Comparison of Bamboo Mat Board (BMB) shovel with conventional shovel on the basis of Life Cycle Assessment (LCA) and performance

Umair Arif
a PG student, Mechanical Engineering Department, Aligarh Muslim University, Aligarh, Uttar Pradesh, INDIA

Abstract: Growing concern about environment, along with pressure from public and stricter international regulations, are forcing companies to produce products which are environmentally friendly. Sustainable materials serve the purpose better. Hence the objective of this study was to study about the sustainable material such as BMB in manufacturing shovel. The study was divided into two parts. The first objective was to gain a better understanding about the environmental impact of industrial bamboo products and their production processes in terms of their CO2 equivalent (carbon footprint) and compare it to conventional shovel material. And second was a comparative analysis between the two types of shovels based on physiological performances and productivity measures. The present study deals with life cycle assessment of bamboo laminates. The mechanical properties of bamboo are comparable with those of other resources in this particular context. Experiment has been conducted and the performances of the two have been compared from mechanical, ergonomics and economic considerations viz. weight, cost, productivity of the worker and the stress induced due to repetitive tasks. The results showed that global warming impact of BMB shovel is much less than conventional shovel and also the shoveling efficiency in terms of physiological parameter such as heart rate increase and productivity of BMB shovel was found to be better than conventional shovel.

1 Introduction

With increasing technology and decreasing distances the population of world is increasing along with pollution. As a result the earth is becoming warmer as CO2 levels on earth is increasing causing more than necessary greenhouse effect. During the twentieth century, the human population increased from less than 2 billion to over 6 billion. During the same time, the number of automotive vehicles in the world has grown from a few tens of thousands to more than half a billion. The consumption of resources such as oil, water, and metals has increased more than 10 times, while pollution has increased even more. Human activities worldwide now add as much as 7 billion tons of carbon dioxide to the atmosphere every year (1). There is only one answer to this problem: sustainable development. Thatcher A. (2012) (2) who defined green ergonomics as "ergonomics interventions that has pro nature focus; specifically ergonomics that focuses on human affinity with the natural world". Life cycle assessment (LCA) is a comprehensive method for analysis of the environmental impacts of products and services over their life cycles (3). The ISO provides requirements and guidelines for the use of LCA through the standard ISO-14044. This standard identifies four phases in an LCA study:

1. Goal and scope definition. The goal of the study answers the question that why is someone considering carrying out an LCA? In our case The goal of our study is to understand the environmental impact of industrial bamboo products (such as bamboo laminates) and their production process had in terms of carbon dioxide released and compare it with the environmental impact of conventional material used in place of bamboo laminates and their production process had in same terms.
2. Scope definition addresses issues related to function, system boundary, and data category. The system boundaries of this LCA are cradle to grave and only blade and shoulder portion is considered as it was only different.
3. Life cycle inventory analysis or LCI. Compilation and quantification of inputs and outputs for a product throughout its life cycle (4). It involves the collection of the data required to meet the goals specified (4);
4. Life cycle impact assessment or LCIA. This phase aims at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout its life cycle (4);
5. Interpretation. Phase in which the findings of either LCI and/or LCIA are evaluated in relation to the goal and scope of the study in order to reach conclusions and recommendations (4)

2 Comparison of Life cycle assessment of BMB and conventional shovel

The product composition, the main source of process information, can be derived either from bill of material (BOM) or by disassembling the product. A conventional shovel and bmb shovel has been disassembled for this study. The product composition are presented in Table 2.1.

Table 3.1 Product components of shovel

Sr no	Part name	Material in conventional shovel	Material in BMB shovel	Weight of parts in BMB shovel(gm)
1	D shaped handle with socket	Mild steel	Mild steel	150
2	Shaft	Wood	Wood	750
3	Shoulder	Mild steel	Mild steel	450
4	Blade	Mild steel	Bamboo mat board	950
5	Cutting edge	Mild steel	GI sheet	100

2.1 Life cycle inventory

Life Cycle Inventory database (DB) is a life cycle inventory data of material, energy, or process that has been developed previously using average data. Data from different institutes and consultants could be used for this purpose. Mostly, the database from world steel, GABI, and some research papers have been used for study. Use of LCI DB greatly simplifies the life cycle inventory analysis and is used for steel. The reason only air emissions are counted for in this inventory category is that the purpose of this analysis focuses on the environmental impact

categories such as global warming are considered.
Table 2.2 environmental impact assessment (cradle to gate) of BMB (5)

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Process	Amount	Carbon fp kgCO2/kg
Cultivation and harvesting from plantation Gasoline consumption	0.224 litre / FU	0.0209
Strip making	1.38 kWh/ FU	0.0201
Rough planning	8.62 kWh/ FU	0.1257
Strip selection		
Carbonization	4.73 kWh/FU	0.0690
Drying carbonized strips	9.66 kWh/FU	0.1408
Fine planning	5.8 kWh/FU	0.0846
Strip selection		
Glue application (1-layer boards)	0.894 kg / FU	0.0480
Pressing strips to 1-layer board	1.89 kWh/FU	0.0276
Sanding 1-layer board	1.62 kWh/FU	0.0236
Glue application (3-layer board)	0.983 kg / FU	0.0528
Pressing three layers to one board	1.65 kWh/FU	0.0241
Sawing	0.29 kWh/FU	0.0042
Sanding 3-layer board	0.86 kWh/FU	0.0125
Dust absorption (during all steps)	8.67 kWh/FU	0.1264
Transportation		0.2461
Total		1.200

2.2 End-of-life Calculations

The end-of-life of bamboo is a combination of:
1. Combustion in an electrical power plant

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2. Combustion in a municipal waste incineration plant

3. Landfill

Best case sinerio is combustion in an electrical power plant
The end-of-life credit for electricity production from bamboo waste is (data from the Idemat database):- carbon footprint: 1.18 kgCO_2 per kg of bamboo waste
In this study we assume that 90% of the bamboo products will be combusted for production of electricity and/or heat, leading to a credit of:- carbon footprint: 1.18 x 0.9 = 1.062 kgCO_2 per kg of bamboo product
The overall scores for LCI ("cradle-to-warehouse-gate" + "end-of-life") of carbonized laminated bamboo board are- carbon footprint: 1.2 – 1.062 = 0.138 kg CO_2 per kg Laminated bamboo board.

2.3 LCI of mild steel

LCI of CO_2 for mild steel includes CO_2 released from
1) Raw material extraction
2) Steel production
3) Manufacturing
4) Use phase
5) recycle

LCI of mild steel taken from world steel report is .950 kg CO_2/kg of mild steel (appendix A) and of GI sheet is .95 kg CO_2 /kg of GI sheet.

2.4 LCI data calculations

2.4.1CO2 foot print calculation for BMB shovel

Weight of Bamboo Mat board in BMB shovel is .95 kg
Weight of hinges in BMB shovel is .10 kg
Weight of shoulder mild steel in BMB shovel is .45kg
Amount of CO_2 footprint in BMB=weight of bamboo mat board*CO_2 released per kg board=0.95*0.138=0.1311 kg co2 released,
Amount of CO_2 footprint in hinges=0.1*0.95=0.095 kg co2 released,
Amount of CO_2 footprint in shoulder=0.45*0.95=0.4275 kg of co2 released
Total co2 footprint in BMB shovel=0.6536 kg of co2

2.4.2CO2 footprint in conventional shovel

Weight of mild steel in conventional shovel= 2.15kg
Amount of CO_2 footprint in conventional shovel= 2.15*.95=2.04kg CO_2
Difference in CO_2 footprint = 2.04-0.6536=1.3864kg of CO_2 is produced in more in conventional shovel than BMB shovel in their life time.

2.5 LCA Impact Assessment (LCIA)

LCIA is a relative approach based on a functional unit. For this characterization factor is used. Characterization factor is derived from a characterization model which is applied to convert the assigned LCI results to the common unit of the category indicator.

Characterization factor used in shovel study for CO2 is 1.00 so characterization impact of BMB shovel is 653 and that of conventional shovel is 2040 in terms of global warming.

Figure 1 Global warming impact for shovel life cycle (gm CO2-eq/shovel)

Experiment

In the experiment participants were asked to perform the shoveling task for checking performance. The task consisted of shoveling for two consecutive minutes. Five subjects were taken for conducting experiments. The first task was to shovel from the conventional shovel for two consecutive minutes then the subjects were given a day break. The task was repeated for the BMB blade shovel. The subjects were then asked to shovel continuously for two minutes transferring the soil from plank B to plank A from the marked points at their normal speed. The planks were set at the distance of 1.2 m which was the optimum throw distance for shoveling as suggested by Freivalds (6). Total amount of soil transferred by the subject was measured by the total amount of soil presented on plank A. Subjective rating of perceived exertion on different parts of body was also taken using corlett bishop scale ranging from 1 to 5,1 being extremely comfortable and 5 being extremely discomfort able and changes in heart rate was also measured.

Results

CO2 equivalent for BMB shovel is 653 which is much less than CO2 equivalent for conventional shovel that is 2040. This implies that BMB shovel is producing much less CO2 in its life time compared to conventional shovel. Hence global warming impact of BMB shovel is much less than conventional shovel. Shovelling performance in terms of load lifted for 2 minutes showed that conventional shovel transferred 46 kg soil whereas BMB shovel transferred 54 kg soil from position A to position B. The shoveling efficiency in terms of physiological parameter such as heart rate increase after shoveling of BMB shovel was found to be 30 units which is better than conventional shovel which was found to be 36 units on average. Subjective discomfort rating were more or less same for both shovel. In both shovel discomfort in lower back was found to be higher

Discussions

From results BMB shovel is better than conventional shovel in terms of global warming potential and performance. Hence to maintain sustainability of environment use of BMB for shovel is desirable. Bamboo in itself is a cost effective material and its physical and mechanical properties are comparable with those of steel to some extent. Life of BMB wood is around 1-3 years but life of BMB shovel under practical conditions needs to be examined more over price of BMB shovel may further go down if in place of hinges BMB wood is compressed to shovel blade shape with help of machines. Shoveling requires a lot of efforts therefore a person doing shoveling experiences a high heart rate, blood pressure, discomfort in the body, tiredness, and fatigue. The shoveling efficiency in terms of physiological parameter such as heart rate of BMB shovel was found to be better than conventional shovel Thus we can conclude that the introduction of biodegradable sustainable material in designing industrial tools and equipment is certainly not a fiction and can bring a revolution. It can bridge the gap between the Nature's model and the human model of work processing cycle

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