"Mircea cel Batran" Naval Academy Scientific Bulletin, Volume XVI – 2013 – Issue 1
Published by "Mircea cel Batran" Naval Academy Press, Constanta, Romania

SUSTAİNABİLİTY OF THE PRODUCTİON OF COMPOSİTE BOAT BY LİFE CYCLE MANAGEMENT APPROACH

Mehmet ÖNAL[1]
Gökdeniz NEŞER[2]
[1] Dokuz Eylul University Institute of Marine Sciences and Technology, Izmir
[2] Dokuz Eylül Üniversity Boat Building Research Center Baku, Izmir

Abstract: *This study is designed on the basis of Life Cycle Assessment (LCA) to conclude quantitavely the "sustainability" of GRP (glass reinforced plastic) boat building process from purchasing raw materials to recycling With LCA, carbon emissions amount, energy consumption, total weight difference between the first usage and recycling and potential contribution to global warming for whole supply chain can be considered for the products' cradle to grave life, even by including the recycling processes cradle to cradle life. In this study, the above mentioned parameters will be presented by making a comparison for two different GRP building methods namely hand-laying up and vacumm asssisted. The results have been obtained from "Umberto" carbon footprint software which is specially developed and designed for all of the material life cycle processes (production, use, waste management) with enhanced material flow. These results have been presented for the benefit of the related industry's stakeholders such as manufacturers, designers, suppliers and recyclers.*

1. INTRODUCTİON

Plastic products are based on polymer materials which are omnipresent in nature (cellulose, proteins) or in synthetic form (textiles, adhesives, resins, etc.). In contrast to metals and other construction materials, polymers are organic materials with properties depend strongly on the environment in which they exist (Lundquist, et al., 2000). They are produced by different techniques such as hand lay up and vacuum infusion.

1.1 Hand Lay-Up Method

Hand lay-up is the oldest and the simplest process for the manufacturing of Fiber Reinforced Plastics (FRP) products. Even if it is slow and very labor intensive, hand lay-up is a very simple, low cost and easy to apply process for FRP products (Rosato, et al., 2004) Hand lay-up process consists of hand tailoring and placing one or more layers of FRP on a mold by saturating the reinforcement layers with a resin. All layers are applied to the molding by hand. Resin is sprayed or brushed on after each layer (Nicholas and Paul, 1995a). According to the resin preparation, the material in or around a mold can be cured with or without heat and pressure. Molds can be constructed by using wood. The hand lay-up process is especially recommended for large and complex products which require moderate strength and reliability (Rosato and Rosato, 2004).

1.2 Vacuum Infusion Method

This method can be applied to the production of high performance, light weight, one-off racing boats. Its biggest advantage is the using of pressure while curing. In a sandwich construction when pressure is applied to a curing laminate it allows a higher fiber to resin ratio through better consolidation, reduces void content and improves interlaminar shear, especially in the adhesive layer next to a sandwich core (Sleigh, 1985). It can be applied by the use of a vacuum bag, matched molds or an autoclave. The vacuum bag is the last complicated and most frequently used system in boat building.

1.3 Life Cycle Assessment (LCA)

The LCA is basically knowledge based comparative environmental assessment and managing tool for product systems (Schench, 2005). This comparison has been established on the concept of a functional unit which represents quantitative expression for the equal pay off of the systems compared. Since this approach is "cradle to grave", this process called as "Life Cycle Assessment" (Ayres et al. 1998). Which, expanding from cradle to grave makes it unique (Hastak et al. 2003). From an environmental point of view, LCA has many benefits. LCA has the capacity to discover and keep a record of tradeoffs which represent the changing of environmental impacts, from one medium to the other or from one stage of the life cycle to another (O'Connor et al. 2012). Since LCA studies need carefully gathering and evaluation and verification of the data, to carry on reliable significant amount of analysis takes time (Klpffer, 1998).

LCA is recognized as a scientific reliable approach regarding the environmental sustainability of human activities. That is why it is applied in many internal and external information supplies and for decision support. Nevertheless, the LCA application must fulfill three basic criteria (Krozer and Vis, 1998):

- Being trustworthy so that it ensures the credibility of information and results
- Fitting with the present information routines and practices in business to ensure applicability,
- Giving quantitative and important information to inform decision makers.

A better industrial practice can be obtained after the understanding of the environmental impact of a product. The today's industrial practice can be encouraged to become more adaptable and to meet the requirements of the present legislations which is becoming more strictly and ask manufacturers to take more responsibility for their production and products (Shenoi, et al., 2011).

2. METHODOLOGY OF LCA

2.1 Goal and Scope

The goal of the study is to define an LCA framework for GRP boat building. This methodology incorporates the main processes for boat building methods. As stated before, the framework must be defined so that it can be used at an early stage of the conceptual design of a boat. To understand the potential impact of boat building to the environment is another objective of the study.

The present study focuses on a certain material, Glass Reinforced Plastics (GRP) as FRP, and two boat building methods namely hand lay-up and vacuum infusion. For comparison the methods, a boat of 11 m length, weighting almost 4000 kg hull has been considered. For the end of life scenarios: sanitary landfill, incineration and granule extrusion processes have been assigned.

2.2 Global Warming Potential (GWP)

The GWP impact category all quantities are to be converted to the unit of "kgCO_2 Eq". The CO_2 is the reference substance for this impact category. To convert these to common units, every quantity will be multiplied by characterization factor. Characterization factors are determined by different scientific groups based on different methodologies and philosophical point of views of the environmental issues (Guinée, 2004).

The impact of a product to the greenhouse effect is calculated while dividing the emissions per greenhouse gas by the GWP of the gas. If, for example, a 100 mg of CO_2 emits equals to 100 GWP, the contribution to the greenhouse effect is one unit greenhouse effect contribution (Landamore et al., 2005).

2.3 Impact Assessment Method

In this study, commercial software UMBERTO Carbon Footprint 1.2 and Ecoinvent v2.2 database have been used. All results calculated in CO_2kg Eq representing GWP_{100} (Global Warming Potential in 100 years).

2.4 Umberto Carbon footprint

UMBERTO is the LCA software used in this study; it is a professional tool to store, analyse and monitor the environmental performance of products and services. By using this tool, complex life cycles can be modelled and analysed in a systematic and transparent way, following the ISO 14040 series recommendations.

For input and output materials, a suitable data have been found in Ecoinvent v2.2 database. After this, desired amounts have been entered. The materials which couldn't be found in Ecoinvent v2.2 database, have been added manually. With manual entry, the name, amount, unit and definition (indicate the product is an input or output) of material has been determined. Data from industry have been obtained from the boat builders in Izmir (Turkey). Because of this, while choosing the materials from Ecoinvent database the region has considered. For polyester resin, MDF, titanium dioxide, methyl ethyl ketone, transport lorry, glass-fiber reinforced hand lay-up and glass-fiber reinforced vacuum assisted moulding, the region of Europe has been chosen. Since Turkey purchases electricity from Bulgaria and disposal process of Trukey very similar to Switzerland, these countries have been assigned in the related stage of the model.

According to the related literature, a worker uses 3000 kcal for the work in one day (8 hours) (Beyhan, 2008). Labor force (kcal) is calculated according to this rate.

GRP hull consumer use process output material is a reference flow for this study. "*The reference flows translate the abstract functional unit into specific product flows for each of the compared systems, so that product alternatives are compared on an equivalent basis, reflecting the actual consequences of the potential product substitution. The reference flows are the starting points for building the necessary models of the product systems*" (Wenzel & Petersen, 2004).

3 RESULTS

Figure 1 and 2 show the shares of GWP_{100} results, for different end of life scenarios for hand lay-up boat building method and vacuum infusion.

Figures 1 and 2 show that raw materials phase have the biggest percentage on emissions for all the end of life cycle scenarios for both methods. It is observed that in raw materials part polyester resin and glass fibre usage percents effect the result more than 2 kg CO_2 eq. This could be reduced if the polyester resin percentage could be determined in an optimum level with glass fiber.

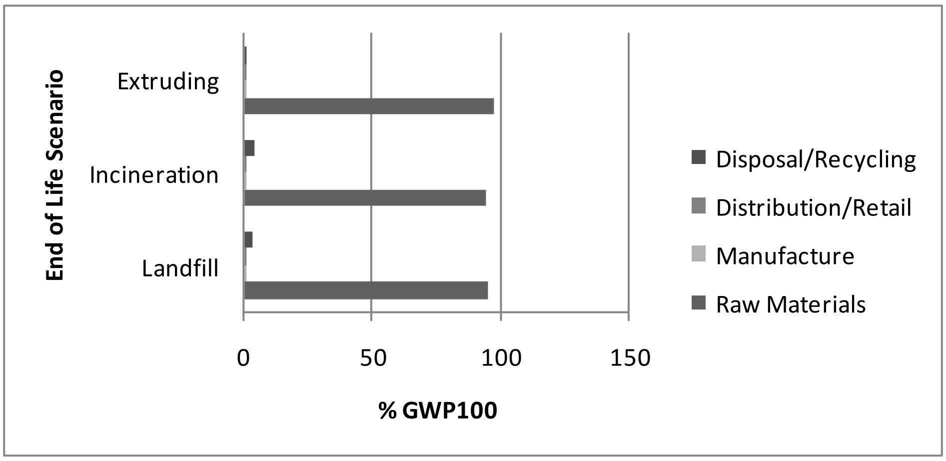

Figure 1 Shares of GWP_{100} impacts for different end of life scenariosfor hand lay-up method

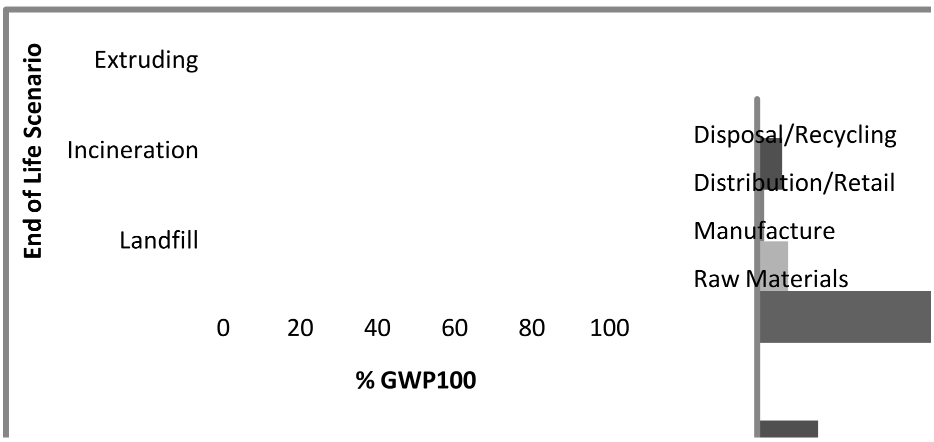

Figure 2 Share of GWP_{100} impacts for different end of life scenarios for vacuum infusion

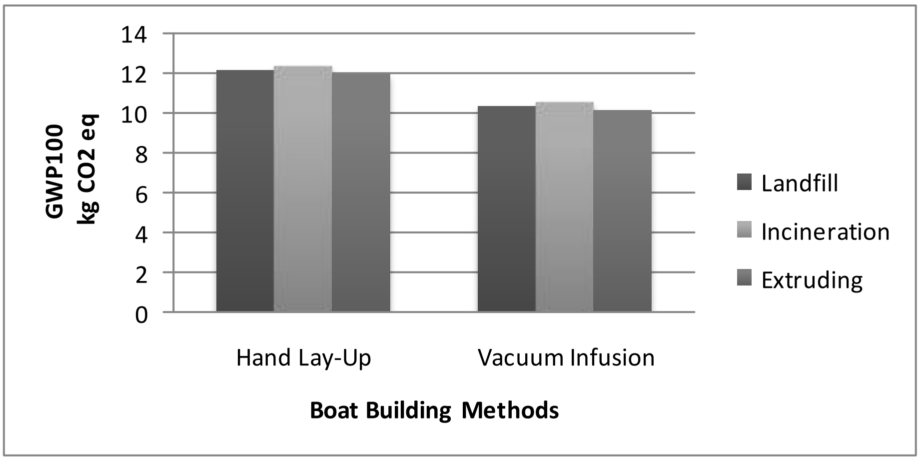

Figure 3 Comparison of GWP_{100} results between hand lay-up and vacuum infusion method

Figure 3 shows the difference of GWP_{100} results between hand lay-up and vacuum infusion method for the three different end of life scenarios. The difference is mainly coming polyester resin in raw materials and manufacture phases. Polyester resin's CO_2 footprint is equal to 7.47 kg CO_2 eq for glass fibre it is 2.64 kg CO_2 eq. The figure clearly shows that to use less polyester resin will cause low CO_2 emissions.

4 CONCLUSİONS

The objective was to develop a proper framework for deciding boat building method by using LCA. In this study these system boundaries have been used for LCA framework: Glass Reinforced Plastics (GRP) and two boat building methods: Hand Lay-Up and Vacuum Infusion. For comparison between boat building methods, a hull of 11m in length and almost 4000 kg in weight has been considered. For the end of life scenarios: sanitary landfill, municipal incineration and granule extrusion processes have been choosen. All results have been presented in CO_2kg eq for GWP_{100}.

In this study emissions recorded for the raw materials, manufacture, distribution/retail and the disposal/recycling phases. There are no emissions or impacts recorded for the hulls during the consumer use phase; it could be stated that the hulls are inert objects in the environment during their life time. Therefore, raw materials and disposal/recycling phases, which have the main impact on GWP_{100} emissions, are of importance of this study.

Overall, this analysis demonstrates that production with vacuum infusion is a better boat building method than hand lay-up. Because less polyester resin has been used in vacuum infusion method for all end of life scenarios the GWP_{100} quantity is lower than hand lay-up method.

It is widely accepted that boat building industry need to form a strategy to make its supply chain more environmentally friendly in order to keep competitiveness and to be prepared new legislative requires.

REFERENCES

Ayres, R. U., Ayres, L. W., & Martina, K. (1998). Exergy, waste accounting, and life-cycle analysis, *The International Journal of Life Cycle Assessment, 23*(5), 355–363.
Beyhan, Y. (2008). *İşçi Sağlığı - İş Güvenliği ve Beslenme*. Ankara: Sağlık Bakanlığı.
Guinée, J. B. (2004). *Handbook on Life Cycle Assessment*. London: Kluwer Academic Publishers.
Hastak, M., Mirmiran, A., & Richard, D. (2003). A Framework for Life-Cycle Cost Assessment of Composites in Construction. *Journal of Reinforced Plastics and Composites*, *22*(15), 1409–1430.
Klpffer, W. (1998). *Editorial : Is LCA Unique ?*, *3*(5), 241–242. Ecomed Publishers, Landsberg, Germany.
Krozer, J., & Vis, J. C. (1998). How to get LCA in the right direction? *Journal of Cleaner Production*, *6*(1), 53–61. doi:10.1016/S0959-6526(97)00051-6
Landamore, M. J., Birmingham, R. W., Downie, M. J., & Wright, P. N. H. (2005). Ecoboat - Boats For A Sustainable Future on The norfolk and Suffolk Broads.
Lundquist, L., Leterrier, Y., Sunderland, P., & Manson, jan-A. E. (2000). *Life Cycle Engineering of Plastics*. Oxford: Elsevier.
Nicholas, P., & Paul, N. (1995). *Fiberglass Reinforced Plastics* (1st Ed.). Oxford: Elsevier
O'Connor, J., Meil, J., Baer, S., & Koffler, C. (2012). LCA in construction : status , impact , and limitations.*Athena Sustainable Materials Institute*
Rosato, Dominic V., Rosato, D. V., & Rosato, M. V. (2004). *Plastic Product Material and Process Selection Handbook* (p. 618).
Rosato, Donald V., & Rosato, D. V. (2004). *Reinforced Plastics Handbook (*3rd ed.*)*. Oxford: Elsevier
Schench, R. (2005). Why LCA ?, *Building Design & Construction*, *Supplement*, 4-5
Shenoi, R. A., Dulieu-Barton, J. M., Quinn, S., Blake, J. I. R., & Boyd, S. W. (2011). Composite Materials For Marine Applications - Key Challenges For The Future. *Composite Materials* (Vol. 44, pp. 69–89). Springer London.
Sleigh, S. (1985). *Boat Building in FRP.pdf*. *Modern Boat Building Materials and Methods* (pp. 157–190).
Wenzel, H., & Petersen, C. (2004). *The Product , Functional Unit and Reference Flows in LCA* , 0–46.