The characterized of the polyester composites reinforced of the hybrid fiber musa acuminata stem fiber (MASF)-hibiscus tiliaceust bark fiber (HTBF) with liquid rubber filler was studied. The object of research is the polyester composite material, hybrid natural fiber reinforcement and filler Carboxyl Terminated Butadiene Acrylonitryle (CTBN). The polyester composite material which is used as a vehicle bumper, is easily broken and has low heat resistance so that its shape easily changes/shrinks due to heat. This research aims to develop the tensile strength, impact toughness and heat resistance of polyester composites. The reason for using the MASF-HTBF hybrid fiber as a reinforcement for polyester composite materials is because MASF and HTBF are natural fibers that have great potential to be developed to improve the mechanical properties of polyester composites, as substitutes for synthetic fibers. In this study, the conditions of MASF and HTBF were given alkaline treatment by immersing them in 5 % NaOH solution for 24 hours then drying. The combined/hybrid ratio between the MASF and CTBF volume fractions is: 5 %:25 %, 10 %:20 % and 15 %:15 %. To increase impact toughness, CTBN filler is added with variations of 5 %, 10 %. The mechanical characteristics of the specimens were carried out by means of a tensile test and an impact test. The change in mass or shrinkage as a result is tested by TGA. The results showed that the MASF-HTBF hybrid fiber-reinforced polyester composite material with CTBN filler has better mechanical properties than single natural fibers, so it is important to develop it further as a material for making vehicle bumper

Keywords: musa acuminata, stem, hibiscus tiliaceust, bark, fiber, polyester composite, tensile strength, impact thoughnes, heat shrinkage, vehicle bumper

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THE DEVELOPMENT OF COMPOSITE REINFORCED HYBRID FIBER MUSA ACUMINATA STEM-HIBISCUS TILIACEUST BARK WITH FILLER LIQUID RUBBER AS VEHICLE BUMPER

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1. Introduction

Tensile strength, impact toughness and heat resistance are important mechanical property characteristics of polyester composite materials that must be identified. The frequent occurrence of damage/failure of automotive bumpers made of polyester composite, shows the phenomenon that the mechanical properties of polyester composite need to be improved. The material for bumper products must have commendable tensile strength, good impact toughness and low heat shrinkage. The material for bumper products shall have commendable tensile strength, good impact toughness and low heat shrinkage. On the other hand, vehicle bumpers made of synthetic fiber reinforced polyester composites such as fiberglass have several disadvantages, high density, poor long-term temperature resistance and expensive compared to other materials (natural fiber). So that the bumber is easily deformed, easy to crack and failure when holding the shock load. Recently, natural fiber reinforced polyester composite materials have begun to be used in the automotive industry for exterior components such as bumpers, extenders and followers [1].

In study [2] to increase impact toughness, resistance to corrosive environments, and shrinkage due to heat, natural fibers are used as reinforcement for polyester composite materials. Comparison of the characteristics of natural fibers compared to synthetic fibers (Kevlar, boron, carbon, nylon and glass fiber) are low production costs, biodegradable, recyclable, non-toxic and flammable. Engineers, researchers, professionals and scientists use natural fibers as an alternative reinforcement for polyester composites, due to their superior characteristics of natural fibers, such as high impact resistance, low weight, low cost, non-abrasive characteristics, environmental friendliness and bio-degradability. Natural fibers that can be used as reinforcement for polyester composites include: abaca, banana, bamboo, cotton, coir, jute, pineapple, sisal and Hibiscus tiliaceust bark fibre [3]. To improve the mechanical properties of Glass Fiber Reinforced Polymers composites are hybridized with natural fibers to increase applications in the field of engineering.

Musa acuminata stem fibre (MASF) and Hibiscus tiliaceust bark fibre (HTBF) is a natural fiber with great potential to be developed as a reinforcement for polyester matrix composite materials. Based on EU End of Life Vehicles (ELV) regulations, it requires car manufacturers to pay attention to the environmental impact of their production and replace the use of synthetic materials with natural fiber-based materials [4]. Polyester composite materials with natural fiber reinforcement have a great opportunity to be applied in the automotive industry, especially in passenger car bumpers. Because it has several advantages, namely low density, light weight, corrosion resistance, cheaper price, easier fabrication process and environmentally friendly compared to low carbon steel plate bumpers [5].

Research to improve the mechanical properties of natural fiber reinforced polyester matrix composites has not been successful. Tensile strength, impact toughness is still below the tensile strength, impact toughness of the impact bumper made of low carbon steel plate. Likewise, the shrinkage that occurs due to heat is also greater. The main molecules that make up the fiber (cellulose, hemicellulose, lignin) cannot yet form interfacial bonds with polyester. As a result, the interfacial bonds formed are imperfect/defective. Defects that arise such as debonding, agglomeration (clumping of polyester), the appearance of voids (voids) which affect the mechanical properties of polyester matrix composites.

Therefore, research on the development of polyester composite materials, reinforced with hybrid natural fibers and CTBN fillers is relevant.

2. Literature review and problem statement

The paper [1], presents the results of research on rear bumpers made of composites, matrix of orthophthalic polyester resin and sisal fiber reinforcement. Composite bumpers are tested for tensile and flexural strength. This experimental stage also aims to obtain practical data for comparative evaluation with theoretical results. Shown, that maximum tensile strength of jute reinforced polyester composite bumper is 32.70 MPa, ruptures when subjected to a shock load (impact) at a speed of 4 km/h, sisal reinforced bumper Maximum tensile strength is 445.00 MPa, does not rupture when subjected to a shock load (impact) at speeds 4 km/h. But there were unresolved issues related to impact speed. The minimum speed of the vehicle is 40 km/h, in actual conditions.

The development of bumpers, with polyester composite materials, with resin matrix and reinforcement and jute, is then compared to impact toughness, production costs and the weight of bumpers made of carbon steel plates [6]. Based on the results of the impact test with the Charpy method, the impact toughness of the composite bumper is 7.14 J/mm^2. When compared with steel bumpers, the cost of composite bumpers is 58 % lower and heat shrinkage is 56.1 %. Research has not provided information on the volume fraction of jute fiber and resin matrix, in conditions of maximum impact toughness. So that the cause of very high heat shrinkage (56.1 %) cannot be explained. Likewise information on the impact velocity, which causes the bumper to be undamaged (in a safe condition). In the United States, passenger car bumpers must be able to absorb, withstand impacts at 5 mph (mile per hour) or about 8.1 km/hour from other vehicles without damaging the car body.

Bumper design for multipurpose country car cabin results expansion [7], the dimensions are length 1430 mm, width 500 mm, and height 500 mm. The material used for the manufacture of bumpers is a fiber glass composite with E-glass type fiber. The selected bumper thickness is 4 mm where the applied stress is 785.98 MPa while the deformation is 18.160 mm, much more smaller than the allowable deformation of 60 mm. E glass is a synthetic fiber, not environmentally friendly, non-degradable, toxic, high heat shrinkage and more expensive than natural fibres.

It applies to front and rear bumpers on passenger cars to prevent the damage to the car body and safety related equipment at barrier impact speeds of 2½ mph across the full width and 1½ mph on the corners. This is equivalent to a 5 mph crash into a parked vehicle of the same weight.

In this study [4] the modified sheet molding compound (SMC) fabrication method was used to improve the mechanical properties of the bumper. Epoxy is considered as a matrix. Using long hybrid fiber in the form of twisted natural kenaf fiber and fiberglass. Five layers have been used to meet the desired thickness of the bumper beam. Samples were made of two layers of kenaf fiber and three layers of fiberglass. Modification of the resin to improve the impact properties of epoxy composites by means of flexibility and toughness. In this study, the toughness of thermoplastics has been used to improve the impact properties in a hybrid natural fiber epoxy composite for automotive bumper beams and has achieved a reasonable increase in impact. The bond formed between the fiberglass resin kenaf is not strong enough. Because the smooth surface of fiberglass often causes peeling of the resin matrix. Properties of epoxy composites, which establish a single-phase or two-phase morphology to make the modifier as an epoxy or from separate phases to maintain thermo-mechanical properties.

Finite element analysis was carried out to compare the performance of unidirectional collisions of Oil Palm Empty Fruit Bunches (OPEFB) fiber epoxy composite bumper beam with aluminum bumper under low speed impact [5]. The performance compared is in the form of: system damage performance, specific energy absorption measures, peak force on impact and velocity diagrams. The specific energy absorption of the composite bumper beam was found to be comparable to aluminum bumper beams with an additional mass reduction advantage of about 56 %. Peak strength required for composite breakdown initiation bumper beams reduced by about 90 % with an 89 % increase in impact time. The higher it is composite plastic deformation contributes to the strength of the composite material to absorb the impact energy from the collision thereby minimizing the collision vehicle passengers.

Study the thermal and mechanical characteristics of a composite made of rattan strip (RS) and glass fiber (GF)-reinforced epoxy resin (ER) has been done [8]. The impact of the coating configuration with respect to the thermal and mechanical characteristics of the RS and GF will be determined. Hand lay-up and hydraulic press techniques are used to produce hybrids, woven laminated RS and GF. The mechanical properties of hybrid composites will be investigated using impact, tensile and flexure tests. The hybrid weave of the GF/RS/RS/RS/GF composite series showed the highest mechanical properties compared to other configuration sequences. Upgrade from one to three layers of RS in a GF hybrid composite core layer effect on flexure, impact, and tensile properties. High decomposition temperature RS and GF hybridization, indicating thermal stability. However there is still rebonding and pull out between rattan and epoxy resin. The cellulose content in rattan is very high. Lignin is hydrophobic in nature and contains three dimensional copolymers, namely: hydroxyl, methoxyl and carbonyl groups.

Biocomposite materials can serve as a replacement for the glass fiber reinforced composites (GFRCs) have been reported [9]. Biocomposite materials have potential to replace steel and aluminium in various applications and it was due to their low density, biodegradability, and ease of recyclability. This research work [10] focused on the use of pine apple leaf fiber (PALF) and Glass fiber reinforced epoxy based composite for the automotive application. The use of biocomposite material for the bumper structure will lead to a weight loss of vehicle, lower fuel consumption and pollutant emissions of greenhouse gases, and higher resistance to impact and corrosion. The PALF and glass fiber reinforced hybrid epoxy composite possess good mechanical properties, which make them suitable for use in structural applications of automobile. The use of biocomposite in automobile can reduce weight and lower CO_2 emission. But PALF has a cellulose content About a 70–80 % cellulose, cellulose which has a crystalline structure. So that it can be used, it must be treated with alkali, by soaking it in 5 % NaOH solution for one week, so it can be good reinforced for composite.

The reasons may be objective difficulties related to heat shrinkage of modified sheet molding compound (SMC) fabrication, performance of unidirectional collisions testing, fiberglass being expensive compared to natural fibres, which make relevant research impractical and difficult. Ways to overcome these difficulties can be in the form of tensile, impact and thermogravimetric (TGA) tests. This is the approach used in [8, 9] but has not been effective. All this allows to argue that it is appropriate to carry out a study aimed at the development of a MASF-CTBF hybrid fiber-reinforced polyester composite material, with CTBF filler.

3. The aim and objectives of the study

The aim of the study is developed polyester composite material reinforced hybrid fiber MASF-HTBF l with CTBN filler as vehicle bumper.

To achieve this aim, the following objectives are accomplished:

– to observe the tensile strength of polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN;

– to determine the impact toughness of specimen;

– to observe the heat shrinkage of polyester composite.

4. Material and methods

Polyester composites reinforced of the hybrid fiber MASF-HTBF with filler CTBN is object of the research. The main hypothesis of the study is the use of hybrid fiber affects the mechanical properties and the heat shrinkage of polyester composite, with filler CTBN. The MASF is taken from the outside of the pseudo stem of bananas of the Musa acuminata variety. Banana tree waste comes from the plantation of North Lombok Regency, which is 13 months old. The HTBF is taken from the bark of the hibiscus tree, which grows around the coast of Senggigi, West Lombok Regency. The extracted fiber is dried in the sun for 48 hours to dry, as shown in Fig. 1. Then the fiber is cut to a length of about 150 cm.

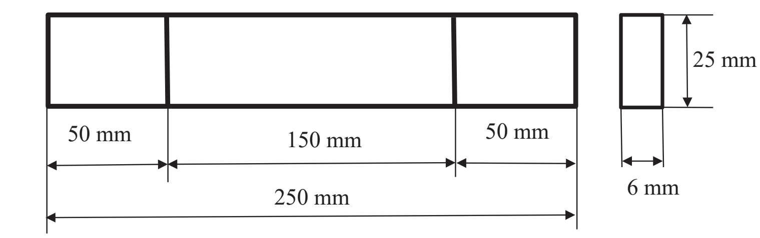
In Fig. 1, it can be seen that the MASF was obtained from the outer layer of the pseudostem of Musa acuminata. HTBF is obtained from Hibiscus tiliaceust bark.

The tensile strength of polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN were obtained using Grafil Test Method 101.13 on an Instron 1026 universal testing machine (serial number H2709) with an Instron 2511–101 500 g load cell (serial number UK953, calibrated with 50 g weights) at a cross-head speed of 0.5 mm/min. The impact test was carried out to determine the effect of the application of hybrid fiber (MASF-HTBF) and filler CTBN on the impact toughness of the hybrid fiber reinforced polyester composite. From the results of the impact test, the impact toughness and impact energy are obtained. Composite specimens were made using the vacuum infusion molding method. The variables of this study are the variation of the volume fraction of MASF and HTBF with the ratio of is 5 %:25 %, 10 %:20 % and 15 %:15 % and variations in the addition of filler CTBN, 5 %, 10 %. The dimensions of the composite tensile test and impact test specimen are 12.7 mm thick according to ASTM D 3039 standard and composite impact test according to ASTM D 256, as shown in Fig. 2. The change in mass or shrinkage as a result was tested by TGA.

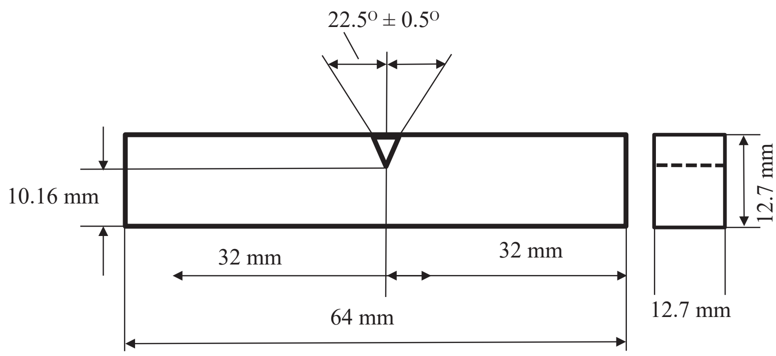
a *b* *c* *d*

Fig. 1. Natural reinforced polyester composite: *a* – Musa acuminata stem; *b* – Musa acuminata stem fiber; *c* – Hibiscus tiliaceust tree; *d* – Hibiscus tiliaceust bark fiber

The thermal resistance characteristics of MASF were studied by Thermogravimetric analysis (TGA) test. Specifications for TGA tool PT 1000, USA, with temperature range up to 1100. Thermogravimetric analysis is a thermo analytical technique, which measures changes in sample weight at a certain time and temperature, to determine the effect of temperature on Weight-Loss. The output of the TGA test contains quantitative and qualitative information on the sample's mass change with temperature. TGA can measure the constituents (important parts) of a material, the decomposition and thermal stability of the sample, and is used as a means of material identification. All tests were repeated 3 times, for each variation of the specimen.



a



b

Fig. 2. Composite specimen dimensions: *a* – tensile test specimen ASTM D 3039 standard; *b* – impact test specimen ASTM D 256 standard

5. Results of the research of polyester composite material reinforcement hybrid fibers

5. 1. The tensile stress and strain of polyester composite material reinforcement hybrid fibers

The results of the tensile test of polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN are shown in Table 1.

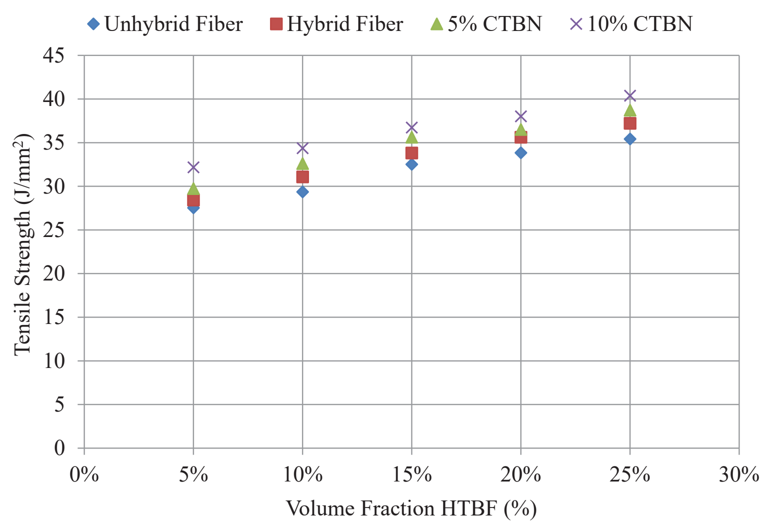
Table 1

The results of the tensile test

Volume Fraction HTBF		5 %	10 %	15 %	20 %	25 %
Tensile Strength	Unhybrid Fiber	27.53	29.36	32.52	33.84	35.42
	Hybrid Fiber	28.42	31.08	33.82	35.62	37.21
	5 % CTBN	29.73	32.61	35.62	36.51	38.72
	10 % CTBN	32.18	34.37	36.73	38.02	40.38
Tensile Strain	Unhybrid Fiber	11.17	10.47	9.25	8.14	5.68
	Hybrid Fiber	12.24	11.49	10.36	9.24	6.69
	5 % CTBN	13.29	12.52	11.39	10.27	8.42
	10 % CTBN	14.32	13.57	12.45	11.34	9.84

Tensile test was carried out to determine the effect of using carboxyl terminated butadiene acrylonitrile CTBN filler on the MASF-CTBF hybrid fiber-reinforced polyester composite material. From the results of the tensile test, the average properties of the tensile strength in Fig. 3, *a* and the tensile strain in Fig. 3, *b* are obtained. The results of the tensile test showed that the highest tensile strength was 40.38 J/mm^2 on the polyester composite specimen with 25 % HTBF reinforcing fiber, 10 % CTBN filler and the lowest tensile strength was 27.53 J/mm^2 on the specimen with unhybrid reinforcing fiber.

The increase in tensile strength of the specimen is due to the bond between HTBF and polyester. The tensile strength of the bond between HTBF and polyester is higher than the bond between polyester, MASF and CTBN, because CTBN is an elastic liquid rubber, so its flexibility is higher, its tensile strength is lower than that of the polyester matrix. It is also shown that the addition of the percentage of HTBF makes a significant contribution to the increase in the tensile strength of the specimen, where specimens without the addition of HTBF have lower tensile strength, for the three polyester composite specimens with 0 %, 5 % and 10 % CTBN filler. This is in accordance with the results of research from [11, 12].



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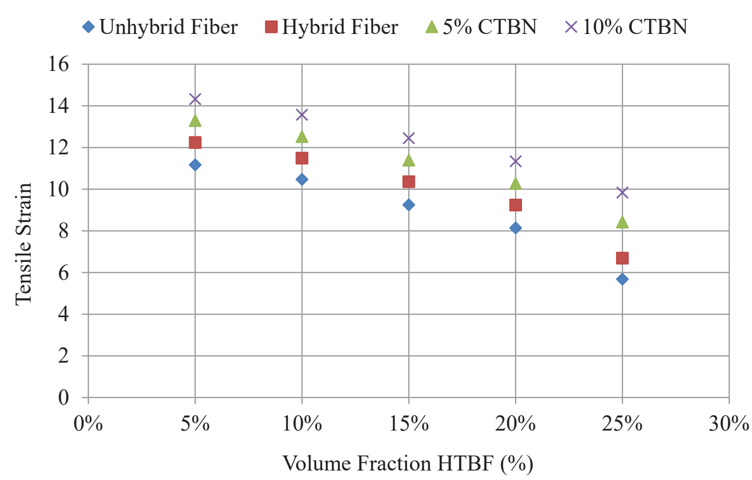

b

Fig. 3. The tensile test results of specimen: *a* – tensile stress of specimen; *b* – tensile strain of specimen

The change in tensile strain of the specimen polyester composite reinforced hybrid fiber MASF-HTBF with CTBN filler is shown in Fig. 3, *b*. The highest tensile strain value of the specimen was 14.32, in the polyester composite specimen with 10 % CTBN filler, the lowest tensile strain was 6.69, in the specimen with 0 % CTBN filler (without the addition of CTBN filler). Increasing the volume fraction of HTBF tends to decrease the tensile strain of the specimen, whereas the addition of the volume fraction of CTBN filler tends to increase the tensile strain of the specimen. The increase in tensile strain is due to the bond between the CTBN filler and MASF, which is more ductile than the polyester bond with HTBF. In addition, CTBN filler bonded to polyester has an impact on reducing the brittleness, tensile strength of polyester, this condition is supported by the results of the study of [13], which suggested that the addition of CTBN to epoxy composites reinforced with carbon fiber increased strain, thereby improving fracture toughness. Interlamina mode I is around 72 % to 84 %.

5. 2. The impact toughness of polyester composite reinforcement hybrid

From the results of chemical composition testing, it is known that MASF fiber contains 73.12 % cellulose, 20.6 % hemicellulose, 4.4 % lignin, 1.88 % extractive compounds/others and a moisture content of 7–8 %. When compared with the chemical content of other fibers, MASF fiber has a higher cellulose content than the Fimbris tylis, hemp, jute, rice straw, wheat straw, seaweed, sorghum straw, coir, and alfa grass fibers but lower than the cotton, flax, sanseviera fibers, and sisal fiber as explained at work [12]. In addition, CTBN filler bonded to polyester has an impact on reducing the brittleness, tensile strength of polyester, this condition is supported by the results of the study of [14] which suggested that the addition of CTBN to epoxy composites reinforced with carbon fiber increased strain, thereby improving fracture toughness. Interlamina mode I is around 72 % to 84 %.

The impact test results of the MASF-HTBF hybrid fiber-reinforced polyester composite specimens with CTBN filler are shown in Table 2.

Table 2

The results of the impact test

Volume Fraction MASF		5 %	10 %	15 %	20 %	25 %
Impact Toughness	Unhybrid Fiber	0.018	0.025	0.072	0.094	0.076
	Hybrid Fiber	0.021	0.03	0.077	0.102	0.082
	5 % CTBN	0.025	0.034	0.082	0.108	0.086
	10 % CTBN	0.031	0.038	0.091	0.112	0.092
Impact Energy	Unhybrid Fiber	2.68	4.14	11.25	14.47	11.17
	Hybrid Fiber	3.75	5.24	12.36	15.49	12.24
	5 % CTBN	4.79	6.27	13.39	16.52	13.29
	10 % CTBN	5.84	7.34	14.45	17.57	14.32

The addition of CTBN filler to the polyester composite specimens increased the impact energy and impact toughness. The highest energy and impact toughness values in the specimen were 17.57 J and 0.112 J/mm^2 occurred in the specimen with 20 % MASF reinforcement, with 10 % CTBN filler, as shown in Fig. 4, *a*, *b*.

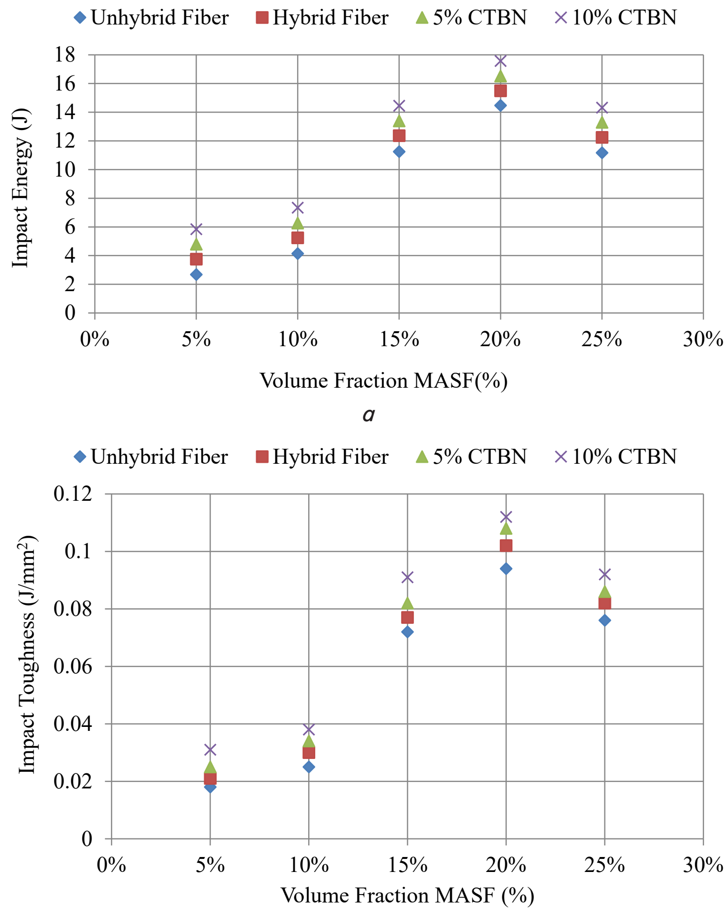

Fig. 4. The impact test results of specimens:
a – impact energy (J); *b* – impact toughness (J/mm^2)

The lowest energy and impact toughness in the specimen were 3.75 J and 0.021 J/mm^2 and occurred in specimens with 5 % MASF reinforcement and 0 % CTBN filler (without CTBN filler). The addition of a MASF volume fraction below 20 % tends to increase energy and impact toughness. The increase in CTBN filler volume fraction also causes an increase in energy and impact toughness, as shown in Fig.4, *a*. Based on research results [11, 12], the MASF ductility more higher than the HTBF ductility. The ductility of a material is a factor affecting the absorption of energy due to external forces. The more tenacious the ability to absorb energy the better/more energy absorbed. So that the percentage of MASF is greater, it has an impact on increasing the impact energy and the impact toughness of polyester composites.

5. 3. Heat resistance character of polyester composite reinforcement hybrid fibers

The heat resistance of the polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN) is determined by observing the decomposition process. Thermogravimetric (TGA) test results of specimen are shown in Fig. 5. in the form of a relationship between mass and rate reduction curves. The decrease in mass was obtained from the thermogravimetric test (TGA). The TGA test was carried out with a sample weight of about 20 mg specimen, with an inert gas (Argon), at a heating rate of 10 °C/min.

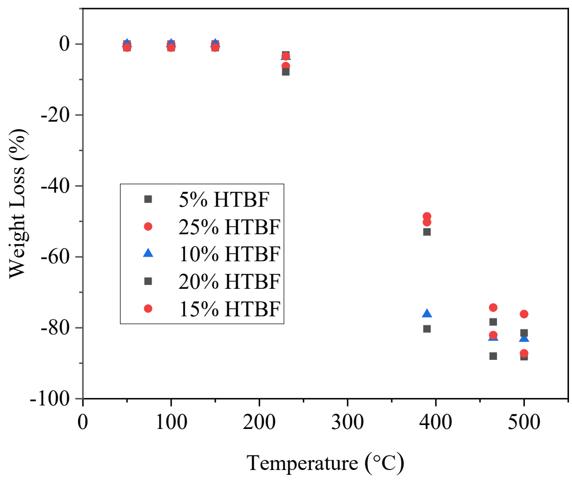

Fig. 5. Thermogravimetric (TGA) test results of the polyester composite reinforcement hybrid fiber musa acuminata stem-hibiscus tiliaceust bark fiber with filler carboxyl terminated butadiene acrylonitryle

Based on Fig. 5 it can be seen that there are decomposition symptoms that occur in the sample due to heating in the Thermogravimetric (TGA) test. Decomposition is a chemical reaction process that releases heat and indicates the occurrence of thermal decomposition of the sample organic matter [15]. From the TGA test result curve for decomposition due to thermal degradation of all samples, there are 4 main steps related to degradation due to decomposition reactions in polyester composite specimens reinforcement hybrid fiber MASF-HTBF with filler CTBN).

Stage 1 is the initial devolatilization process, characterized by the first depression in the reduction rate curve. The weight loss that occurs is very low ranging from 05–6.23 % for the condition of the HTBF volume fraction of 5 %, 10 %, 15 %, 20 % and 25 % respectively. This stage is related to the release of water content present in the MASF-HTBF hybrid fiber and very light volatile compounds [12]. The devolatilization process in the specimen occurs at a temperature of about 160 °C. Stage II is a transitional stage characterized by a relatively stable rate of mass loss compared to the devotilization stage. The transition stage is marked by the release of volatile compounds, which have begun to decrease, and the fiber begins to degrade slowly. The transition stage occurs up to 245 °C. In step III, the MASF-HTBF hybrid fibers decomposed rapidly and the decomposition of the entire biomass occurred at 250 °C, then the MASF-HTBF hybrid fibers also decomposed completely up to 360 °C. The weight loss that occurred decreased due to an increase in the volume fraction of HTBF. Weight reduction is: 80.3 %; 76.2 %; 50.24 %; 47.24 %; 43.26 % for the condition of the HTBF volume fraction of 5 %, 10 %, 15 %, 20 % and 25 % respectively. Stage IV is the slow combustion reaction of the residue (residue) which is accompanied by a very slow decomposition which is characterized by a very small rate of weight loss (mass reduction) and a relatively stable mass amount up to a temperature of 500 °C. The weight loss that occurred were 88.18 %; 88.15 %; 83.12 %; 78.37 %; 76.16 % for the condition of the HTBF volume fraction of 5 %, 10 %, 15 %, 20 % and 25 % respectively.

6. Discussion of the effect hybrid fiber and filler reinforcing polyester composite

The percentage of HTBF fibers affects the tensile strength of hybrid fiber reinforced polyester composites, as shown in Fig. 3, *a* and Table 1. The tensile strength of the MASF-HTBF hybrid fiber reinforced polyester composite is higher than that of the MASF single fiber reinforced polyester composite, based on the results of [11]. The tensile strength of HTBF fiber is higher than that of MASF fiber, on the other hand the tensile strength of HTBF fiber is lower than that of MASF fiber. The tensile stress is higher than that of the Laminated Bamboo Composites (LBCs), with a thickness of 2 mm as a result of [16] research, is 2.5 MPa. According to [4] the tensile strength of natural fibers/biofibers such as MASF, HTBF is influenced by cellulose as the main component in natural fibers. The strength and stiffness of natural fibers are produced by the cellulose component through hydrogen bonds and other bonds. The use of HTBF fiber as a reinforcement reduces the tensile strain of the polyester composite, as shown in Fig. 3, *b*, so that the elongation and flexural stress also decrease. Based on the results of the study [12] the use of MASF, (without hybrid with HTBF), increased the flexure stress by 31.9 %.

CTBN filler functions to increase impact energy as well as impact toughness, a polyester composite reinforced with MASF-CTBN hybrid fiber, as shown in Fig. 4 and Table 2. The impact toughness of polyester composites without CTBN filler was lower than the impact toughness of polyester composites reinforced with MASF-CTBN fiber-reinforced hybrids, with CTBN filler. CTBN is physically in the form of liquid rubber, which functions to fill in the gaps in the interfacial bonds between polyester, MASF and HTBF fibers. This phenomenon is supported by the results of a study [17], which concluded that CTBN elastic strain, the flexibility of the polyester, causes the tensile strain to increase. The increase in tensile strain has the effect of expanding the stretched area so that, if there is a shock load, more energy is absorbed. In other words, the impact toughness is better than polyester composite without CTBN filler.

The heat resistance causes the heat shrinkage to occur on the polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN. It is determined by observing the decomposition process of the specimen, after a thermogravimetric test (TGA) has been carried out. The increase in the heat resistance of the specimen results in a decrease in heat shrinkage, which is indicated by a decrease in the percentage of weight loss of the polyester composite reinforcement hybrid fiber MASF-HTBF with filler CTBN, as shown in Fig. 5. The MASF-HTBF hybrid fiber, which causes an increase in the heat resistance of the specimen, is supported by the results of [15].

The volume fraction limit of the MASF-HTBF hybrid fiber is 30 %. Exceeding the volume fraction limit, the physical condition of the polyester composite material tends to be rough, with lots of voids, which is its weakness. Although shrinkage due to heat is reduced.

It is difficult to improve the distribution of tensile strength, toughness over the entire surface of the MASF reinforced polyester composite specimen. The tensile strength of MASF is low, the interfacial bond between MASF and polyester is not perfect, pores still occur on the surface of the specimen, so the heat shrinkage process is so high.

The disadvantages of this study are the difference in surface roughness between MASF and HTBF causes weak surface bond between fibers, HTBF surface roughness is low and is water repellent so that the hybrid fiber bonds with polyester peel off, the difference in fiber diameter causes voids thus affecting the strength of the polyester composite.

The development of this research, the influence of surface roughness, filler, diameter of hybrid fiber reinforcement polyester composite material. Because these parameters are the basic physical properties possessed by natural fibers. So, it is very urgent to study to improve the mechanical and physical properties of polyester composite materials.

7. Conclusions

1. Application of reinforcement hybrid fiber MASF-HTBF increases the tensile strength of polyester composite with filler CTBN. The increase in tensile strength is 27.53 J/mm^2 to 40.38 J/mm^2.

2. The impact toughness and energy impact of polyester composite with filler CTBN also increased due to reinforcement with hybrid fibers MASF-HTBF. The increase in impact toughness is 0.021 to 0.112 J/mm^2 and the increase in impact energy is 3.75 to 17.57 J.

3. The heat resistance of polyester composite increased so that the heat shrinkage decreased, indicated by a decreasing in the percentage of weight loss from 88.18 % to 76.16 %.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has data included as electronic supplementary material.

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