STUDY OF AUTHORIZED TREATMENT FACILITIES FOR END-OF-LIVE VEHICLES IN THE PROVINCE OF CASTELLÓN

Muñoz, C.

Vidal, R.

Garraín, D.

Franco, V.

Design Engineering Group, Mechanical Engineering and Construction Department, Universitat Jaume I de Castellón (España)

Justel, D.

Espartero, S.

Mechanics and Industrial Production Department, Escuela Politécnica Superior de Mondragon (EPS), Mondragon Unibertsitatea

Abstract

The role of Authorized Treatment Facilities (ATFs) for end-of-life (EOL) vehicles within the recycling chain is to take charge of decontaminating and disassembling EOL vehicles, thus enabling the reuse, recycling or recuperation of substances and components of said vehicles. The intervention of ATFs is crucial to the reuse, recycling and recuperation goals set for EOL vehicles by the Royal Decree 1383/2002 (which transposes European Directive 2000/53 EC into Spanish Law). The time frame for the achievement of said goals comprised two phases. The initial phase started in 2006, whilst the second will begin in 2015.

The analysis of ATF waste generation data in the province of Castellón (Spain) for the year 2008 is taken as a reference to verify compliance with current environmental goals. Said analysis is used to propose operational strategies to help ATFs meet the forthcoming environmental goals set by the Royal Decree 1383/2002 for the year 2015.

Keywords: *Authorized Treatment Facility (ATF), end-of-life vehicle (ELV), recycling, reuse.*

1. Introduction

The European Union adopted Directive 2000/ 53/EC on end-of-life vehicles in order to prevent the generation of waste and encourage the collection, reuse and recycling of their components to protect the environment.

Directive 2000/53/EC and its transposition into Spanish legislation in RD 1383/2002 on the management of end-of-life establish the current and future environmental objectives to be met. These goals set the levels of reuse, recycling and recovery of ELVs to be achieved. Table 1 shows the objectives expressed as percentages of ELV weight.

Aim	Year 2006	Year 2015
Reuse and Recycling [ELV weight %]	80%	85%
Recovery (including reuse and recycling) [ELV weight %]	85%	95%

Table 1 Objectives of ELV weight percentage to be reused, recycled or recovered under Directive 2000/53/EC

The focus is on preventing waste generation. In addition, provisions are made for the collection of all ELVs. In that sense, the legislation establishes that EU member states should set up systems to collect the ELVs and extract reusable spare parts and components. This task is carried out by the so-called Authorized Treatment Facilities (ATFs).

ATFs are responsible for the following tasks, which are essential for the achievement of the goals set in the legislation:

- Issuance of the certificate of destruction of the vehicle,
- Decontamination of ELVs prior to further treatments,
- Recovery of all the components that may be harmful to the environment,
- Encouragement of the reuse and recycling of components found in ELVs.

2. Objectives

The objectives of our study are as follows:

- To assess compliance with current goals set by Directive 2000/53/EC in a particular geographical area of Eastern Spain (province of Castellón) for the year 2008, and
- To find working strategies for the ATFs to ensure future compliance with the goals set for 2015.

3. Methodology

An initial study of the processes and activities carried out by ATFs was performed. Secondly, a characterization of mixed waste materials derived from EOL vehicles was performed through bibliographic sources and own studies.

Finally, real data on waste generation were collected. To this end, a questionnaire was designed to quantify the ELVs that were processed at each facility and to characterize and quantify the hazardous and nonhazardous waste generated per ELV processed.

The questionnaire was sent to the twelve ATFs existing in 2008 in the province of Castellón (Environment Department, 2009).

4. Authorized Treatment Facility

Spain's Autonomous Communities are responsible (through their competent environmental agencies) for granting administrative licenses to operators of hazardous waste in their territory. They must verify the adequacy of facilities to current regulations. Currently most of the existing ATFs are old (refurbished) scrapping yards.

To improve the understanding of how waste is generated by ELVs, the processes taking place in the ATFs are described next.

4.1. Vehicle reception, verification and de-registration

When a vehicle owner decides to get rid of it, he or she is required to obtain, either directly or through a third party –a car dealer, for example-, a deregistration and destruction certificate issued by an ATF. From that moment, the vehicle is considered an ELV, ready for environmental treatment.

4.2. Decontamination

According to the European Waste Catalogue (EWC) the ELV generated is classified as hazardous waste (HW) 160104 *Discarded* vehicles. The HW must undergo decontamination, i.e., the removal of all liquids and fluids, and other substances and items that are classified as HW, such as: hydraulic oils from engine, differential and gearbox (unless the engine block

is reused, in which case it can maintain lubrication), fuels, brake fluids, antifreeze/coolants, filters, batteries, and other elements.

These HW are then sent to authorized agents for specific treatment. ATFs usually do not perform such treatments.

At the end of the waste decontamination stage of the vehicle is considered non hazardous waste (NHW) 160106 EWC *end-of-life* vehicles, containing neither liquids nor other hazardous components. This residue can be shipped to a shredding plant -where the ELV is cut to pieces in order to recycle or recover the component materials- or move to a later stage in the ATF itself in which some components will be removed before shipment to a shredding plant. This further disassembly allows for the reuse and recycling of a greater number of components from the ELVs.

4.3. Dismantling

The nonhazardous waste EWC 160106 that the ELV was turned into after decontamination undergoes some further transformations. The initial amount of NHW is reduced by the disassembly and removal of components with a higher market value than the original residue. This includes those components that can be marketed as spare parts in the second hand market, and with the specific waste that has a significantly higher market value than that of the bulk of EWC 160106.

Some of the NHW that are extracted for their commercial value and subsequently sent to authorized treatment centres include the following: EWC 160103 *end-of-life tires*, 160116 *tanks for liquefied gas*, 160117 *ferrous metal*, 160118 *nonferrous metals*, 160119 *plastic*, 160120 *glass*, 160801 *spent catalysts containing gold, silver, rhenium, rhodium, palladium, iridium or platinum* and others. The components that are usually traded in the secondary market include the following: tires, engine blocks, batteries, gearboxes and others.

Some components may be waste or possible replacements, depending on their condition and the commercial value they may have as waste or spare part.

4.4. Compaction and fragmentation

The compaction of EWC 160106 after EWC 160104 is decontaminated and spare parts are disassembled and removed from it a mechanical pressing process to minimize its volume before it is transported to a shredding plant. The commercial value of the ELV compacted depends on the mixture of materials and components that comprise it.

The fragmentation of EWC 160106 yields three fractions:

- Ferrous and non ferrous materials: iron and steel used in industry for melting and subsequent production of steel and foundry products.
- Heavy metals free waste: rubber, plastics and other materials.
- Light Fragmentation Waste: textiles, foams and other.

The latter two waste fractions are currently sent to landfill, although there are alternatives under study for their recovery (SIGRAUTO, 2007).

The management of ELV in the ATF ends with the issue of waste EWC 160106 to the plant shredder.

4.5. Characterization of waste

The composition of the ELV can be defined in three different yet equivalent ways:

- according to the average composition of vehicles that are part of vehicle fleet, expressed in generic categories of materials,

- as possible residues that form the ELVs defined in the EWC,
- according to literature sources and own sources.

4.6. Average composition of vehicles in the fleet

The composition of the ELV should approximately correspond with the average composition of the vehicle fleet. Most ELVs entering ATFs do so for reasons related with their obsolescence or end of natural life, and to a lesser extent by other causes such as accidents. Table 2 shows the average composition of vehicles manufactured in the last 35 years. In this period, there was an increase in weight percentage of plastics and a decrease of all metals. On average, overall metal content makes up for 75% of vehicle weight. Although not reflected in the data presented, the increased use of aluminium is the main cause of increased non-ferrous metals. Plastics are stabilized at 10%. All other materials make up for the remaining 15%.

<table>
<tr><th>Class / Type of material</th><th>1965(*)</th><th>1970(*)</th><th>1990(*)</th><th>1990(**)</th><th>1994(*)</th><th>2000(**)</th></tr>
<tr><td>Ferrous metals</td><td>80.0%</td><td>80.0%</td><td>72.0–75.0%</td><td>70.0%</td><td>65.0–67.5%</td><td>65.4%</td></tr>
<tr><td>Non-ferrous Metals</td><td>2.0%</td><td>2.0%</td><td>6.0%</td><td>4.9%</td><td>5.5–8.0%</td><td>9.0%</td></tr>
<tr><td>Plastics</td><td>2.0%</td><td>5.0%</td><td>10.0–13.0%</td><td>8.5%</td><td>9.1–10.0%</td><td>11.8%</td></tr>
<tr><td>Tires</td><td rowspan="5">16.0%</td><td rowspan="5">13.0%</td><td rowspan="5">6.0–12.0%</td><td>4.0%</td><td>5.5–6.0%</td><td>3.8%</td></tr>
<tr><td>Glass</td><td>3.2%</td><td rowspan="4">9.4-14.0%</td><td>2.8%</td></tr>
<tr><td>Fluids</td><td>1.8%</td><td>1.5%</td></tr>
<tr><td>Textiles and foams</td><td>1.5%</td><td>1.2%</td></tr>
<tr><td>Others, mixtures</td><td>6.1%</td><td>4.5%</td></tr>
</table>

Table 2 Time evolution of the average vehicle composition. (*) (IHOBE, 2003), (**) (SIGRAUTO, 2007)

In line with these generic values, the Spanish Integrated National Waste Plan (Plan Nacional Integrado de Residuos, PNIR) 2008-2015 (Ministerio de Medio Ambiente, 2007), estimates the composition of waste generated by the scrapping of ELVs 2006-2010 as follows:

Ferrous metals	70.0%	Non-ferrous metals	4.9%	Other materials	25.1%
Sheet	39.0%	Aluminum	4.5%	Plastic	8.5%
Steel machining	13.0%	Copper, Zinc an others	0.4%	Rubber	4.0%
Casting	18.0%			Glass	3.2%
				Textils	1.5%
				Fluids	1.8%
				Others	6.1%

Table 3 Estimated composition of waste generated by the scrapping of ELVs, classified by type of material for 2006-2010

The data shown correspond to the period ranging from years 1990-2000 in Table 2.

Considering the deregistered vehicles (Dirección General de Tráfico, 2008; SIGRAUTO, 2008), the average age of vehicles in the Spanish fleet is 15 years. Thus the average composition of the ELVs should be similar to that of vehicles built in around the year 1995.

4.7. Waste characterization according to EWC

Under the EWC, we can identify potential ELV waste among those described in sections 1301 *waste hydraulic oils*, 1302 *waste engine, gear and lubricating oils*, 1307 *wastes of liquid fuels*, 1308 *oil wastes not otherwise specified*, 1502 *absorbents, filter materials, wiping cloths and protective clothing*, 1601 *end-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance*, 1606 *batteries and accumulators* and 1608 *spent catalysts*.

This classification should not be understood as a list of components / substances that are removed from the ELV. In practice, some of these residues may not be present (because they are only found in older vehicles), or they may not be removed from the ELV when it is processed in the ATF. In this regard, it is worth indicating that:

Sections 1301, 1302 and 1308 are often grouped under the generic category oils.

- Absorbents used are not considered as waste from ELV own.
- Brake shoes of any kind are not usually counted independently.
- The components containing mercury, PCBs, explosives and airbags, liquefied gas tanks and most of catalysts, are usually managed as a part of waste EWC 160106 sent to plant EWC shredder.
- Antifreeze liquids are lumped into a single characterization.

4.8. Waste characterization from literature sources and own studies

a) According to Generalitat Valenciana (2005), the generic composition of ELV is as follows:

EWC Classification	Percentage
Ferrous metals, iron pieces (EWC 160117)	85.59%
Non-ferrous Metals (EWC 160118)	2.38%
Plastics, other plastics and rubbers (EWC 160119)	0.50%
End-of-life tires (LER 160103)	3.94%
Fluids	1.48%
Engine oil (EWC 130205)	0.44%
Gearbox oil, transmission oil (EWC 130206)	0.33%
Fuel (EWC 130703)	0.36%
Brake fluids (EWC 160113)	0. 02%
Antifreeze fluids (EWC 160114)	0.31%
Air-conditioning unit fluids (EWC 160121)	0.02%
Glass (EWC 160120)	1.13%
Other materials	4.97%
Oil and fuel filters (EWC 160107)	0.05%
Airbags, seat belt pretensioners (EWC 160110)	0.25%
Textiles and foams, paper and cardboard (EWC 160122)	0.60%
Miscellaneous (EWC 160199)	1.56%
Electrical equipment (EWC 160213)	1.39%
Batteries (EWC 160601)	0.83%
Catalysts (EWC 160807)	0.29%

Table 4 Composition of waste generated in 2003 and 2004 based on the waste inventory of the Valencian Community, and its classification according to the EWC

Vehicles deregistered in these years should approximately match those made in the 1990s. A comparison of the data in Table 4 with those in Tables 2 and 3 reveals that:

- The percentage of ferrous metals is higher than expected (85% versus 70-75%).
- Non-ferrous metals are almost halved (2% versus 5 to 6%).
- Plastics are almost nonexistent (0.5% compared with 8 to 10%).
- The percentages attributed to glass and tires are similar.

There are significant deviations between the composition of vehicle produced and those of the waste generated according to Generalitat Valenciana (2005).

b) Other studies (SIGRAUTO, 2007) set the current level of recovery, recycling or recovery of ELVs at 85.5% (see Table 4).

EWC Classification	Percentage
Tires (EWL 160103)	3.0%
Ferrous metals (EWL 160117)	69.5%
Non-ferrous Metals (EWL 160118)	7.1%
Plastics (EWL 160119)	3.8%
Glass (EWL 160120)	0.8%
Fluids	1.3%
Total ELV reused, recycled or recovered	**85.5%**
Other, mixed remnants (landfill)	14.5%

Table 5 Current recovery levels (SIGRAUTO, 2007)

Comparing Table 5 with vehicles built in the 1990s, it becomes apparent that:

- The data presented are comparable. The percentages of materials that are recovered, recycled or recovered are plausible considering the composition.
- The percentage of non-ferrous metals recovered is slightly higher than that predicted from the composition of the vehicle produced. This may be due to the existence of newer cars that are deregistered due to accidents and not by end-of-life obsolescence.
- The 14.5% attributed to 'other materials' -which are mainly sent to landfill- represents those materials which are difficult to remove or recover.

c) An own study conducted on a modern ATF located in north-western Spain, reveals the most significant fractions extracted by ELV, see Table 6.

EWC Classification	Percentage
Other oils (EWC 130208)	0.55%
Fuel oil and diesel fuel (EWC 130701)	0.46%
Petrol (EWC 130702)	0.77%
Tires (EWC 160103) 2.69%	2.69%
ELV without liquids or other hazardous waste (EWC 160106)	70.55%
Oil Filters (EWC 160107)	0.03%
Brake fluids (EWC 160113)	0.03%
Antifreeze (EWC 160114)	0.19%

EWC Classification	Percentage
Ferrous metals (EWC 160117)	20.91%
Non-ferrous Metals (EWC 160118)	0.97%
Plastic (EWC 160119)	1.20%
Glass (EWC 160120)	0.62%
Batteries (EWC 160601)	1.02%
Catalysts (EWC 160801)	0.03%

Table 6 Waste fractions generated by ELV in a modern ATF in north-western Spain (own study)

Waste EWC 160106 represents 70.55%. This percentage corresponds to the decontaminated and dismantled vehicle that, after compaction, is sent to a shredding plant for processing. During fragmentation, ferrous metals are separated by mechanical and magnetic processes, and non-ferrous metals are sorted by manual separation. The ferrous and non ferrous metals separated represent 80% of this fraction. The remaining surplus is made by the heavy waste excluding metals and the lightweight fragmentation waste. The lightweight fragmentation waste is made up of various materials including plastics and textiles, rubber, land and other inert materials. Table 7 shows the composition of the waste lightweight fragmentation waste (SIGRAUTO, 2007).

Classification	Percentage of light waste	Percentage of ELV
Plastics and textiles	40.0%	5.65%
Rubber	30.0%	4.23%
Glass	13.0%	1.84%
Non-ferrous Metals	2.0%	0.28%
Earths and other substances	15.0%	2.12%

Table 7 Composition of the lightweight fragmentation waste

The presence of earth in the lightweight fragmentation waste may be due to accumulation on the underside of the vehicle or handling techniques: gathering in fields, use of wheel loaders, etc.

The rubber present in the lightweight fragmentation waste comes in part from the tires that have not been managed as special waste and most of other vehicle components.

4.9. Baseline data

Based on the data presented, the following baseline characterization of ELV waste composition by weight is presented (Table 8).

EWC Classification	Weight Percentage Range
Oils (EWC 1301 and 1302)	0.50-0.75%
Fuels (EWC 130701, 02 and 03)	1.00-1.50%
Tires (EWC 160103)	3.50-4.50%
Oil Filters (EWC 160107)	0.25%
Brake fluids (EWC 160113)	0.25%
Antifreeze (EWC 160,114 and 15)	0.25%
Ferrous metals (EWC 160117)	70.00-75.00%

EWC Classification	Weight Percentage Range
Non-ferrous Metals (EWC 160118)	5.00-9.00%
Plastics (EWC 160119)	8.00-12.00%
Glass (EWC 160120)	2.50-3.50%
Other waste (EWL 160199)	5.00%
Textiles and foams (EWC 160122)	1.00-1.50%
Batteries (EWC 160601)	0.75-1.25%
Catalysts (EWC 160801)	0.25%

Table 8 Baseline characterization of ELV waste

The baseline characterization of the waste found in table 8 is generated in terms of ranges or brackets in order to account for the variability values of bibliographic data studied, and the actual variability existing in the composition of the vehicles deregistered at the ATFs.

5. ATFs questionnaire results for the province of Castellón (Spain)

Out of the 12 existing ATFs surveyed in the province of Castellón, 8 responded fully to the questionnaire, representing an 80% of the of 85000 square meters of land devoted to ATFs in the area of study.

Table 9 shows the data sorted as per the EWC.

EWC Waste	ATF01	ATF02	ATF03	ATF04	ATF05	ATF06	ATF07	ATF08
160104 [ton]	440.80	1014.81	822.80	506.70	90.00	337.60	421.20	1020.00
160104 [Uds]	530	1274	379	615	100	332	484	1206
130205 [ton]	2.30	3.20	4.90	3.00	1.95	0.14	0.00	0.00
130208 [ton]	2.30	0.00	4.90	3.00	1.95	0.14	4.50	6.28
130703 [ton]	0.00	1.50	0.00	0.00	0.00	0.00	0.00	3.00
140603(1) [ton]	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00
150202(2) [ton]	0.15	0.00	0.00	0.00	0.01	0.00	0.00	3.75
160103 [ton]	11.50	1.40	2.96	6.70	1.20	3.41	3.00	0.00
160106 [ton]	397.44	520.13	230.38	359.16	63.54	241.00	262.16	0.00
160107 [ton]	0.15	0.80	0.20	0.13	0.40	0.05	0.12	4.00
160111(3) [ton]	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
160113 [ton]	0.09	0.07	0.08	0.30	0.01	0.03	0.02	0.21
160114 [ton]	0.70	0.00	0.30	1.00	0.40	0.10	0.05	2.50
160117 [ton]	0.00	0.00	422.57	0.00	0.00	0.00	0.00	0.00
160118 [ton]	0.00	0.00	13.37	0.00	26.46	0.00	2.92	0.00
160119 [ton]	0.25	0.00	1.00	0.50	0.00	0.40	0.02	0.00
160120 [ton]	0.00	0.00	0.20	0.00	0.00	0.00	0.03	0.00
160601 [ton]	5.20	10.00	15.73	3.55	4.50	1.00	5.30	18.80
160801 [ton]	0.10	0.00	0.10	0.16	0.00	0.04	0.03	0.00

Table 9. Details of waste from ELVs surveyed

(1) EWC 140603 other solvents and solvent mixtures.

(2) EWC 150202 absorbents, filter materials (including oil filters not otherwise specified and fuel filters), wiping cloths, protective clothing contaminated by dangerous substances.

(3) EWC 160111 brake pads containing asbestos.

6. Discussion

By comparing the reference characterization shown in Table 8 with data of the waste generated from Table 9, it can be seen that:

- Liquid waste or fluids have lower-than-expected ratios -except oils (EWC 130205 and 130208) which match the expected values-.
- The used tires (EWC 160103) generated represent one fifth of the expected quantity.
- Batteries (EWC 160601) generated double the expected quantity.
- Virtually no catalysts (EWC 160801) were been collected.

For the other waste (solid waste), a join analysis must be performed in order to understand what happens to them. A low number of waste material categories is obtained, as compared to the number of categories that would be possible. This situation is anomalous and may be due to a poor removal of components, which causes the following:

- EWC waste 160117, 160118, 160119, 160120, 160122 and 160199 are nonexistent or generated at very low percentages as compared with the baseline characterization.
- The highest percentage -77%- is due to EWC waste 160106. This residue corresponds to the decontaminated ELV, from which some components have been extracted before shipment to a shredding plant.

The data point out to a low level of disaggregation, extraction of parts and components of the ELVs after ATF processes.

7. Conclusions

23% of the mass of waste generated in the ATFs EWC is reused or recycled at these facilities. The remaining residue -77%- corresponding to EWC 160106 is sent to the shredder plant. 80% of this residue corresponds to metallic materials, which are recovered after fragmentation. Furthermore, fragmentation allows for the recovery of small percentages of other materials including plastics and elastomers mainly. The percentage recovered in the ATFs -23%- plus the percentage of metals recovered after fragmentation -62%- and the small percentage of recovered plastics and elastomers after fragmentation support the conclusion that current targets set by Directive 2000/53/EC are being met.

However, the analysis of EWC waste generate indicates that (roughly) only half of the possible EWC waste categories are extracted from the ELVs. This is attributed to the fact that the ATFs surveyed use traditional (manual) processes for the removal of the ELV. The application of traditional processes makes it difficult and costly to disassemble components, which prevents them from being reused or further treated as specific waste. The bulk material is grouped as waste EWC 160106. This causes subsequent processing in shredding plants to generate large amounts of waste in the form of lightweight fragmentation waste and heavy waste (excluding metals). The greater the mixture of waste materials present in 160106 EWC, the greater the generation of lightweight fragmentation waste and heavy waste (excluding metals) will be, thus increasing the amount of waste typically sent to landfill.

Therefore, in order to achieve an increase in the amount of waste recovered and thus able to meet our goals for 2015 is necessary to increase the level of disaggregation of ELVs in the ATFs. This will reduce the amount of non-metallic material to be fragmented and thus the amounts of lightweight fragmentation waste and heavy waste (excluding metals) being sent to landfill.

The increase in waste collected in the ATF is only possible if the existing traditional processes are optimized, substituting the work methods of scrap yards of the past for more automated and industrial processes. The current work methods of the ATFs are technologically obsolete. Manual techniques should be replaced with more technological processes which are also more efficient and exhibit higher returns in terms of ELVs treated and better and greater differentiation of waste generated. The increased commercial profitability of waste –which is attainable by the introduction of improved disassembly methods- should help to achieve the targets set by Directive 2000/ 53/EC for the year 2015.

Acknowledgments

This study is part of the project "Reducing the environmental impact of cars through structural lightening carbon composites based on low cost without compromising safety and comfort (ref. PSE-370100-2007-1)", funded by the Ministry Science and Innovation in Spain.

The collaboration of Armonía VFUs (Galicia, Spain) is gratefully acknowledged.

References

Dirección General de Tráfico, “Anuario Estadístico General 2007”, ISSN: 1575-3395, 2008.

Environment Department, “Empresas autorizadas por la Generalitat Valenciana para realizar actividades como: Centros Autorizados de Tratamiento de Vehículos al Final de su Vida Útil”, Consellería de Medi Ambient, Aigua, Urbanisme i Habitatge, http://www.cma.gva.es/intro.htm, fecha de consulta enero/2009.

Generalitat Valenciana, “Actualización del inventario de residuos de la Comunidad Valenciana 2003-2004. Anexo XI, Producción de VFU”, Consellería de Medi Ambient, Aigua, Urbanisme i Habitatge, 2005. http://www.cma.gva.es/intro.htm, fecha de consulta enero/2009.

IHOBE, Sociedad Pública de Gestión Ambiental, “Monografía sobre vehículos al final de su vida útil”, 2003.

Ministerio de Medio Ambiente, “Plan Nacional de Vehículos al Final de su Vida Útil 2008-2015 (II PNVFU)”, 27-11-2007.

SIGRAUTO, “Sustitución de combustibles fósiles en hornos de cementeras por residuos de la fragmentación de vehículos fuera de uso” Abril 2007 – Junio 2008, disponible en http://www.sigrauto.com/sigrau.html, fecha de consulta enero/2009.

SIGRAUTO, “Memoria Anual 2007”, 2008, disponible en http://www.sigrauto.es, fecha de consulta octubre/2008.

Corresponding author

Carlos Muñoz Marzá
Grupo de Ingeniería del Diseño, Dpto. de Ingeniería Mecánica y Construcción
Universitat Jaume I
Av. Sos Baynat, s/n 12071 Castellón (España)
Tel: +34 964 729 252
Fax: +34 964 728 106
E-mail: cmunoz@emc.uji.es
URL: http://www.gid.uji.es