11 ECO DESIGN: SELECTION OF MATERIAL FOR IMPORTANT PARTS OF A TRI-CYCLE THROUGH LCA

Suman Sharma* **and Smita Manepatil†**

**Reader, Department of Mechanical Engineering, TRUBA College of Engineering and Technology, Indore (M.P.) India. Tel: 09425959966. E-mail: ersumansharma@yahoo.co.in*

†*Professor, Department of Mechanical Engineering, SGS Institute of Technology and Science, Indore, (M.P.) India. Tel: 09425075009. E-mail: smita_mp@rediffmail.com*

Ecodesign is an approach to design of a product with special consideration for the environmental impacts of the product during its whole lifecycle.Design for environment (DFE) and sustainable design have more broder view since they are supposed to enlarge product life cycle from the raw materials production and energy requirement upto the final disposal and recycling. To develop a good understanding about significant environmental aspects of the product, LCA (Life Cycle Analysis) is carried out.

LCA is a means of deriving a quantitative evaluation of environmental impact of product design and thereby refining product quality and characteristics. LCA analyzes total impact of product on environment from extraction of raw materials that go into product through manufacture, usage and final disposal.

This paper discusses the proper material selection using LCA technique. It presents some results of case study on eco design of the important part of a Tri-cycle. As per Eco-Indicator 99, the results show that the use of Plastic has very less impact on various impact categories of Eco Indicator 99 as compared to the Steel.

Keywords: Eco Design, Design for Environment (DFE), Life Cycle Analysis, Environmental Impact, Life Cycle Inventory

1. INTRODUCTION

The environmental impact of products and processes has become a key issue that has lead companies to investigate ways to minimize their effects on the environment. Ecodesign is an approach to design of a product with special consideration for the environmental impacts of the product during its whole lifecycle. The life cycle assessment of a product usually starts from its procurement and covers manufacture, use and finally ends with the disposal.

LCA is used for effecting quantitative evaluations of individual products in terms of their environmental issues and the effectiveness of improvements, thus providing a piece of information that helps to ascertain the best direction for design and development efforts.

As the whole product life cycle should be regarded in an integrated perspective, representatives from advance development, design, production, marketing, purchasing and project management should work together on the ecodesign of a further developed or new product as they have together the best chance to predict the holistic effects of changes of the product and their environmental impact. Environmental aspects which ought to be analysed for every stage of the life cycle are:

- Consumption of resources (energy, materials, water or land area)
- Emissions to air, water, and the ground as being relevant for the environment and human health
- Miscellaneous (e.g. noise and vibration)

2. LITERATURE REVIEW

LCA has its roots in the 1960s, when scientists' concern over the rapid depletion of fossil fuels developed this approach for understanding the impacts of energy consumption. A few years' later, global-modeling studies predicted the effects of the world's changing population on the demand for finite raw materials and energy resource supplies. An impact assessment and improvement analysis thus evaluates the impacts caused by the proposed products, processes, or activities. The final result of an impact assessment is an environmental profile of the system.[1] LCA has been widely used for Design for Environment to identify environmental 'hot spots' in a reference product's life cycle and to select new environmentally optimized solutions for a new product.[2]

Global environmental impacts due to production, use, and end of life treatment of a vehicle are quantified and evaluated based on LCA, Life Cycle Assessment. Case study results on ISUZU FORWARD, middle-duty-truck are introduced. Eco-Design, which is defined as a major concept for Environment Conscious Product Design, is addressed and discussed in the paper.[3] Through the application of the environmental management system (EMS) that encompasses the total life cycle, the systematic environmental management of product development and design becomes possible. The paper provides a description of the product EMS and touches the thoughts concerning the effective utilization of the EMS and the LCA in eco design.[4]

An Eco effective product may be regarded as a compromise through integration of environment, technical and economical requirements. This challenge can lead to fewer and less hazardous materials, lower weight disassembly friendly structures etc. of any product. It may also promote higher life cycle effectiveness, combination of functions and more fit to customer needs appropriately.[5] It also suggests that selection of better material at design stage with low impurity content of iron and aluminum in copper can result in major reductions in environmental impact. LCA analysis is performed using software with in-built databases of emissions and characterization factors as per LCA method. One popular software is Simapro® developed by pre consultants.[6]

3. METHODOLOGY

LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product selection. The LCA process is a systematic, phased approach and consists of four components: goal definition and scope, inventory analysis, impact assessment and interpretation.

Life cycle assessment methodology is commonly a four-step procedure.[7]

Goal and scope assessment: To specify the objective of study and determining the system boundaries.

Inventory analysis: Data collection for various stages of life cycle. These data are emissions to air, water and soil. This data is commonly referred as Life Cycle Inventory (LCI).

Impact assessment: The above is examined from an environmental perspective using category indicators, such as global warming, acidification, eutrophication etc. These indicators are specific to LCA methods.

Interpretation: In this step the results are analyzed in relation to the goal of the study. Conclusions are drawn, and recommendations are provided to reduce the environmental impacts of the product.

4. BASIS OF ANALYSIS

Objective of Eco design is to **do the changes in design by proper selection of material for important parts of a product through Life Cycle Assessment for evaluating and improving their Impact on Environment. This analysis is presented for a product, i.e. Tri-Cycle** in the subsequent sections.

In this work the LCA method i.e. Eco-Indicator 99 is considered which is widely used by the industries for impact analysis.

4.1. Steps of Analysis

- The first step is to select the product for which the LCA is to be carried out. The Product is of any kind. The Tri-cycle is selected for this work.
- Preparation of the bill of material, which has details about the raw material and manufacturing process of the parts of the product.
- The main assembly of the Tri-cycle distributed into number of sub assemblies for interpreting the environmental impact sub-assembly wise.
- To compute the quantitative impact of particular life cycle inventory item. These are then grouped into respective impact categories of Eco Indicator99 as per LCA methodology.
- The data and the corresponding graphs for result-generation are saved for comparison purposes as well as for future reference.
- In the interpretation, the data are analyzed for various types and levels (i.e. quantitatively) of impacts to environment and human health.
- The next step is to analyze the alternative for the material selection.
- Compare the results and do the required changes in the design of the part, sub-assembly or assembly for improvement in environmental impacts.

For the life cycle assessment of typical products the above steps are presented in the following frame work (Figure 1).

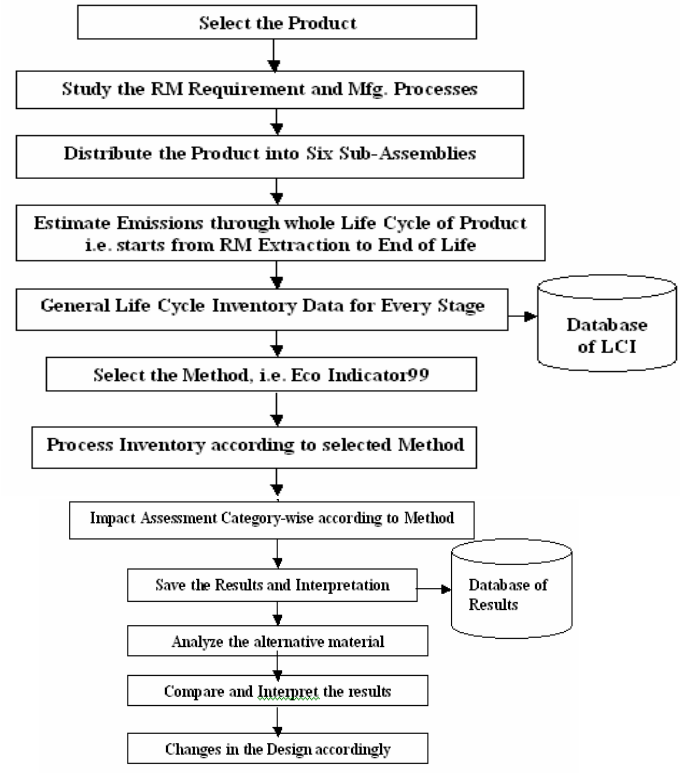

Figure 1. Framework for LCA of typical product.

5. CASE STUDY

The product selected for this work is Kid's Tri-cycle. The quantitative evaluation of environment impact for selected product is done by the method Eco-Indicator 99.The assembly of product i.e. Tricycle is distributed in six sub-assemblies mainframe assembly, seat assembly, front wheel assembly, back wheel assembly, paddle assembly and handle assembly. The Mainframe assembly (MFA) has parts of steel material and as per Eco Indicator99; the environmental impact of mainframe assembly is more as compared to other sub-assemblies.[8] To control these environmental impacts, the analysis is being carried out for alternate material, i.e. plastic (HDPE) for MFA. We find out the cross section area of the frame of plastic at allowable stress, that could bear ultimate load of 100 kgs.The outer diameter of plastic will be same as steel, but wall thickness is more in case of plastic (HDPE). It will impart the required strength to the frame. Consequentially overall weight of the Tricycle will be reduced by 75.4%. Table 1 shows various parameters of steel and plastic related with design.

6. RESULTS AND DISCUSSIONS

The graphical presentations of the results are shown in the following figures. Figure 2 shows the comparison of Steel MFA with Plastic MFA (Impact category wise) during raw material manufacturing. Figure 3 shows the comparison of Steel MFA with Plastic MFA (Impact category wise) during parts manufacturing.

The results show that Plastic has very less impact on various impact categories of Eco Indicator 99 as compared to the Steel. Steel as well as plastic both have a larger impact on Ecotoxocity and acidification & Eutrophication as compared to other impact category of Eco Indicator 99. The Steel and plastic both can be easily recycled. But during recycle process Steel has more impact on environment as compared to Plastic (Figure 2: Process of RM).

Table 1. Various Parameters of Steel and plastic (HDPE).

S.No.	Parameters	Steel	Plastic (HDPE)
01	Load	100 kgs	100 kgs
02	Allowable Stress	3466 Kg/cm^2	237.64 Kg/cm^2
03	Cross Section	0.28156cm^2	0.420804578 cm^2
03	Density	7.98gm/gmcm^3	0.965 gm/cm ^{3}
03	Weight	392 gms	96.5 gms

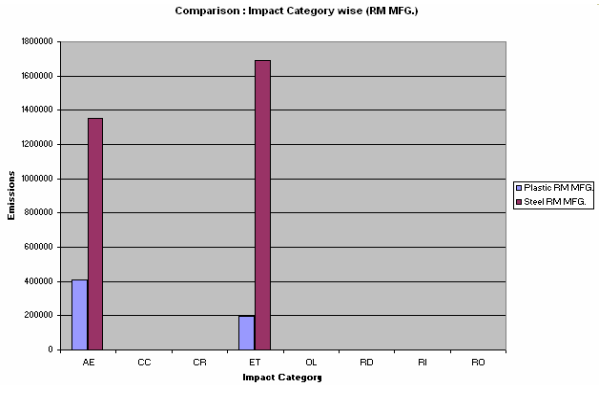

Figure 2. The comparison of Steel MFA with Plastic MFA (Impact category wise) during raw material manufacturing.

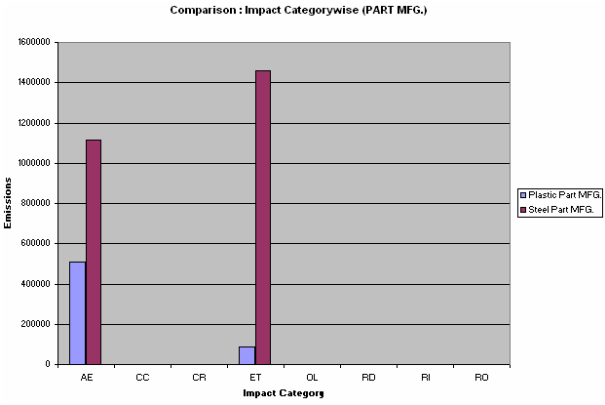

Figure 3. The comparison of Steel MFA with Plastic MFA (Impact category wise) during raw material manufacturing.

7. CONCLUSIONS

The quantitative method of LCA can be used to provide the quantitative environmental evaluation of the product by impact categories on local, regional and global level. The results can support the designers to develop the products with improved environmental properties. The Eco Design guidelines will be the basis for developing the new concept. The benefits envisaged from this work are:

- Quantitative evaluation of impact of various parts of different material of product.
- Comparison of alternative material for some important parts of the product.
- Suggesting product design changes for improvement in environmental impacts

The above framework demonstrated the use of LCA method to compute the environmental impacts of one product. This framework and its implementation can be easily expanded to include more products and LCA methods as well as to compare alternative product process combinations for eco-friendliness.

REFERENCES

[1] Svoboda, S. (1995). Pollution Prevention in Corporate Strategy Note on Life Cycle Analysis, University of Michigan Corporate Environmental Management Program, www.umich.edu/~nppcpub.

[2] Nielsen, P. H. and Wenzel, H. (2002). Integration of environmental aspects in product development: a stepwise procedure based on quantitative life cycle assessment, Journal of Cleaner Production, Vol. 10,pp. 247–257

[3] KASAI JUN'ICHI (Isuzu Motor Ltd.(2002) JPN),; Life Cycle Assessment and Eco-Design of Automobile,*Proceedings. JSAE Annual Congress, Journal Code: S0434A, ISSN: 0919–1364*, Vol.**;** NO.53**-**02; PAGE.9–12.

[4] Masako Yamato (Toyota Motor Corporation).(1998) A Study of EMS and LCA Application in Automobile Eco Design, 982203, November.

[5] Conrad Luttroff KTH Machine Design.(2002) Eco design: product design for sustainability, Reasearch school of Environment Management.

[6] Pre Consultants.(2004) Simapro-6 Database Manual Methods Library, http://www.pre.nl/download/manuals/DatabaseManualMethods.pdf.

[7] Environmental Protection Agency USA.(2001) EPA/600/R-00/095, Framework for Responsible Environmental Decision making (FRED): Using Life Cycle Assessment to Evaluate Preferability of Products, http://lcacenter.org/pdf/fred.pdf.

[8] Suman Sharma (2006). Dissertation of the course Master of Engineering in Computer Integrated Manufacturing, SGSITS Indore.