Energy for Sustainability 2013
Sustainable Cities: Designing for People and the Planet
Coimbra, 8 to 10 September, 2013

COMPARATIVE LIFE-CYCLE ASSESSMENT OF TWO CAR ARMRESTS PRODUCED AT CIE PLASFIL

Carlos Ferreira[1*], Cláudia Esteves[2], Pedro Silva[2], Gonçalo Tomé[2] and Fausto Freire[1]

1: ADAI-LAETA
Department of Mechanical Engineering
Faculty of Science and Technology
University of Coimbra
Polo II Campus, Rua Luís Reis Santos, 3030-788 Coimbra, Portugal
*e-mail: carlos.ferreira@dem.uc.pt, fausto.freire@dem.uc.pt
web: http://www2.dem.uc.pt/centerindustrialecology/

2: CIE Plasfil
Plasfil-Plástico da Figueira S.A.
Zona Industrial da Gala Lote 6, 3081-852 Figueira da Foz, Portugal
e-mail: claudia.esteves@plasfil.pt, pedro.silva@plasfil.pt, goncalo.tome@plasfil.pt

Keywords: Life-Cycle Assessment (LCA), Plastic, environmental impacts, automobile, weight reduction

Abstract *Ecodesign is the integration of environmental aspects in the concept phase aiming at improving the environmental performance of products throughout its whole life-cycle. Ecodesign can be applied to automobiles, namely to reduce vehicle weight by different design and/or material substitution. The Life-Cycle Assessment (LCA) methodology is used to support ecodesign since it permits a comprehensive and holistic assessment of the environmental impacts associated with alternative (eco)design solutions for automobiles. This paper aims at presenting a comparative LCA of two car armrests produced at CIE Plasfil, which designs and manufactures plastic components and sub-assemblies for automotion in Portugal. A Life-Cycle model was developed focusing on the armrest production process (including production and transport of raw materials and ancillary materials) and automobile use phase. A life-cycle inventory was implemented for two armrests (J and B). Armrest J is made of polibutylene terephthalate and polyethylene terephthalate with 30% glass fibre (total weight: 0.41 kg). Armrest B is made of steel and polypropylene (total weight: 0.63 kg). For the use phase, a fraction of fuel consumption over the total automobile lifetime should be allocated to automobile components, based on their weight. In this context, the amount of fuel and combustion emissions associated with the weight of armrests was calculated, as well as the savings associated with the vehicle weight reduction achieved with substitution of steel (armrest B) by plastic (armrest J). This short paper shows how ecodesign is a valuable approach, which can be implemented to improve automobile component design and material selection in order to reduce the environmental impacts of automobiles.*

1. INTRODUCTION

The Ecodesign European Directive [1] describes ecodesign as “the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life-cycle”. Ecodesign has been applied to automobiles, focused on reducing vehicle weight by different design and/or material substitution [2, 3]. Plastics have been one of the materials selected for vehicle weight reduction (with no performance change), because they also permit great design flexibility, since plastics can be moulded in complex shapes [3]. The Life-Cycle Assessment (LCA) methodology is used to support ecodesign, since it permits a comprehensive and holistic assessment of the environmental impacts associated with alternative (eco)design solutions for automobiles.

This paper aims at presenting a comparative LCA of two car armrests produced at CIE Plasfil. CIE Plasfil designs and manufactures plastic components and sub-assemblies for automotion in Portugal, being part of the CIE Automotive industrial group, a worldwide supplier of components and subcomponents for the automotive industry (aluminium, forging, plastic and steel).

2. METHODOLOGY

Life-cycle assessment (LCA) is a methodology for assessing the potential environmental impacts of a product system throughout its life-cycle. LCA can be used to identify opportunities for improving the environmental performance of a product or range of products [4, 5]. Ecodesign can be implemented in the selection of materials with lower environmental impact. Table 1 presents the Life-Cycle greenhouse gas (GHG) emissions associated with materials generally used in the manufacture of automobile components (an example of environmental data used to support Ecodesign).

Table 1. GHG emissions per kg of type of material produced.

Type of material	GHG emission (kg CO_2eq/kg)
Reinforcing steel [6]	1,5
Steel low alloy [6]	1,8
Polypropylene (PP) [7]	1,9
Polyamide (PA) [7]	3,3
Polyethylene terephthalate (PET) [7]	2,7
Acrylonitrile butadiene styrene (ABS) [7]	4,3

2.1 Goal and Scope

The main goal of this study is to present a comparative LCA of two car armrests (J and B) produced at CIE Plasfil. A Life-Cycle model and inventory were implemented addressing production and transport of raw materials, armrest production process at CIE Plasfil, and automobile use phase. The functional unit is defined as one piece of armrest used over the lifetime of a car (18 years), corresponding to an average of 200 000 km [8]. Because there is some variability associated with the total number of kms driven in the lifetime of a car, it was adopted two extreme values: 100 000 and 300 000 km. The reference flow includes: i) the pieces incorporated in the armrest and ii) the fraction of fuel consumed in the use phase associated with the car component weight. Table 2 shows the detailed material constitution of armrests J and B. **Armrest J** is mainly made of polibutylene terephthalate and polyethylene terephthalate with 30% glass fibre (PBT PET GF30). **Armrest B** is mainly made of steel and polypropylene (PP).

Table 2. Constitution of the armrest J and B.

Armrest J		**Armrest B**	
Raw material	Amount (kg)	Raw material	Amount (kg)
PBT PET GF30	0,361	Steel	0,512
Steel	0,048	PP	0,108
Silicone	0,004	POM	0,002
		Stainless steel	0,010
Total	0,413	Total	0,632

Figure 1 represents the system boundary and main life-cycle stages. The plastic structure of Armrest J is produced at CIE Plasfil, and the small steel part is produced in another company. The final assembly takes place at CIE Plasfil. The main structure and the hinge of armrest B is made of steel with a cataphoresis treatment (process of painting by immersion, based on the movement of charged particles in an electric field towards the painted metallic surface). The plastic parts of armrest B (used to cover and protect the metal part) are manufactured at CIE Plasfil, the steel part are manufactured at other companies, and the final assembly takes place at CIE Plasfil. It has been assumed that both armrests are transported 900 km by trolley, to be assembled in automobile manufacturers.

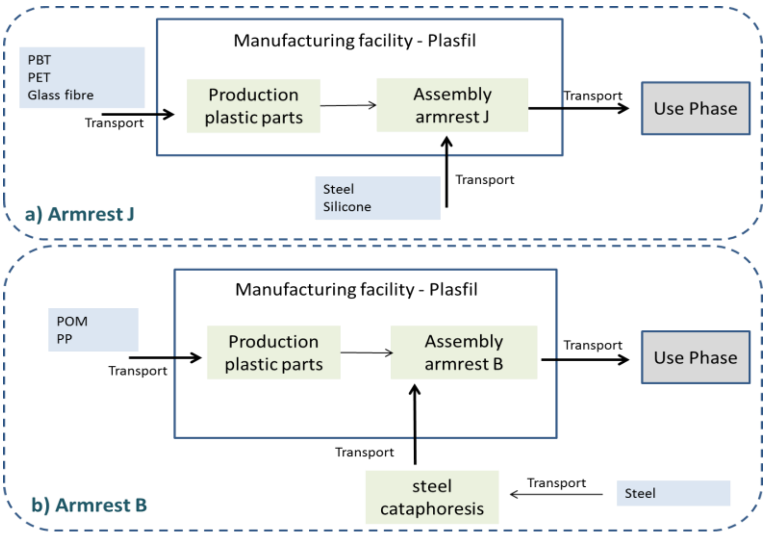

Figure 1. System boundary: a) armrest J; b) armrest B.

2.2 Production phase

CIE Plasfil designs and manufactures plastic components and sub-assemblies for automotion, being part of the CIE Automotive industrial group. Table 3 presents CIE Plasfil Inventory Production for the last three years, detailing the main raw materials, total plastic component produced and plastic lost on purges. Purges result from the cleaning between the changes of raw materials in the production process. Because of global automobile market recession, there was a reduction in CIE Plasfil annual plastic production volumes, and a slight increase of plastic lost in purges. Table 4 shows the annual average energy requirement per kilogram of plastic produced. In spite of an annual electricity consumption reduction, it can be observed that there was a 4% increase in the specific electricity requirements (kWh/kg plastic) from 2010 to 2012 due to a loss of economies of scale associated with the mentioned reduction in production volumes and with a typology of plastic processed (in 2012) requiring more energy (higher process temperature).

Table 3. CIE Plasfil Inventory Production (2010-2012).

Inputs (Ton)	**Year of production**		
	2010	**2011**	**2012**
Polypropylene (PP)	623	572	495
Polyamide (PA)	935	858	743
Acrylonitrile butadiene styrene (ABS)	935	858	743
Other Plastics	623	572	495
Total input	3116	2862	2476
Outputs (Ton)			
Total component plastic produced	3100	2849	2455
Plastic Purges (losses)	16	13	21
Total output	3116	2862	2476

Table 4. CIE Plasfil Energy requirement (2010-2012).

Energy	Year of production		
	2010	2011	2012
Annual electricity (MWh)	7848	7507	6484
Average specific electricity requirement (kWh/kg plastic)	2,53	2,63	2,64

2.3 Use phase

The use phase accounts the vehicle operation during its lifetime, including fuel consumption and maintenance (usually considered insignificant, compared to fuel consumption [1]). The fuel consumption is related with aerodynamic drag, drive style and efficiency, acceleration resistance and vehicle weight [9]. In the literature, various equations have been proposed to allocate use phase fuel consumption to vehicle components [1]. For the LCA of vehicle components, the following equation has been adopted [1, 10, 11, 12]:

$$F_{comp} = C_{ref.veh} \times [M_{comp}/M_{ref,veh}] \times c \times D \tag{1}$$

in which
$\mathbf{F}_{comp}$ is the fuel consumption allocated to the component over the total vehicle lifetime (kg);
$\mathbf{C}_{ref.veh}$ is the fuel consumption of the reference vehicle (kg/km);
$\mathbf{M}_{comp}$ is the mass of component (kg);
$\mathbf{M}_{ref,veh}$ is the mass of reference vehicle (kg);
c is the fuel-mass coefficient (correlation between fuel consumption and vehicle weight;
D is the lifetime travel distance (km).

The following values have been adopted for the parameters: $\mathbf{C}_{ref.veh}$ = 5,87 kg/100 km; $\mathbf{M}_{ref,veh}$ 1080 kg. According to [1], parameter **c** usually ranges between 0,315 and 0,71. The value 0,6 was adopted, since it is considered representative in automobile LCA studies according to EUCAR [10, 11].
Regarding the lifetime distance, two extreme scenarios were adopted (following the functional unit defined in section 2.1): 100 000 and 300 000 km, for which the amount of fuel consumption allocated to the two armrests were calculated using equation 1 ($\mathbf{F}_{armrest\ J}$ = 1,3 to 4,0 kg; $\mathbf{F}_{armrest\ B}$ = 2,0 to 6,1 kg). Therefore, the fuel consumption reduction associated with the vehicle weight reduction achieved with substitution of steel (armrest B) by plastic (armrest J) was estimated between 0,9 and 2,9 litres of fuel, which correspond to an emission range of 2,9 to 8,7 kg of CO_2eq.

3. CONCLUDING REMARKS AND LIMITATIONS

This short paper presents an LCA model and inventory of car armrests. A comprehensive Life-Cycle model and inventory is currently being implemented to compare two armrests (J and B) produced at CIE Plasfil. The model addresses production and transport of raw materials, armrest production process at CIE Plasfil, and automobile use phase Detailed LC impact Assessment (LCIA) results will be presented at the Energy for Sustainability Multidisciplinary conference in September. The selection of materials towards weight reduction of components is a valuable approach to the ecodesign of automobiles.

3.1 Limitations and future research

This is an on-going project currently being developed with CIE Plasfil with some data limitations associated with the comparison of armrests, since data for some plastic raw materials are not available yet. Another limitation is associated with the cataphoresis process for the steel parts, also with no available data. To include the cataphoresis process in the model will increase the impacts of armrest B (steel). Future research will address the implementation of LC inventories for the processes with no available data. Last but not least, armrests are a minor component of an automobile, in which the application of ecodesign to more relevant components, with greater weight could lead to more significant global savings.

ACKNOWLEDGEMENTS

The authors would like to thank Pedro Marques from CIE, University of Coimbra for helpful suggestions. The authors also thank Fundação para a Ciência e a Tecnologia (FCT) for support under the projects MIT/SET/0014/2009, MIT/MCA/0066/2009, and PTDC/SEN-TRA/117251/2010.

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