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A COMPARATIVE ANALYSIS OF NATURAL FIBER REINFORCED FOR AN INTERIOR ELECTRIC CAR

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ABSTRACT

The environmental awareness and sustainable manufacturing trend have replaced polyvinyl chloride (PVC) and fiberglass with natural fiber reinforced composite for a car interior. This paper aims to point out the natural fiber opportunity in developed country market with many car manufactory. The use of natural fiber as textile, rope, and food in developing countries can be shifted to car interior that has higher added value. This paper will also provide the market trend for natural fiber reinforced car interior, material comparison to show the characteristic and mechanical properties for each material, and analyze the value chain of car interior manufacturing. We also discussed the economic advantage and competitiveness of natural fiber composite for car interior manufactory in the form of sheet molding composite (SMC) compared to conventional material like fiberglass reinforced SMC. From these studies, it can be suggested to produce natural fiber reinforced composite for car interior with further development in order to increase the durability of the composite.

Keywords: *natural fiber, car interior, value chain, economic, sustainable manufacturing*.

1.0 INTRODUCTION

The automotive industry sector is one of the most industry that contributes pollutant in form of material that cannot be recycled or harmful substances from the fuel emission in order to produce a car which causing an environmental concern around the world. The environmental concern pressing automotive industry to come with a sustainable manufacturing solution in which make the industry more eco-friendly like increase recycling material possibilities and improve material and fuel economy by using alternative energy like electric vehicle battery or lighter material so waste reduction and also material and energy recovery can be achieved [1]. In the past few years, a global automotive industry for interior development and production are increasing steadily in term of using natural fiber based bio-composite, thus make the usage of synthetic and conventional material such as fiberglass, Carbon, Silicone Carbide, PVC, and Aluminium Oxide shifted [2]. The share of natural fiber varies greatly consist of flax, hemp, sisal, etc. When using a natural fiber based bio-composite a 20% - 50 % weight reduction, thickness reduction, and production cost reduction can be obtained. Natural fiber based bio-composite also more environmentally friendly compared to petrochemical injection molded plastics [3].

The development of ecologically sustainable car interior takes the most part in increasing the usage of natural fiber based bio-composite which makes the bio-composite able to fulfil the Premium OEM's demands for a high-quality appearance that also makes major car manufacturer like BMW choose to follow suit, it can be seen in BMW i3 door panel that made of kenaf (*hibiscus cannabinus*) fiber based bio-composite [4].

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The rising price of petroleum based product and the declining environment condition make the bio-composite get a higher acceptance and positive growth. The government support for this eco-friendly product will also drive the natural fiber based bio-composite growth into a new horizon and trigger the growth of natural fiber producer to fulfil the demand of the increasing natural fiber based bio-composite car interior [5].

Figure 1: Natural fiber (kenaf) based bio-composite in BMW i3 door panel

Based on the potential and competitiveness of natural fiber based bio-composite as the car interior material it is needed to conduct a research in order to analysis the value chain and feasibility of composite manufacturing. The value chain analysis is used to show the relationship between suppliers-producer-retailer and to evaluate all activities regarding bio-composite manufacturing from raw fiber material until it becomes a good product [6-7]. The feasibility analysis will be used to justify the production of bio-composite based on global supply and demand, and also the competitiveness of the

2.0 METHODS

The methods that used to analyze the problem in this paper are pointing out the global market trend for car interior made of natural fiber based bio-composite that also shows the market share and demand available for that particular product, then a comparison study is needed to analyze the characteristic and mechanical properties of varying fiber based and conventional material such as PVC and fiber glass, after that a value chain of the bio-composite production is needed to show each stage that has an added value to the fiber based material, as all kind of natural fiber plants follow the same procedure to be a bio-composite, this paper will only use one kind of plant as an example. The value chain is based on cantala fiber bio-composite production for car interior in SebelasMaret University's National Electric Vehicle Manufacturing (namely MOLINA) because it is still under development and cantala farmers and plantations are available nearby so this paper can be used as a preliminary study. Finally an economic analysis is used to show the opportunity and competitiveness of the natural fiber reinforced composite, those following methods can be seen in Fig. 2.

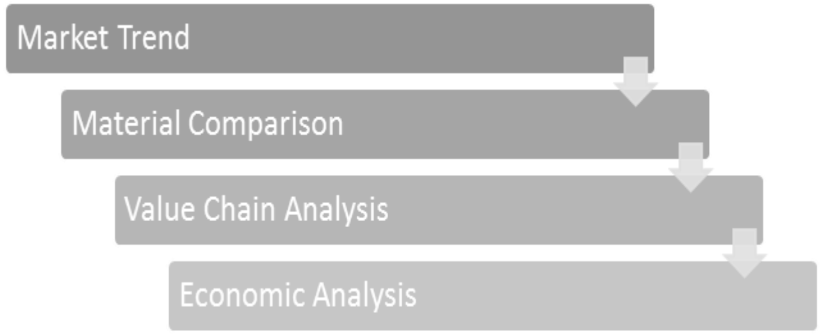

Figure 2: Method to analyze

3.0 RESULT AND DISCUSSION

In this case, a comparative study and value chain analysis of natural fiber reinforced bio-composite car interior will be described in four parts, *i.e.* market trend, material comparison, value chain analysis, and economic analysis.

3.1 Market Trend

The world and mostly in Europe (including Russia) with total market share of 61% of the total sales of € 4.5 billion in 2013 as shown in Fig. 3 [8]. Europe has the biggest market share because of car manufacturers that use natural fiber based bio-composite come mostly from Europe (shown in Table 1.) but the 2016 forecasted market share in Asia increases from 3% to 9% whereas the market share from other territory are decreasing. However Europe still has the biggest market share (59%) from the total sales of more than € 4.5 billion, so it can be stated that Europe has the most demand for natural fiber compared to other territory and it can be concluded that the supplier of natural fiber has a good prospect in the European automotive market [9].

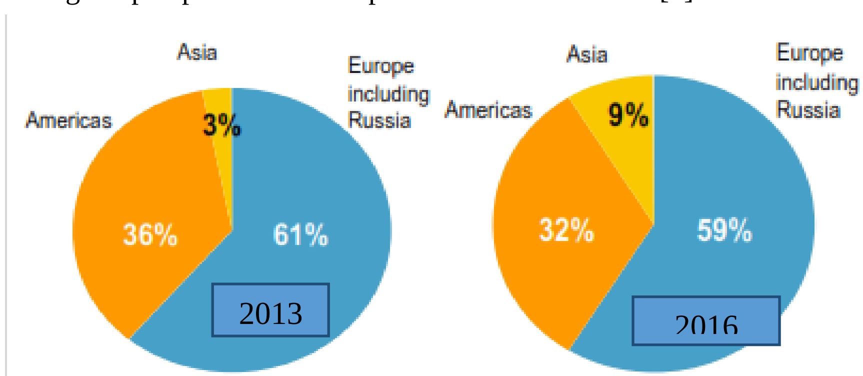

Figure 3: Market share growth estimation for car interior of natural fiber

The suppliers of natural fiber come mostly from developing country like India, Brazil, and South East Asian country where those natural fibers used as a traditional equipment, food, and textile with lower added value compared to car interior [10]. Export of natural fiber to developed country in Europe or America that produce car with bio-composite interior will increase the profit margin of the farmer and distributor because the developed country has a higher financial standard compared to developing country [11]. In order to do the natural fiber export an investment in the fiber plantation and production is needed to achieve a good quality and sufficient quantity of natural fiber that can be used as bio-composite car interior.

A study in 1999 stated that up to 20 kg of natural fiber is used in each of the 53 million vehicles being produced globally each year. It also means that 1000 – 3000 ton of natural fiber are used to produce a new model of cars per annum [12]. From the data stated before we can say that the demand for natural fiber is around 1.06 billion kg each year globally and those amounts will keep increasing until today where the environmental issue is one of the main concerns of the manufacturer and natural fiber gives a cheap solution for degradable and sustainable manufacturing. When the demand keeps increasing annually it is considered as an attractive field for investment in the natural fiber plantation and production to provide the necessary supply.

3.2 Material Comparison

Car interior material main characteristic concern is durability, weight, and price of the raw material itself. The increasing trend of sustainable manufacturing makes recyclable characteristic and energy consumption also becomes important. Car interior should also be a good heat and sound absorber for the convenience of the consumer [13]. This paper will analyze each characteristic of varying car interior material as shown in Table 2. That consist of natural fiber, fiberglass, and PVC[2], [14-16].

Table 2. Material characteristic and properties comparison

	PVC	KENAF	FLAX	CANTALA	SISAL	JUTE	COIR	E-GLASS	S-GLASS
Tensile Strength (Mpa)	2883	284-800	800	412	511-635	393-773	175	2000-3500	4570
Young Modulus (GPa)	1.5	21-60	60		9.4-22.0	26.5	4.0-6.0	70	86
Price (US$/Ton)	$1,210	$800	$1,000	$740	$720	$700	$360	$1,500	$1,600
Density (g/cm3)	1.4	1.4	1.4	1.45	1.5	1.3	1.2	2.5	2.5
Thermal Conductivity	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.04	0.04
Accoustic Properties			0.65		125-4000 Hz; 0.58	250-7000 Hz; 0.8	1400-6300 Hz; 0.5	0.9	0.9

Material durability shown in the tensile strength and young modulus score. Fiberglass S-Glass with the highest price is the best material in term of durability with 4570 Mpa tensile strength and 86 Gpa young modulus. Coir fiber with the cheaper price, less than 25% of S-Glass price is shown as the worst material in term of durability with 175 Mpa tensile strength and 4.0-6.0 Gpa young modulus. Natural fiber with the highest tensile strength and young modulus are Kenaf and Flaxfiber with 800 Mpa and 60 Gpa, but also comes with the highest price among other natural fiber material.

Material with lightest weight is Coir fiber with 1.2 g/cm^3 density. Both fiberglass (E-Glass and S-Glass) are the heaviest among other material with 2.5 g/cm^3 density but also has the highest mechanical properties. Car interior need to be a bad heat conductor so the temperature inside the car do not keep increasing, that characteristic is shown in thermal conductivity of the material. Most of the comparative material has thermal conductivity 0.19 W/(m.K) except fiberglass with 0.04 W/(m.K) and it can be concluded that fiberglass is a better heat insulator.Six out of nine compared material acoustic properties have been researched. Material with the longest sound absorption frequency range is Jute Fiber but Fiberglass still has a better NRC (Noise Reduction Coefficient) [17-18].

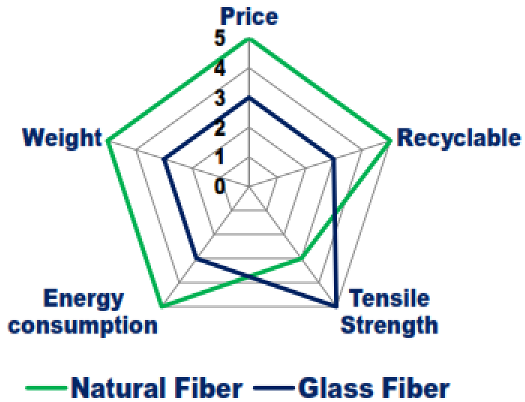

Figure 4: Natural fiber and fiberglass reinforced composite trade off

Natural fiber with worse tensile strength compared to Fiberglass has better price, more effective energy consumption, lighter weight, and can be recyclable for sustainable manufacturing [5] . In order to strengthen the mechanical properties of natural fiber so that in can be used as car interior lay in the bio-composite making process where other material like HDPE can be added to boost the mechanical properties. With lower production cost using natural fiber raw material the company can have a more competitive selling price in the market and higher profit and sell is possible to achieve.

3.3 Value Chain Analysis

Sebelas Maret University is actively involved in research and development (R & D) of EV in Surakarta, Indonesia and was developed an electric vehicle, namely MOLINA. Value chain analysis is used to evaluate all the activities that give an added value in the chosen strategic plan for the company in order to have a competitive advantage [19]. The value chain of cantala fiber based bio-composite for car interior can be found in Fig 5. The first stage is the fiber raw material (Cantala plants) that available in government forest, farm, or grow wild in the dry and lime stone ground. In Indonesia Cantala fiber is one of the farmer main income in Madura as about 561.25 acre land planted with Cantala and 521.48 ton dried fiber produced yearly. Agave Cantala also grow in Yogyakarta (KulonProgo) that considered near to MOLINA head quarter, but is not well explored, however the characteristic of Agave Cantalamake it possible to do a plantation expansion around Yogyakarta and Solo so a supply route can be secured for MOLINA interior production [20].

The next stage of the value chain is fiber production from Agave Cantala leaves.Farmer produced half-finished fiber traditionally using sharp bamboo to scrape the leaves until fiber is shown. The fiber, then cleaned in an H_2O_2 solution about 10-15 minutes and soaked in salt solution before letting the fiber dry under the sun. After the fiber is completely dry, then the fiber is combed to untangle any lump and wrinkle then the fiber is ready to be sold or processed further into bio-composite. Dried fiber, then mixed with HDPE powder (crushed plastic) and pressed with hot press machine to make a flat bio-composite sheet before drying further using an oven. Car interior can be produced after bio-composite is dried using press machine to shape the interior contour as desired.

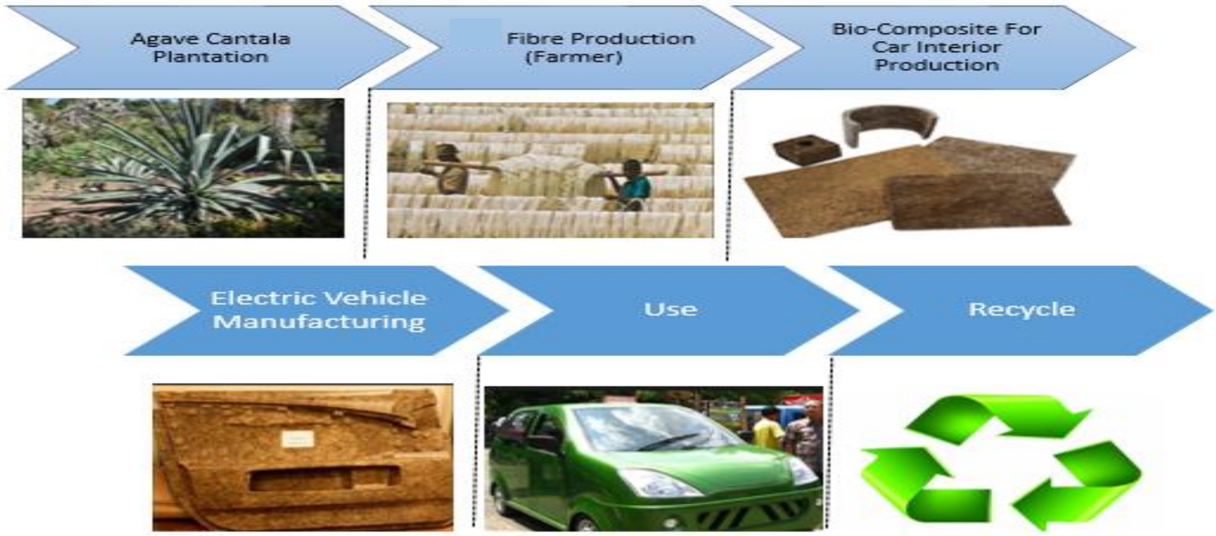

Figure 5: Value chain of natural fiber composite for car interior production

After car interior is assembled with other car component, then the car is ready to use during the life span. The final stage after the car reached the end of its life span is recycling the bio-composite using the grinding reprocessing method to recycle and reuse both the plastic and fiber [21]. Considering unexplored Agave Cantala plantation potential in Indonesia, especially in Yogyakartait is important to expand the plantation and improve the performance of Agave Cantala farmer in order to overcome the obstacle in the value chain's first stage such as raw fiber shortage and crop failure so the next stage of the value chain can be ensured.

3.4 Economic Analysis

One of the most used composite type is Sheet Molding Composite (SMC). SMC usually consists of fiberglass because it traditionally will not work on natural fiber due to entangled fiber remain lump in the resin, but using Biolicht scattering model by ATO now it is possible to create flax fiber reinforced SMC. Flax fiber reinforced SMC has more advantage compared to conventional fiber glass SMC as shown in Table below [22-23].

Table 3. Flax fiber SMC and fiber glass SMC comparison

Flax fiber SMC	Comparison	Fiberglass SMC
$1,000	Fiber Price Per Ton	$1,500
9.7 MJ/Kg	Energy Required for Production	54.8 MJ/Kg
1.49 kg/ltr	Weight	1.86 kg/ltr
$ 752/m2	Production Cost	$ 807/m2
57% Resin+Additives, 13% filler, and 30% fiber	Properties	57% Resin+Additives, 25% filler, and 18% fiber
Thermal Recycling and Grinding Reprocessing	Renewable Properties	cannot be thermal recycled, causing problem on combution furnace

Flax fiber SMC has lower raw material price and energy consumption. From the composition of SMC between flax and fiberglass reinforced shows that fiberglass use less fiber and more filler, thus makes the production cost of flax reinforced SMC is about 7% lower. Flax fiber SMC also 20% lighter than Fiberglass SMC so the total weight of the car is reduced and fuel usage can be more efficient. Flax fiber is a natural fiber, whereas it can be recycled using thermal recycling method or grinding reprocessing thus make it as a sustainable and eco-friendly product.

4.0 CONCLUSION

Natural fiber even less durable than other comparable material has shown to have many advantages compared to other material like PVC and Fiberglass. Raw natural fiber that used as rope, textile, and food in the developing country can be exported to get higher added value and support the economic growth. Compared to conventional material like PVC and Fiberglass, natural fiber is cheaper, lighter, can be recycled, and also used lower energy so it is an eco-friendly material that can be used in sustainable manufacturing.The best kind of natural fiber are Kenaf and Flax as it has better mechanical properties than other natural fiber but also comes with a higher price. However, in an electric car of MOLINA the most effective and efficient fiber to use is cantala because of the availability, but it still needs plantation expansion and exploration to ensure the sustainability of the manufacturing.After making into composite natural fiber (flax) reinforced SMC has shown to be competitive with conventional fiberglass SMC and has a big market opportunity because of the flax SMC advantages compared to fiberglass SMC. From these studies, it can be suggested to produce natural fiber reinforced composite for car interior with further development in order to increase the durability of the composite.

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