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Procedia CIRP 48 (2016) 10 – 15

www.elsevier.com/locate/procedia

23rd CIRP Conference on Life Cycle Engineering

Is the Australian Automotive Recycling Industry heading towards a Global Circular Economy? – A Case Study on Vehicle Doors

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Abstract

The increasing use of lightweight materials and multi-material concepts in vehicle design has create challenges for traditional vehicle recycling. This has consequently caused the increasing contamination rate for valuable recovered materials, and increasing plastic materials being landfilled for end-of-life vehicles in Australia. A life cycle comparative analysis will be carried out based on the car door material audits for different vehicle age and model. The paper shows that the trend in vehicle design has improved the environmental impact in use phase; however, it has led to the exhaustive use of natural resources due to the down-cycling impact, hindering a sustainable global circular economy based on the Australian case scenario.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering

Keywords: Life Cycle Assessment; multi-material designs; end-of-life vehicles; vehicle recycling; circular economy

1. Introduction

Environmental concerns have instigated the need for reducing fuel consumption and recovering material at the end-of-life (EOL). In the move toward more sustainable vehicles, manufacturers have been designing different power train vehicles and also adopting lightweight materials in car manufacturing.

In recent years, alternative materials have been increasingly used in manufacturing vehicles for weight reduction while retaining the safety performance and robustness. Vehicle manufacturers have focused on designing lightweight vehicles that use materials with high strength-to-weight ratio to reduce vehicle mass such as aluminium, magnesium, advanced high strength steel, fibre reinforced plastics, and composites.

Combination of lightweight materials is widely used in the mass-optimised design approach in vehicles. The adoption of multi-material designs has been increasing to further optimise the overall mass of the vehicle for fuel efficiency, safety, comfort, and better environmental performance. However, material recovery at the EOL by traditional techniques is difficult due to the complexity of separating the material types while maintaining a high level of material purity [1].

Life Cycle Assessment (LCA) is a widely used tool to assess the environmental performance of vehicle life cycle, and to assist manufacturers to produce low emission vehicles. Nevertheless, LCA is often limited by time delays and the inability to account for material degradation in a closed-loop system [2]. The materials and processes used to improve the quality of valuable materials recovered need to be included in the recycling phase rather than just accounting for the avoidance of virgin material production. This is crucial to ensure the resultant environmental performance from the life cycle analysis is targeted towards a realistic cradle to cradle approach.

This paper investigates the impact of vehicle design trend on current recycling practices in Australia through a vehicle door case study. A thorough material audit was carried out for 4 vehicle doors made from different manufacturers and years, 1982 to 2013 providing a comprehensive material data for a comparative LCA highlighting the presence of contaminants during recycling phase. This study also assesses the sensitivity of the vehicle doors' life cycle impact under different end-of-life scenarios, to better understand the increasing challenges to achieve the sustainable circular economy.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.03.099

2. End-of-Life Vehicle Recycling in Australia

From 2001 to 2015, new motor vehicle sales in Australia have increased by 48% [3]. When coupled with the average vehicle life in Australia of 10.1 years [4], it is expected that the number of vehicles reaching EOL will continue to increase. Based on the Australian Bureau of Statistics, about 765,828 vehicles reach their end of use life between 2014 and 2015 [4].

In Australia, end-of-life vehicles (ELV) are passed from the last owner to the auto recyclers directly or through insurance companies, used car dealers or vehicle repairers [5]. Firstly, the ELV undergo depollution process to remove batteries and fluids. Valuable or high demand auto parts are removed and sold by the auto recyclers for financial gain. The ELV are then displayed for a period of time in the auto recyclers' yard for further auto part removal by customers based on the market demand. After that, the remaining ELV are baled to ease transportation to metal shredding facility for further material recovery. The high level ELV material flow based on the current observation in the automotive industry can be seen in Figure 1.

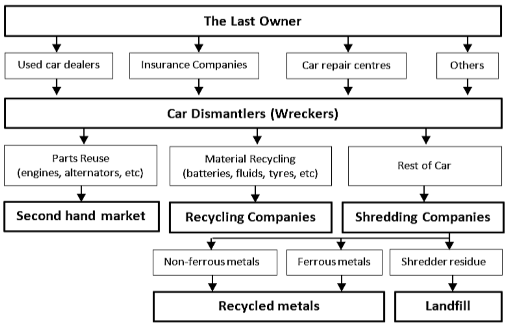

Figure 1: High Level ELV Flow in Australia.

The ELV recycling industry in Australia is solely driven by financial gain [6]. There are no specific ELV recycling policy mandated to ensure safe disposal and recycling of ELV. The framework to address specific waste issues through co-regulatory schemes by industry and government is captured under voluntary product stewardship arrangements such as the Product Stewardship Act 2011 [7]. However, ELV are not captured under this Act.

2.1. ELV Material Flow in Shredder Facility

As seen in Figure 1, other vehicle parts that are not recycled for secondhand market are sent to metal shredding yards for metal recovery. For many years, steel has been the major material recovered due to the high steel content in vehicles. Moreover, metal shredding yards in Australia serve as the feedstock for large steel mills such as OneSteel and Sims recycling. The business model focused on steel recovery is facing increasing challenges due to the complexity of multi-material designs with the use of more light metals, plastic, and composite materials reducing yield.

Automotive shredder residue (ASR) consisting of plastic, composites, rubber, and other non-recoverable materials is landfilled. This is a major concern due to the negative environmental impacts particularly with the increasing use of plastic and composites to further optimise the vehicle mass. Landfilling has been a driver for the implementation of vehicle recycling policy for countries such as Japan [8] but not in Australia. This practice is still common due to the relatively low ASR landfill costs in comparison to other countries [9].

2.2. Quality of Recovered Material

Material degradation is inevitable due to the presence of contaminants in each valuable recovered material stream through the current recycling practice. This is caused by the combination of different material types or the part designs such as steel encapsulated with rubber, or the use of steel fasteners to combine steel and plastic materials. The contaminants' material type has a large effect on the material quality when they are recycled to be reused as secondary material [10].

There is a range of tolerable amount of contaminants that could be present in the steel scrap to ensure the secondary steel grades are fulfilled. For instance, bar steel made of steel scrap could have a maximum of 0.4wt.% copper content, whereas cold-rolled sheet only accept a maximum of 0.04wt.% copper content [11]. If the contaminated vehicle steel scraps were to be used to reproduce the original steel grade such as the cold-rolled sheet, contaminants such as copper will need to be diluted using more high purity steel [2].

The recovery of different non-ferrous metals poses a more difficult challenge. The separation of different non-ferrous metals such as aluminium, magnesium, copper, and others can be costly to recyclers. Therefore, smaller fractions of non-ferrous metal such as magnesium often ended up in other light metal fraction such as aluminium, or used as alloying additives [12].

3. Methodology

3.1. Objective of Study

This paper assesses the environmental impacts of the material trend for different vehicle door designs in accordance to the ISO 14040 series [13]. Vehicle door material audits were carried out for a full-size sedan Australian vehicle made in 1982 (Ford Falcon XE) and 1999 (Holden Commodore VT), a subcompact hatchback European vehicle made in 2009 (Ford Fiesta), and a subcompact hatchback Japanese vehicle made in 2013 (Mazda 2). The sensitivity of the results with regard to varying recycling scenarios was explored. To account for a more realistic cradle to cradle analysis, the effect of material quality loss, and the use of primary materials for the production of acceptable material grades were included.

3.2. System Boundary

The environmental impact associated with production, use, transportation, and recycling phase of vehicle doors were included in this study. As door parts such as outside rear view mirror, vehicle door hinge, and cylinder door lock were missing for some vehicle door models, the analysis excluded them for comparability. The analysis only considered gasoline