Composites Part B 79 (2015) 197–203

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Environmental advantage by choice: Ex-ante LCA for a new Kraft pulp fibre reinforced polypropylene composite in comparison to reference materials

Franziska Hesser*

Market Analysis and Innovation Research Team, Kompetenzzentrum Holz Wood K plus, Feistmantelstraße 4, 1180 Vienna, Austria

ARTICLE INFO

Article history:
Received 24 February 2015
Received in revised form
20 April 2015
Accepted 23 April 2015
Available online 1 May 2015

Keywords:
A. Fibres
A. Polymer-matrix composites (PMCs)
A. Wood
B. Mechanical properties

ABSTRACT

This study analyses the circumstances of environmental advantage by benchmarking a novel Kraft pulp fibre reinforced polypropylene against its matrix material and two other composites with talcum and glass fibres. With one exception, all composites use less non-renewable energy (−1% to −29%), but only the Kraft pulp fibre reinforced polypropylene achieves a reduction in global warming potential (14% to 35%) considering different functional units compared to polypropylene. The comparisons on basis of function—strength and stiffness in this case study—show that the adequate application of specific material properties, are key to achieve environmental advantages.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The use of composite materials has been increasing due to enhanced material performance in comparison to traditional materials [1,2]. Whereat, material performance can be described by several attributes. The improvement of established materials or the development of new materials can be driven by several aspects such as enhancing material properties; decreasing cost of raw material and/or processing; meeting cultural criteria; reducing dependency on fossil feedstock; increasing the share of renewable feedstock; reducing potential environmental impacts.

The reduction of environmental impacts from products and processes by manufacturers gains importance considering new governmental regulations and strategies [1]. To give an example, the EU's growth strategy “EUROPE 2020” aims at directing economies towards sustainable growth by targeting a reduction in greenhouse gas emissions and an increase in renewable energy use and efficiency [3]. Several roadmaps under the flagship initiative of a resource-efficient Europe (Energy Roadmap 2050, Low Carbon Economy, Bio-economy, Resource Efficiency Roadmap; see European Commission for more details) propose the reduction of fossil resources dependency in the European economy. Cohen and Vandenbergh [4] state that carbon emissions and climate change are significant product claims among the sustainability-related ones brought forward by producers.

Considering the latter, the material selection process including environmental attributes should be thought of being crucial. Indeed, several material selection methodologies [1,2,5] allow for their implementation. However, restrictions in an environmentally informed material selection process are common, due to a general lack of relevant information on the environmental performance of materials. Not only producers using materials face this problem, also material researchers/developers do. Several studies [5–7] identified the polypropylene (PP) share within a composite as being the most environmentally intensive component of a composite. However, assessing the environmental performance of a composite is not as simple as following the basic idea of reducing its environmental impact by e.g. replacing a share of a resource-intensive material by a less resource-intensive one. By doing so, additional processes related to compounding, modification of material properties and product service are not accounted for. In their review article, comparing natural fibre reinforced composites to conventional materials, Duflou et al. [8] conclude that bio-based composites can be an alternative to reduce environmental impacts, but identify the need for further research on improving material properties and eco-profiles in parallel. Yan et al. [9] specifically

---

* Tel.: +43 1 47654 3569.
E-mail address: f.hesser@kplus-wood.at.

http://dx.doi.org/10.1016/j.compositesb.2015.04.038
1359-8368/© 2015 Elsevier Ltd. All rights reserved.

address that an environmental superiority of bio-composites needs careful analysis in light of relatively resource-intensive processing requirements of bio-fibres.

The main objective of this study is to estimate an eco-profile of a newly developed Kraft pulp fibre reinforced polypropylene composite (KFPP) during its material-development-phase. This phase was driven by the aim to develop a KFPP for injection moulding which is environmentally advantageous compared to the neat PP. Following, the aim further is to environmentally position this novel material amongst identified benchmark materials and at different bases of comparison (functional units). In addition to referencing the eco-profile of KFPP to the one of neat polypropylene, the eco-profiles of talcum reinforced polypropylene (TPP) and glass fibre reinforced polypropylene (GFPP) are also included as reference materials in order to illustrate other substitution strategies of polypropylene (PP) and to identify the scope for KFPP development in terms of environmental criteria during the material-development-phase.

2. Method and materials

2.1. Ex-ante LCA

Introducing life cycle assessment (LCA) as an approved, standardized (ISO 14040-series) and widely practiced method [10,11] to estimate potential environmental impacts of products, it needs to be pointed out that the concept of LCA is about relating the environmental impacts to a service provision rather than just to a product, its mass respectively [12]. Following this, the functional unit in LCA, is of central meaning, leading to a fundamental dilemma when it comes to “ex-ante” LCA which can accompany product or material research and development. A product at point of sale might be attributed several services, very much depending on the user's behaviour. In contrast, the service of a (raw) material or semi-finished product itself can only be defined via its mechanical, physical, magnetic, electrical, thermal or surface properties amongst others, which also describe material selection criteria [2]. The environmental assessment of new materials however, often faces major uncertainties due to process parameters, material formulation and material properties especially if materials are still in the research and development or pilot production stage. In such a case only a simplified LCA approach as environmental screening is possible. Niero et al. [13] characterize the simplified application of the LCA methodology by the use of generic datasets, standard modules for transportation and energy production e.g. as well as by the use of proxy indicators such as the cumulative non-renewable energy use (NREU) for the impact assessment [14]. In addition to NREU, the resource depletion perspective from fossil energy use, the global warming potential (GWP) within a time horizon of 100 years is often assessed in simplified LCAs, together representing the two most threatening environmental impacts [15]. Following, the main objective of this study is to estimate an eco-profile consisting of NREU and GWP of a newly developed KFPP composite in order to environmentally position this novel material amongst identified benchmark materials at different bases of comparison (functional units).

The novel composite consists of a PP matrix, reinforced by 20% Kraft pulp fibres per unit of mass (20 wt%). The Kraft pulp fibres are derived from a chemical pulping process. The advantage of this bio-based filler is its homogeneity and independence of season, contrary to natural fibres.

In a first step, this eco-profile is benchmarked against the eco-profile of the neat PP which is used as matrix for the composite material. Further, the composites TPP and GFPP both replacing the same amount of PP (20 wt%) are also benchmarked against the neat PP. The idea is to analyse the relative difference of potential environmental impact of the three composites referring to neat PP. With that, the environmental effect of replacing 20 wt% of PP by three different fillers can be illustrated.

2.2. Data

As pointed out in the previous section, a simplified LCA is conducted which results in only modelling the major inputs from resource extraction (cradle) to composite pellets at factory gate, which are: the matrix material PP; the fillers Kraft pulp fibres, talcum, glass fibres; energy for transportation and compounding related processes. Data sets are derived from literature, GEMIS Database [16] as well as on site data collection and experimental data considering the KF20PP.[1]

Due to incompleteness of life cycle perspective and data collection for the production phase, such as final process parameters, not all additives, packaging, etc. the results of this simplified LCA are to be rated as preliminary.

2.3. Indicators

The impact assessment for establishing the eco-profiles is reduced to calculating NREU representing the input perspective and GWP representing the output perspective. In contrast to NREU, which only indicates on the use of fossil resources, the GWP from cradle-to-factory gate also indicates on biogenic resources: Atmospheric carbon which is taken up by plants for photosynthesis is accounted for as negative greenhouse gas emission following [17].

2.4. Bases of comparison/functional units

The definition of the functional unit representing the service of the product which is environmentally assessed is fundamental, for all results refer to this unit. For this reason, the assessment of the materials also considers different functional units as bases of comparison. The eco-profiles are calculated referring to different bases of comparison:

- Comparison at equivalent mass in MJ/kg material for NREU and kg CO_2e/kg for GWP;
- Comparison at equivalent volume given in MJ/m^3 material for NREU and kg CO_2e/m^3 for GWP;
- Comparison at equivalent strength given in MJ/panel for NREU and kg CO_2e/panel for GWP;
- Comparison at equivalent stiffness given in MJ/panel material for NREU and kg CO_2e/panel for GWP.

For the latter two bases of comparison, an example following the material selection methodology of Ashby [18] for a panel with given strength/stiffness properties is given. This method is used to identify substitutes for conventional materials [19] and is useful for initial screening of material alternatives [2] including also the possibility to implement environmental selection criteria [10,20]. Using the performance equations for minimum weight and minimum NREU/GWP design of strong panels and stiff panels [19], two examples of functional comparisons are given.

3. Results

The results shown below are structured in line with the research process. To begin with, data for developing the eco-profiles are gathered as explained in the section above (2.2 Data).

---

[1] 20% by weight Kraft pulp fibre reinforced polypropylene.

Download English Version:

https://daneshyari.com/en/article/817249

Download Persian Version:

https://daneshyari.com/article/817249

Daneshyari.com