PP production is expected to reach 83.17 million metric tons. PP is very important for industry and everyday life, such as textiles, packaging, electronics, construction, and automotive. PP is widely used in composite fabrication because it has many excellent characteristics, PP is also suitable for reinforcing, blending, and filling [3], [4]. Materials that have chemical and physical properties consisting of two or more materials are called, a composite will produce a new material with different properties and characteristics. Composite materials are widely used in bridges, buildings, ship hull structures, racing car frames, bathtubs, swimming pool panels, storage tanks, sinks, and marble countertops [5], [6], [7].

Composites with good properties and functions are composite fabrications between their compositions, namely fiber and matrix. Good properties composite are made from arrays of smart materials such as shape memory polymers, magnetorheological, elec-trorheological, magneto-electro-elastic, and piezoelectric [8]. Because of the large number of composites used in various fields of application, many scientists have to analyze the condition of the composite structure during its life. Due to its complexity, the simulation of composite behavior is still very challenging, which causes in the analysis of the long-term properties of the composite structure is an empirical investigation [9]. Lately, the development of making composite materials is more dominant using cellulose-based fibers as reinforcement, this is because the manufacture of composites with synthetic fiber materials such as glass fibers causes higher environmental pollution. Generally, polymer composite applications are applied in many fields such as the household appliances and vehicle industry. While the use of natural fibers for the manufacture of composite materials has various advantages over synthetic fibers such as environmentally friendly, biodegradable, easy to obtain, lightweight, and has high strength. Currently, various types of natural fibers are being developed so that they can be used as environmentally friendly composites [10]. A fiber that comes from vegetable and animal sources is a natural fiber. Natural fibers also include various natural cellulose fibers including flax, coconut fiber as well as silk, wool which is a protein-based fiber. Various conditions can affect natural fibers such as environmental conditions of plants. The higher the cellulose content and the microfibril content in the fiber, the better the fiber properties produced. Natural fibers, such as kenaf and flax, are natural fibers with high cellulose content and good structural advantages [11], [12].

In the current era, natural fiber composites are the most popular composites that are widely used as composite materials. Various applications of natural fiber composites such as medical implants, industry, textiles, and mining. The manufacture of environmentally friendly composite materials is closely related to natural fiber composites. Generally natural fiber composites have good damping properties and low strength properties, therefore research to increase the strength of natural fiber composite materials is very feasible [13-17]. Various advantages that can be obtained from the manufacture of natural fiber composites include density, sustainability, ease of availability, and low cost. The natural fibers that are widely used are sisal, curaua, hemp, coconut husk, and sugar palm. Palm fiber or sugar palm has a scientific name as (Arenga pinnata) is a plant that grows faster than other types of plants. Traditionally, palm trees are usually planted to use the sap which can be used as raw material for sugar and brown sugar [19]. Sugar palm is a tree that grows in many Asian countries and has a lot of fiber. Fibers derived from sugar palm trees have been used for various purposes such as construction. This is a very good opportunity for researchers to further study palm fiber to be a potential material as a reinforcement in polymer composites. Along with the development of research, palm fiber-reinforced composites have been shown to have high advantages, such as fibers having a low price, abundant in nature, biodegradable, and so on. In terms of its properties, fibers have good mechanical strength, low density, and good thermal properties [19]–[21].

Many studies have tested the flammability of fiber-reinforced polymer composites to increase fire resistance strength. Various methods have been carried out, such as adding additives chemical fiber modification, to reduce the flammability of the composite. However, this treatment has side effects, namely the mechanical properties and biodegradability, on the development of refractory composites [22], [23]. Several reinforcing or filler fibers are used as compositions in the manufacture of polymer composites to increase the fire resistance of the composite. Halogenated flame retardants have been used to improve fire resistance with good results and produce undesirable effects such as toxic dioxins during the combustion process [26]. From the description above, the following research has the main objective: to determine the fire resistance strength of polypropylene (PP) and elastomeric composite materials with sugar palm fiber *(Arenga pinnata)* reinforcement various weight fractions.

II. Materials and Methods

A. Materials

The materials used in this study were sugar palm fiber *(Arenga pinnata)* obtained in the Gianyar area of Bali Indonesia, then elastomer purchased from direct or commercial factories, and polypropylene polymer (PP) as a matrix, which was obtained from recycled glass beverage packaging as seen in Figure 1-3.

Fig. 1 Sugar Palm Fiber *(Arenga pinnata)*

Fig. 2 Elastomer

Fig. 3 Polypropylene

The composite has a total weight of 200 grams, consisting of 3 variations of weight fraction, among others: 40% (60:40) = fiber 80 grams, elastomer 84 grams, 36 grams of PP. 30% (70:30) = fiber 60 grams, elastomer 98 grams, PP 42 grams. 20% (80:20) = fiber 40 grams, elastomer 112 grams, PP 48 grams. The hot press machine tool for printing specimens can be seen in Figure 4 and the fire resistance test equipment is shown in Figure 5.

Fig. 4 Hot Press Machine

Fig. 5 Fire Resistance Test Equipment

B. Procedure

The procedure for this research is to first prepare materials and tools, then proceed with the process of cutting the elastomer into small sizes, as well as the process of cutting the fibers and the washing process of PP. And after finishing cutting the fibers, the fibers were immersed in a 5% NaOH solution for 1 hour. Then proceed with the process of preparing all the materials into a composite mold. The research flow chart can be explained in Figure 6. The layout for the composite mold can be seen in Figure 7.

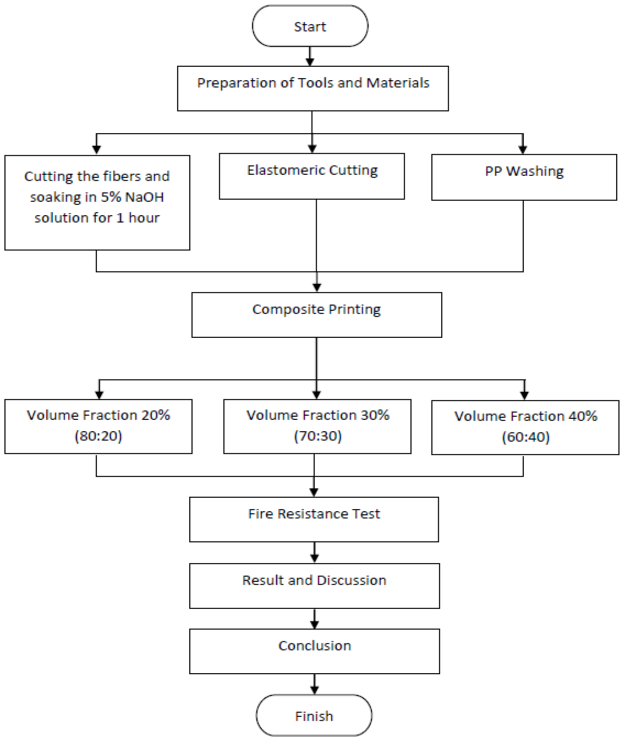

Fig. 6 Research Flowchart

Fig. 7 Composite Layout

The method used in molding hybrid composites of polypropylene and palm fiber reinforced elastomer is hot press. The first step is to prepare a clean mold that has been smeared with glycerin with the aim that the composite will not stick to the mold. Then the process of weighing PP, elastomer, and palm fiber with each variation. Then continued the printing process on a hot press machine with a pressure of 3000 psi for 2 hours and a temperature of 160°C. Figure 8 shows the printed composite.

Fig. 8 Composite Mold

The finished composite was then cut according to ASTM D635-03 as a standard for fire resistance testing, as shown in Figure 9. Composites with a weight fraction of 20% (80:20), composites with a weight fraction of 30% (70:30), and composite weight fraction of 40% (60:40) can be seen in Figure 10-12. Then proceed with the process of testing the fire resistance of each composite.

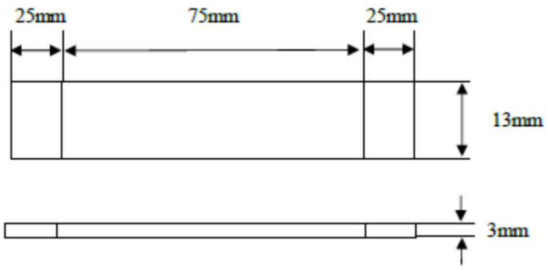

Fig. 9 ASTM D635-03

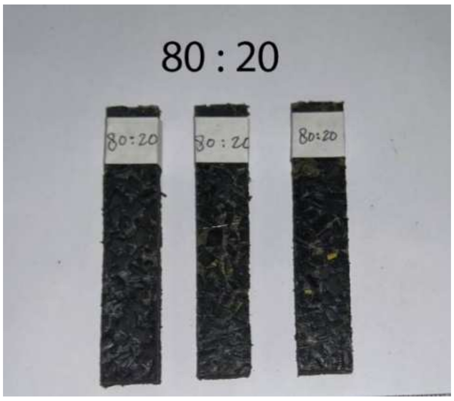

Fig. 10 Weight Fraction Composite 20% (80:20)

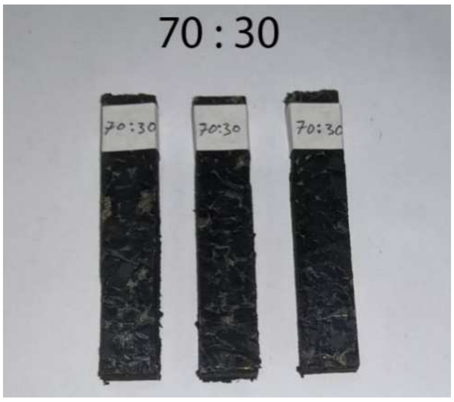

Fig. 11 Weight Fraction Composite 30% (70:30)

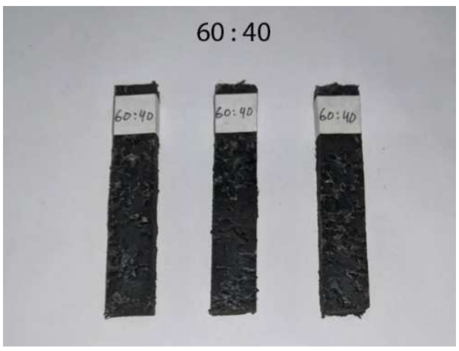

Fig. 12 Weight Fraction Composite 40% (60:40)

III. Result and Discussion

A. Linear Combustion Rate

Based on the results of research that have been carried out on taking test data, namely composites with a weight fraction of 40% (60:40), 30% (70:30), and 20% (80:20), the results of the linear combustion rate test as described in Table 1. The linear combustion rate graph for each composite can be seen in Figure 13.

TABLE I
LINEAR COMBUSTION RATE

Weight Fraction	Long Burning (mm)	Time Burning (mnt)	Linear Combustion Rate (mm/mnt)	Linear Average Combustion Rate (mm/mnt)
80-20	75	9.05	0.121	
	75	10.04	0.134	0.202
	75	9.71	0.129	
70-30	75	13.21	0.176	
	75	13.43	0.179	0.177
	75	13.10	0.175	
60-40	75	14.81	0.197	
	75	15.75	0.210	0.128
	75	14.95	0.199	

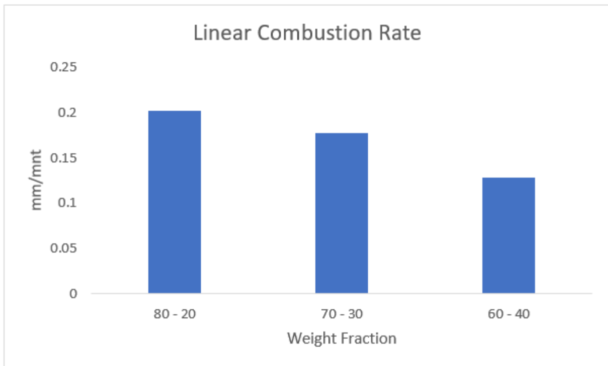

Fig. 13 Linear Combustion Rate

Figure 13 shows the results of the linear combustion rate of each specimen, where the specimen with a weight fraction variation of 40% (60:40) gets the best results because the lowest linear combustion rate is 0.128 mm/minute due to the increasing concentration of sugar palm fiber in the composite is able to inhibit the rate of fire. Sugar palm fiber has a higher decomposition temperature than polypropylene-elastomer matrix, and has a higher hydroxyl group content or as a moisture, which causes it to be more capable of inhibiting heat. Then the specimen with a weight fraction of 30% (70:30) obtained the combustion rate of 0.177 mm/minute, and the specimen with a weight fraction of 20% (80:20) obtained the highest combustion rate of 0.202 mm/minute. With various compositions of sugar palm fiber *(Arenga pinnata)* such as cellulose 54.39%, hemicellulose 5.01%, lignin 31.30%, moisture 6.45%, and ash 1.01%, which makes sugar palm fiber a difficult to burn [27], [28].

B. Weight Loss Rate

Based on the results of the study, composites with a weight fraction of 40% (60:40), 30% (70:30), and 20% (80:20) got the value of the rate of weight loss as described in Table 2.

Graph of the rate of weight loss for each composite can be seen in Figure 14.

TABLE II
WEIGHT LOSS RATE

Weight Fraction	Losing Weight (gr)	Time Burning (mnt)	Weight Loss Rate (gr/mnt)	Average (gr/mnt)
80-20	7.02	9.05	0.776	
	7.13	10.04	0.710	0.759
	7.68	9.71	0.791	
70-30	9.28	13.21	0.702	
	9.70	13.43	0.722	0.692
	8.53	13.10	0.651	
60-40	6.99	14.81	0.472	
	7.10	15.75	0.451	0.480
	7.72	14.95	0.516	

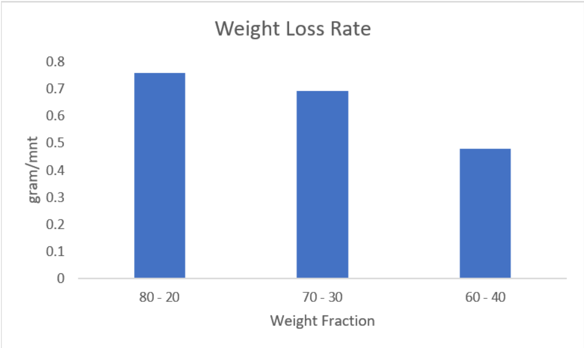

Fig. 14 Weight Loss Rate

Figure 14 shows the test results, namely the rate of weight loss for each specimen. The rate of weight loss is a characteristic that is inversely proportional to the linear combustion rate. Where the results obtained in specimens with a weight fraction of 40% (60:40) obtained a late weight loss rate of 0.480 grams/minute, while specimens with 30% (70:30) weight fraction obtained results of 0.692 grams/minute and specimens with 20% (80:20) weight fraction resulted in the fastest loss rate of 0.759 gram/minute. Increasing the matrix concentration or increasing the matrix's weight fraction can inhibit the linear combustion rate, but the smaller the matrix, the smaller the rate of weight loss. This is because the matrix constituent materials such as polypropylene and elastomers are materials that are more flammable than *(Arenga pinnata)* or sugar palm fiber [29], [30].

IV. CONCLUSION

This study concludes that in the study of the fire resistance test of hybrid polypropylene and elastomer composites with sugar palm fiber *(Arenga pinnata)* reinforcement, specimens with a weight fraction variation of 20% (80:20) obtained the most optimal linear combustion rate of 0.128 mm/minute while specimens with 40 % (60:40) weight fraction got the most optimal weight loss rate which is 0.480 gram/minute.

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