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Research Article

Sustainable Design and Development of a Trolley

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Abstract

Traveling from place to place is inevitable in today's world; a travel bag or trolley is a must for every person. We can see millions of trolleys rolling in and out of airports and railway stations. The number of trolleys present in the world and the amount of money, material and manpower spent in manufacturing different shapes and sizes is shockingly high. The cost-per-trolley has also risen over the years due to the extensive use of high-priced materials. There is no consideration for the design for increasing product lifetime. Some parts are recycled while others are just non-biodegradable waste content in the environment. This paper deals with the material analysis for Eco-Trolley, an innovative product whose design has been made abiding to the guidelines of green manufacturing concepts and sustainable design parameters. The design of Eco-Trolley has many innovative features and high grade points under Life Cycle Analysis i.e. from cradle to grave approach. Bamboo framework and jute/bamboo fibre bag makes the Eco-Trolley light weight and eco-friendly. Bamboo has a high strength-to-weight ratio which makes it ideal to withstand sudden impact loads. As most of the framework consists of bamboo, manufacturing costs and time is significantly reduced. The Indian Government, too, has planned to diversify its uses to reap the benefits in the $7.5 billion global bamboo product market. Hence, Eco-Trolley is an eco-friendly and customer friendly design concept with an extensive use of sustainable and eco-friendly materials.

Keywords*: Bamboo, Green Manufacturing, Material analysis.*

1. Introduction

The process of product design is actually the process of understanding and realizing materials for making things and creating new ideas. New materials are introduced every day, and they have a great role in promoting product design. New material can bring about new design, new form style and new enjoyment for human beings. While studying the design trend, we need to learn the cutting-edge products in the related fields, and acquire the overall impression on fashion trend in the aspects of aesthetic appreciation and vision by analysing the design elements (shape, colour, material, surface treatment, etc.). (Yizhou Lu, 2009) In the trends of smaller and simpler products, the application of new materials may cause revolution of material technology, and produce a new design altogether. (Hongyun Xiong *et al*, 2008)

In the same way, Eco-Trolley advocates the use of Bamboo to make it sustainable. Bamboo is a versatile, strong, renewable and environment-friendly material. It is a member of the grass family and the fastest growing woody plant on earth. Most bamboo species produce mature fibre in 3 years, sooner than any tree species. Bamboo can be grown quickly and easily, and sustainably harvested in 3 to 5 years cycles. It grows on almost any land condition- marginal and degraded land, elevated ground, along field bunds and river banks. It adapts to most climatic conditions and soil types, acting as a soil stabilizer, an effective carbon sink and helps to counter the greenhouse effect (Wenbin Yao *et al*, 2011). In India, the area of bamboo forestry is about 20 million hectares, and distributed widely from tropical to subtropical places. Since bamboo grows rapidly and has a high economy value, it is planted much all over the world. Coming after several natural fibres such as colour cotton and spider silk, bamboo fibres as a new kind of natural fibre was developed. According to modern concept of consumption, bamboo fibre comes from renewable resource, and the exhausted is biodegradable which meets the requirements of environmental protection, so bamboo fibre as a packaging material has a bright future. And because of the fibre's unique properties, it has attracted much attention of the international market. Clothes made of bamboo fibre are loved by people, not only because it meets people's need of return to nature and the requirement of environmental protection, but also because it has some excellent characteristics which other fibres don't. In recent years a number of researches have been involved in investigating the exploitation of cellulosic fibres loadbearing constituents in composites materials.

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The use of Bamboo fibre materials in polymer composites has increased recently due to their low cost compared to the synthetic alternatives, their ability to be recycled, and the fact that they compete well in terms of specific stiffness and strength. Material reactions under loads are the stresses and strains generated within the materials and usually results in deformation. A sufficient knowledge of the mechanical behaviour of bamboo enables a safe design for the materials service life. Bamboo reacts in the same fashion as other building materials. However, being a biological material like timber, it is subjected to greater variability and complexity, due to various growing conditions as moisture, soil, and competition. Bamboo is an orthotropic material, which means it has similar mechanical properties in the three directions: longitudinal, radial, and tangential. Bamboo as sustainable resource, abundantly available and biodegradable, is widely used in producing bamboo-based composites such as bamboo fibre reinforcing polymer composites, which have extensive applications in furniture, flooring, building and civil engineering field, especially in China and India.

Based on the perspective of eco-friendly manufacturing, this paper analyses the main influential factors of the low-carbon performance, including low-carbon innovation ability of green manufacturing- low carbon industry upgrading of manufacturing and low-carbon benefits of manufacturing. Green manufacturing is a term used to describe manufacturing practices that do not harm the environment during any part of the manufacturing process. It emphasizes the use of processes that do not pollute the environment or harm consumers, employees, or other members of the community. Green manufacturing addresses a number of manufacturing matters, including recycling, conservation, waste management, water supply, environmental protection, regulatory compliance, pollution control and a variety of other related issues. In green manufacturing, environmental impact of all stages of production is considered. The manufacturer will not use materials which are harmful to the ecosystem in the design, production, field application and end of life disposal stages of the product. Substantively, green manufacturing is the embodiment of the sustainable development strategy and the cycle economy mode in modern manufacturing. In order to implement green manufacturing the following principles should be followed:

- Recycling.
- Wealth-from-Waste Resources
- Biodegradable Materials.
- Alternative Energy Development
- Energy Efficiency
- Enhanced Product and Packaging Design.

Some of the benefits of green manufacturing are listed below:

- Controls and reduces material waste in manufacturing cycles.
- Preserves capital and saves money.
- Improves productivity and increases cost savings.
- Helps drive and influence corporate behavior both internal and external to ensure sustainability,
- Easy adaptability to changing rules in environmental regulations and legislation. (Chen Ying Jian, 2012)

The present research work focuses on the sustainable design of Eco Trolley and validation of the design concept by analysing stress and displacement analysis. A Sustainability report is also generated using Solidworks to validate the materials used in EcoTrolley.

2. Design description

2.1 Properties of Bamboo

Results from wide bamboo with steel plates and with two strain gauges
Outside Tensile Strength=15103 psi
Outside E=1.96*10^6 psi

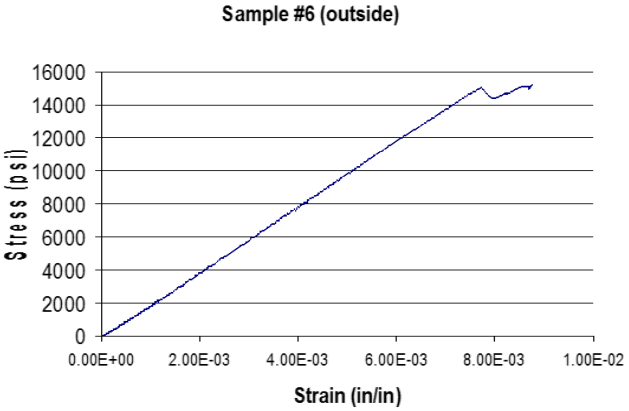


Fig 1: Results from wide bamboo with steel plates and with two strain gauges

¬ Inside Tensile Strength=14811 psi
¬ InsideE=3.17*10e^6

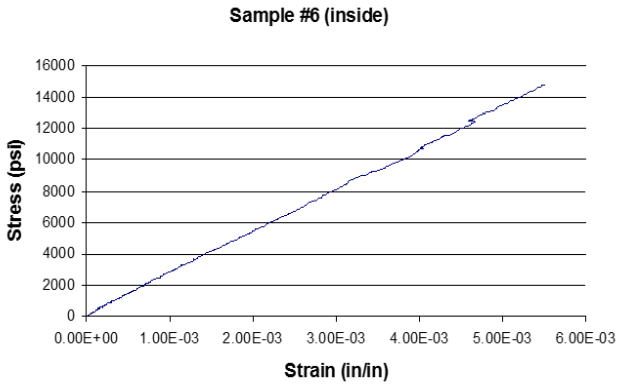


Fig 2: Results from narrow bamboo with steel plates and one strain gauge

¬ Outside Tensile Strength=11461 psi
¬ Outside E=1.74*10^6 psi

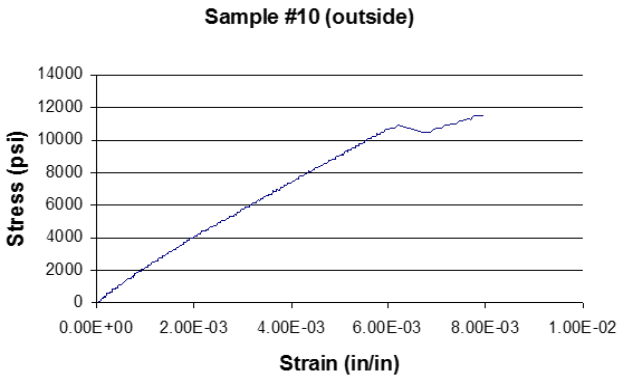


Fig 3: Results from wide bamboo without steel plates and one strain gauge

- Outside Tensile Strength=1017 psi
- Outside E=6.81*10^6 psi

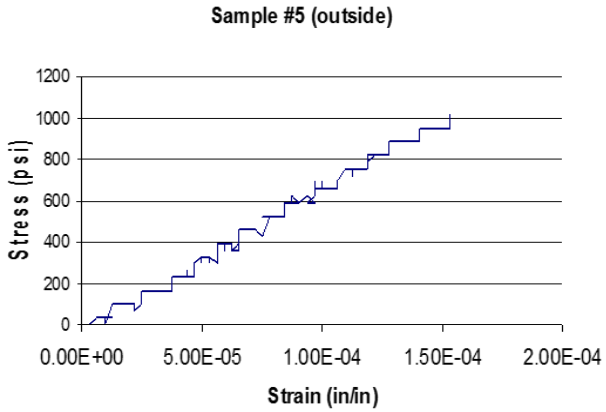


Fig 4: Outside strain is larger than inside

Inside modulus (E) 1.7 times higher than outside (E)

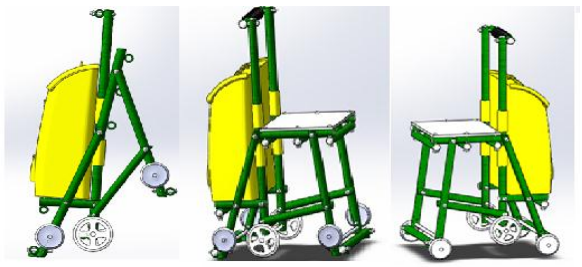
Ave. inside (E)= 2.86*10^6 psi

Ave. outside (E)= 1.68*10^6 psi

Total Ave. (E)= 2.27*10^6 psi

Ave. tensile strength for narrow samples is 11232 psi

Ave. tensile strength for wide samples is 14196 psi



2.2 Product Description

TROLLEY : The trolley has a support on which it can stand and can be used as a normal trolley.

CHAIR : The trolley can be unfolded and used as a chair.

WHEEL CHAIR: The wheels can be adjusted into the required position by restricting the motion with the help of a threaded pin.

2.3Material selection

Bamboo (frame) bamboo is a versatile, strong, light weight, renewable and environment-friendly material.

easy to cultivate and used for cost-effective manufacturing.

Jute (bag) most durable than other bags. eco-friendly jute is biodegradable and is thus environmentally friendly when compared to plastic.jute is cheaper as compared to other stuff.

Aluminium (fixtures) aluminum is a light weight metal, corrosion resistant, cost effective, easily available and can be manufactured. it has one-third the density and stiffness of steel.

Wheels the wheels are made of biodegradable plastics which don't pollute the environment at the end of the life cycle of the product.

3. Design Validation

Static analysis

We performed static analysis on the design by giving customized material properties, to study the reliability of design. The results are shown below:

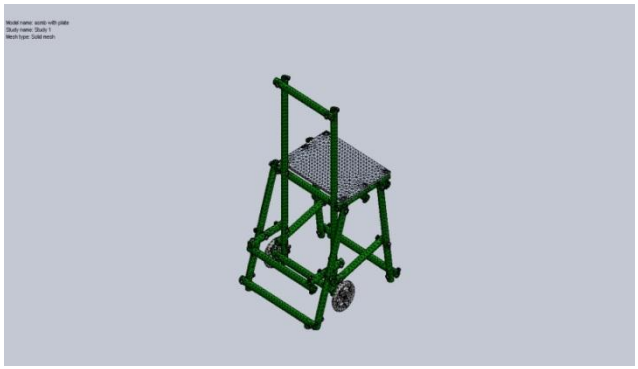
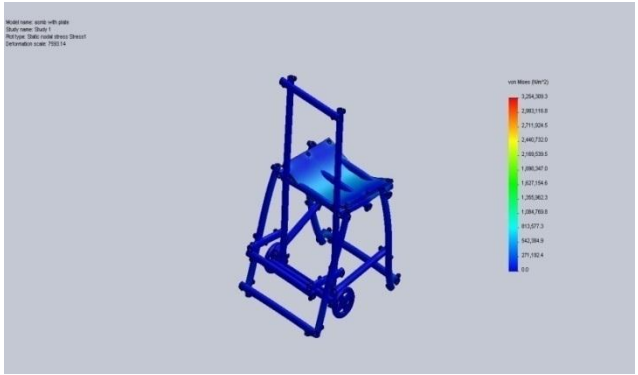
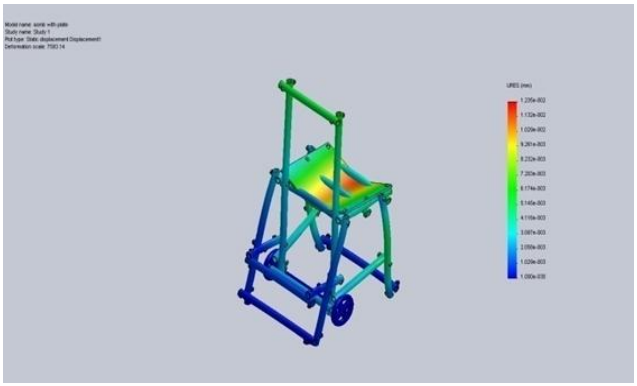


Fig 6: Solid meshing of the frame



Stress Study



Displacement Study

4. Sustainability report

A sustainability report is made using SolidWorks software, but bamboo material was not available. Hence the report generated produced results on aluminium used in the product without considering the sustainable materials bamboo and jute. Incorporating the properties of bamboo and jute, we can expect much lesser consumption of energy and carbon footprint. Summary of results:

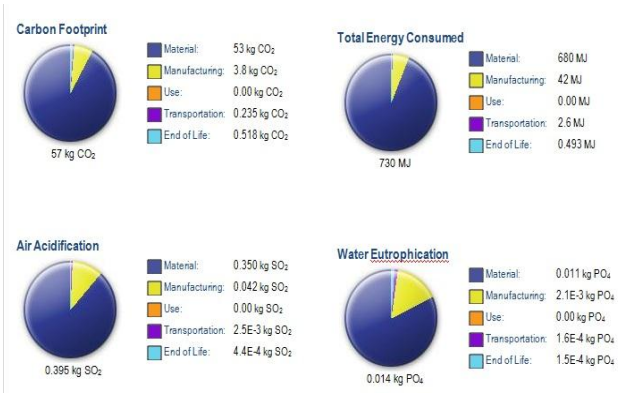


Fig 9 :Sustainability chart

Conclusion

(1) Through this research, it can be analyzed that bamboo framework is the most suitable material for the design of this eco-trolley. Corresponding Stress-Strain analysis have been carried out and favorable results have been obtained.
(2) Sustainable report for Aluminium material has been analysed and in the entire lifetime of Eco-trolley, 56kgs of Carbon Dioxide is emitted. (Bamboo material wasunavailable and it is expected to be less than 20kgs of Carbon Dioxide.)
(3) Total energy consumed in its entire lifetime is 730MJ.
(4) Total Air Acidification is 0.395Kg of Sulphur Dioxide-Total amount of sulphur dioxide emitted to the environment in its entire lifetime.
(5) Total amount of Water Eutrophication for Eco-Trolley is 0.014Kg of PO4
(6) Eco-Trolley is an aesthetically appealing, eco-friendly and affordable product which can reduce the use of normal trolleys with expensive and non-recyclable materials.

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