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Influence of geometrical characteristics on eco-designed products

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Abstract

Purpose:
Our work consists on helping the designer to create eco-designed product and allow the industry to still present in the market by respecting new established ecological laws.

Method:
In this paper we are focused on searching a simple ecological tool to the designer which is inspirited from researchers done to couple Computer Aided Design (CAD) and Life Cycle Assessment (LCA) tools.

Result:
As a result we proposed a framework which consists firstly on a special geometric data base (D.B) containing the impact of all existing solutions in a given industry. Secondly, it consists on a macro applied to CAD and LCA tools which can calculate the impact of a new geometrical solution and adds it to the data base (D.B).

Discussion & Conclusion:
The need of ecological tools used on the design phase by a designer non expert in terms of environnement is still exists. In our work we tried to exploit existing geometrical solution environnemently evaluated to reduce the time of choosing the most ecological solution from used solution in industry and giving the possibility of new evaluation in case of a new one. This is done because the influence of geometry on the whole life cycle product. Our framework can be applied to each industry but the numeric tool is not yet developed; this can be the aim of a future work .

Introduction

Today, the integration of the environmental impacts in the product design process becomes an application required by competitive industrial to guard their marketplace.
In the design phase, the designer can act at the source without resorting to a realization, so why it is necessary to assess the impacts that will be generated on all stages of the life cycle, upstream in order to reduce them to the maximum at this phase.
The innovation in our work is to choose the most ecological solution between existing ones or to create an ecological one during the design process, which is an important phase in the product life cycle by reducing its environnemental impacts before assessment results given by LCA tool.
This process involves several steps, in our work we are focused essentially on the detailed design phase which is characterized by the use of CAD tools. In order to make eco-products it is important to reduce their environnemental impacts which can be calculated by LCA tool. In order to choose the most ecological solution environnemental parameters were introduced for the comparison between different solution and estimate impacts. These parameters are essentially related to data given by the CAD activity.
All possible scenarios in the same industry will be established on the aim to evaluate and compare them.

The environnemental evaluation will be based on geometric characteristics, that we show their influence in the reduction of the product impacts along its whole life cycle process from the extraction of raw materials until the end of life.
We translate our thoughts, in the second part, by a methodology to evaluate the product impact before finishing geometric modeling.
To do this, we illustrate the validity of our methodology on a concrete example which shows that changing the geometry can conserve ecological quality of the environnement.

1 What is design what is eco-design?

1.1 What is the design Process?

The design process is a phase of a product life cycle, which impacts all activities of a company. Thos process aims at bringing a new product to the market.
Searching solutions and ideas is an important step which call to creativity tools and its aim is to provide a maximum of possible solutions. The problem is globally complex from one side, and the product has to satisfy a user from another side, so it is preferable to solve a function by function (step by step). It means, searching a maximum of possible solutions that respond to the service functions. To choose the optimum solution, in terms of cost or feasibility for example, the designer has to assess all functions and combine all solutions.
CAD activity.

1.2 What is the Eco-design

The Eco-design is to assess and reduce the environmental impacts of a product from the design phase [3]. The environnemental stress has been integrated in multiple ways in the process of classic design [4, 5]. In addition, several works have presented the concepts, methodologies, and even tools that can exploit some geometric model data for environmental analysis. Integrations are designed to couple a CAD tool to a LCA one. [6].
Most solutions developed in the CAD/ALCA coupling tried to introduce a suitable simple tool to non-expert designer in terms of environment. This will allow visualizing the impacts of its model during its life cycle. Our contribution to this axis is to present a methodology that allows exploiting the expertise of the designer in his field to produce eco-designed products.

2 State of the art of coupling CAD and LCA tools

During the product life cycle many activities are involved, in our work we are focused on the design phase. The aim is to exploit this phase in order to develop eco-friendly products. In the first step the designer has to realize a CAD model which contains form, geometric characteristics, etc.
In order to make it a more ecological product, the second step, then, is to realize a LCA which can identify environmental hot spots. Then, the environnemental expert team will send a report to the designer team containing environmental impact sources and give suggestions on their minimization we represent this exchange by fig. 1

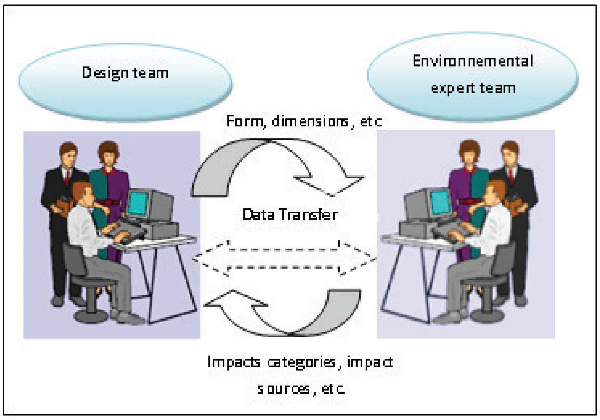

Fig. 1 Data transfer between CAD and LCA teams

The operations of assessing product and making changes to obtain an eco-product can take a long time and the product can not respond to time to the market. So, improving environnemental product performances during its development can be carried out by exchanging data between CAD and LCA software tools.
In presence of the lack of environnemental knowledge of the designer, many researches tried to surpass it by realizing a coupling between the two tools in order to help him to locate impact sources and improve his product performances in a short time.
This coupling consists of exchanging data between CAD and LCA tools.
To perform integration between the two different tools, it is necessary to identify the input-output entities of each one in order to adapt them and make one in the service of the other.

2.1 Input- output data of geometric modelling tool

CAD model is the computer representation of the object in design fig. 2. It is digital, virtual object model. Today, the geometric model is the heart of a CAD system. [7]

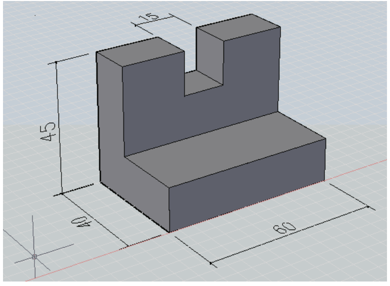

Fig. 2 CAD geometric modeling

To design a product, in a geometric Modeler, designer have to provide dimensions, volumes, etc. the output is a virtual model which is similar to a real product. The table below tab.1 presents entities of input-output for an example of geometric modelers "SolidWorks" [9].

Input	Output
Component noun	Impact by stage
Product weight	Comparison between
Material	stages impacts
Mean of transport	Comparison between
Distance	product
process	Etc.
Etc.	

Tab.1 Input-output data of CAD tool "CATIA" [22]

2.2 Input-output data of life cycle assessment tool

Practicing an LCA consist on analyzing different life cycle stages. These stages are in number of five: it begins with the extraction of raw materials, then manufacturing, then use and end of life without forgetting the logistics that exists between the other stages fig .3. To use specialized LCA tools, it is necessary to provide some data; this data may be quantities, processes, distances, parentages, etc. We conclude that introduced data are from of different types. The table below tab.2 displays input-output data of the software "Bilan Produit" developed by ADEME [10].

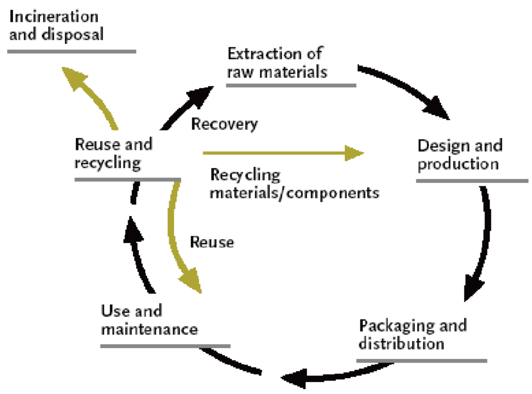

Fig. 3 Life cycle product stages

Input	Output
Part geometry Links between parts Material Tree system Etc.	Volume and weight Material Form Tree system Part name

Tab.2 input-output data of a LCA tool "Bilan Produit "

The integration of the two different tools seems to be contrasted by many stresses that we can find: Incompatibility of existing formats of the tools.

- CAD data transferred are not sufficient to practice LCA
- Data bases are incompatible.
- Lack of synchronization between assessments and design of the virtual model
- Misunderstanding of the results achieved by a non-expert designer in terms of environment
- Loss of time in iterations made to calculate product impact after each change
- Inability of some companies to adopt eco-design for its high cost
- Etc.

Researchers in this axis tried to resolve some of these problems, in order to help and guide the designer to reduce his product impacts with using only his know-how. Here we show some works aiming to connect CAD an LCA tools.

2.3 State of the art of Coupling CAD/LCA

Through literature review and research observations, it appears that numerical interfaces between usual design and eco-design software are needed to help the various experts involved in the design process to interact with each other. In fact, many researches were done in the last decade in this axis. We show some of them that we classify into three major categories: concepts and methodologies for connection, prototypes based on PDM system and finally interfaces, macros and special simple tools developed.

For the first category chosen we found Walace et al [12]. They have created models of stroke configured taking into account all stages of the life cycle of a product. These models are based on existing products; the problem analysis persists if it is a new product. Capelli [13] developed a generic algorithm for exchanging data between CAD and environmental analysis, except that this analysis is not based on specialized software. Yang [14] has used LCA software for its coupling that relates only to the product he has seen (a DVD). Marosky [15] presented the structure of an algorithm that allows a mutual transfer of data between CAD (SolidEge) [16] and LCA tool (SimaPro) [17], except that his model was not developed to a functional tool which is the same case to Maud Rio [6], who also proposed recently a framework to an interface between CAD and LCA tool. Concerning the category that includes all the tools and prototypes based on the PDM system that manages data. Hagstrom [18] have used for its coupling simplified environmental assessments, based on PDM system, which can be understood by the designer, however it does not detect the potential impacts for several products that require a detailed environmental assessment. Melk [19] also presented a prototype PDM operator to extract more data to realize a complete LCA and get closer to the actual impacts, but the tool still exist on paper. For the last category that we considered and consists of computer developed tools realizing the CAD / LCA connection. In this axis we find the work of Takao [20] and Al with their support system design that puts into consideration the recycling from the beginning it has reduced the amount of waste at the end of life over time reduction disassembly. This system seems pretty reliable on this phase but it is not for the other stages of the life cycle. These tools have been developed. Mathieux [21] have developed a demonstrator that binds CATIA (CAD) [22] EIME (LCA) [2] a tool based on the programming language Visual Basic. But this tool is not generic because of the lack of compatibility between databases primarily those materials. In addition to the connections between parts and manufacturing processes are not exportable. Abad [11] also conducted a connection between Solidworks [9] (CAD) [15] SimaPro (LCA) using macros. But the manual introduction of the missing data to perform an environmental analysis persists in the absence of an interface combining the two types of software and wasting time in the absence of an automatic transfer is not preferred by the industry.

Different solutions have eliminated many barriers that exist to integrate the environment into the design process. The API of a geometric modeler used to extract data on product and therefore an automatic transfer of data so there is considerable reduction in time taken between design and impact assessment. Moreover, the incompatibility of formats and the lack of a common format is no longer a problem to transfer data. In addition, the designer is an independent environmental expert to determine the most environmentally friendly solutions. Increase recyclability rate for many products and waste reduction rate while maintaining the most natural resources.

Then, researchers, who have opted for coupling tools of CAD with the LCA tools tried to remedy the non-designer expertise in the field of eco-design. These various studies show concepts which consist of extracting data, managed automatically, a CAD tool for transferring in an LCA tool through interfaces or by using macros, [6]. Missing data that geometric Modeler cannot are introduced by the designer manually. In addition, the impact evaluation activity is considered as post-modeling step.

3 Influence of the choice of geometrical characteristics on environnemental impacts of a product life cycle

A product is geometry. This geometry is a combination between technical solutions. Every technical solution presents a geometrical solution with its forms, weight, box, geometrical specification, etc.
For example to transform a rotation to a translation we can use many solutions which differ on geometry such as connecting rod, gear-rack, cam system, etc. Every choice done by the designer has its environnemental impacts on all life cycle stages.
For this, some strategies to eco-design are developed. Fig.4 shows one of these strategies.

In this section we present some relations given in the literature between geometry and environnemental impacts which are given in the form of guidelines to help the designer to think earlier in reducing its product impacts.

3.1 Influence of geometrical characteristics on extraction of raw material phase

The first phase in a product life cycle is the extraction of raw materials. The designer will be able to address the impacts of this phase through the choice of the geometric characteristics of its virtual model by following these instructions:

- Promote mono-material design, if it is possible, or to optimize the number of materials used.
- Consolidate functions in one item to save material.
- Optimization of forms and volumes that can with equal mechanical resistance to reduce the amount of material needed (extracted primary resources are diminished).
- Use materials issued from renewable resources.
- Use recyclable materials (magnesium, is totally recyclable it is almost light as well as plastic, but more strong and it ha exceptional properties against electro-magnetic interferences.

With his knowledge designer has an idea which materials are present in his product and their characteristics. So that, he adopt materials derived from renewable ones having similar mechanical characteristics.

3.2 Influence of geometrical characteristics on manufacturing phase

Manufacturing phase consist on realizing geometrical form elaborated by designer. This means that he can influence this phase by his geometrical choices:

- A mono-form promote a mono-manufacturing process
- Optimizing technological solutions can reduce manufacturing stages number (reduce the number of holes, this rise the lifetime of tools).
- A simple form promotes easer and rapid manufacturing processes. This lead to reducing energy consummation.
- Thinking about technological solutions avoiding the use of toxic products and substances.
- Optimizing geometric form can reduce industrial waste.
- Optimizing volumes can reduce the quantity of resources used.

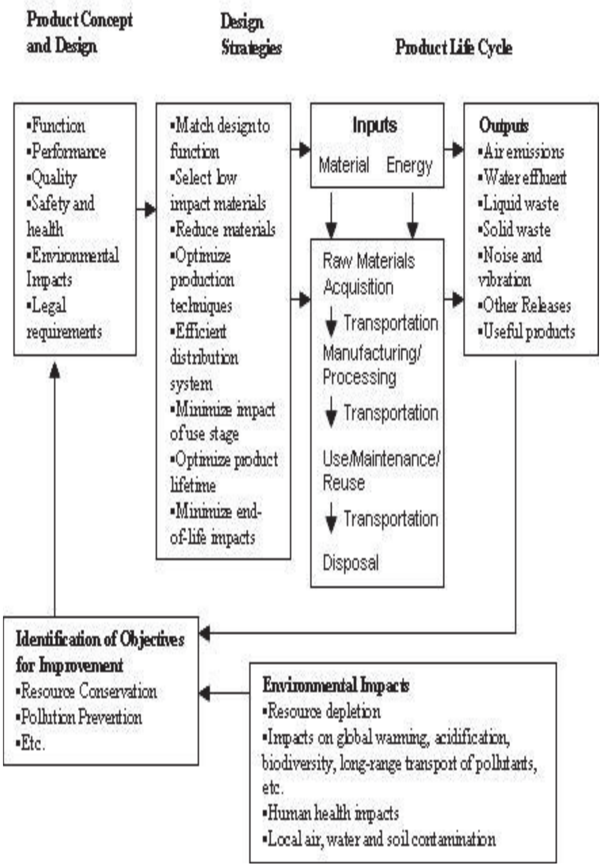

Fig .4 Example of Eco-design strategy [23]

3.3 Influence of geometrical characteristics on use phase

A product has to accomplish his main function for which it is designed. This function is the basis for the use phase. The model to create has to respond to it, but with fewer impacts:

- The product can be optimized to use less natural resources
- It is collapsible to promote the use of spare parts.
- Life is quantified in the applied constraints hence proposed geometry should resist them the longest time possible
- - Imagined multipurpose solutions can avoid multi-process.
- Used solutions which generate less waste.
- Prevention of simple solutions, which have no effect the other phases, but reduce the impact of it.
- -A form, showing an affluence of handling, increases the lifetime of the product.

The designer can oblige the user to adopt some manner with the product, which has less impact on environment, despite the random appearance of this phase depends on the behavior of humans.

3.4 Influence of geometric characteristics on end of life phase

The designer may impose less impact with his design for EOL scenarios. This can be done by:

- Promoting the reuse of parts
- Increasing the number of recyclable parts in a product
- Optimizing a disassembly easy to avoid impact processes as well as reduces disassembly time through less power consumed.
- Reduce the number of components of a product permits a parallel decrease in the amount of waste.

The amount of waste presents the alarm that triggered the motivations towards the adoption of eco-design. A product makes service to man but carries out mountains of waste in end of life. Reducing volumes decline garbage quantity.

3.5 Influence of geometric characteristics on transport phase

The need to reduce the high impacts of the transport step in the product lifecycle some recommendations may be offered to the designer:

- The designer has to promote materials extracted from the region having similar mechanical characteristics.
- The compact form takes a little volume in transport, so that more product quantity transported. So that, less means of transport used, less energy consumed and less emissions on the air.
- Expect bended product also can be a solution to transport more products.

4 Proposed methodology based on geometrical solution

Each industry disposes of its own products data base. Each product has its special CAD design process and its technical solutions severally used. We can model a product structure as shown on fig.5. Our contribution, in the first side, is to create a special data base that contains all possible pertinent design scenarios of technical functions, optimum solutions and necessary components (parametric architecture, choices of different components on make-or-buy, etc.). To each technical solution (T.S) of each technical function (T.F) we associate its environnemental impact "I" given by a LCA practice. Then, it will not necessary to assess the geometrical solution when it will be used for another time.

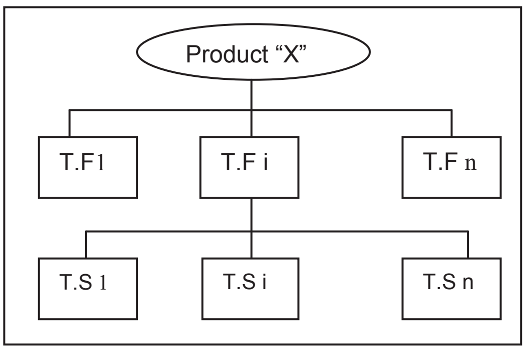

Fig. 5 technical structure of the product

In the second side, we propose to develop a macro, such the one developed by Cebrián [1] that can extract geometry data from a geometric modeler such as SolidWorks [9]. Throwing a window macro from the CAD design, the user is prompted to choose a part or an assembly. The API contains the material data, mass manufacturing and transportation process previously established for each piece [26]. Then, the environnemental impact will be calculated for the new technical solution.

The special data base and the macro will be gathered in a user interface. This interface will allow the designer to choose for a product, an existing solution and to see its impact or to add a new geometrical solution for the technical function chosen and calculate its impact.

The next step is the decision of the product designer who has his own bundle of knowledge and know-how (material properties etc.) to choose the optimum geometrical solution in terms of cost, feasibility, environnement respect, Etc.

Changes that be done to involve the ecological product quality are necessary done on geometry and its characteristics.

The following figure fig 6 show the framework that we propose to eco-innovate on existing and new products in terms of environnemental respect, also on reducing the environnemental evaluation time.

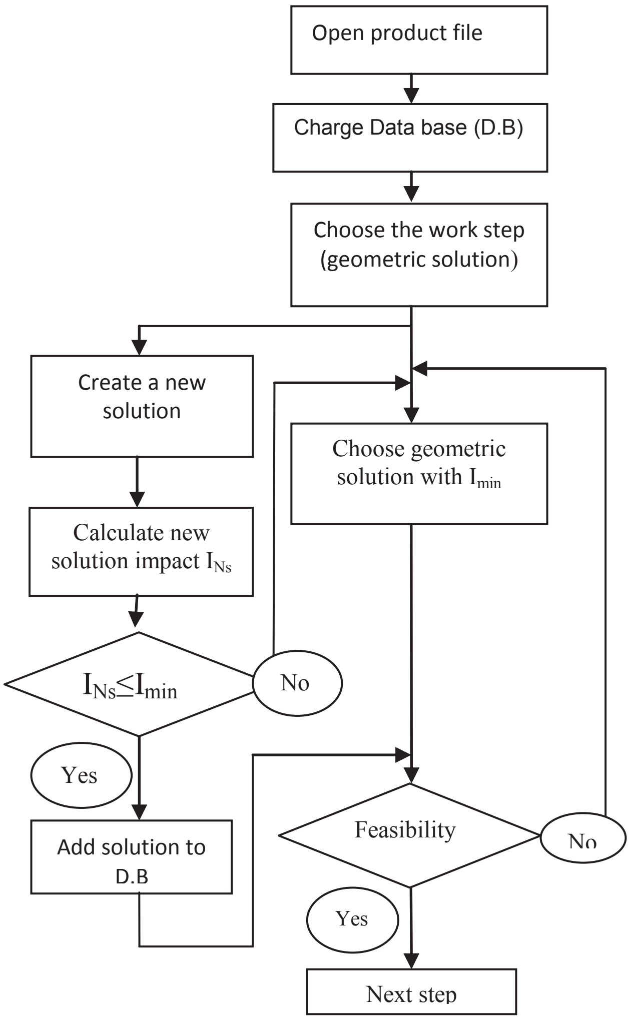

Fig .6 proposed framework to optimize ecological product geometry

5 Conclusion

In this paper we first identified the scope of our study that is to connect a CAD tool to an LCA tool to allow the designer to eco - design without the assistance of environmental expert.

To perform such integration, we defined, in the second part, input / output entities of each tool in the next section. This integration is faced to many problems such as format incompatibility between Cad and LCA tools. Despite, the big number of researches that aimed to surpass the majority to these problems, the need to a simple, rapid and available one is still exists. Because acting in the design phase can reduce significantly environnemental impacts, it is necessary to choose the most ecological design which consists of technical geometrical solutions that have an influence of the entire life cycle of the product. In this field, we proposed a framework which give the designer a comparison table between all possible existing solutions and allow him to asses a new solution if it is the case. The test of feasibility of the selected technical solution is done by the designer based on his knowledge.

In our future research work, an interface will be developed and applied to the Tunisian "AMS" industry in order to valid our proposed framework. A case study will be presented to show the validity of the research.

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