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Aluminium cables recycling process: Environmental impacts identification and reduction

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ABSTRACT

Life cycle impact of European generic primary and secondary aluminium are well defined. However specific end-of-Life scenario for aluminium products are not available in the literature. In this study, the environmental assessment of cable recycling pathway is examined using the Life Cycle Assessment (LCA) methodology. The data comes from a recycling plant (MTB Recycling) in France. MTB Recycling process relies only on mechanical separation and optical sorting steps on shredder cables to obtain a high purity aluminium (above 99.6%). The life cycle assessment results confirm the huge environmental benefits for aluminium recycled in comparison with primary aluminium. In addition, our study demonstrates the gains of product centric recycling pathways for cables. The mechanical separation is a relevant alternative to metal smelting recycling.

This work was done firstly to document specific environmental impact of the MTB Recycling processes in comparison with traditional aluminium recycling smelting. Secondly, to provide an environmental overview of the process steps in order to reduce the environmental impact of this recycling pathway. The identified environmental hotspots from the LCA for the MTB recycling pathway provide help for designers to carry on reducing the environmental impact.

1. Introduction

1.1. General context

The European demand for aluminium has been growing over the past few decades at a rate of 2.4% per annum (Bertram et al., 2006). The aluminium mineable reserves are large, but finite, an average value for the ultimately recoverable reserve is about 20–25 billion tons of aluminium. Nowadays, the aluminium production is about 50 million tons per year (Sverdrup et al., 2015). Increase for aluminium demand in Europe is mainly supported by the rise of recycling which growth was in the same time about 5% per annum (Bertram et al., 2006; Blomberg and Söderholm, 2009). The abundance and the versatility of aluminium in various applications have made it one of the top solutions for lightweight metal strategy in various industries such as automotive (Liu and Müller, 2012). In the cable industry, substitute copper for aluminium can considerably reduce the linear weight without degrading too much the electrical properties (Bruzek et al., 2015). To obtain optimal electrical conductivity, aluminium use for cables has purity above 99.7% (Goodwin et al., 2005). Because secondary aluminium does not meet the quality requirements for aluminium cables manufacturers; only primary aluminium is used for the aluminium cables supply chain. Nevertheless, improvement in recycling could help reach quality targets, by using new sorting technologies.

Aluminium properties are not deteriorated by recycling. However, in most cases aluminium parts are mixed together at the end of life step without considering their provenance and use. According to this, the seven series of aluminium are mixed together in waste treatment plant. All aluminium series do not have the same purity and alloying elements pollute aluminium. When aluminium series are mixed together, the cost-effective solution for refining use furnaces. As the metal is molten, the separation is done by using the difference of density and buoyancy (decantation methods, centrifugation, filtration, flotation, etc.) (Rombach and Friedrich, 2003). Despite the technology optimisations, some alloying elements are lost in the process (Paraskevas et al., 2013) and a fraction of metal is not recycled (Ohno et al., 2015). It leads to a drop of the metal quality which is akin to a down-cycling (Allwood, 2014).

By mixing all the aluminium waste streams, it becomes very difficult to maintain a high level of purity for the recycled aluminium. Streams

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Nomenclature

List of acronyms

BIR	Bureau of international recycling
EAA	European aluminium association
ENTSO-E	European network of transmission system operators for electricity
EoL	End-of-Life
ETV	Environmental technology verification
IAI	International aluminium institute
ILCD	International life cycle data
JRC	Joint research centre
LCA	Life cycle assessment
LCI	Life cycle inventory
PE	Polyethylene

of material available for recycling become increasingly impure as they move further along the materials processing chain, and therefore refining the stream for future high-quality use becomes more difficult. In particular, recycling materials from mixed-material products discarded in mixed waste streams, is most difficult (Allwood et al., 2011). To make a step toward the circular economy, it is essential to achieve a recycling industry (Sauvé et al., 2016).

Upstream, the solution lies in a better separation of aluminium products to steer each flow to a specific recycling chain. This strategy should enable products to be guided through the best recycling pathway and maintain the quality of alloys. This strategy makes it possible for manufacturing companies to take back their own products and secure their material resources (Singh and Ordoñez, 2016). Increasing the quality of recycled materials should allow recycling company to integrate close loop End-of-Life (EoL) strategy.

1.2. Morphology of aluminium cables

The cables are composed of numerous materials. As illustrated in Fig. 1, the cables are composed of an aluminium core cable (a), covered with a polymer thick layer (b). Additional metallic materials (c) are coaxial integrated into the matrix of cables. These cables are manufactured by extruding together all the materials that compose it.

The Table 1 shows the mass proportion of materials contained in cables. Mass proportions are extracted from MTB monitoring data of cables recycled at the plant between 2011 and 2014. Aluminium in cables represents between 35 and 55% of the total weight. Other metals are mainly steel, lead, copper and zinc. The variety of plastics contained in the sheath is even stronger than for metals: silicone rubber, polyethylene (PE), cross-linking PE (xPE), polypropylene, polychloroprene, vulcanised rubber, ethylene vinyl acetate, ethylene propylene rubber, flexible polyvinyl chloride (PVC), etc. (Union Technique de l'Électricité (UTE), 1990). Although aluminium cables represent about 8% of aluminium products in Western Europe (European Aluminium Association (EAA), 2003), the inherent purity of aluminium used for cables justifies differentiate recycling channels to optimise processing steps and to improve cost efficiency. At the end of life, the challenge concerns the separation of materials from each other. The most economical way to separate different materials rely on a smelting purification (European Aluminium Association (EAA), 2006).

1.3. Presentation of MTB recycling process for aluminium cables

An alternative process for EoL cables uses only mechanical steps instead of thermal and wet separation as developed for several years by MTB Recycling, a recycling plant located in south-east of France. The specific processes were developed by MTB engineers and the system is sold worldwide as cables recycling solution. It reaches standard aluminium purity up to 99.6% for quality A and B (Table 2). This performance is obtained using only mechanical separation and optical sorting processes on shredder cables. Aluminium quality D production mainly comes from flexible aluminium, our study does not consider this production.

Each batch of aluminium (25 t) produced by MTB is analysed by laboratory spectrometry. The Table 2 presents the averaged analysis results of the chemical elements present in aluminium batches. Between 2012 and 2014, more than 400 lots were analysed. During this period only 40 batches were below the average. The aluminium obtained from recycled cables is specially appreciated by the smelter. Its high purity makes it easy to produce a wide variability of aluminium alloys. Recycled aluminium can then be used in many aluminium products and not only in applications requiring high alloy aluminium.

1.4. Issues of the study

The initial motivation for our study was to rank the environmental performance of the MTB recycling pathway in relation to other aluminium recycling solutions. In addition, we wanted to identify the main process contributing to the global environmental impact. What are the environmental gains to overcome the aluminium recycling by smelting? Firstly, this article attempts to present the environmental assessment results that enabled the comparison of the three aluminium production scenarios. On the one hand, the study demonstrates huge environmental benefits for recycled aluminium in comparison with primary aluminium. And on the other hand, the results show the harmful environmental influence of the heat refining by comparison with the mechanical sorting processes used at the MTB plant. The study demonstrates the interest of recycling waste streams separately from each other.

Although the starting point of the study was to assess and document the environmental impact of a specific recycling pathway; the results of this study have allowed to identify several environmental hotspots of the MTB Recycling process. Thus, leads to the development of the effectiveness implementations to reduce the environmental impacts of the MTB recycled aluminium. This article presents how the Life Cycle Assessment methodology allowed the engineering team to improve the environmental efficiency of MTB Recycling processes.

2. Methodological considerations

2.1. Environmental assessment of aluminium recycling

To evaluate the environmental performances of the MTB cable recycling pathway, we chose to use the Life Cycle Assessment (LCA) methodology. Today, the environmental LCA of European generic

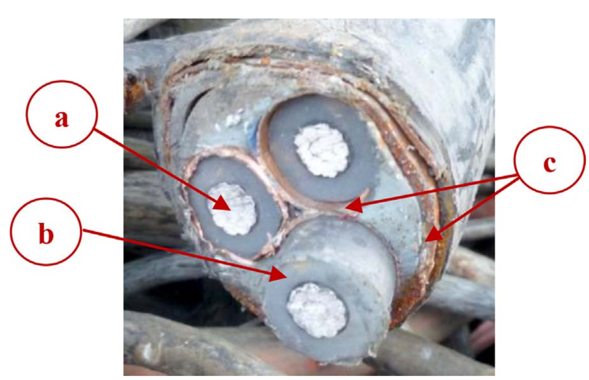

Fig. 1. Section of a cable with multiple aluminium beams.