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Recycled wind turbine blades as a feedstock for second generation composites

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ABSTRACT

With an increase in renewable wind energy via turbines, an underlying problem of the turbine blade disposal is looming in many areas of the world. These wind turbine blades are predominately a mixture of glass fiber composites (GFCs) and wood and currently have not found an economically viable recycling pathway. This work investigates a series of second generation composites fabricated using recycled wind turbine material and a polyurethane adhesive. The recycled material was first comminuted via a hammer-mill through a range of varying screen sizes, resinated and compressed to a final thickness. The refined particle size, moisture content and resin content were assessed for their influence on the properties of recycled composites. Static bending, internal bond and water sorption properties were obtained for all composites panels. Overall improvement of mechanical properties correlated with increase in resin content, moisture content, and particle size. The current investigation demonstrates that it is feasible and promising to recycle the wind turbine blade to fabricate value-added high-performance composite.

1. Introduction

The demand for wind and other forms of clean energy is increasing in the US and throughout the world. Wind energy is also expected to provide 14.9% of the global electricity demand by 2020 (Liu and Barlow, 2017). Under this scenario, a significant amount of wind turbine blades will continue to burden our current landfills until a viable recycling strategy is found. Repurposing or recycling of end-of-use wind turbine blade material will provide both economic and environmental attributes.

While some components of the wind turbine are recyclable (such as the metal parts in the tower and gearbox) (Martínez et al., 2009; Schleisner, 2000), recycling the blades has been difficult due primarily to the thermoset binder used in the synthetic fiber (primary glass) composite (The Europen Commission for the Environment, 2016). In most WTBs, approximately two-thirds of the total weight of the blade is made of GFC (Papadakis et al., 2010). Most GFC-based WTBs have a predicted life expectancy of 20 to 25 years (Beauson et al., 2016). Estimations predict that the amount of end-of-life WTB materials will account for 100,000 tons per year in Europe in 2030 (Larsen, 2009; Marsh, 2017). Furthermore, reusing the blades is not recommended due to design limitations that are quite challenging (Beauson et al., 2013; Jongert et al., 2016) and costly. Options to incinerate or disposal has negative environmental contributions (Wackernagel and Rees, 1996; Sikdar, 2003; World Commission on Environment and Development, 1987) and disregards the potential rWTBs have as a feedstock for second generation products. There is a potential to recycle the glass fiber from the thermoset matrix via chemical or thermal treatments (Phoenix Fiberglass Inc, 1994), however the resulting fiber is often lower in mechanical properties than virgin fibers and are very difficult to disperse into many matrices due to their crimped and entangled form. Mechanical techniques that employ shredders, hammer-mills, knife-mills, etc. provide a low-cost option to deliver a reliable feedstock (Phoenix Fiberglass Inc, 1994; Bledzki and Goracy, 1993; Petterson and Nilsson, 1994). However, the methods and classification procedures within the mechanical refining process are vital parameters to address to achieve the maximum potential of the rWTB materials while maintaining minimal energy and costs.

Much research with recycled synthetic fiber composites has been targeted to liberate the glass fiber from the composite matrix (Kennerley et al., 1998; Pickering et al., 2000) or reuse of shredded composites (SC) in new thermoset polymer composites in order to reduce the amount of virgin glass fiber in existing composite (Palmer, 2009; Jutte et al., 1991; Palmer et al., 2009; Derosa et al., 2004; Method of Determining and Expressing Fineness of

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Nomenclature

GFC	glass fiber composite	BW	balsa wood
WTB	wind turbine blade	TGA	thermogravimetric analysis
rWTB	recycled wind turbine blade	IB	internal bonding
SC	shredded composite	MOE	module of elasticity
MSS	mill screen size	MOR	module of rupture
MC	moisture content	EW	eucalyptus wood
pMDI	polymeric methyl-diisocyanate (Rubinate 1840)		

Feed Materials by Sieving; Derosa et al., 2005; Silva et al., 2012). However, just a few studies considered the SC as the predominate component (above 90%) within the composite (Kouparitsas et al., 2002; Zheng et al., 2009; Dangtungee et al., 2012; Yazdanbakhsh et al., 2018).

The work within this paper investigated the development of a composite panel derived from mechanically refined rWTB using a thermoset adhesive as a binder. The second generation composite was evaluated to determine the influence of mill screen size (MSS), moisture content (MC), density, and resin level had on the mechanical and physical properties.

2. Materials and method

2.1. Materials

Recycled wind turbine blade (rWTB) material supplied by Global Fiberglass Solutions at an incoming MC of 1.25%. A polymeric methyl-diisocyanate (Rubinate 1840) (pMDI) resin was kindly supplied by Huntsman and was used as the binder for the second generation panel product. The rWTB material was then hammer-milled through 12.7, 6.35, 3.18, and 1.59 mm screen size, respectively. Particle size distribution of the hammer-milled was performed, which is illustrate in Fig. 1.

2.2. Thermal analysis

TGA was carried out to determine the thermal stability of the rWTB material and to also provide an estimate of the composition of materials within the rWTB. For this analysis the glass fiber composite and BW (genus *Ochroma*) were separated and run independently along with a sample of the unseparated rWTB. The specimens were heated from ambient to 800 °C under nitrogen at the heating rate of 20 °C min^{-1}.

2.3. Manufacturing of rWTB composites

The various size fractions of the rWTB materials were sprayed with resin and water (to obtain the targeted MC) within a drum blender according to Table 1. The blended rWTB was then hand-formed and hot pressed to a size of 355.6 × 355.6 mm composites panels (duplicate) with a thickness of 7.62 mm. The hot press temperature and time were set as 138 °C and 5 min accordingly, typical for pMDI composite processing (Gurke, June 2002) (Fig. 2(c)).

Mechanical and physical tests (Flexural, IB, water sorption, and thickness swell) were performed based on ASTM D1037-12 and compared with ANSI 208.1-2009. One-way CoANOVA was performed to determine the differences of mechanical properties of fabricated panels. The actual density was used as a covariate to eliminate and effects from the final specimen density. The confidence level was selected as 95%. Duncan grouping was used to identify statistically significance between the means.

3. Results and discussion

3.1. Thermogravimetric analysis (TGA)

The thermal degradation profiles of BW, GFC, and rWTB (mixture of BW and glass fiber composite) material by TGA reveal that most of the degradation events occur between 300 °C and 450 °C

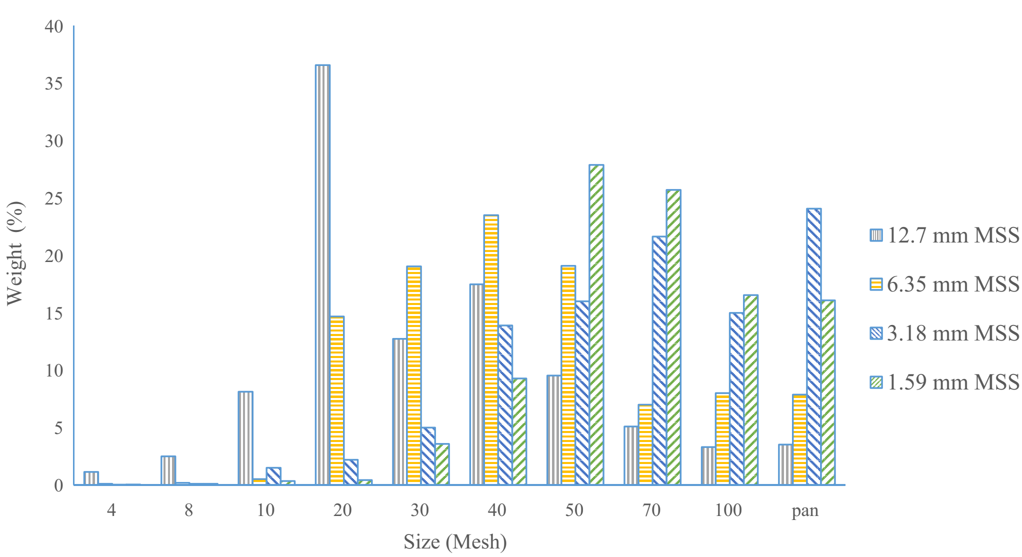

Fig. 1. Particle size distribution from varying MSS (Method of determining and expressing fineness of feed materials by sieving).