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Improving the environmental performance of bedding products by using life cycle assessment at the design stage

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ABSTRACT

Improvement of the environmental performance of processes and products is a common objective in industry, and has been receiving increased attention in recent years. The main objective of this work is to evaluate the potential environmental impact of two bedding products, a polyurethane foam mattress (PFM) and a pocket spring mattress (PSM). These two types are the most common mattresses used in Europe. A Life Cycle Assessment (LCA) shows that the PFM has a higher environmental impact than the PSM. For both products the main cause of environmental impact is the manufacturing process, respectively the polyurethane foam block moulding process for the PFM, and the pocket spring nucleus process for the PSM. A scenario analysis shows the possibility of reducing the environmental impact of the products' life cycle using an alternative End-of-Life scenario, resorting to incineration rather than landfill. Two strategies were also studied in order to reduce the environmental impact of the PFM: (1) reutilization of foam that was sent to the waste system management, and (2) a 20% weight reduction of the polyurethane foam. The second strategy has proven to be the most effective.

1. Introduction

Companies are being held accountable for their environmental load. Hence, they should have an inside look into their processes in order to reduce resource consumption and waste production. Companies need to review their processes and, for every step, analyse the possibility of reducing production waste, energy and/or raw material consumption. The ultimate goal is to manufacture with the lowest possible environment impact using a "Clean Technology". "Clean Technology" (Clift, 1997) considers four concepts: concentrate on human benefit instead of product, avoid waste instead of reducing it, systematic reuse, and selling a service and not a product. The "Clean Technology" is focused on obtaining the maximum outputs for human benefits from materials and energy or, in other terms, it means to systematically use and reuse materials to be able to enhance the materials' productivity.

Currently a great issue that the European Union (EU) has been managing with strong emphasis is to reduce the effect of the waste management. Due to changes in economic activity, technological innovation, demography, production and consumption patterns, the production of waste has been growing every year. According to Eurostat Statistics (European Commission, 2012), every year 3 billion tonnes of waste are thrown away, some 90 million tonnes of it hazardous, in the EU only. Until now most of it (about 67%) is incinerated or landfilled. Both solutions create risk for health and environmental damage. As simulations and forecasts only show this trend to increase, the EU decided to act and defined three main lines of action (Wilts, 2012): waste prevention (avoid waste or eliminate dangerous substances), recycling and reuse (as many as possible materials should either be recycled or reused), and improving final disposal and monitoring (when recycling or reuse is not possible, then it should be incinerated or landfilled, but both solutions must be closely monitored).

A common component of the generated waste is polyether. Indeed this material is present in our everyday life, and can be used for a large variety of purposes and in a wide range of different products. One of the main uses are rigid and flexible foams, adhesives, coatings, and sealants. The combination of polyurethane (PUR) with other materials is employed in the automotive, textile, footwear, buildings, upholstered furniture and bedding industries. According to the Polyurethane Foam Association (PFA) (Polyurethane Foam Association, 2010a) around 1.2 billion pounds of flexible PUR foam are produced every year in the United States of America (USA). But as PUR is widely used in the most diverse applications, the downside is the quantity to be treated at the End-of-

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Life (EoL). It is mostly used in durable products with a long lifespan such as upholstered furniture, mattresses and automobile parts. PUR waste appears in the municipal solid waste stream as discarded goods from consumers or industries. According to a study by the Centre for the Polyurethane Industry (CPI) (Polyurethane Foam Association, 2010b), in 2003 in the USA, the generation of municipal solid waste was about 229 million tons, 11.1% of it from all kinds of plastics. From these 11.1%, only 5% represent PUR; in terms of weight it is approximately 1.3 million tons a year. Looking at European data in a study realized by ISOPA/EUROPUR (European Bedding Industries Association, 2005) in 1998, from the municipal solid waste stream, about 9% are constituted by all kinds of plastics, of which 3% was PUR and 1% was PUR flexible foam.

The Life Cycle Assessment (LCA) methodology (Bauman and Tillman, 2004; Guinée, 2002) allows evaluating the potential environmental impacts of a product system throughout its life cycle. Over the past years, different LCA studies of consumer products were published (Alves et al., 2009; Peças et al., 2009; Ribeiro et al., 2008; Simões et al., 2010, 2012a), being a well-established and widespread methodology. Actually the LCA methodology is internationally normalized by the ISO 14040 series standards (ISO, 2006a; ISO, 2006b). Previous LCA studies of furniture products used this methodology, but have largely assessed one environmental issue: greenhouse gas emissions. Gamage et al. (2008) used LCA to compare two different chair models and analyse their environmental impact due to greenhouse gas emissions. The results show a significant impact contribution from the raw material extraction/refinement stage for both chair models. It also suggests that a high use of recycled aluminium in chair manufacturing is environmental beneficial. A LCA study comparing a natural fibre pocket spring mattress and a foam pocket spring mattress, considering different EoL scenarios, was performed recently (Glew et al., 2012). The environmental analysis focused only on the greenhouse gas emissions, suggesting that the foam pocket spring mattress performs worse than the natural fibre pocket spring mattress regarding that environmental impact. This study focused only in pocket spring mattresses, and it is thus necessary to assess also non-pocket spring mattresses, in order to verify if the conclusions drawn are common to other mattresses. Also, since tradeoff between environmental impacts can occur, it is important to investigate a broader range of environmental impacts regarding this type of products, as suggested by the LCA standard.

Regarding the mattress market distribution, within Europe the market is led by the springs mattresses, with about 64%, followed by polyether mattresses with 22% and latex with 14% (Association Française de Normalisation, 2006). Based on export/import reports, most of the mattresses are made and sold within the same country. This can be explained by the preference of customer for national brands and also because the transport fees are considerable. In this context, the two bedding products selected for this study were: a pocket spring mattress (PSM), and a polyurethane foam mattress (PFM). The main objective of the present work is to evaluate the potential environmental impact of PSM and PFM, considering a broad range of environmental impacts. Furthermore, it was defined as an aim to identify, for each product system, the life cycle phase that contributes the most to its environmental impact. A scenario analysis using an alternative EoL scenario was also performed, in order to identify the possibility of reducing the environmental impact of the products' life cycle. Finally, another objective was to identify and analyse viable and efficient solutions in order to reduce the environmental impact of the product with higher environmental impact. This work demonstrates the advantage of performing environmental analyses to provide valuable input for decisions being made during the design stage of a new product.

2. Material and methods

The method selected to evaluate the potential environmental impact was the LCA methodology, which considers all phases of a product's life, according to the ISO 14040 series standards (ISO, 2006a; ISO, 2006b). This methodology comprises the definition of goal and scope, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and interpretation of the results.

2.1. Goal and scope definition

This case study was conducted in a Portuguese mattress company. This company was developing a new mattress product, with the intent of introducing a new offer to the customers. Usually producing PFM, the company decided to invest in a new process and produce PSM. This study was conducted in parallel to the research and development (R&D) stage of the product, providing useful information in the decision-making processes being made at the design stage. The function of a mattress is to provide a surface to sleep or rest upon, that are fit for use by human beings for a long period of time, and that can be placed on an existing supporting bed structure (Association Française de Normalisation, 2006; Deliege et al., 2010). In LCA, comparison between products can be made using the same functional unit. Several features of the mattress must be considered, such as durability, lifespan, quality, comfort, size, price, etc. Some of these features cannot be measure easily. In this study it was considered that the selected mattresses have the same features. Durability, quality and comfort are assumed similar since all mattresses in EU are manufacture according to standard BS 1957:2000 (British Standards Institution, 2000), and both mattresses are the same size and price range. The lifespan of the mattresses is approximately 10 years (Glew et al., 2012). Therefore, the functional unit considered in this study was defined as one unit mattress fitting a person of maximum weight 120 kg over 29,200 h of sleep. The person's maximum weight is based on the characteristics of the mattress (density, hardness, resilience, etc). The value of sleeping time is based on assuming a person sleeping 8 h a day for 10 years. Consequently, the reference flows to support this functional unit is one unit mattress with 1 m width and 2 m length.

The system boundaries are shown in Fig. 1. The system boundaries consider the full life cycle of the systems, from the raw materials production, the raw materials transport, mattress production, transport to the client, transport to the EoL treatment, and the EoL. The transport of the raw materials has been considered as the distance between the supplier production site or supplier warehouse to the company manufacturing site. The manufacturing process of the PFM (Fig. 2) can be divided in three sub processes, each one corresponding to the three main components: the PUR foam block, the inside cover and the outside cover. The manufacturing of the PSM (Fig. 3) can also be divided into three sub processes: the pocket spring nucleus (group of metal pocket springs and a PUR foam box), the covers and the border. The mattress is delivered by the company. The PFM has a special characteristic because of its removable cover that can be washed to improve and maintain hygiene of the mattresses. According to the manufacturer, the cover should be washed at least once a year. In the case of the PSM, there are no suggested maintenance operations. The use and maintenance phase was excluded from the study; on the one hand, since this information is not readily available, but on the other hand, also because informal queries to users lead us to believe that they will very rarely perform any maintenance, which would render this phase identical for both products. Regarding the EoL treatment of these products, this phase of the life cycle of the product is not always under the control of the