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Bamboo Composite Welding Cart Conceptual Design for Oil and Gas Industry

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Abstract – *Cart is a one type of vehicles that design for transport with two or more wheels and normally was pulled or pushed by one or more people. The function of cart is to carry heavy items/industrial goods and typically works as carriage. The paper presents a conceptual design of a welding cart in oil and gas industry application with a base fabricated using natural composite which is Bamboo. The idea of the design is to test and propose weight reduction yet not compromise in load bearing capability and structure integrity of the welding cart. The design process undergone conceptual design, Pugh method, analysis of design, fabrication and testing stages for the proposed bamboo based welding cart. The conceptual design welding cart could be catalyst for other material handling equipment design used in oil and gas industry especially in tackling weight to strength ratio and corrosion resistance issues.*

Keywords: bamboo cart, natural composite, welding cart, composite design, bamboo composite

1.0 INTRODUCTION

The subject of project under study is improvisation of existing welding cart used in oil and gas industry. The welding cart is an equipment of material handling category to transport welding machine such from one point to another within platform. Normally, the cart is made up by many type of steel as ERW (Electric Resistance Welded) round steel tube, ERW steel square tube, mild steel sheet, swivel casters with plate mounting, and steel bar. This type of steel is easy to fabricate, easy to cut at any size, and very good tensile strength but poor corrosion resistance and having substantial weight due to nature of steel [1]. Normal cart in industry especially in oil and gas industry have poor corrosion resistance, heavy in weight and pricey. Bamboo fibre could be used as a more sustainable and far cheaper alternative to steel for oil and gas industry application [2]. Besides, it produces a material that has great material properties such as Tensile Modulus,Compressive Modulus, Flexural Modulus although not as high as steel [3]. Bamboo is only a quarter of the weight of the steel and in terms of strength to weight ratio better than steel [3,4]. Fig. 1 shows the example of welding cart available in the market including the one used as material handling tool in oil and gas industry and Fig. 2 depicts the example of product based on bamboo composite for architectural application [1]. The project is proposed to challenge and improvise the existing welding cart used in oil and gas industry which is all made of steel. This being the motivation and research gap for this project.

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Figure 1: Example of welding cart [1].

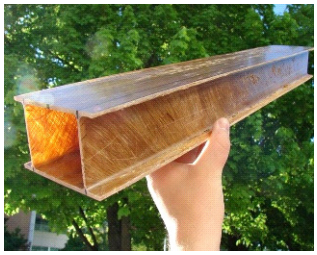

Figure 2: Example of product based on bamboo fiber composite [2].

2.0 MATERIAL PREPARATION

2.1 Bamboo as Base Material for Welding Cart

There are various application of bamboo fiber composite based material that been used to replace steel or fiberglass in engineering structure of building. Bamboo fiber composite can also act as environment protection plate due to capability of high hardness and toughness while cost of material is 15% lower than fiber glass based product [5]. Bamboo material produces parts such as Chipboard and Flake Board, Plywood and Laminated, Medium Density Fiberboard and Hybrid Bicomposite [6]. This composite is sustainable and a cheaper alternative to the ones use in construction industry. Moreover, bamboo is a renewable source due to the plant rate of growth is can be categorized as fast[7]. The bamboo fiber composite can be pressed into any shape while it can be sawn and sanded as shown in Fig. 2. In this project, the bamboo used for designing and fabricating the base is of approximately 3 years old bamboo then undergone the process of crushing and fiber extraction as shown in Fig. 3a and Fig. 3b. A mould is used to obtaining precise size of composite panel. The size of this moulding is 90 mm x 73mm x 40mm. In order to get uniform distribution of resin, the layup and arangement of bamboo fiber is accompanied by pouring resin systematically on the mould. Volume fraction of 68 percent fiber has been chosen based on literature for this project [5,7,8].

Figure 3a: Bamboo fiber extraction from raw material.

Figure 3b: Bamboo fiber arrangement in multidirection before resin pouring.

2.2 Mechanical Properties of Bamboo

Basically, bamboos consist of the roots, culm and leaves. They are usually hollow and vary in sizes, diameters, colours and textures. Countless tiny black spots can be seen at the cross-section of the culm (hollow stem) [8]. These are the cellulose fibers which run the length of the culm carrying nutrients between roots and leaves. According to the analysis of mechanical

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properties of the bamboos, the investigation of behavior specimen is different according to the materials under different loading conditions which is the types of the bamboo used. Information about the deformation behavior, such as tensile strength, compressive strength, shear strength, etc is an important requirement engineering applications for example in this project [9]. Generally, bamboo is an orthotropic material. Bamboo does not contain the same chemical extractives as wood, and can be glued very well. Bamboo's diameter, thickness, and internodal length have a macroscopically graded structure while the fiber distribution exhibits a microscopically graded architecture, which lead to favorable properties of bamboo [10].

2.3 Polyurethane 5157 Resin and Hardener

For this project the matrix material in this composite is polyurethane 5157 resin and hardener as this type of resin in the most appropriate to act as binder for natural composite, bamboo.Composition of bamboo fiber with respect to resin involved in this project is 68 percent volume fraction which is based on basis of optimizing the optimum extraction of bamboo mechanical properties than epoxy. Abundance supply of bamboo making it relevance for high weightage and volume fraction of bamboo composite in this project. As reccomended by the manufacturer, it is best to be cured at room temperature for at least 6-7 days for great formation and setting of matrix.

3.0 DESIGN FRAMEWORK OF BAMBOO WELDING CART

The workflow started with finding and collecting bamboos and then they were cut into smaller pieces for easier fibre extraction processes (milling). Milling machine was used to slice the bamboo into pieces and use natural enzymes to break the bamboo into mushy mass. The individual fibers are combed out and spun into yarn. Furthermore, the outer layer (skins) and the inner layer of the bamboo are removed. It is then cut into 0.5cm thick and 2.0cm width and 20 cm long. The bamboo is then dried for 7 days to make sure that the bamboo is completely dry. Next, bamboo then rolled/crashed by using the rolling machine and the bamboo fiber is obtained. Fig. 4 illustrates the flowchart of the design process up to fabrication carried out.

3.1 Proposed Design

There are three (3) proposed designs Design A, Design B and Design C after undergone the brainstorming among group members in regards of innovation of existing welding cart with the use of natural composite. From conceptual design, the characteristics of each design are listed which included the product design, parts and materials involved, critical parts, the great aspect of each design, the bad aspects of each design, the safety aspects of each design and the effect of the design to the environment. Table 1 depicted all the proposed conceptual design with its characteristics.

Penerbit Akademia Baru

Journal of Advanced Research Design
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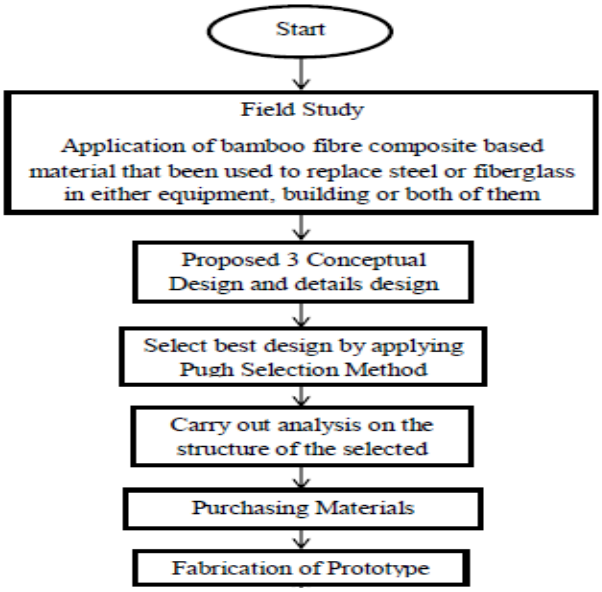

Figure 4: Flowchart of design process up to fabrication

Table 1: Characteristics of each conceptual design.

Characteristics	Design 1	Design 2	Design 3
Product Design			
Parts & Materials	**Frame/Pillar** *foam, bamboo composite fiber* **Upper platform** *bamboo composite fiber and steel tube* **Lower platform** *bamboo composite fiber and steel tube* **Handle** *steel tube/bamboo* **4 Wheels** *big wheels* *small wheels*	**Frame/Pillar** *foam, bamboo composite fiber* **Upper 30 degree of Inclination Platform** *bamboo composite fiber and steel tube* **Lower Platform** *bamboo composite fiber and steel tube* **Handle** *steel tube/bamboo* **4 Wheels** *big wheels* *small wheels* **Upper Platform Holder** *foam, bamboo composite fiber*	**LowerFrame** *foam, bamboo composite fiber* **Pillar and the support** *foam, bamboo composite fiber* **Shielded Gas Tank Holder** *steel* **Main Platform** *bamboo composite fiber* **Handle** *steel tube/bamboo* **4 Wheels** *big wheels* *small wheels*
Critical parts	• *Slotting Parts* • *Lower Platform*	• *Upper 30 degree of Inclination Platform*	• *Shielded Gas Tank Holder* • *Slotting parts*

Penerbit Akademia Baru

Journal of Advanced Research Design
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	• *Wheels Attachment*	• *Slotting parts* • *Lower Platform* • *Wheels attachment*	• *Wheels (small and big wheels)* • *Wheels attachment*
PROs	• *Minimize the usage of steel* • *Bamboo is cheap material* • *Light weight cart* • *Bamboo fiber composite will not oxidized.*	• *Minimize the usage of steel* • *Bamboo is cheap material* • *Light weight cart* • *bamboo fiber composite does not oxidized* • *Have incline angle at the upper platform to make worker easy to see*	• *Minimize the usage of steel* • *Bamboo is cheap material* • *Light weight cart* • *bamboo fiber composite does not oxidezed.* • *Can be move up the stair and down the stair with full of equipment.*
CONs	*Still need to use combination of the composite and steel.*	• *Still need to use combination of the composite and steel.* • *The presence of angle at the upper platform.* • *Does not have enough pillar to support the upper platform.*	• *Still need to use combination of the composite and steel.* • *The holder only cannot support the shielding gas tank.* • *No space to put the power supply on the cart while the cart remain at its static position.*
Safety	*Wearing the gloves and proper clothes during fabrication process* *Make sure all the material handling is in good condition before use it.*	*Wearing the gloves and proper clothes during fabrication process* *Make sure all the material handling is in good condition before use it.*	*Wearing the gloves and proper clothes during fabrication process* *Make sure all the material handling is in good condition before use it.*
Environment	*Does not cause any pollution.*	*Does not cause any pollution.*	*Does not cause any pollution.*

3.2 Pugh Selection Method

In order to finalize the design concept and starting the fabrication work, it is essential to select the best design out of the three (3) proposed. Pugh decision criteria have been chosen as design tool in this case as Pugh Concept Selection is a qualitative tool utilized to rank the multi criteria of an option set. It is frequently used in engineering for selection of best design. It is a scoring based matrix used for concept design selection in which options are assigned scores relative to criteria [11]. The selection is made based on the consolidated scores. The Pugh method helps to compare different concept designs, create strong alternative concepts from weaker concepts and arrive at an optimal concept that may be a hybrid or variant of the best of other concepts as per Table 2.

Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2462-1943 | Vol. 25, No. 1. Pages 1-10, 2016

Table 2: Pugh Selection Method

Scope	Criteria	Datum	1	2	3
Efficiency	Rate of oxidation	**DATUM**	+	+	+
	Durability		-	-	+
	Reliability		S	S	S
Aesthetics	Shape of bottom		S	+	+
	Light		-	+	+
Maintenance	Ease to usable		+	-	-
	Simplicity of design		S	-	+
Marketable	User friendly		+	+	+
	Low cost		+	+	+
	Σ+	**NA**	**4**	**5**	**7**
	Σ-	**NA**	**2**	**3**	**1**
	ΣS	**NA**	**3**	**1**	**1**

3.3 Comparison between Design 1, Design 2 and Design 3 with Existing Design

3.3.1 Design 1 comparison to existing welding cart

Rate of Oxidization - For 'Design 1', the rate of oxidization will not happen because all parts are made up from bamboo fiber composite to replace steel of existing welding cart.

Durability - The durability of 'Design 1' is lower than existing welding cart because all the parts was made up from bamboo fiber composite and this is subjected to break/rupture due to high pressure or load from welding cart equipment. Under impact and dynamic loading, bamboo will exhibit brittle behavior.

Reliability - The durability of 'Design 1' is lower than existing welding cart because all the parts was made up from bamboo fiber composite and subjected to break/rupture due to high pressure or load from welding cart equipment. Under impact and dynamic loading, bamboo will exhibit brittle behavior.

Weight - The net weight for 'Design 1' is much higher than existing welding cart due to the presence of two platforms which contribute to the total net weight of the 'Design 1' welding cart.

Cost - The total cost for making the 'Design 1' is much lower compared to the existing welding cart due to material made up from bamboo fiber composite which is cheaper than steel.

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3.3.2 Design 2 comparison to existing welding cart

Rate of Oxidization - For 'Design 2', the rate of oxidization is lower than existing welding cart due to the material made up from the combination of steel and bamboo fiber composite. The use of steel is as support/pillar to strengthen the structure.

Durability - The durability of 'Design 2' is slightly lower than existing welding cart because the design utilizes quite substantial percentage of bamboo for main and critical parts.

Reliability - The durability of 'Design 1' is lower than existing welding cart numerous parts were made up from bamboo fiber composite and subjected to break/rupture due to high pressure or load from welding cart equipment. Under impact and dynamic loading, bamboo will exhibit brittle behavior.

Weight - The net weight for 'Design 2' is much lighter than existing welding cart due to the design of the frame is simple and made up from bamboo composite fiber which is lighter than the steel.

Cost - The total cost for making the 'Design 2' is lower compared to the existing welding cart due to the usage of steel is reduced and replaced by the bamboo composite fiber.

3.3.3 Design 3 compared to existing welding cart

Rate of Oxidization - For 'Design 3', the rate of oxidization is lower than existing welding cart due to design is made up from combination of steel and bamboo fiber composite. The bamboo fiber composite is chosen for the 'base' while the steel remain as material for supporting structure.

Durability - The durability of 'Design 3' is almost similar with existing one due to main part (base) is replaced with bamboo composite and the rest of the structure still remain as steel. The new base material is able to withstand the welding equipment load under static compression, shear and dynamic loading.

Reliability - The reliability of the 'Design 3' is almost similar with existing welding cart and the replacement of the base material with composite material improve the corrosion risk, lighter in weight hence reduce the accident while steering the cart.

Weight - The nett weight for 'Design 3' is lighter than existing welding cart due to the design of the frame is simple yet able to withstand the load from all the equipment.

Cost - The total cost for making the 'Design 3' is lower compared to the existing welding cart due to the usage of steel only for making the support for the platform.

3.4 Details Design of Proposed Welding Cart

The detailed design of "Design 3" is developed in order to facilitate and assist in fabrication works. Fig. 5 shows the bill of materials for the design and Fig. 6 is the exploded view of the design. Table 3 depicted all the materials properties of bamboo fiber as compared to conventional material of steel. Finally the fabricated welding cart with bamboo composite base is shown as in Fig. 7. It is understood that after the criteria selection process, for Design 3, it is decided that only base part is made out of bamboo composite while other structures and parts are made from steel. Fig. 6 shows the exploded view of the proposed welding cart.

Penerbit Akademia Baru

Journal of Advanced Research Design
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4.0 DISCUSSION

The main aim for this project is to design a prototype and conceptual design welding cart with composite materials that is not easy to corrode, lighter, and cheaper for the TIG (Tungsten Inert Gas). Hence bamboo is chosen as replacement materials. The welding cart produced in this project is made up from the combination of bamboo fiber for the base and steel for its structures. Literature research about the existing welding cart, characteristics, mechanicals and physicals of all the materials used especially bamboo were studied for example Table 3 [12,13,14]. The cart provides solution for easier maintenance with less risk of exposure on rust and easier handling ability to move the cart to any area in a plant. Rust is formed on the surface of stainless steel when a condition develops in which the metal molecules at the surface are not sufficiently alloyed with chromium to create or maintain the required oxide layer.

ITEM NO.	PART NUMBER	MATERIAL	QTY.
1	base	bamboo fibre composite	1
2	gas tank plate	bamboo fibre composite	1
3	handle & frame	bamboo fibre composite	1
4	back tyre	polyurethane	2
5	back tyre shaft	steel	2
6	bearing back tyre	steel	2
7	hollow steel bar	steel	1
8	hollow steel bar front	steel	1
9	front shaft holder	steel	2
10	front tyre	polyurethane	2
11	countersunk head screw 3.5X0.3	steel	5
12	front shaft	steel	2
13	nut	steel	2
14	hook for chain	steel	2
15	support member	bamboo fibre composite	2

Figure 5: Bill of Materials of TIG Welding Cart Design

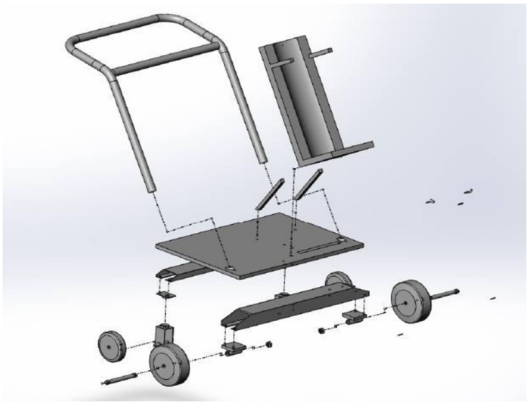

Figure 6: Exploded view of welding cart design

Figure 7: Fabricated welding cart with bamboo composite base

Table 3: Mechanical properties of the bamboo[12].

Properties	Bamboo fibre	Steel
Density(kg/m3)	700	7800
Elastic Modulus (MPa)	17500	200
Poisson's Ratio	0.39	-
Shear Modulus (MPa)	1285	330
Tensile Strength (MPa)	240	460
Compression Strength (MPa)	80	80
Fatigue Strength (MPa)	34.4	57.4

As the base of this design of welding cart is made of bamboo composite, the rust problem can be lessening, the task for maintenance also can be reduced. Bamboo composite is extremely light as compared to normal steel. It is important to have light cart so that it is able to bring the cart up to a higher platform or place in a plant. Bamboo composite is the mixture of bamboo fibre and resin epoxy (polyurethane epoxy). Polyurethane is a material that has the ability to be recycle. There are ways to recycle polyurethane such as crushing it with some chemical substances. With the ability to be recycled, we can avoid from polluting the environment [13,14]. It builds with unharmed material, non-corrosive chemical (epoxy), easy to use, and safety factor being considered in it [15].

5.0 CONCLUSION

This paper presents a systematic design, engineering and fabrication activities of conceptual design of bamboo based welding cart in oil and gas industry. Bamboo composite has been used as replacement material for the base of proposed design of welding cart and the extraction of dry bamboo fiber is mixed with polyurethane 5157 resin and hardener as the binder. Three conceptual design have been developed and each characteristics are evaluated from parts and materials, critical parts, safety, and environment perspectives. It is then further assessed by the use of Pugh Method to selecting the best design. Detailed design has been performed for Design 3 after selection and the prototype has been fabricated based on detailed drawing as well as undergone testing. There are loads of advantages of having a lighter welding cart with ease to maintenance, eco-friendly, corrosion free and strong with ample of improvement and innovation opportunities in the future for welding cart.

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