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Scrapping steel components for recycling—Isn't that good enough? Seeking improvements in automotive component end-of-life

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ABSTRACT

Life cycle management (LCM) suggests that companies take responsibility for the entire lifecycle of their products, either alone or together with other lifecycle actors. This paper examines the case of an automotive component manufacturer that has committed to LCM and wants to investigate product end of life (EoL) management despite the fact that it is a couple stages removed from the vehicle end-user and EoL vehicle (ELV) handling. Material flow analysis (MFA) is used to estimate and create Sankey diagrams of the downstream flows of two components made of low-alloyed steel, one wheel component and one gearbox component. Product sales data was analyzed and composition and design trends were considered to add perspectives beyond those yielded by looking at the bulk material flow. The components of interest are not remanufactured themselves but the gearboxes in which they sit are. Remanufacturers of gearboxes visited indicated a great variability in how much they replace the components of interest suggesting an opportunity for the case company to support remanufacturers in quality control and extension of use life. In regards to component EoL, many components are sent through shredding as part of ELV treatment but a comparable amount is liberated from vehicles and scrapped during vehicle maintenance. Regardless, the components end up in mixed scrap and alloying elements are rarely functionally recycled. According to commodity experts, an alternative to handle such components separately for functional recycling is practically limited. Component quantities and their values do not appear to justify additional administration and transport that would be require to sort, store and collect them. Accordingly, when considering societal interest to increase functional recycling and to activate the circular economy, it seems warranted to investigate what a recycling program for similar material grades could yield and subsequently, to consider what collaborative efforts or policy intervention would be relevant.

1. Introduction

Life cycle management (LCM) is a concept that implies that companies take responsibility for the entire lifecycle of their components and services *or* that multiple organizations cooperate to do the same. Whereas traditional standards for management systems, such as ISO 9001 for quality, and ISO 14001 for environment place focus on individual organizations (Jörgensen, 2008), LCM encourages interaction of life cycle actors (Westkämper et al., 2001).

Operationally, LCM can be implemented by a company with a wide range of approaches, ranging in scope from making transformational changes to evaluating specific phases of the life cycle. First, a company can consider making a transformational change with consideration to the life cycle perspective. For example, a company can assess its very foundations and change the very way it does business to maximize life cycle resource efficiency, such as by selling function or service instead of products (Williams, 2007a,b; Mont, 2004). It is also possible to make smaller changes to the existing business or organizational structure by integrating life cycle thinking into already-used management systems, such as those for component design, sourcing, health and environmental risk management, and even component labelling (Jörgensen, 2008; UNEP/SETAC, 2007). Finally, a company can look at the details and assess the lifecycle of an individual product or possibly on different phases of the life cycle, from the supply chain, production (Löfgren et al., 2011), and customer use (Price and Coy, 2001; UNEP/SETAC, 2007) to product end-of-life (EoL) processes waste handling, recycling (Rose, 2000) and remanufacturing (Kerr and Ryan, 2001).

This paper focuses on the end-of-life phase and presents the case study of a multi-national component manufacturer (the case company) and one of its mechanical component types, which is prolific in automotive and industrial equipment alike. In this paper, the case

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company's automotive components are in focus. The case company had already addressed and continues to work on the environmental impacts related to manufacturing and component use but wanted to know if there were improvement opportunities in end-of-life. As a component manufacturer and supplier, the case company does not have direct contact with the end-user nor does it have much influence on decisions related to component EoL. The case company knew nonetheless that its mostly-steel components are recycled to a significant extent. However, it wanted to know more about the fate of its components, where potential points of used component capture might exist, as well as with which actors it could potentially cooperate with to improve the EoL of its components[1].

The purpose of this study was to answer the question: *What possibilities to improve component EoL management are there for a component manufacturer that is a couple levels upstream and does not have direct influence over the EoL of its components?* Material flow analysis (MFA) was used to evaluate the case company's component-material flows and place them in context with processes and actors. As a complement to the MFA, an analysis of the case company's sales data, referred to here as *component flow analysis*, was done to learn more about the mass and number of components sold and to screen potential opportunities.

The concrete results of the case contribute examples and analysis of an auto component manufacturer's component-material flows. In more general terms, it shows where in the system EoL components are separated from vehicles. In addition, it provides a snapshot of one mechanical component type that is commonly consumed in automotive and industrial equipment alike. Moreover, results provide an indication of what types of opportunities and challenges for improving the end-of-life of mechanical components, regardless of sector. Finally, the case offers insights into the process of seeking opportunities to improve component end-of-life.

2. Background—Automotive sector and EoL

There are several factors that make component EoL management in the automotive sector interesting. These factors include: (1) prevalence of and drivers for automotive component reuse, (2) remanufacturing successes by respected automotive companies, (3) legislative initiatives that focus on the material efficiency of end-of-life vehicles (ELVs), (4) environmental benefits and opportunities related to additional or improved reuse and recycling, and (5) EoL challenges related to the light-weighting of automobiles.

2.1. Prevalence of reuse

Component reuse is prevalent in the automotive sector (Kumar and Putnam, 2008). Since all vehicle parts do not become functionally obsolete at the same time, EoL vehicles (ELVs) invariably contain some parts that are reusable. BMW estimates that 60% of parts are reusable at the end of their specified lifetime (BMW, 2014) and dismantling and salvaging parts from ELVs is a common source of second-hand parts to the automotive aftermarket (market for replacement parts). As an example of a well-developed dismantling system, about 24% of vehicle weight from dismantling in the Netherlands was estimated to be reused as second-hand parts (ARN, 2011).

There are reasons that component reuse is so prevalent in the automotive aftermarket. Traditionally, drivers for reuse in the automotive sector include: simplifying and ensuring future aftermarket part supply (Seitz and Peattie, 2004), economic savings compared to new component manufacturing (Lund, 1985; Bras and McIntosh, 1999) and competitive-advantages from being able to offer customers different price alternatives (Lund, 1985) such as those represented by Bosch remanufactured parts, which are typically 30–40% less expensive than new ones (Bosch, 2014).

2.2. Remanufacturing

Remanufacturing is a process that makes extensive reuse possible—this is evident when looking at the automotive aftermarket. According to Polk (2013), 45% of gearboxes and 23% of engines on the aftermarket inventories of original equipment manufacturers (OEMs) are remanufactured.

Many companies within the automotive sector are successful remanufacturers. Examples include: Scania, Volvo trucks, Ford, Renault, Fiat, Cummins (Sundin, 2004; Kumar and Putnam, 2008; Mont, 2002; Bras and McIntosh, 1999; Rathore et al., 2011). Many of these and other companies prominently market remanufactured components (e.g. BMW, 2014; Ford Parts 2014; Volvo Trucks, 2014). In order to be able to offer remanufactured components, 'cores' (used components) must first be retrieved. The logistics of core retrieval (reverse logistics) is well-developed for many companies as they have been retrieving and remanufacturing for decades and there are even shared services that provide the same. For example, Bosch, a prominent provider and remanufacturer of brake calipers, starters, and many other components, has developed an expansive logistics system for retrieval of component cores called CoremanNet, which is available to other auto part providers as well (Bosch, 2014; CoremanNet, 2014). Thus, not only is reuse prevalent in the auto aftermarket, but it is supported by, as Guide (2000) calls it, the infrastructure of a closed-loop business, which includes remanufacturing, marketing, and reverse logistics.

2.3. Material and ELV focused legislation

In addition to economic drivers to reuse components, there is also material-focused legislation, which in recent years has provided additional reason to reuse and recycle automotive components. One example of legislative action is the European Union directive 2000/53/EC (ELV directive). The directive establishes required levels of ELV material reuse, recycling, and disposal, but also requires OEMs to publish vehicle disassembly guidance. Required recycling levels increase over time—the next target is to be reached by 2015 and allows only 5% of ELV mass to be disposed. The directive further stipulates that only a maximum of 10% mass can be sent to energy recovery—the remaining 85% has to be sent for reuse or material recycling (EC, 2014a).

2.4. Environmental opportunities and challenges related to reuse and recycling

The fourth factor of interest is the environmental benefits of reuse and recycling. First, material recycling reduces energy use in comparison to refining new (virgin) raw material. By avoiding raw material acquisition and refining, recycled steel is 44% less exergy intensive than virgin steel (Michaelis et al., 1998). Material recycling also reduces the need for raw material. However, it does result in tangible material losses (Reuter et al., 2013).

When material is recycled, some of the material's original function is often lost (Reuter et al., 2013). *Functional recycling* occurs only when the function of a material is retained for the next use. *Non-functional recycling*, a common result of the society's mostly open-loop recycling infrastructure, results when original material qualities are simply not utilized in the next use (Graedel et al., 2011; Dubreuil et al., 2010). As an explanation, if alloyed steel scrap is used as raw material in the making of carbon steel, alloying

[1] Due to confidentiality agreements, neither the case company's name nor the common component name is disclosed.