Circularity and Desirability in Aluminium Product Design

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ABSTRACT

Circular economy, which aims to enclose this cycle: To connect the ends and let the outcome of one product life be the start of a new cycle. As aluminium is a material of a circular nature, it is relevant to investigate possibilities and challenges associated with aluminium products and raise questions about aluminium products and their potential for integration with the circular economy. The paper discusses the challenges of circular economy and user integration and discusses environmental issues associated with aluminium product design in a circular system. Traditionally, aluminium is considered an industrial material, and furniture made from aluminium is associated with hospitals, institutions and workplaces. It is interesting to question why aluminium still, in the twenty-first century, is used in the furniture industry to a small extent. The paper further highlights the challenges of aluminium both in environmental and aesthetical aspects and discusses the possibility for, and relevance of desirable circular aluminium products.

KEYWORDS: Circular products, circular economy, sustainable design, aluminium products, emotional products

INTRODUCTION

As a consequence of the abundant consumer culture society on the western hemisphere have adopted over the last century, a culture the rest of the world is trying their best to replicate, materials and resources are in scarcity, while waste is in abundance (Stahel, 2016). The solution to all of this, according to some economy theorists (European Commission, 2015), lies in the potential of a circular economy.

Closing the material loop means switching from a linear economy model to a circular one. This is a megatrend we see a shift towards today(Geissdoerfer, Savaget, Bocken, & Hultink, 2017), and according to the European Commission of Sustainable Finance(European Commission, 2015), it is necessary to implement a more circular economy to ensure material access for the future.

But what does circular economy mean in practice for product designers? As aluminium is a material of a circular nature, it is relevant to investigate possibilities and challenges associated with aluminium products and raise questions about aluminium products in general. When talking about consumer products that customers bring into their lives, a discussion of desirability is inevitable.

Because aluminium is a material that has been available for manufacturers in large quantities since the end of the second world war(Edwards, 2001), it is interesting to question why such a small amount of the products we surround us with in everyday life is made from the material. Does this absence of aluminium in the domestic market just come from financial or technical reasons, or does aluminium have problems in relation to the human body? In other words: Why is aluminium not a desirable material in products in close proximity to the human body?

1: METHODOLOGY

A review of relevant literature is an essential feature of any academic projects, states Webster and Watson (2002). It is a time-consuming endeavour and requires an investment of a lot of time in locating and reading research paper and articles, summarizing and synthesising literature. Considerable quantities of literature are required to identify patterns in literature, to secure the relevance and support of the findings.

The goal of this literature review is to close off and identify pain point and challenges of aluminium products, seen through a designers eyes from a circular economy point of view. The article touches many domains of research in an attempt to summarize the important aspects of each field. Throughout the paper, when concepts of relevance are explored, they are critiqued consecutively.

The searches that yielded the most results were clearly those regarding the circular economy. Articles about design and implementation of design theory in circular economy articles were scarce and harder to come by, albeit more relevant when discovered. The findings from the literature are sorted into topics in the theory part of the text, and discussed further in the discussion part of the text.

2: CIRCULAR ECONOMY

In this part of the text terms in circular economy will be presented, along with theories and results of research conducted in the field.

2.1 What is circular economy?

In linear economy, resources are dug out of the ground, minded, refined, products made and sold, consumed and at the end of the life end up on a waste depot. This is in contrast to circular economy, which aims to enclose this cycle: To connect the ends and let the outcome of one product life be the start of a new cycle (The Ellen MacArthur Foundation, 2018). The value of resources, products and materials is maintained within the circular economy model for as long as possible, while waste generation and demand for virgin material are minimized (Mugge, Jockin, & Bocken, 2017).

2.2 Principles of circular economy

In practise, however, the circular economy integration has yet to catch on (Park & Lee, 2016), as traditional industry and society builds on the linear model. But in certain restricted domains forms of circular economy are integrated. The simplest form of circularity lies in the familiar practise of *reuse*, defined by Atlason, Giacalone and Parajudy (2017, p. 1061) as “the use of the product again for the same purpose in its original form or with little advancement or change”. This type of circularity often lies within the decision domain of the consumer and is arguably not fuelled by the industry, but rather by conscious consumer behaviour as a reaction to big company’s reluctance towards implementing circularity in their business models (The Ellen MacArthur Foundation, 2018).

The second type of circularity is *remanufacturing*, defined by Atlason et al. as “the process of disassembly and recovery at the subassembly on component level”. In remanufacturing reusable part are collected, and used products are refurbished and rebuilt into a new one. Quality assurance and possible enhancements or alterations can be performed. Due to the unpredictable nature of remanufactured materials, this process is resource demanding and hard to implement on an industrial scale. As stated by Singh & Ordoñez *(2016, p. 348):*

"It is hard to standardize a product from something (waste streams) that is not standard."

The third alternative, with a larger potential for scalability, is *recycling*. Recycling is not a new concept, and is a necessary means to reduce material- and energy consumption for a sustainable development (Atlason et al., 2017). Through the process of recycling, materials are recovered for new purposes. This means that the energy consumed for primary production is not recovered, and the new production requires new energy input. Recycling will be discussed later in the article, with emphasis on aluminium alloys and their associated environmental challenges (see chapter 3.4).

2.4 End of Life Cycle Strategies and Closed Product Loops

End of life for a typical consumer product requires strategies for how to handle waste and preserve resources(Stahel, 2016). Products designed with consideration to practises like material separation and recycling are preferable over comparable products without an end of life cycle strategy (EoLCS). A truly closed loop production, however, considers every aspect of the life cycle from start to end. As stated by the European Commission in their *Closing the loop - An EU action plan for the Circular Economy* (2015, p. 3)*:* **"**A circular economy starts at the very beginning of a product's life. Both the design phase and production processes have an impact on sourcing, resource use and waste generation throughout a product's life".

In EU's Waste Framework (2008), the commission suggests organizing material resources in a hierarchy of waste management, ranging from prevention, reuse, recycling, other recovery to disposal. The first two methods are preferred, and disposal should be avoided, but if necessary, carefully managed. For designers, who operate at the beginning of the cycle, this translates into careful consideration of production resources, and leaving out the end of life scenarios that include discarding waste to categories of "other recovery" and "disposal". In a fully circular business model, these categories do not contribute (Bakker, Wang, Huisman, & Den Hollander, 2014).

Another principle of circular economy is reduction and narrowing of resource use. Reducing environmental impact by designing for increased life expectancy is a way of slowing down the cycles of consumption(Atlason et al., 2017). Deciding the optimal life longitude of a certain product requires a lot of research. One study conducted in the Netherlands (Bakker et al., 2014) suggests that shortening of product lifespans could also be beneficial for the environment in some cases. Factors that determine whether a product gets a long life are many: Both technological and material mechanical, and emotional. An example from the abovementioned study is the case of refrigerators, which are found to be low-interest products, demonstrated by the fact that of the 6000 households surveyed, 57 per cent keep their refrigerator until they break (Hendriksen, 2009). As long as the technological breakthroughs are not significant in the refrigerator domain, designing for minimum deterioration in function, mechanics and aesthetics would be beneficial for the environment.

For economists reduced consumption resulting in a decreased gross domestic product (GDP) is the opposite of what they were taught in school about creating wealth (Stahel, 2016). Nevertheless, considering the preservation of physical stock and materials important, instead of only viewing revenue or GDP as a measure of a healthy economy, will be necessary in a shift towards circularity. A shift requires cooperation from all stakeholders, from factory owners and businessmen to designers and end users. The interest in circular development is, according to the article *The Circular Economy–A new sustainability paradigm?* (Geissdoerfer et al., 2017), increasing among companies and scientists, but in terms of customer acceptance and involvement, a lot is still unknown(Mugge et al., 2017).

2.5 User concerns

The green product market distinguishes itself from traditional markets(Park & Lee, 2016) because although consumers, in general, are not exhibiting clear preferences for green commodities(Majid & Russell, 2015), the production and availability of these products are increasing (Olson, 2013), albeit slowly (Borin, Cerf, & Krishnan, 2011). Studies show that these products are considered less valuable and less affordable than non-green ones by the consumer (Griskevicius, Tybur, Van Den Bergh, & Simpson, 2010).

An investigation of consumer's willingness to purchase EoLCS-products conducted in Denmark (Atlason et al., 2017) found that certain consumers groups preferred products with an EoLCS , and regarded them more attractive than comparable products without an EoLCS. Especially among women, the researchers found a willingness to pay a premium price for environmentally friendly products. The study, however, only investigated acceptance among primary products consumers, meaning that the acceptance of second-hand products was not considered, even though reuse was found to be the most desirable end of life scenario.

Another challenge for circular products is the consumer's waste behaviour: There is no guarantee for manufacturers or designers that consumers will recycle their products (Singh & Ordoñez, 2016). The article by Atlason et al (2017) therefore suggests that instead of designing for desirability in purchase, one should design for desirability of recycling. This includes considering which user group will handle the discarding process after the desired product life longitude is over. In the case of reuse as a desired EoLCS, the acceptance of the second user cannot be guaranteed, making the idealistic circularity difficult to prove profitable.

An important step towards users being involved in the circular process will be to make waste management more effective and make products with an EoLCS favourable both at the point of purchase and discarding. Combined with better-quality collection and treatment systems, this will reduce the leakage of materials out of the circle, helping to close the economic loop (The Ellen MacArthur Foundation, 2018).

3: ALUMINIUM'S SUSTAINABILITY

In this part of the paper some of the challenges associated with aluminium products is discussed. The goal is not to determine whether aluminium is a suitable material for the future, but rather to highlight some of the benefits, challenges and pain points of aluminium production, use and recycling.

3.1 Brief History

Industrial-scale production of aluminium is less than 150 years old (Brown & Buranakarn, 2003). In that time, particularly after the second world war, the growth has been substantial. Since the seventies, the use of aluminium has increased linearly, and is still growing (Liu, Bangs, & Müller, 2012). Today, aluminium production seconds only to iron and steel production in the metal industry. The largest aluminium consumption is found in the building, transportation and power sectors. However, aluminium is also used in many product categories, including beverage cans, sport equipment, automotive uses and window frames.

3.2 Benefits and manufacturing possibilities

Benefits of aluminium over more traditional materials like iron and wood were recognised during the previous century: Aluminium is, as explained by Edwards in the article *Aluminium* *furniture, 1886-1986: the changing application and reception of a modern material,* known for its "corrosion resistance, light weight, malleability, flexibility and resilience, and, not least, the silver-like finish". (2001, p. 207)

For existing metal manufacturers, the adoption of aluminium as a material demanded little new investments, as all standard metalworking techniques could be applied, including forging and drawing, extrusion, vacuum moulding, casting, rolling, spinning, stamping and blowing (Edwards, 2001).

3.3 The circular properties of aluminium

Aluminium production of primary material consumes large amounts of energy, 186 MJ/kg, while secondary production from recycled aluminium is much more efficient, using only 20 MJ/kg (Gaustad, Olivetti, & Kirchain, 2011). Furthermore, when properly sourced from waste, it can be melted down and recycled without losing material quality infinitely. Combined, these two properties should make for a material with a seemingly endless potential for circularity.

3.4 Challenges of aluminium circularity

It is, however, proving difficult and expensive to recycle aluminium properly. The material composition of aluminium alloys is both hard to reverse and distinguish between. On top of this comes the different surface treatments and composite materials, making waste recovery of aluminium alloys challenging. Material purity is hard to obtain from recycled material, and mixed alloy material is not suitable for all applications. In automotive part production, most of the aluminium used is recovered (Modaresi, Løvik, & Müller, 2014), while in food packaging only 5 percent of the aluminium used is recovered, due to strict regulations about material purity (Gaustad et al., 2011).

When aluminium alloys are reclaimed from old products, uncertainties of use and end of life makes recycling challenging (Singh & Ordoñez, 2016). An example is in the case of a chair: Two chairs start out the same, produced in the same aluminium alloy. From here the use and the end of life separates the two: One might be discarded after a couple of years and set to be remanufactured while the other ends up in a mixed waste bin years later. The consequence of this is that the material quality of one chair is obtained, while the other deteriorates. Hence, high-quality material escapes the circular loop.

In addition to challenges following the many types of alloys, are the ones regarding surface treatments: Coating, varnishing and anodizing is widely used on all aluminium alloys (Stahel, 2016). Together with laminations, aluminium-composites, and glued joinery, surfacing complicates material separation, making it almost impossible to obtain material quality when recycled.

3.5 Is it sustainable?

As production of primary aluminium consumes a lot of energy, it is safe to say that the environmental benefits of freeing ourselves from the dependency on primary material would be substantial. End of life cycles strategies and improvement in recycling information may improve aluminium sourcing (Borin et al., 2011), but to recycle excising products, waste management will be important. To be able to incorporate aluminium in a closed circular material loop, we will need new techniques for de-coating, de-anodizing, de-laminating and de-polymerizing aluminium (Stahel, 2016).

4: DESIRABLE PRODUCTS

Do discuss desirability of a material, it is expedient to look at examples of material application. Therefore, this part of the article will revolve around furniture in close proximity to the human body, as the hypothesis is that this is where aluminium struggles to suffice.

4.1 Aluminium in product design

One of the pioneering companies involved in making aluminium more desirable is *Apple*. Their obsessive demand for high build quality, led them to great innovations in aluminium production (Schulze, Grätz, & Borries, 2011). Other companies have followed, and the use of aluminium in consumer electronics is more popular today than ever before (Liu et al., 2012). In the domain of furniture, the story is different.

Traditionally, aluminium is considered an industrial material, and furniture made from aluminium is associated with hospitals, institutions and workplaces (Edwards, 2001). It is interesting to question why aluminium still, in the twenty-first century, is used in the furniture industry to a small extent. When walking into a high-end domestic furniture store, what strikes you is the total dominance of hard wood, fabrics and leathers, and, if needed for constructional measure, lacquered steel surfaces (Gusrud & Linder, 2017). This can be explained by the fact that the furniture industry traditionally made furniture from wood. Consequently, there has been a reluctance to invest in new equipment and to introduce new materials to customers (Edwards, 2001). In the furniture domain, this is still the current situation after the millennium shift:

"Ultimately, the aluminium furniture-makers were not able to engineer the cultural shift that would have usurped the hegemony of wood-based products." (Edwards, 2001, p. 224)

Aluminium has some challenges in terms of aesthetical and tactile qualities, even though aluminium's technical qualities surpass those of wood and steel (Edwards, 2001). Michael Ashby (2014, p. 4) argues that "market share is won (or lost) through its visual and tactile appeal, an exploration of other senses or emotional connection, the associations it carries, the way it is perceived and the experience it enables". Although this seems like "soft" or unmeasurable properties, design theorist Donald Norman (2004) have tried to put the different entities into system in his book, *Emotional Design.*

4.2 Three Levels of Design

Norman presents three levels of design, which appeal to three different parts of the human perception and processing of impressions. The first of which is the visceral, the one connected to the first of the abovementioned Ashby's factors of industrial success: visual and tactile appeal. Second is the behavioural level, relating to the pleasure and effectiveness of use, and third is the reflective level, relating to human self-image, personal satisfaction and reflection, and memories.

4.2.1 Visceral Design

Visceral design is all about immediate emotional impact. As flowers have evolved over generations to become attractive to birds and insects, have human produced products relating to concepts of perceived beauty. The visceral level is the lowest level of processing, and it is done subconsciously whenever rapid judgements are made. The reaction is based on sensorial input and the receiver's predisposition. Designing for purely visceral level means relating to initial reactions and being conscious about the viewers limited aesthetic information and processing time: It's all about judging a book by the cover.

4.2.2 Behavioural Design

On the behavioural level appearance does not matter, only the performance does. In his book *The Design of Everyday Things* (2013), Norman explains that there are four principles of good behavioural design: Function, understandability, usability and physical feel. Reaction on a behavioural level is unconscious, as long as tasks are performed without reflection. When actions are no longer intuitive, the reflective part of the brain must act.

4.2.3 Reflective Design

The reflective level is non-automatic, which means that the receiver is in control over this part of the cognition. As the name suggests, this is where reflection on experiences is processed, and because the time frame is not just immediate, we compare experiences with past reflections. This is done by reviewing memories regarding concerns and worries, or personal preferences to make up our mind. The reflective design level is opinionated and can override the other two levels.

4.3: Principles of product experiences

Paul Hekkert (2006), professor of form theory at Delft University of Technology, presents three levels of a product experience as *"The entire set of effects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meaning we attach to the product (experience of meaning), and the feelings and emotions that are elicited (emotional experience)" (Hekkert, 2006, p. 160).*

Hekkert argues that positive emotional impact is what makes a product or an interaction enjoyable, and emphasizes, like Norman, the importance of aesthetic and cognitive impression. Function and rationale only goes so far, the *feeling* of a products, its gratification of the senses, matters.

5: DISCUSSION

Aluminium in product design poses a contradiction: its long-lasting qualities challenges the easy of recycling (Gaustad et al., 2011). A principle of circular economy is to extend the lifespan of products, and given aluminium's corrosion resistance and durability, designing for long product lifetime seems ideal. The alleged easy of recycling, however, makes aluminium ideal for a closed circular loop. As discussed, these loops of recycling have some limitations that make aluminium recycling challenging. Deterioration of material purity is one of the major pain points of today's aluminium industry.

Considering the theory of desirably in product design, we can start to conclude on some of the problems aluminium face in relation to the human body and, allegedly more important, mind. Based on the findings done in chapter 4, it seems that people's reluctance towards aluminium could be that it fails to trigger initial positive emotional impact. In furniture for the domestic market, aluminium fails to communicate on a visceral. Aluminium is well-established as a rational, high-technological material with great mechanical attributes, in addition to being a material advertised as a sustainable alternative to steel. It should, said in the terms of Norman, comply with both the reflective and behavioural level of the brain. However, where the cold surfaces and raw nature of aluminium furniture fail to appeal, is on the visceral level.

In the future, when issues relating to management of aluminium waste is overcome, aluminium could be fully integrated with a circular economy. Raising awareness of what the offered products consists of might be a good way of involving users in circular processes (Singh & Ordoñez, 2016). It is however today little implication that consumers will prefer circular products over comparable products if they do not feature any other advantage over the alternative. On the contrary, if they are deemed less valuable (Griskevicius et al., 2010) and less appealing, it will remain unpopular (Majid & Russell, 2015).

The issue of desirability will still withhold aluminium furniture if product designers fail to appeal to the visceral level of the brain. Hekkert (2006) argues that a conscious evaluation of a product rarely is able to change the initial impression of the said product. Furthermore, negative emotional impact towards a product might be triggered by something as simple as not being able to understand it: When it takes time and cognition to comprehend a product, the initial lack of "understanding" might create a negative impression. Making a product understandable is difficult when traditional products in the same domain are following completely different "rules". This challenges the perceiver's mental model of the object, alienating the product as something unfamiliar. This type of response demands activity on the reflective level, which can be challenging and often result in an ambiguous impression (Hekkert, 2006).

A product whose relevance and appeal last as long as, or outlasts its material, is one that will be subject of reuse or remanufacture (Stahel, 2016). In anticipation of future separation technologies, designers should strive to slow down the rate of consumption. This is best done by designing products based on fundamental life and wellbeing needs, regardless of passing trends. Creating longlasting value is easier said than done, but according to Norman, products “must be effective, understandable, and appropriately priced. In other words, it must strive for balance among the three levels of design” (Norman, 2004, p. 58). The simples answer is: Well-designed products are likely to live longer, as their functional and aesthetical attributes last longer. Which in turn is sustainable.

Bringing together circularity and desirability in aluminium products nevertheless seems to be an appropriate response to today’s environmental challenges. And when aluminium’s circular challenges are overcome, it might be a future-proof material when suitably applied.

6: CONCLUSION

In this literature review, I have raised questions about aluminium products, circular design and desirability, and the relationship between the three concepts. It has led me to the conclusion that if all the mentioned concepts are executed well, the result has great potential.

Limitations of the article lies in the sometimes superficial coverage of topics. By scoping down one or more part of the text, I could have presented more design theory, meaning that conclusions could be made with greater certainty. The perspective highlights the designer’s role in the development of new aluminium products. The research takes limited account to user behaviour: change in consumer habits is a large part of a transition to a circular economy.

Implications for further research, if the goal was to democratize aluminium, would be to look further into the emotional impact of aluminium surfaces and structures in close relation to the human body. Further exploration of manufacturer-user communication and, and how this can be used to promote closed loop products.
When discussing future markets, and future ownership *shared econom*y is also a trend with great potential. Further research here could be on how shared products and service-based economies will affect the role of product manufacturers and in turn the role of the designer, and how shared products might differ from conventional, privately owned products.

The subject of the text is furniture design, but the findings could apply to most products made from materials of a circular nature.

7: RESOURCES

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