Life Cycle Analysis for Manufacturing Process Sustainability in the Aeronautical Industry

Rafael Linares[1], Cristina Martínez-Ruedas[4], Antonio López-Uceda[2], Adela P. Galvín[*1]

[1]Department of Rural Engineering, Civil Constructions and Engineering Projects, University of Córdoba, Ed. Leonardo Da Vinci - Campus de Rabanales, 14071 Córdoba, Spain; g82libur@uco.es (Rafael Linares); apgalvin@uco.es (Adela P. Galvín)

[2] Department of Mechanics, University of Córdoba, Ed. Leonardo Da Vinci - Campus de Rabanales, 14071 Córdoba, Spain; p62louca@uco.es

[4]Department of Electronic and Computer Engineering, University of Córdoba, Ed. Leonardo Da Vinci - Campus de Rabanales, 14071 Córdoba, Spain; z42maruc@uco.es

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Presenting author email: apgalvin@uco.es

Abstract

The exponential growth of materials innovation and additive manufacturing technologies is not only advancing production processes to improve product performance, it could also minimize their environmental impact. To align a green product lifecycle management vision, aeronautical companies must implement emerging technologies and define a set of metrics that measure the benefits of change. Each product requires a particular and optimized manufacturing process plan, and each production phase must achieve impact reduction throughout its Life Cycle. Given the growing concern to measure circularity and sustainability, as well as to properly integrate them in the development of products that respect the environment, economy and society, the development and application of methodologies and tools that allow the measurement of sustainability and circularity should be encouraged.

The present research work implements the Life Cycle Analysis (LCA) methodology in the production process of aeronautical parts for an aeronautical industry sited in the southern of Andalusia region. The main objective is optimizing the production process from an environmental, energy and economic point of view. The study defines a specific Life Cycle Analysis methodology after digitization of processes and data collection responding to the need of producers to quantify the sustainability criteria.

Introduction

The growing concern to measure circularity and sustainability, as well as to properly integrate them in the development of products that respect the environment, economy and society, means that sustainability criteria are increasingly implemented. IN the case of fuselage parts, previous research as Bachmann et at. (2017) states that there is a lack of information in the database when trying to evaluate the impact of using innovative materials (materials of biological origin/recycled for use in aviation) which highlights the need for studies in this field of research.

It is essential that LCA methodology is integrated from the initial phases of the product as in this way, the evaluation of the different processes will be developed in the economic, environmental, and social dimensions. For this reason, previous studies such as Torres-Castillo et al, 2020, which implemented a comparative LCA of two manufacturing process plans for an aircraft engine turbine blade (one by conventional mechanization methods and the other by additive manufacturing) concluded that the most impacted categories were: global warming potential (GWP), acidification potential (AP), ozone layer depletion potential (ODP), human toxicity potential (HTP) and human toxicity (HT) with carcinogenic effects and non-carcinogenic. The study identified which of the two processes reduces environmental impacts and reduces the carbon footprint of said production system.

The present study evaluates the process data of a company in the aeronautical sector that has been completely digitalized. The objective has been to analyze the digital data from the sensors and equipment to be incorporated into the inventory of the LCA system, and based on this, improve decision-making in the production process in the factory.

Experimental methodology

Throughout the development of the present study, LCA methodology will be applied to the manufacturing process of the aeronautical part. In the present research work, the boundaries of the system (see Fig. 1) include the procurement of primary resources, all manufacturing and transportation processes of product components and their raw materials, as well as all phases of the finished product life cycle, and LCA application develops a "From door to door" approach.

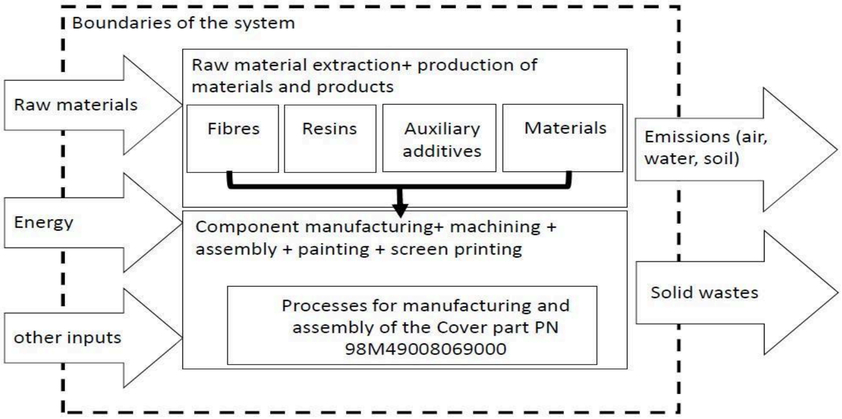

Figure 1. Boundaries of the system for production process of Cover PN 98M49008069000.

The functional unit is established as the production of a single cover piece for aircraft (model: "Cover PN 98M49008069000"), against which indicators are quantified to reveal the environmental impacts, including effects on soil, water, and energy consumption, as well as the generation of liquid or solid waste, among other factors. The main processes involved in the functional unit are identified, which is defined as the manufacture of a piece of cover for Aircraft, to which the indicators are quantified and show the impacts generated on the environment: soil, water, or energy consumption, generation liquid or solid waste, etc.

In the case of this project and, based on scientific articles and previous research such as those carried out in Sweden by the CHALMERS UNIVERSITY OF TECHNOLOGY (Gothenburg, Sweden) the optimal impact categories for this type of products are selected. These categories have been categorized according to CML, an impact method developed by the Center of Environmental Sciences of Netherlands, based on the studies of Dassault Systemes, 2017. Therefore, combining the different references mentioned in Table 1 are shows the 10 impact categories selected for the LCA system:

Table 1. Environmental impact categories applied to the present study in IMPACT 2002+.

Impact categories	Midpoint reference substance	Impact categories	Midpoint reference substance
Aquatic acidification, AQ	kg SO2 eq	Abiotic Depletion - elements	kg Sb eq
Aquatic eutrophication, EUQ	kg PO4 eq	Marine aquatic ecotoxicity	Kg 1,4-DB eq
Global Warming Potential, GWP	kg CO2 eq	Fresh water aquatic ecotoxicity	Kg 1.4-DB eq
Photochemical potential	kg C2H4 eq	Terrestrial ecotoxicity	Kg DCB eq
Ozone layer depletion, ODP	kg CFC-11 eq	Human toxicity	Kg 1.4-DB eq.

Conclusions

In general, according to previous analysis, it can be stated that the manufacturing of aeronautical parts contributes to GHG emissions, with energy consumption being a critical point, being necessary to quantify the environmental impacts of the treatment of solid wastes, paints and for machining equipment resulting from the process.

The present study demonstrates the need to take data in situ in the factory itself, since using real data has an impact on the quality of the LCA application. The data came from a factory located in the south of Spain and it is concluded that these real data from the equipment and sensors for digitizing the processes gave rise to maximum reliability of the inventory, facilitating decision making from the point of view of sustainability of the processes.

References

Bachmann, J., Hidalgo, C., & Bricout, S. (2017). Environmental analysis of innovative sustainable composites with potential use in the aviation sector—A life cycle assessment review. Science China Technological Sciences, 60, 1301-1317.