Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 7 (2017) 183 – 190

Procedia MANUFACTURING

International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2017, 23-25 January 2017, Kruger National Park

Carbon Footprint Analysis of Fibre Reinforced Composite Recycling Processes

Norshah Aizat Shuaib*, Paul Tarisai Mativenga

School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester, M13 9PL, United Kingdom

Abstract

Global rise of composite material demand has led to major legacy problems of manufacturing and end of life waste. The heterogeneous nature of composite material is the main challenge for recycling. In the European Union, tighter legislation on landfill, increasing landfill tax and loss of valuable material are driving the need for development of composite recycling technology. However, the recycling environmental benefits may not be optimised due to lack of high integrity environmental datasets. This study considered mechanical, high voltage fragmentation (HVF) and chemical recycling methods. New carbon footprint models were developed for each process. Experimental modelling was used to provide detailed process data associated with the processes. The Environmental Product Declaration (EPD) of the processes were evaluated through life cycle assessment studies. This work identifies that the electrical energy demand dominates the overall resource footprint in mechanical and HVF recycling methods. For both processes, extended tool life and optimised processing rate could significantly reduce the carbon footprint per unit of weight of waste processed. Environmental impact of the chemical recycling method was highly dominated by acetone used as the solvent. The refined datasets generated in this study enable better resource analysis to minimise carbon footprint of composite recycling processes. This is hoped to help increase market value of the recyclates by highlighting the environmental benefits gained through potential reuse applications.

Peer-review under responsibility of the organizing committee of SMPM 2017

Keywords: Composites; Recycling; Carbon footprint; Life cycle assessment; Sustainability

1. Introduction

The usage of composite materials spans across demanding and critical sectors such as, automotive, construction and aerospace. A recent example of the usage is the incorporation of 50% carbon fibre composites in latest aircraft models such as Airbus A350 and Boeing 787 Dreamliner [1]. The rapid production growth is due to the excellent

* Corresponding author
E-mail address: norshah.shuaib@manchester.ac.uk

Peer-review under responsibility of the organizing committee of SMPM 2017
doi:10.1016/j.promfg.2016.12.046

mechanical properties of composites such as high stiffness to weight ratio and corrosive resistance.

The main issue is the disposal of manufacturing and end of life composite material waste. Recycling of composite materials is not as straightforward a process as recycling monolithic materials such as metals and plastics. The heterogeneous nature of composite materials makes the separation of matrix and fibre very difficult. In addition, most high grade applications use thermoset binder which unlike thermoplastics cannot be easily melted and remoulded. These are the main challenges for recycling composite material. Currently, recycling of composite waste is not a regular practice [2]. For example, in the United Kingdom, disposal to landfill is most common for manufacturing and end of life composite waste [3]. However, disposal to landfill is the least preferable waste management strategy according to waste hierarchy [4].

The other issue of landfill is the loss of valuable and high embodied energy materials. Carbon fibre reinforced plastics (CFRP) and glass fibre reinforced plastics (GFRP) have average embodied energy of production around 380 MJ/kg and 145 MJ/kg respectively [5]. In terms of monetary value, the carbon fibre has a price in the range of £15 to £23 per kg compared to £1 and £21 for glass fibre. Therefore, there is also a clear financial opportunity in recovering carbon fibre material, although environmental concern is the main driver to reuse glass fibre composite waste.

The core principle of composite recycling technology is to separate the reinforcements (fibre/filler) from the matrix (resin) components. The technology can be divided into several categories namely mechanical, chemical, thermal, electrochemical, biotechnological and high voltage fragmentation (HVF). At present, the mechanical and pyrolysis (thermal) are the most advanced technique to recycle GFRP and CFRP respectively [6]. These processes are available at industrial scale and commercially active. The solvolysis process (chemical recycling), was found to be very promising in recovering clean and high quality carbon fibre by degrading resin in solvent at a given temperature and pressure [7]. Several companies such as Panasonic Electric Works Co Ltd and Hitachi Chemical have developed pilot scale chemical recycling processes, however their long term commercial viability is still unknown. New processes such as HVF were found to be feasible to produce clean recovered fibres and long mean fibre length [8]. From the past decades, mechanical recycling was found to be the most rapid technique to recycle glass fibre composites [9, 10].

High integrity environmental assessment depends on the quality and availability of inventory or input data [11]. While previous studies have mainly focused on process feasibility and reusability of recyclates [6], the environmental credentials of composite recycling methods has not being thoroughly analysed.. A robust energy modelling approach has to be considered in estimating overall resource footprint of these recycling methods. In previous studies, the emission factor of composite recycling methods was only considered from the direct electricity energy demand. However, the impact of recycling processes needs to be further assessed by including other process inputs and consumables.

This paper analyses the environmental footprint of mechanical, high voltage fragmentation (HVF) and chemical processes as fibre reinforced composite recycling methods. The environmental impact of process consumables is important, especially on an industrial scale. This is still missing in the literature. Analytical and experimental modelling was used in this study to provide detailed resource footprint data. The generated models were combined with life cycle assessment studies and the contribution of energy components in each process was elucidated. The model and assessment of environmental impact allows relevant strategies to be implemented in order to minimise impact. The methodology allows resource hotspot to be identified and targeted and is in line with global and national strategy to minimise the overall footprint of manufacturing processes.

2. Research methodology

The methodology used in this study was a combination of experimental work and life cycle assessment studies. The data generated in experimental trials and authors' previous studies were used as an energy signature inventory for the life cycle assessment study. A model, which considers main contributors for process carbon footprint, was developed for each recycling method.

2.1 Recycling equipment and processes