LIFE CYCLE ASSESSMENT FOR HELICOPTER AIRFRAME STRUCTURES

ULRICH EBERTH [1], CHRISTOPH PUDENZ, HELMUT SCHWARZE

EUROCOPTER Deutschland GmbH, Donauwoerth, Germany

[1]*ulrich.eberth@eurocopter.com*

ABSTRACT

Life cycle assessment (LCA) is defined as the compiling and evaluation of the inputs and outputs and the potential environmental impacts of a product system during its life cycle. A life cycle assessment is commonly divided into the phases of goal and scope definition, inventory analysis with an impact analysis according to the life cycle phase, impact assessment and interpretation. The modelling was performed with the software package GaBi 4.

The results presented were obtained from life cycle assessment analyses for structural carbon fibre reinforced parts and for the whole airframe structure of a mid-weight helicopter, including the use phase and the End-of-Life (EoL) phase of the product. Potential opportunities to improve the environmental performance of the part were identified and a number of ecological information obtained.

The environmental impact of the production of the helicopter structure is extremely low compared to the impact caused by the fabrication and consumption of fuel for operating a helicopter over its whole life time.

INTRODUCTION

"Reducing our environmental footprint is a permanent driving factor. At EUROCOPTER, we are committed to continuously improving our processes to further reduce the impact of both our group and our products & services on the environment." This statement by Dr. Lutz Bertling, President & CEO, EUROCOPTER Group highlights that the protection of the environment is today at the heart of EUROCOPTER innovation strategy.

This policy is strongly supported by the BLUECOPTER initiative of EUROCOPTER providing advanced technology solutions in different fields of investigation as BLUE EDGE blades or improved aerodynamic drag.

To realize the vision of "Eco-efficient helicopters designed and manufactured in low carbon factories" the methodology of *Life Cycle Assessment (LCA*) is an important tool to calculate the environmental footprint in order to manage the reduction of carbon dependency.

DESCRIPTION OF LIFE CYCLE ASSESSMENT (LCA)

The increased awareness of the importance of environmental protection, and the possible impacts associated with products, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts [1].

LCA is one of several environmental management techniques to support making environmental-oriented decisions relating to the production in various interfaces and on various levels. It is an instrument which processes the respective lifecycle, collects and summarizes the comprehensive data – also their opposite impacts on environment, assesses and finally transfers them to an evaluation [2].

LCA can assist in

- identifying opportunities to improve the environmental performance of products at various points in their life cycle,
- informing decision-makers (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign),
- selection of relevant indicators of environmental performance, including measurement techniques, and
- marketing (e.g. implementing an ecolabelling scheme or producing an environmental product declaration).

LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material extraction, production of intermediates, production of main products, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave) [1].

The manufacturing phase is just one of the many stages the product goes through during its life cycle. The product life cycle starts when raw materials are extracted, forged, ground or milled and ends with waste treatment. In every stage of the product life cycle there are emissions causing impact on air, water or soil.

LCA allows a manufacturer to quantify how much raw materials are used and CO_2 is emitted, and how much solid, liquid and gaseous waste is generated at each stage of a product's life. Also comparisons for finding out the most sustainable process are feasible. LCA enables all impact effects of a process or product on the environment to be evaluated.

METHODOLOGICAL FRAMEWORK FOR LCA

As shown in Figure 1, a LCA is standardized into the following methodological phases - goal and scope definition, inventory analysis, impact assessment and interpretation [1].

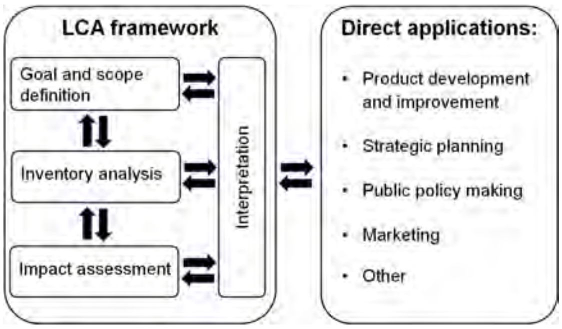

Figure 1: Phases of a LCA

The figure identifies the reciprocal influences of the individual phases and therefore shows the iterative character of a LCA. The application and the framework of the LCA have been purposely separated to show that an application or a decision is not automatically given through the results of a LCA study.

Goal and scope definition

Defining the research question is the task of the goal and scope definition phase, determining the system to be studied, whether it is an industrial production line, a product, a process or a service. The reasons for carrying out the study and the intended audience, i.e. to whom the results of the study are intended to be communicated, are stated.

Based on this definition of the questions to be answered, why they should be answered and for whom, the scope of the LCA can be determined. Defining the scope contains, in essence, the following points: system description, fundamental procedures, and data requirements.

The system description contains an analysis with a description and a transparent presentation (e.g. flow charts). An important step in the system description is the definition of the functional unit. By describing the system under consideration, a first draft for the system boundaries is given.

At the beginning of the analysis the balance or system boundaries of the investigated product are defined. This step contains the definition of each module, the so called unit processes, and their specific boundary conditions (see Figure 2).

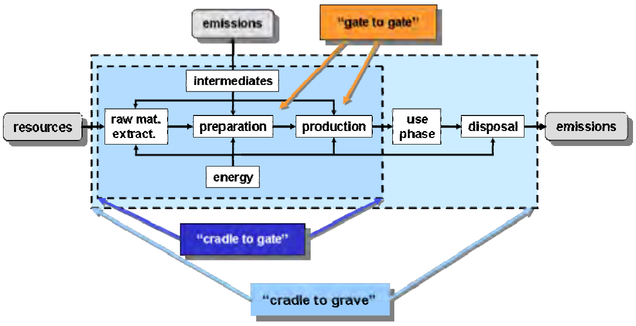

Figure 2: Structuring the life cycle into processes

Defining and documenting the fundamental procedures is important when performing a LCA. This includes basic rules as well as specific issues. These could be, for example, the desired "level of detail" and depth or the “choice of impact categories" within the study.

The application of cut-off criteria for input and output flows (which allow the exclusion of insignificant contributions in order to focus the conclusions of this study on the relevant aspects) is described [3].

The data quality has a significant influence on the LCA results. Depending on the goal, the requirements on the quality of data are to be stated. Data quality will be specified and documented in terms of precision (measured, calculated or estimated, literature, interviews of experts), completeness, consistency and representativeness. In this context the data sources and assumptions are mentioned. Data gaps shall be closed by appropriate and justified estimations.

Life Cycle Inventory analysis (LCI)

Inventory analysis phase involves data collection and calculation procedures to quantify relevant inputs and outputs. This is a matter of drawing up a quantitative assessment of the consumption and disposal of materials and energy by the system previously defined.

For each step, an exhaustive list of impact factors is drawn up, taking into account the consumption of energy and raw materials, the use of liquid effluents and solid waste and atmospheric emissions [2].

The process of carrying an inventory analysis out is iterative. As data are collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the data collection procedures so the goal of the study will still be met. Sometimes, issues may be identified that require revisions to the goal or scope of the study [1].

Life Cycle Impact Assessment (LCIA)

The impact assessment is carried out on the basis of the inventory analysis data. These data are categorized according to their potential impact on the environment in terms of their environmental effects (resource depletion, human health, global warming, acidification of the air, eutrophication of water, etc.).

These categories describe the potential environmental impacts rather than the actual effects. Such an impact category is for instance, the global warming potential. All emissions which produce a potential contribution to the greenhouse effect are assigned to this category.

The most important and well-known emission in this category is carbon dioxide. By classifying and comprising the inventory data according to their potential environmental impacts, the quantity of data is considerably reduced without neglecting information, and the results can be better interpreted by referring directly to the environmental impacts. These results and data obtained from the impact assessment can be used for the interpretation phase of a LCA.

Life cycle interpretation

The final stage of a LCA is an interpretation and evaluation in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope.

An important issue is the transparent presentation of the LCA results. This includes the identification of the significant issues and an evaluation which considers completeness, sensitivity and consistency checks.

Recommendations and conclusions can be established on these as long as the quality of data is acknowledged and uncertainties are defined. In order to determine the significant issues, the main contributions of each impact category have to be identified.

CASE STUDIES

As a bottom-up approach a LCA was performed on a frame used in the centre fuselage of a mid-weight helicopter produced as an example for a structural fibre-reinforced part.

The data for the production of the frame, the material and weight data and the processing steps, were collected in a detailed data acquisition at EUROCOPTER in Donauwoerth.

The modelling of the flow charts was performed with the software package GaBi 4 (Figure 3).

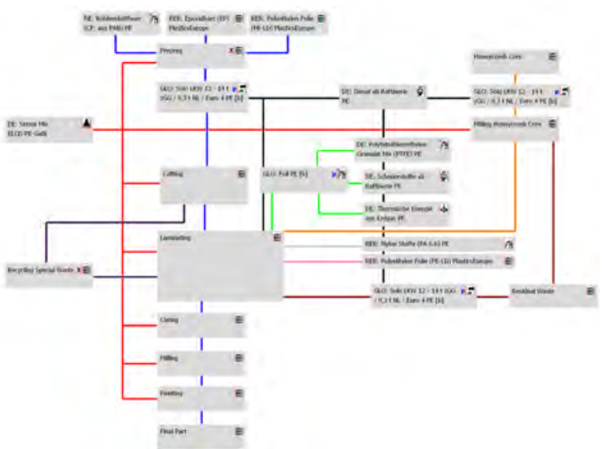

Figure 3: LCA flow chart for the production of a structural carbon fibre reinforced plastic (CFRP) part

As a result it turned out that the prepreg-material is responsible for the majority of the environmental effects due to their energy-intensive production (Figure 4).

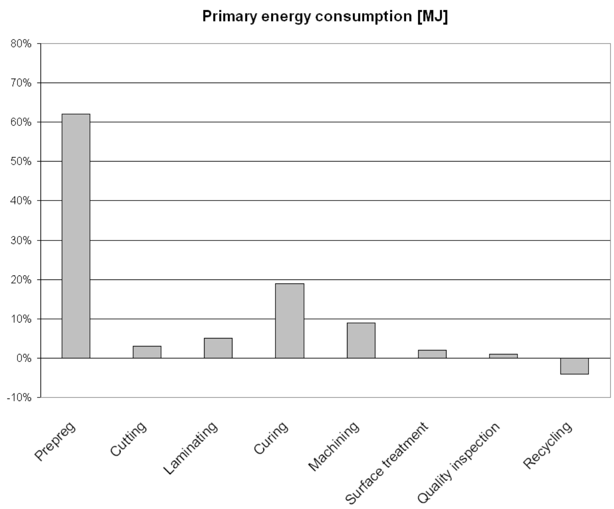

Figure 4: Primary energy consumption for the production of a structural CFRP part

This includes the precursor and the carbonization process for the carbon fibres, but although the resin and the bagging sheet. A reduction of the scrap rate would have a positive effect. However, it is difficult to further optimize the geometry of the prepreg fabric layers or to switch to a new production method as fibre placement with its significant lower scrap rate.

The second step in the process chain that has a big impact on energy consumption is the curing of the composite parts. This is caused by the conditions for the curing in the autoclaves, where high temperatures (about 180°C) and a high pressure are applied for several hours. Clear improvements can be achieved by a more efficient utilization of the autoclaves, the use of heat recovery system and the use of renewable energy.

On the contrary to the bottom up approach for a single part, a top down approach was used for the LCA of the complete structure of a mid-weight helicopter including the cabin and fuselage structure and the tailboom. For these structures monolithic and sandwich composite parts are used as well as aluminium and titanium parts.

It turned out that the carbon fibre prepreg material and the metal raw materials have a high environmental impact because of their energy-intensive production (Figure 5).

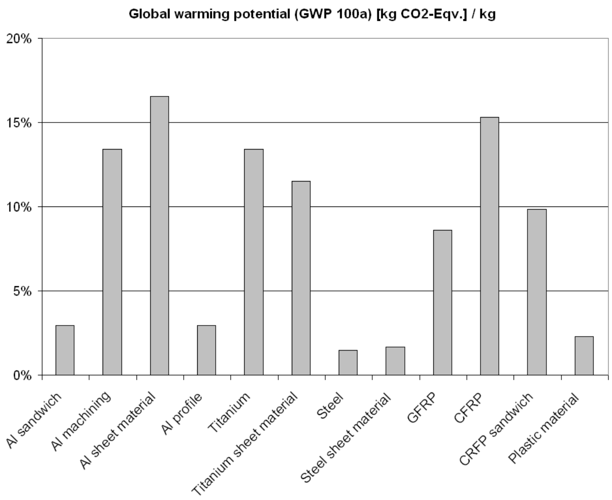

Figure 5: Global warming potential for the production of a helicopter structure (Al=aluminium, GFRP=glass fibre reinforced plastic, CFRP=carbon fibre reinforced plastic)

Regarding the production of parts for the helicopter structure the moulding and solution treatment of metallic parts during the plate production and the curing of composite parts were identified as the most significant steps in terms of relevant inputs.

Improvements in terms of the life cycle assessment can be obtained by means of a significant reduction of the material scrap of these materials, which particularly holds true for the carbon fibres. At present large blend quantities of this material end up in the waste incineration.

It was investigated how the supply of fuel, which is used over the maximum life cycle of a helicopter, has an impact on the environment. Moreover, a comparison was drawn between the environmental impacts provoked by the production of the fuselage with those of the manufacture of fuel over the life span of a helicopter.

It turned out that the impact on the environment due to the production per kg helicopter fuselage is extremely low compared to the impact on the environment generated by the generation and consumption of the aviation jet fuel.

For the end-of-life phase a disposal concept for a complete helicopter structure was created and evaluated regarding its environmental effects. The process steps disassembly, material separation and assortment were identified as essential processes for an effective recycling.

As shown in figure 6 the recycling of a helicopter airframe delivers a positive contribution to the potential impact on the environment due to the recycling of aluminium, titanium and the thermal recycling of the fibre reinforced plastic material.

So for metallic parts a lot of energy can be saved for the primary production. The quantity is directly linked to the individual structure and the material mix used with the absolute weight of each material.

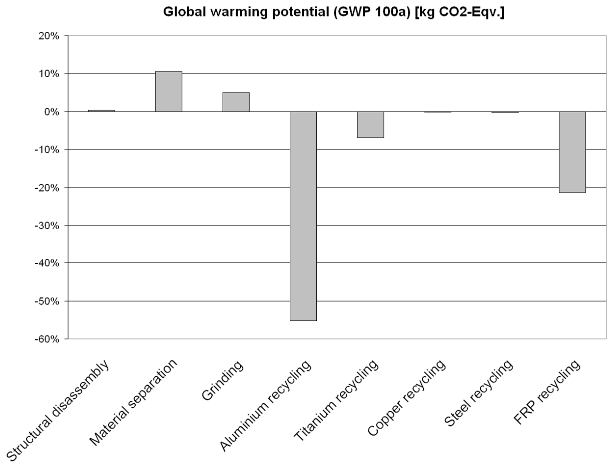

Figure 6: Global warming potential for the recycling concept of a helicopter structure

Discussion and Conclusions

The concept of performing a detailed examination of the life cycle of a product or a process is a relatively recent one which emerged in response to increased environmental awareness on the part of the general public, industry and governments. The results of the life cycle assessment studies performed serve to several internal and external objectives as they deliver information about the whole life cycle by detecting the most significant environmental impact factors.

Deciding which the 'cradle' is and which the 'grave' for such studies always leaves room for discussions. Carrying out a LCA can be a tedious and very detailed exercise. The data collection stage is comparatively complicated and high-quality data are often difficult to get and must be estimated. The incorporation of external suppliers complicates the analysis, but is mandatory to obtain transparency of the resources [2].

The most important result is the quantification of the energy consumption and the related environmental impacts for the production, use and disposal phase. The impact on the environment due to the production of the helicopter fuselage is extremely low compared to the impact on the environment provoked by the generation and consumption of the aviation jet fuel, which is burned in use phase of the helicopter. Therefore it will be very important in the future to further reduce the weight of the helicopter structure in order to reduce the fuel consumption significantly even by using production process that cause a slightly increased energy consumption. The recycling of the materials at the end of life can contribute to a small amount to the reduction of the primary energy consumption.

The results of such analysis should be included into the development process as early as possible, because the ecological profile is specified at that point. For instance a statement about the ecological reasonableness of light-weight concepts can contribute to a Design for Environment (DfE) or a recycling-fair design.

Depending on the goal and scope of a study, life cycle assessment does not produce clear-cut straightforward assertions, but it rather gives diverse and complex results.

For EUROCOPTER life cycle assessment is an important method to describe its products over their lifetime. Together with the BLUECOPTER technologies they contribute to further reduction of the environmental impact for the production and use of EUROCOPTER helicopters.

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