Environmental impact of an innovative aeronautic carbon composite produced via heated vacuum-assisted resin transfer moulding

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Autoclave manufacturing processes have been commonly used to fabricate high-performance composites for aerospace applications. Although the quality of composites manufactured using an autoclave could be outstanding compared to other processes, high capital and tooling costs make these composites expensive. Also, large parts cannot be manufactured easily as they are dependent on the capacity of the autoclave. Nowadays, alternative Out-of-autoclave (OOA) processes have been gained acceptance because of the ability to produce equivalent autoclave-quality composites (Centea et al., 2015).

In this context, vacuum-assisted resin transfer moulding (VARTM) process (also known as vacuum infusion) is becoming one of the most robust alternatives for autoclave processes (Park et al., 2021) due to its ability to reliably manufacturer relatively low-cost composites with good mechanical properties, void content, and surface finishes. VARTM is a closed-mould process in which low-viscosity resins are injected under pressure into a one-sided mould with a sealed flexible membrane (vacuum bag) to impregnate the dry reinforcement.

However, one of the shortcomings of VARTM is long cycle times due to long mould filling times (Mathuw et al., 2001). In the present study, an innovative heated VARTM was used to process high temperature mono-component epoxy resins, which cannot be used in conventional VARTMs due to their high viscosity and curing schedules, to produce innovative high performance carbon composites The reinforced composites allow aircraft weight to be reduced thus improving the overall energy consumption. However, the life cycle environmental impacts associated to the production of these new components are yet to be understood. Given such challenge and the current climate change awareness, it is important to better comprehend the overall life cycle environmental impacts of a reinforced composite produced via VARTM, not only to enlarge data available, but also to evaluate and support future composite components improvement. Making use of life cycle assessment (LCA), the study here presented aims to assess the environmental performance of carbon composites manufactured by heated-VARTM. Based on in-situ data, the production process includes the following steps: (1) cutting carbon fibres and technical textiles; (2) resin preparation; (3) cleaning and mould preparation; (4) fibre staking; (5) impregnation with the resin; (6) curing.

This LCA study showed that the main environmental hotspots are related to i) the use of carbon fibres, whose production is still highly energy intensive, and ii) the waste management required to deal with composite waste both at production stage and at end-of-life (EoL) of the part. Alternative prospective improvement scenarios were considered to assess the influence on varying electric energy supply, and EoL scenarios. The types of waste generated along the process and at EoL are often difficult to separate, process or recycle and for this reason they are usually sent to landfill or incinerated, resulting in high environmental burdens. In order to optimise this process and make it environmental more appealing, it is necessary to reduce carbon emission at production stage (e.g. through low carbon energy mixes), to minimize the waste generated at production and to improve the refurbishment or recycling of such components (Wegmann et al., 2022).

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References

Centea, T., Grunenfelder, L. K., & Nutt, S. R. (2015). A review of out-of-autoclave prepregs – Material properties, process phenomena, and manufacturing considerations. *Composites Part A: Applied Science and Manufacturing*, *70*, 132–154. https://doi.org/10.1016/J.COMPOSITESA.2014.09.029

Mathuw, R., Advani, S. G., Heider, D., Hoffmann, C., Gillespie, J. W., & Fink, B. K. (2001). Flow front measurements and model validation in the vacuum assisted resin transfer molding process. *Polymer Composites*, *22*(4), 477–490. https://doi.org/10.1002/PC.10553

Park, D. C., Yu, T., Park, S. J., Shin, D. H., & Kim, Y. H. (2021). Improvement of impregnation quality on out-of-autoclave processed CFRP aircraft wing spar through resin flow simulation. *Functional Composites and Structures*, *3*(2), 025001. https://doi.org/10.1088/2631-6331/ABF480

Wegmann, S., Rytka, C., Diaz-Rodenas, M., Werlen, V., Schneeberger, C., Ermanni, P., Caglar, B., Gomez, C., & Michaud, V. (2022). A life cycle analysis of novel lightweight composite processes: Reducing the environmental footprint of automotive structures. *Journal of Cleaner Production*, *330*, 129808. https://doi.org/10.1016/J.JCLEPRO.2021.129808