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Recycling of polymeric fraction of cable waste by rotational moulding

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ABSTRACT

This study focuses on the mechanical recycling of polymeric waste that is produced in considerable amount from the cable industry. Every year large amounts of cables become waste; wires recycling has traditionally focused on metal recovery, while the polymer cover has just been considered as a residue, being landfilled or incinerated. Nowadays, increasingly restrictive regulations and concern about environment make necessary to reduce landfilling as much as possible. Main novelty of the study is that the material used in the research is a post-consumer material and the entire residual material is used, without a previous purification, in contrast with similar studies. Characterization of this residue was performed by thermal analysis, showing that the material is mainly made up of a heavy fraction (84% of the residue), which is not able to melt, fact what makes recycling more difficult. Once characterized, the material was ground, blended with virgin polyethylene and reprocessed by rotational moulding. The influence of the amount of residue and parts structure (1, 2 and 3 layers) was assessed, studying the mechanical behaviour of obtained parts (tensile, flexural and impact properties). It has been found that although mechanical properties get reduced with the increased amount of residue, up to a 35% of residue can be used without an important decrease in mechanical properties. On the other hand, the use of multiple layers in the mouldings allowed obtaining a better external appearance without compromising the mechanical properties.

1. Introduction

Since the first industrial scale production of plastics in the 1940s, both the production and consumption of plastics have increased exponentially (Bajracharya et al., 2016) reaching 311 million tonnes in the global production of plastic in 2014 (Plastics Europe, 2015). However, this fact has been accompanied by a significant waste generation. The recycling of plastics has become extremely important in the industrial world as plastics are now an integral part of modern living. With their large and varying applications, plastics contribute to an ever increasing volume of the solid waste stream (Siddique et al., 2008). In 2014, 25.8 million tonnes of post-consumer plastics waste were generated in EU27 plus Norway and Switzerland. 69.2% was recovered through recycling (30.2%) and energy recovery (39%) processes while 30.8% still went to landfill (Plastics Europe, 2015).

Nowadays, with the increasing cost and decreasing space of landfills, there is a growing worldwide concern that the disposal of plastic solid waste will soon become a major problem, as reflected in different European directives like Directive 94/62/EC, Directive (EU) 2015/720 or Directive 2008/98/EC. Furthermore, the European Strategy for Plastics in a Circular Economy establishes some objectives to reduce wastes and increase recycling; some of these targets are: recycling of 65% of municipal waste by 2030; recycling of 75% of packaging waste by 2030; reducing landfill to maximum of 10% of municipal waste by 2030; recycling more than half of waste plastics by 2030. One of the best options for managing the plastic solid waste is recycling rather than incineration to decrease the waste volume and reduce environmental issues (Rajendran et al., 2012). The facts that most recycled plastic cannot be used for the same application for reasons of health and environmental protection (Bajracharya et al., 2016) and that plastics arriving to landfills are often blends of different polymers,

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making them not economically feasible to separate them, explain the low recycling rate.

One of the sources of this kind of waste is the wire industry. As with all industrial activity, waste is generated during the manufacturing of cables and when cables are scrapped. Only in Sweden approximately 40.000 tonnes per year of wires and cables become waste (Boss, 2014). For economic and environmental reasons recycling or recovery of the material components from this waste is essential. The driving force of cable recycling has since long been the high value of the conductor, copper and aluminium; also for environmental reasons it is very important to recycle these metals. However, not much effort has been made concerning the recycling of the polymer fraction (Collin and Alm, 2007). For a sustainable future, the recycling of cables not in use needs to increase and improved methods for recycling both metals and polymers in cable waste need to be implemented (Boss et al., 2011). Besides, recovery of cable plastic is motivated by the need to avoid costs associated with waste disposal, as well as by the potential for generating income from the sale of recovered plastics that can replace virgin raw materials.

Waste from end of life and scrapped cables that are collected from different sources constitute a broad mix of cable types and material components, such as metals, plastics, rubber, paper and glass fibres (Borealis AG, 2014). The most common way to recover metals from cable waste in the developed countries is by the cable granulation process. A pre-sorting of these cables is made as a first step, then granulation and separation of the plastics from the metal occurs (Borealis AG, 2014). Typically, once the metal fraction has been recovered, the remaining material (up to 70% of the total cable) is a mixture of the various polymers and is contaminated with metal residue (1–2%) (White et al., 2000). The main plastic components in cable waste from cables recycled today are polyvinyl chloride (PVC) and polyethylene, either in crosslinked (XLPE) or thermoplastic (PE) form. Some alternatives exist today for these materials. The separation technique in use today enables effective separation of the two main types. The PVC fraction can be re-melted and processed to new products, as in the Vinliloop process. As the separated components are less clean than virgin material, the recycled material is typically used in applications with lower quality requirements (Borealis AG, 2014). However, cross-linked polyethylene (XLPE) is still difficult for material recycling because of its non-thermoplasticity (Ashihara et al., 2008). Thermosets are generally not considered recyclable due to the relative inability to process these materials by melting. However, the need to develop strategies for the economical reclamation and reprocessing of thermosets has become important, due in part to consumer and legislative pressures (White et al., 2000).

Several studies have been conducted with the purpose of reprocessing these difficult recycling materials; this is the case for XLPE, which constitutes one of the major problems for wire residues plastic recycling. Some authors (White et al., 2000; Qudaih et al., 2011; Janajreh and Alshrah, 2013) studied the mechanical recycling of XLPE, mixing the XLPE with PE and reprocessing it by compression, extrusion or injection moulding. Others, instead of a mechanical recycling, studied the chemical recycling of XLPE by chemical, mechanical or mechanochemical de-crosslinking (Lu et al., 2015; Tokuda et al., 2003; Goto et al., 2003; Ashihara et al., 2008; Lu et al., 2009; Triboulet et al., 2000). Particularly interesting is Vinnova sponsored project "Recycling of electrical cables with focus on mechanical recycling of polymers in end-of-life cables" (Boss, 2014), where separation methods for selected waste flows were tested; this project also conducted an assessment of the mechanical recycling of electrical cables with focus on recycling the various polymers in the cable waste: PVC, PE, XLPE and halogen free flame retardant materials (HFFR). They analysed different plastic processing technologies (injection and rotational moulding and extrusion) using different virgin polymers to do the compounds and varying process parameters.

As summary, although some progress has already been achieved, recycling of the polymeric components of cable continues being a problem to be solved. Sustainable methods for sorting and mechanical recycling of cable plastics are needed (Boss, 2014) in order to increase sector's sustainability. But, as the main problem in recycling polymeric multi-material products is related to difficulty in separating their components, it could be also interesting to find solutions to allow recycling without separating them. In this context, this research aimed at analysing the technical feasibility of mechanical recycling of the entire waste material coming from wires recovery, without the need of a previous separation.

Rotational moulding has been chosen to obtain test parts, due to some specific features of the process, but also to the fact that only one study dealing with this process and wire wastes has been found in literature (Boss, 2014). This process is an interesting application area for recycling of cable polymers for several reasons. On the one hand, the process utilizes powder, which means there is no need of compounding. On the other hand, cable plastic compounds generally have a high level of antioxidants to prevent thermal oxidative degradation, which is required for rotational moulding due to long processing times and relatively high temperatures used in the process. In this work the influence (in terms of mechanical properties) of the amount of residue incorporated into the rotomoulded parts together with the part structure (mono or multilayer) was studied.

2. Material and methods

2.1. Material

The residual material was supplied by the company Recuperadora Canaria de Chatarra y Metales S.L., once the metal fraction has been recovered by the company. The material consists in a mixture of different polymers of colour, size and shape, as it can be seen in Fig. 1. Besides, the plastic fraction is polluted with metal particles due to the impossibility of achieving a full metal recovery. According to White et al. (2000) the common metal content in cable waste is 1–2% by weight.

Medium Density Polyethylene Lumicene M 3581 V, supplied by Total Refining & Chemicals, was mixed with the residue to obtain the pieces by rotational moulding. Polyethylene is the main material used in this technology due to its low melting point, low cost, and good thermal stability; in fact, about of 85% of the

Fig. 1. Polymeric components of cable residue after separation of metals.

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