Key Engineering Materials
ISSN: 1662-9795, Vol. 897, pp 51-56

Submitted: 2021-05-02
Accepted: 2021-05-06
Online: 2021-08-17

Sustainable Fabrication Technology of Composite Board by Kenaf-Polypropylene for Automobile Door Interior Applications

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Keywords: Resin, Kenaf-Polypropylene, CO_2, Pre-board, Door trim

Abstract. Polypropylene resins have been enfolded with the automotive industry and suppliers to produce several spare parts. This is aimed at achieving zero emissions, kenaf plant which in Latin is *Hibiscus Cannabinus* is a natural fiber replacement resin. Natural fiber composites come in many different types, but kenaf has been exploited extensively over the last few years. The pre-board flow process of kenaf-polypropylene starts from mixing kenaf about 40% with 60% polypropylene, forming a pre-mat as the first output, entering the main treatment with the hot press into pre-board as the final output. Kenaf-polypropylene door trim is very absorbent of CO_2, which is related to natural fiber base material. Door trim with kenaf-polypropylene as the base material reduces the weight by about 30% of the previous polypropylene resin and still provides high rigidity even at a reduced weight. The entire process is requiring 48382.4 kWh / month per cycle of total power consumption.

Introduction

Nowadays, environmental awareness is a common problem that faces around the world. Based on the 21st Session of the Conference of the Parties (COP21) Paris agreement to the United Nation Convention on Climate Change (UNFCCC) held on December 2015, 196 countries in the world agree to reach the agreed upper limit temperature which is below 2ºC with zero emissions of greenhouse gases in the second half of this century as an action [1-3]. Paris agreement has a maximum target of 1.5ºC, the 1.5ºC target can be achieved if big efforts are implemented to reduce greenhouse gas emissions between 2030 and 2050 [2]. Morocco is currently a leader in terms of efforts to fight climate change, emphasize the country's commitment towards the Paris Agreement on climate action [2]. Morocco has one of the largest solar farms in the world near Ouarzazate, a city known as the gateway to the Sahara, which has been provided electricity to approximately 650,000 people since 2016 [2]. This solar mega-project is used to assess performance by considering the four categories those are greenhouse gas emissions, renewable energy, energy use, and climate policy.

On the other side, Indonesia's participation in the Paris Agreement is a priority for President to increase the global role mandatory to enhance international cooperation in overcoming global problems that intimidate people include climate change. Indonesia will be part of the Conference The Parties will have a strong voice every decision-making process is related to everything form of climate change and adaptation policies [3]. Indonesian National Development Planning Agency (Bappenas) explains that the transportation sector is one of the biggest contributors to gas emissions with a trend of significant increases year by year [4]. There are four gas emissions caused by vehicles, HC (Hydrocarbons), CO (Carbon Monoxide), CO_2 (Carbon Dioxide), and NOx (Nitrogen Oxide). Bappenas issued a guideline that the national action plan in the transportation sector is emission reduction targets in the transportation sector must be approximately 0.8 gigatons of CO_2 [4].

There is a local company that provides soundproofing door trim with coconut fiber as natural fiber base materials. Coconut fiber is a natural fiber material which very easy to find in all corners of Indonesia. Coconut fiber is an eco-friendly material that contributes to reducing CO_2. Currently, that local company processed 300 tons of coconut fiber per month fabricate become soundproofing door trim and supplied to vehicles manufacturing company [5, 6]. However, this research will be focused on the manufacturing industry in Indonesia that produces interior parts of the vehicle that became a pioneer to used kenaf-polypropylene as replaced resin-polypropylene raw material for its interior automotive components. Generally, kenaf is a short term plant life which around 100-140 days old, developed by seeds. Almost all parts of the plant can be used as raw materials for various industries. Kenaf leaves contain 24% crude protein which is very good for poultry feed and ruminant. Kenaf seeds containing 20% fat are good for cooking oil because they contain lots of unsaturated fatty acids. Kenaf wood is very good as raw material for the particleboard industry for various purposes such as furniture, doors, and windows. Kenaf fiber is widely used as raw material for various industries such as fiberboards, pulp and paper, textiles, carpets, and handicrafts. Fiberboards from kenaf fiber are currently used as materials for car interiors such as door trim, dashboard, etc. In order to minimize CO_2, one auto part company in Indonesia has used kenaf fiber as raw materials to produce the pre-board [5, 6].

Currently, kenaf-polypropylene base materials are applied in the latest model of vehicle manufactured by one Automobile Company [6]. Middle executive car which produced in Japan used in all over the world. Natural-fiber composites have many different types, however, kenaf fiber has a high tensile strength which can reach the maximum stress before the material is crack [7]. Kenaf fiber offers potential reductions in weight, cost, CO_2, and recyclability. Kenaf fiber also provides additional advantages that eco-friendly materials [6]. Cultivation of kenaf occurred in the rainy season in Indonesia which around October to April, except the dry selection process usually occurred at the beginning of May which the dry season starts to begin in Indonesia and developed nanofiber electric spinning machines or electrospinning. The main purpose of an electrospinning machine is to maximize the retting process and dry selection process of kenaf fiber. Accordingly, kenaf fiber can produce without considering the season and weather. Therefore, kenaf fiber can be used as raw materials for mass production. Production of kenaf fiber needs an appropriate environment. Electrospinning is an alternative way to support the realization of mass production of pre-board. Thus, this research is very important in pursuing a continuous improvement and as the awareness to reach zero emission challenge due to COP21 Paris agreement in the transportation sector. The objective of this research is to reduce the weight of door trim using kenaf-polypropylene base materials. The total power consumption per cycle per month during fabrication, and gas emission reduction through CO_2 with the eff resin polypropylene against environmental effects are discussed in detail.

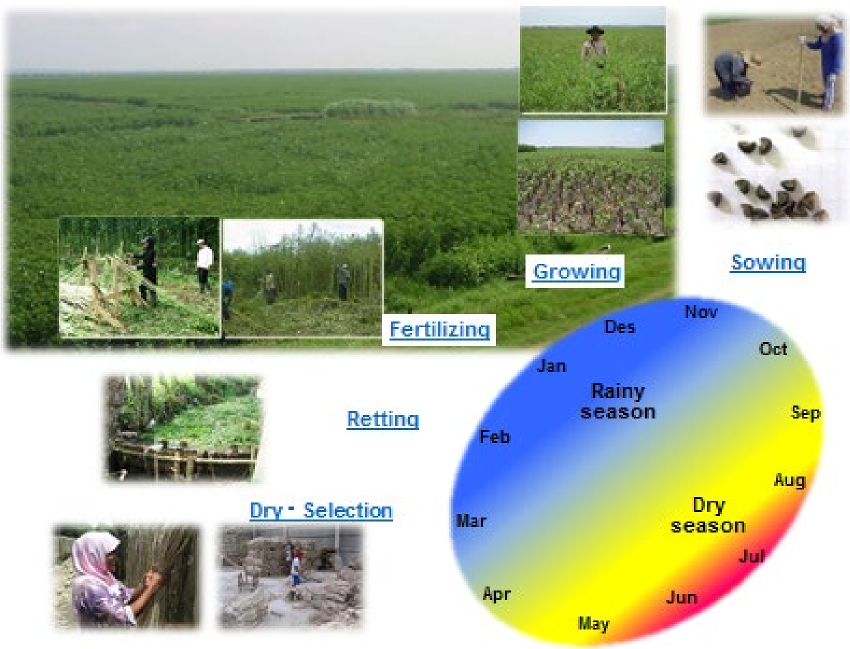

Figure 1. Step by step of kenaf processing from sowing to dry processing in one-year cycle.

Experimental Procedure

The flow cultivation of kenaf simply illustrated as shown in Fig. 1. Step by step of kenaf cultivation consists of sowing process, growing, fertilizing using nitrogen and phosphorous, retting process, and dry selection. The sowing process is the method to put the seeds inside the soil, then kenaf seeds would grow up. The sowing process of kenaf seeds can be done by hand sowing the seeds or by using seed drills. Sowing basically a method to put the seeds inside the soil at the desired depth. Kenaf seed is planted 1.25 until 2.5 cm deep. In Indonesia, kenaf can be planted and grown as early as November. Kenaf plants grow up approximately three to four meters in height. Plant populations of kenaf grow up approximately 185,000 until 370,000 plants per hectare. Kenaf grows better on supplemental nitrogen application is to optimize kenaf yield, which gives the best result. Nitrogen (N) and Phosphorus (P) are applied at the rate of 100: 200 kg.ha^{-1}. The fertilizing process using nitrogen and phosphorus showed significant positive effects on the growth of the kenaf plant. The retting process is the process of separating or extracting fibers from non-fiber material by immersing kenaf stems or ribbons in water and involving the enzyme activities of the complex microorganisms. Duration of immersion can simplify the retting process from 10-25 days to 8-13 days. In the final step, kenaf fibers must be selected in the dry condition. This process is usually occurred on the beginning of May which dry season in Indonesia started. The macrostructures of pre-board manufacturing from kenaf-polypropylene base materials have analyzed. In addition, the door trim weight has measured as a final product of kenaf-polypropylene base materials with a weight reduction from resin-polypropylene base materials. Furthermore, the environmental effects of kenaf-polypropylene are analyzed by Statistics Indonesia (BPS) data [8-10]. The total power consumption during the process and the price of kenaf, resin, and polypropylene are manually calculated.

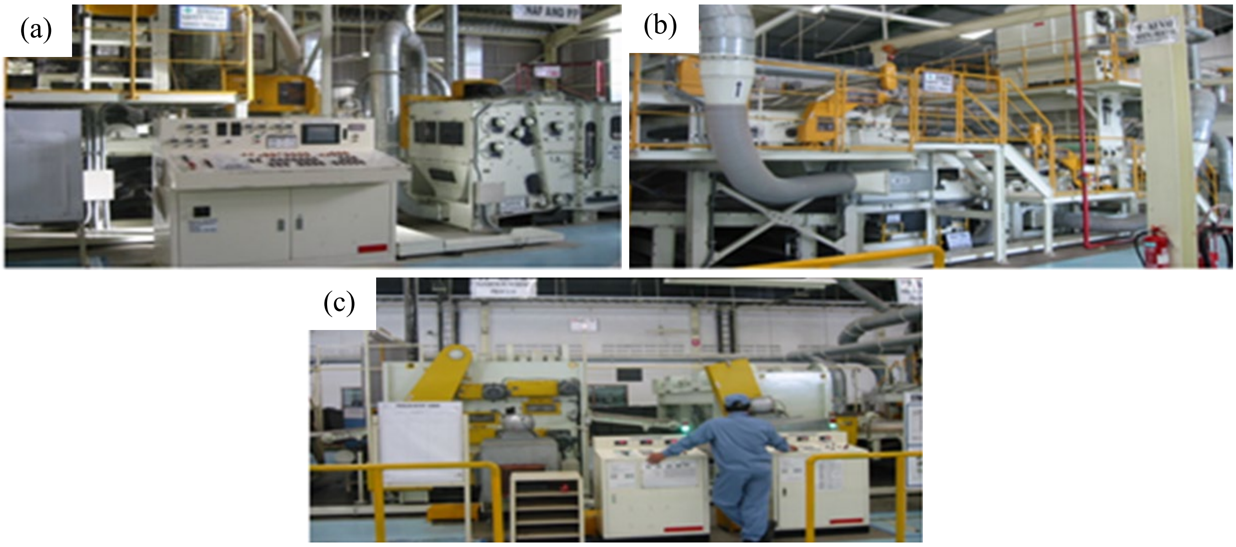

Figure 2. Manufacturing process of pre-board (a) opener machine, (b) forming machine, and (c) needle punch.

In order to avoid agglomeration, kenaf fiber is cut around 7 cm and polypropylene together entering the opener machine. Both polypropylene and kenaf entering the forming machine simultaneously after out from the opener machine. Forming machine is purposed to mixing 40-60% of kenaf with polypropylene as the rest which used to be 100%. The manufacturing process of the pre-board from the opener machine, forming machine, and needle punch are shown in Fig. 2. The manufacturing process of the pre-mat condition is followed by entering the needle punch machine. A needle punch machine is a machine used to process fibers that have been processed by forming machines in the form of pre-mat into the mat. The needle punch machine can produce a mat by binding the fibers to each other in the web form with needles that move up and down or in other words its bonding phase form solid to filaments. One palet mat from one cycle can be cut into 100 pcs mats. One cycle can produce ten pallets which mean 1,000 pcs mats as a stock. Each mat has a width of 75 cm and a length of 150 cm approximately.

Results and Discussion

Fig. 3 shows the output form of pre-mat or filaments condition. Furthermore, mats arrived at the last treatment which is entering a hot press machine. Hotpress is the main treatment for making pre-board. Hotpress machine gives a load of 4 bar with 150ºC has a cycle time of 2 minutes per sheet. The output of the pre-board is with high rigidity, where at the finishing step, pre-board has a condition check and cutting process width of 50 cm and length of 75 m with adjusting as needed until one palet of pre-board finishes good and ready to fabricate become a door trim. Kenaf fiber continues entering the manufacturing of pre-board after proceeds by the manual selection process done.

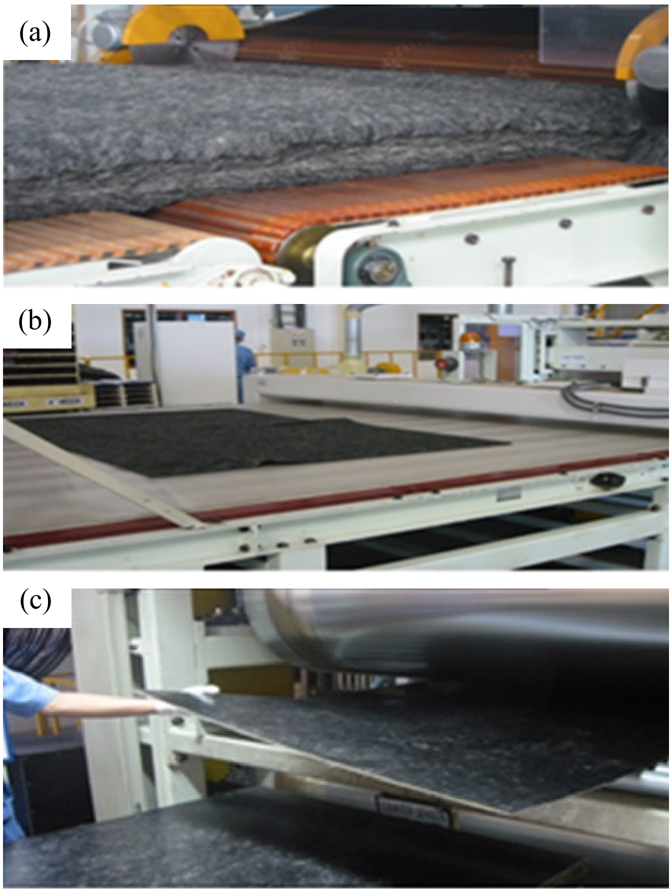

Figure 3. The shape of (a) pre-mat, (b) mat, and (c) pre-board.

The finished good of pre-board is ready to export to all over the world except Europe such as Japan, North America, China, ASEAN countries, and Australia. Which after that the pre-board process becomes a door trim that uses for the car. There is a set of fabrication process has done. However, the analytical result of shape or structure, electricity consumption, crack propagation, and cost are also discussed.

Fig. 4 shows the crack on the direct door trim in which resin-polypropylene is used as base materials. Door trim with kenaf-polypropylene base materials has no crack occurs is used compare with resin polypropylene. Therefore, in long time use is without decreasing the aesthetics and reducing the maintenance cost of the interior vehicle body. Meanwhile, door trim with kenaf-polypropylene base materials has a weight reduction from resin-polypropylene base materials. This phenomenon occurs, because resin-polypropylene has acid-modified polypropylene then improves the adhesion to kenaf which has no adhesion by a one-shot simultaneous manufacturing process. Hence, the weight of door trim was slightly decreased from 1.8 kg/m^2 become 1.5 kg/m^2 occurred because of kenaf fiber lighter rather than resin as raw materials. The direct weight measurement graph on the door trim production is shown in Fig. 5.

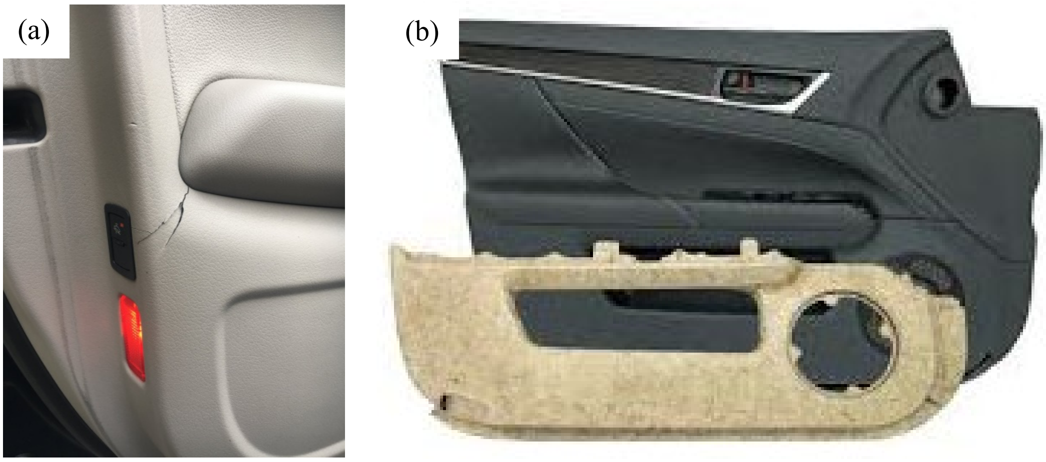

Figure 4. Door trim made by (a) Resin Polypropylene and (b) Kenaf Polypropylene.

Based on the universal prices of resin and kenaf seeds, the price of resin and kenaf per kilogram has slight differences. However, kenaf seeds contain around 35,000 to 40,000 seeds per kilogram. The requirement of kenaf seeds is about 8 kg/hectare. Meanwhile, producing the epoxy resins is require about one ton in one cycle of injection molding to generate a door trim [9-12]. The power consumption in each machine that applied in manufacturing of pre-board kenaf polypropylene are 2305.6 kWh of the opener machine, 5761.8 kWh of the forming machine, 19300.6 kWh of the needle punch, and 21014.4 kWh of the hot press machine in a month approximately. Therefore, the total power consumption per month during fabrication process is 48382.4 kWh / month or equal 60.478 kVA, where the price of high voltage more than 30.000 kVA is equal 1063.80 Rupiahs / kWh.

There are many advantages of choosing kenaf as door trim production, one of the advantages is the kenaf plantation is easy to grow in Indonesia, cheaper than imported resin [13]. Furthermore, the process with kenaf-polypropylene base materials only needs a heat press machine as the main treatment. Meanwhile, in the resin-polypropylene there are three longer phases required, continuing with the resin-polypropylene in melt form [14]. Besides, the resin-polypropylene has been injected, the final resin-polypropylene has been obtained in freeze form [14, 15]. As a brief consequence, the kenaf business in Indonesia has an impact on cost flow, whereby Indonesia spends less to get kenaf fiber. Thus, by enlarging the cultivation and production of kenaf in Indonesia, there will be a high potential for exporting pre-board supplied worldwide.

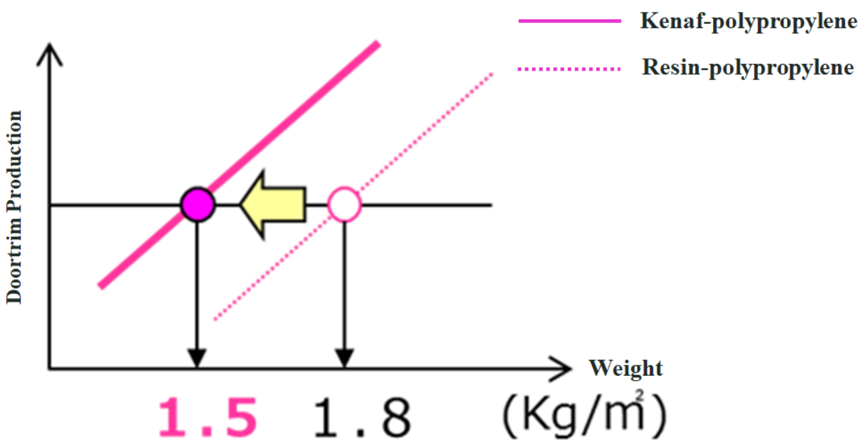

Figure 5. Weight reduction graph of door trim production.

Conclusions

Based on the sustainable fabrication technology of composite board by kenaf-polypropylene for automobile door interior applications, the conclusions are as follows:

1. Door trim with kenaf-polypropylene base materials has no crack occurs is used compare with resin polypropylene. Therefore, in long time use is without decreasing the aesthetics and reducing the maintenance cost of the interior vehicle body.
2. Weight of door trim kenaf-polypropylene decreases 30% from resin-polypropylene.
3. Total electricity consumption per cycle per month during the fabrication process of kenaf-polypropylene pre-board is 48382.4 kWh/month. Thus, by enlarging the cultivation and production of kenaf in Indonesia is such a promising business.

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