Ecodesign tool for pyrotechny

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Abstract

Ecodesign is widely integrated in the development of new products in a lot of industries. It concerns the conception but also the industrialization. Regarding ammunition, their environmental impact throughout all their life cycle has begun to be taken into account through eco-design methodology.

Many software and tools have been proposed. They result from need of specific industry like automobile or organism, like ADEME for example. Even if the methodologies are quite similar, databases never include many chemical substances, except wide used polymers. For energetic materials or system these different tools are not convenient. It's impossible to implement data base with explosives or pyrotechnic compositions. Even if their production process can be described, their environmental impact can't be assayed. For these reasons, ammunition's life cycle analysis can't be performed.

Actors of the pyrotechny joined together into a committee of the GTPS to elaborate a guide of eco-design, simple in use and adapted to the specific area of energetic materials. This tool completes the whole life cycle of the ammunition from energetic material production to system dismantling. It includes different criteria like regulation compliance (REACh, ROHs,…), environmental impact (human, aquatic, atmosphere), resources decreasing, recycling.

Fictive ammunition with three levels of design were proposed to validate the pertinence and sensitivity of the chosen criteria. The presentation of results has been design to identify the environmental impact of the different part of the life cycle and validate the choice of conception in term of material and process.

1 INTRODUCTION

In a lot of industries, Ecodesign is widely integrated in the development of new products. It concerns the conception but also the industrialization. For a long time considered as an obstacle for the production of a product at efficient costs. Ecodesign is now well integrated in company procedures. Many societies have taken the opportunities to increase their environmental performance non sole without more constrains but also by developing new concept and innovation.

At the same time many tools have been developed, in a first time by industrials themselves and after by organism specialized in environment.

Pyrotechnic area is also concern. This industry also integrated the demarche but regarding ammunition, existing tools for ACV or eco-design don't suit. Companies of the pyrotechnic group together to propose a methodology and a tool specific for the conception of their product.

It covers all the life cycle of ammunition or pyrotechnic device form the impact of raw materials to recycling or dismantling.

2 ISO 14001

ISO14001 defines the framework for the implementation of environmental management systems (EMS) in companies. Created in 2004, it was updated in 2015 to encompass the product in the system.

When defining its EMS, a company used to assess its major environmental impacts, only looking at the manufacturing phase (inside industrial sites), leading to indicators such as energy, water consumption and waste generation. However, assessing and improving only the manufacturing phase is not always the most relevant strategy to reduce their environmental impact for companies depending on the products they manufacture. Take the example of an aircraft: most of its environmental impacts come from the use phase. As a result, with the new ISO14001 standard update, companies must assess the environmental impacts of the products they manufacture over their lifecycle that is to say from raw material extraction to end of life.

In this context, eco-design appears to be an opportunity of operationalization of this new way of thinking. Eco-design is the systematic integration of environmental aspects during the conception phase with the objective of reducing environmental impacts over the life cycle. This tool is therefore more than relevant in the context of the new standard, because it will allow companies to develop environmental impact reduction strategies through the whole life cycle and reach the environmental objectives that they set in their EMS.

Ecodesign can be applied in the context of ISO14001 standard, following the 4 steps below (adapted from Pole Eco-conception methodology):

1. **Set Environmental objectives for the product**: environmental performance assessment to identify the hotspots over the life cycle must be carried out. This can be done using commercial software such as SimaPro or GaBi. However, pyrotechnics data are not yet available publically. That is why the ammunition industry, through GTPS, is developing an assessment tool specifically designed for the needs of the sector. This environmental performance assessment leads to the definition of environmental objectives. This is an ISO14001 requirement.
2. **Translation into design objectives**: environmental objectives must be translated into design objectives. For example, for a military system transported on a vehicle, if the objective is to reduce CO2 emissions during the use phase, then the design objective can be, among others, to reduce the weight of the system developed.
3. **Definition of eco-design strategies**: this can be done through brainstorming for example to identify a set of solutions that will allow the company to reach its environmental objectives.
4. **Check the efficiency of the eco-design projects**: that way, one can validate that environmental impacts are not transferred from one life cycle phase to others.

Eco-design if therefore a powerful tool that will help companies reach their environmental objectives and manage their environmental system efficiently from a product perspective.

3 FRENCH MOD INTEREST IN ECODESIGN

The French MOD wants to be a responsible administration. That is why it has adopted a Sustainable Defense Strategy 2016-2020, whose one of the major challenges is ecodesign and control of the environmental footprint of infrastructures and equipment. As a result, the French Defence Procurement Agency's contracts (DGA) increasingly include requirements for the acquisition of equipment that not only complies with environmental regulations, but also consumes less energy, are less exposed to the risk of obsolescence (substances) and are more sustainable.

The integration of environmental issues into a weapon system design process is not currently done in a routine framework and requires the implementation of an approach with objectives of continuous improvement from measurement of an initial level of environmental performance. DGA recently has developed two tools, two assessment grids, "GRECO Management" and "GRECO Product" (GRECO = ECOdesign GRid), included in the contracts. They will measure the ecodesign maturity of industrial companies both in terms of organization (work procedures, methods and tools, training of staff, communication, etc.) and their equipment (concrete actions put in place to reduce the environmental footprint of equipment at different stages of their life cycle). From an initial level of maturity, work areas will be discussed between DGA and its suppliers in order to achieve the wanted level of control.

Ecodesign can imply additional costs (innovation costs, new materials and/or processes, new tools), but it will mean benefits for the French MOD in terms of availability, autonomy and sustainability.

Ecodesigning equipment requires an initial assessment of its environmental impacts throughout its life cycle in order to identify possible areas for improvement to reduce its environmental footprint. Several assessment methods exist including one, efficient, internationally recognized and standardized: the life cycle assessment (LCA).

Regarding ammunitions, carrying out a LCA with software is made complex and inoperative by the lack of data on pyrotechnics on the one hand and the non-inclusion of regulatory aspects on the other hand. These drawbacks led the Ecodesign Commission of the GTPS to the development of a simple and an open-access tool. This tool will be used by the ammunition manufacturers to improve their environmental performance and the results presented, when the GRECO grids will be completed, as proof of the ecodesign efforts of industry.

4 ECODESING METHODOLOGY

For mechanic pieces or devices lot of software can be used to carry out life cycle assessments: SIMAPRO, GABI, … are the most common used. Their data bases have been constructed first for automobile industries. They contain lot of data on materials like steel, aluminium or plastic, but few chemicals. Data for their production and recycling have been integrated.

Organism like ADEME proposes tools for ACV. If they are more adapted to the industry of the chemistry, they don't enable to conduct complete ACV and more less eco-design studies.

Some industrials develop their own methodology without communicating about it or propose some guide (agro alimentation for example).

The new version of ISO 14001 standard includes ACV studies. Companies have to justify that they take into account this problematic into the development of their products.

For pyrotechnic, no specific tools exists. Some studies were conducted with existing software but they take into evidence the lack of specific data for energetic materials.

For example, Green GALIX study was a French MoD contract conducted by NEXTER Munitions and Etienne LACROIX, in cooperation with FOI. This study is realized in the dynamic of the sustainable development. The aim is to establish a methodology of environmental impact applicable to ammunition. The ammunition object of the analysis was the GALIX ammunition used by French and Swedish army.

The projects purpose has been to investigate whether it is possible to use life cycle methodology to improve the environmental performance of munitions. For this study the smoke munitions was chosen since it exists in both countries inventories

The objectives of the study were to:

- Realize the life cycle analysis of the ammunition.
- Identify the parts of the ammunition which generate the most important environmental impact.
- Propose more friendly materials or processes to decrease its environmental impact.

The life cycle assessment ACV was realized with SIMAPRO software, currently used by FOI for other ammunition impact studies.

The product was fractioned in functional sub-assemblies in order to identify the most critical functions regarding human health, eco-system, and resources through the method “Eco-indicators 99(I)". The SIMAPRO data base was implemented with chemical substances and energetic materials. Collecting data is difficult and time consuming. Moreover, it’s impossible to calculate or get environmental data concerning human toxicity or biodiversity, because very few studies on these specific materials have been conducted.

The results of calculation took into evidence this lack of data for energetic materials (pyrotechnic compositions, propellants …). The most important impacts were due to the mechanical parts of the ammunition.

Other studies have been conducted and conclusions were de same. It’s the reason why the eco-design commission of GTPS proposed a guide and the EcoPyro tools specific for pyrotechnics.

5 GTPS’s ECODESIGN GUIDE

This document describes the first step which goal is to determine the environmental profile of the ammunition and to classify the impact on human and environment to get orientation to the designer to find best materials and process to decrease the environmental impact of his ammunition:

- Raw materials (MP): impact linked to the choice of all materials, components, … of the unpackaged ammunition;
- Fabrication (F): impact linked to the all processes needed for the manufacture of the ammunition;
- Use (U): linked to the use (chemicals emitted during burning and wastes)
- End of life: linked to the deconstruction and recyclability of the ammunition when not used.
- Transport and et distribution (T): linked to the localization of suppliers, number of expeditions,

To carry out the analysis we need to define the objet through its overall nomenclature.

5.1 Raw materials (MP)

Five effects are taken into account:

- Impact on environment: presence of dangerous substances with following risk mentions: H400 à H 402, H410 à H413 and H420 (ozone layer)
- Impact on human presence of dangerous substances with following risk mentions:
  - Toxic: H300 à H304, H310 à H312, H330 à H332, H336, H370 à H373
  - CMR type 1A, 1B ou 2
  - Other: H314, H315, H317, H318, H334, H335
- Regulations concerning a substance:
  - Included in REACh annex XIV,
  - Included in REACh candidate list,
  - Non authorize by ECHA for this use,
  - Included on COV list established by the commission by listing all existing data,
  - Included on POP list established by the commission by listing all existing data,
  - Very persistent very and/or Persistent Bio accumulative,
  - Biocide,
  - Greenhouse effect gas,
  - Included on conflict mineral act list,
  - With impact on ozone layer (Montreal protocol),
  - Included in ROHS list in case of electronic component.
- Resources decreasing: use of rare metals as substances or included in steel.
- Recycled metals.

For each effect or impact, a ponderation is applied to differentiate them. The values have been proposed by the commission.

5.2 Manufacture

It concerned all the processes used in the factory or by suppliers for:

- Raw materials manufacturing (inert or pyrotechnic),
- Components manufacturing (materials transformation),
- Assembling of component.

For this phase, quantified environmental impact, issued of the ADEMME 2011 database. Four impact are considered:

- Resource's consumption,
- Green warehouse effect GWP 100,
- Aquatic toxicity,
- Human toxicity.

The data base includes materials and processes used currently. Data base has to be upgraded by each industrial by each specific data for pyrotechnic manufacturing.

5.3 Transport

The methodology is the same than that proposed for manufacture.

5.4 Use

During phase use different solid and gaseous cash rejections will be taken into account. They correspond to impact of products of reaction of the energy materials or of the degradation of plastic materials.

Energies outer the object used to initiate it are not taken into account.

The metal or organic parts which stay on rifle range are considered as inert wastes. We considered that these elements are buried.

The products of decomposition of active materials of the object are able to be determined from software of thermodynamics or of the appendix 12. This appendix gives examples of products of decomposition by family of energy materials: propellant powder, secondary explosives, explosive poured – melted and pyrotechnic composition.

If the user determined the products of decomposition from tools of calculation or of tests laboratory, he will point out the mansions of danger of the issued products. If he does not have data, he will relate to the appendix 12 of the guide and point out the typical family which corresponds most to its pyrotechnic material.

The environmental profile of phase use is based on two main effects, each able to contain different impacts:

- Effect on environment: presence of dangerous substances with mention of danger :
    - Impact mattering on environment: H400 and H410,
    - Very important impact on environment: H 402, H411, H412, H413.
    - Impact on the ozone layer: H420

- Effect on the man: dangerous substances with mention of danger :
    - From type CMR 1A and 1B: H340, H350 and H360,
    - From type 2 CMR: H341, H351, H361, H362,
    - Lethal and very toxic: H300, H310, H311, H314, H318, H330, H331, H370, H372,
    - Toxic and damaging: H301, H302, H304, H312, H315, H319, H332, H335, H336, H371, H373VLEP 8 h or French regulatory VLCT or European VLEP (directives).

5.5 End of life

This phase corresponds to the demilitarisation of ammunitions. It is going to be about the treatment of the not used ammunitions, including their packaging.

The evaluation of this treatment is only qualitative, for lack of quantitative data. It's based on three main criteria which are going to characterise the ammunition:

- Disassembly capability: with or without specific tool (= not standard)
- Recyclability of its not made dirty components
- Treatment of its pyrotechnic part or its components made dirty

6 EcoPyro

EcoPyro is a tool for eco-design new products or improve environment impact of exiting ammunition.

It based on a methodology developed by industrials grouped in GTPS Ecodesign commission. The method is applied on the whole life cycle of the ammunition. Its objective is to initiate a eco-design demarche in company. It's based on the five following steps:

- Step 1 : determination of the environmental profile of the pyrotechnic object
- Step 2 : selection and hierarchisation of the directive lines
- Step 3 : choice of the appropriated indicators;
- Step 4 : indicators following
- Step 5 balance sheet- capitalisation

7 Examples of eco-design

7.1 French MOD Interests in Ecodesign

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7.2 Primary explosive synthesis: liquid waste treatment

In its constant will to protect environment, Davey Bickford continue to reduce the impact of its activity on natural environment.

The waste collected in the loading workshops *and the workshops of manufacturing of primary explosives are put in solution by acidification.*

The acid solutions resulting from these operations are collected and sent to a specific treatment facility.

The purpose of the station is to treat physicochemical effluents where they are neutralized and removed before rejected in the local treatment plant in Hery. These wastes respect the rejection standard signed between the local administration and Davey Bickford.

This standard fixes maximum concentrations for several kinds of analyses that have to be respected.

For example, Table 1 shows limit concentrations we have to fulfil in our case.

TABLE N°1: ALLOWED LIMIT PARAMETERS IMPOSED BY REJECTION STANDARD ON A STATION OF PURIFICATION.

Liquid waste parameters	**Allowed limits**
Flow rate	≤ 6 m^3 / day
COD (Chemical Oxygen Demand)	≤ 12 kg / day (2000 mg / l)
COD / BOD5 (Biological Oxygen Demand)	≈ 2
Total nitrogen percentage	≤ 21 kg / day (3500 mg /l)
Suspended matter rate	≤ 0.2 kg / day (30 mg / l)
pH	[6;8]
Lead concentration	≤ 5 g / day

There are two principles of treatment: Lead cycle and Fenton cycle.

The lead cycle is a treatment reserved for the effluents of primary explosives containing lead. Waste treatment was based on a precipitation as lead carbonate and a filtration after a flocculation. At first, mother liquors of lead styphnate and lead azide precipitation reaction are treated with appropriate reactive in order to dissolve solid particles and to destroy pyrotechnic molecules. Then, sodium carbonate is added to collect lead atoms in the solution as lead carbonate.

That operation step is necessary to destroy the pyrotechnic properties of the molecules in order to avoid safety problems in the treatment plant.

FENTON treatment is a treatment reserved for lead free primary explosive liquid wastes; it has to be done in a very different way. Before rejecting liquid wastes, we have to decompose the dissolved molecules.

The Fenton oxidation method is based on the use of hydrogen peroxide as oxidant and sulphate iron II as catalyst. This method is really cheap. It is not necessary to use large quantities of hydrogen peroxide and it's possible to recycle iron catalyst.

The Fenton oxidation method is a very efficient way to decontaminate explosive molecules. This method is usable on a very large type of organic molecules in aqueous wastes. It is also very useful to reduce high COD rate (>500 mg/l) but has no influence on the nitrogen rate.

In both cases, the filtration is done on a NIAGARA filter on which a layer of diatomaceous earth has been previously deposited.

The only waste resulting from this treatment is lead carbonate. It is collected in drums, stored and identified before recovery by an approved external company.

7.3 Toxic or REACh impacted material replacement

Lots of studies have been conducted all over the world to replace toxic substances:

- DBP DibutylPhtalate in propellant (EURENCO, SIMMEL, ROXEL):

  Cast double-base (CDB) propellants manufactures have conducted many studies for DEHP and DBP replacement They are specified as components of certain propellant formulations in the 1960's and continue to be used for this purpose in several current ammunition systems.

  These propellant formulations have been developed over many years based on progressive optimisation of numerous parameters that combine to provide the overall performance characteristics of the propellant. It is expected that both DEHP and DBP have multiple functions within the propellant (e.g. plasticiser, extrusion/flow aid, propellant coolant, ballistic catalyst), which makes the process of substitution more complicated.

  Alternatives to DEHP/DBP cannot be considered available until the replacement programme, including re-qualification of the propellant formulations and relevant customers in the supply chain, is successfully completed and the new propellant and charge has been manufactured.

  Many companies have identified potential candidates for replacement of DEHP/DBP in propellant (SIMMEL DIFESA, EURENCO, ROXEL, …)

- Lead free primer with lead azide

  Primary explosives such as lead azide (LA) are essential to a huge range of military items, yet suffer from serious drawbacks related to their toxicity. We have recently begun investigating a number of alternative, green replacement candidates, with a focus on application. Candidates include small molecules such as high nitrogen compounds, as well as inorganic materials based on the newly emerging energetic field.

7.4 Effluent treatment

Some specific installations have been used in pyrotechnic facilities to be able to decrease the nature and quantities of pollutants emitted during processing or trials. For example:

- Installation of biofilter for solvent treatment in NEXTER facilities,
- Design of smoke characterization tunnel with specific filters in NEXTER Munitions or LACROIX.

7.5 Demilitarization

Demilitarisation or Dismantling installations are used all over the world for different kind of products. For example, SIMMEL and MBDA have facilities, which enable to demilitarize ammunition.