Life Cycle Assessment of an innovative aeronautic thermoplastic carbon composite produce by stamping

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The 1960s and 1970s are considered turning point decades in the history of composite materials. At that time, the first commercial modern carbon fibre precursors were introduced to the market (Choi et al., 2019). Successful commercial production of carbon fibres leads that the requirements of the aerospace industry, especially for critical military and space applications, for better and lightweight materials to become of paramount significance (Park, 2015)

The successful experience in military aircraft has greatly contributed to composites' acceptance in commercial aircraft. The applications and technology of composites have expanded dramatically since the 1980s. Despite their generally high cost, they have gained popularity in high-performance products that need to be lightweight and to take high loads such as aerospace structures.

Although the thermosetting resins dominate the composites market today, the use of thermoplastic resin systems in large-scale composite parts have long been discussed. However, currently there are still many research open questions. The use of these resins versus their thermosetting counterparts can potentially introduce cost savings due to non-heated tooling, shorter manufacturing cycle times, and recovery of raw materials from the retired part (Cousins et al., 2019), i.e., they can be recycled by recovering and reusing composite material from a used component.

Different promising manufacturing processes can be used to produce aeronautic components from thermoplastic composites, one of them is thermo-stamping. In this process, thermoplastic prepreg tapes are preheated to the melting temperature of the polymer matrix and then placed in a mould at a lower temperature. The mould then shapes the thermoplastic composite to the desired shape of the component (Vaidya & Chawla, 2008).

Despite the potential benefits of thermoplastic composite components for aeronautics, the environmental impacts associated to the production of these new components are yet to be understood. At this moment there is a lack of environmental analyses regarding the use of prepregs and thermo-stamping to produce aeronautic components. To advance the knowledge in this field, the goal of this study is to apply Life Cycle Assessment (LCA) to evaluate the environmental performance of an aeronautic component made of a thermoplastic composite and produced through thermo-stamping and identify potential hotspots for improvement.

A carbon fibre composite material was produced using PEEK (polyetheretherketone) polymer. The manufacturing processes involved six phases: (1) polymeric tapes cutting; (2) stacking and spot welding; (3) consolidation of the tapes; (4) mould preparation; (5) thermo-stamping; (6) cooling and final cut. Process data (documenting material, energy use and waste generated) was collected in situ. Alternative end-of-life scenarios were considered to deal with waste management namely refurbishment and reuse, recycling, incineration, and landfill. Finally, to better understand how the environmental profile of these materials is affected by regional context, this study also presents a sensitivity analysis regarding the production and end-of-life processes in different European zones.

From the preliminary environmental analysis, this study showed that at production stage, the energy consumption is responsible for the vast majority of the environmental impacts. The waste generated, coming mostly from the final cutting phase, also presents significant impacts. Most of the impacts associated with waste come from the waste management and end-of-life scenarios considered. For instance, the treatment of plastic waste through incineration, holds significantly higher impacts than refurbishment. Thus, solutions that promote energy efficiency and aeronautic composite refurbishment or recycling activities are a hot topic for future research.

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