Analyzing the sustainability of an automotive component using SolidWorks CAD software

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Abstract. Design stages have been widely recognized as a milestone in the life cycle of a product in sustainability implementation, and this is of major importance for leading organizations that produce cost-effective and environmentally friendly products. This paper focuses on analyzing some aspects of environmental impact and ecological sustainability of design models using SolidWorks CAD design software. The material from which the piece was made was evaluated, with emphasis on its strength, durability and environmental pollution in terms of carbon footprint, energy consumption, air acidification, and eutrophication. Consideration was given to the whole life cycle of the product under consideration, from raw material extraction, processing, product production, assembling and use to the end of life, taking into account the mode of transport and the distance between these stages. In the case study is presented the virtual model of the analyzed product and the sustainability report that the SolidWorks software provides us and which can be analyzed later by the whole organization for the adoption of the right decision.

1. Introduction

The ideas of durability and sustainable design are an increasingly important part of today's design discussions. But what is a sustainable design and how can a more eco-friendly product be created? In this paper, there are some answers to these questions.

The World Commission on Environment and Development defines sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*."

Elkington [1] indicated that the concept of sustainability should cover economic, social and environmental aspects. This concept is also known as the "triple bottom line" where the profit, the planet, and the people are considered simultaneously. Therefore, the scope of sustainable design covers all the spectrum of product life.

Sustainable design is generally the process of developing a product that performs successfully, generates profits for the company, is socially acceptable, and uses a minimum amount of energy, that is, a minimal amount of material that produces hazardous waste.

One of the major challenges of sustainable development is encouraging the search for ecological ways and discouraging ways that harm the environment (air, water and soil or subsoil).

Contemporary design engineers should integrate the principles of sustainability into their work for at least one of the following reasons: *personal interest, professional growth, the intention of the company, industry rules.*

2. Literature Review

To analyze the sustainability of a product, there are dedicated software programs for these types of analysis, which can do much more in detail than those in the CAD range, for example. Such a dedicated software, which we can mention, is the GaBi Life Cycle Assessment.

Lately, global awareness of environmental issues has never been more acute. Consumers are increasingly looking at the environmental impact of the products they buy. It does not just look at recyclability. They want to know about the materials used and how they were produced. Producers, in turn, are trying to respond to rising demand. [6]

Why SolidWorks Sustainability?

Having implemented in SolidWorks and LCA mode as an engineer or product designer, there is the possibility to dramatically change how we interact with our environment. The question is how. Many designers do not know about the life cycle assessment process (LCA) or how they can guide them to more sustainable models. [5] Others may think that the process is too complex and consumes a lot of time or is the responsibility of someone else.

SolidWorks Sustainability provides this intelligent analysis module to make informed decisions about what materials to use. It can also be analyzed how the supply, manufacture, use, and disposal of region-specific materials will affect the life cycle of the product before starting the manufacturing process.

2.1. The concept of sustainability

Sustainable design analyzes how the product will evolve [7] from concept to recycling, focusing on four key factors to report on environmental impact::

- *Acidification of air* - combustion fuels creates sulfur dioxide, nitrogen oxides, and other acidic air emissions. This causes an increase in the acidity of the rainwater, which in turn acidifies lakes and soil, subsequently making the soil and water toxic to plants and aquatic life. Also, acid rain can slowly dissolve hand-made construction materials such as concrete.

This impact is usually measured in kilograms of sulfur dioxide equivalent (SO2).

- *Carbon footprint* - Carbon dioxide and other gases from combustion of fossil fuels accumulate in the atmosphere, with the consequence of increasing the average temperature of the earth. Also known as "global warming potential" (GWP), the carbon footprint is measured in carbon dioxide equivalent units (CO2e).
- *Total Energy Consumption* - A measure of non-renewable energy sources associated with the piece's life cycle in megajoules (MJ) units. This impact includes both the electricity or the fuels used during the life cycle of the product as well as the upstream energy required to obtain and process these fuels as well as the built-in energy of the materials that would be released in the event of combustion. Total energy consumed is the net calorific value of primary energy demand from non-renewable resources (for example, oil, natural gas, etc.). Efficiencies in energy conversion (for example, energy, heat, steam, etc.) are also factors.
- *Water Eutrophication* - Appears when a supernatant of nutrients is added to a water ecosystem. Nitrogen and phosphorus in wastewater and agricultural fertilizers cause overlapping algae that flourishes, which then diminishes oxygen water and results in the death of both plants and animals. This impact is usually measured either in kilograms equivalent to phosphate in kg (PO4) or nitrogen equivalent (kg).

3. Case study

In this chapter, for the case study, a component of a rotating nut jack-screw was selected for analysis. In Figure 2 shows the structural diagram and the main components of the assembly, these being: 1 - the cup, 2 - the screw, 3 - the rotating nut, 4 - the body, 5 - the actuator attached to the rotating nut. From this diagram it is possible to notice the operating mode, namely by rotating the nut 3 with the mechanism of action 5, the screw 2 will perform only a translational motion in the direction of load displacement Q, the rotation is prevented by the translation coupling made between the screw movement and body. [3]

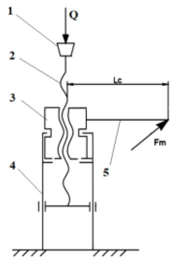

Figure 1. Structural scheme for jack-screw with rotating nut

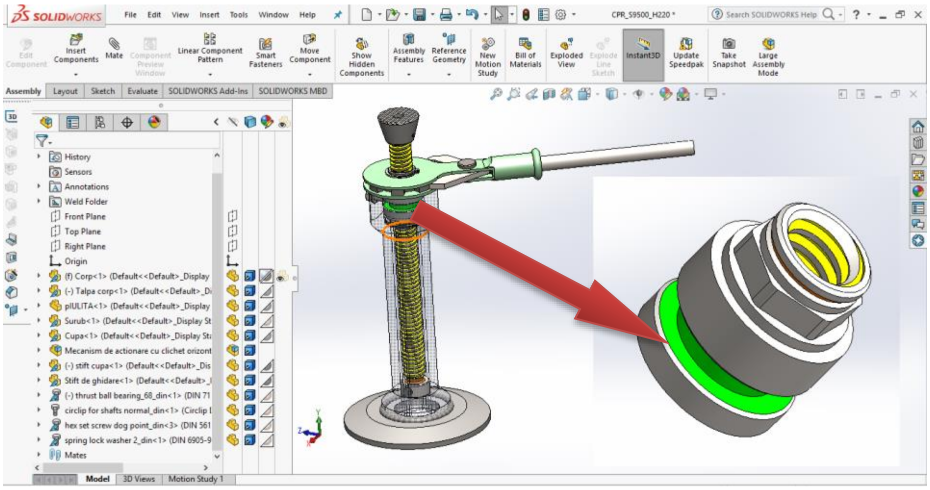

Figure 2. Jack-screw with rotating nut

In Figure 2, is presented SolidWorks CAD software interface, in which the 3D model of the jack-screw with the rotating nut has been made, having the input data a maximum stroke, Hmax = 220 mm and a maximum load, Qmax = 9500 N. For a result with a major impact, the sustainability analysis must be done for each benchmark with the necessary modifications, but in this paper only the rotating nut.

After finalizing the modeling, the Sustainability Study of the "rotating nut" was started using the "Sustainability" menu (Figure 3). By accessing the "Material Set" tab, the database of materials provided by the CAD software was launched. Figure 4 being sorted material quality carbon steel range. In this database, some features are shown for each material, for example, "Modulus of elasticity", "density", etc.

As mentioned in Chapter 2, besides the type of material used to manufacture the product, the impact on the environment is influenced by other factors such as the territory where it is manufactured and then used, the transport between the two territories, the manufacturing process, painting piece, etc. In the present case, a location in Europe was chosen as the manufacturing area (Figure 5), and as the location of use of the product, South America (Figure 7). The greater the distance between the two areas, the less environmentally friendly the product. [8]

In the first step, the manufacturing process used (Figure 6) is a machining process, after which a hot forging process has been chosen.

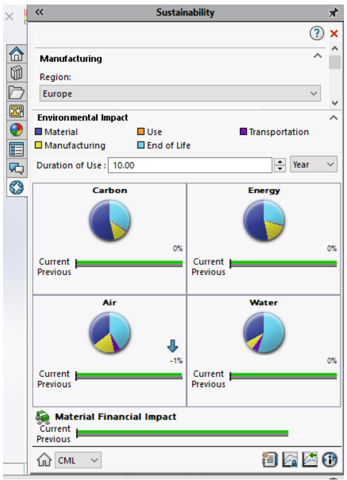

Figure 3. The product "Sustainability" menu

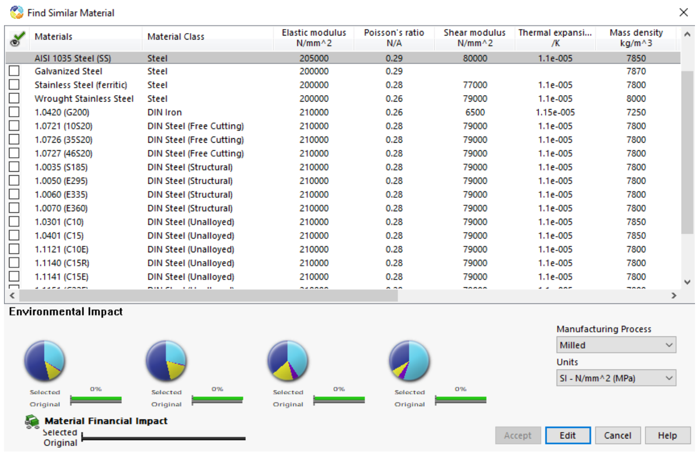

Figure 4. The steel materials datebase

In the first step of the production process used (Figure 7) is a cutting machining process, was subsequently machining process especially a hot forging.

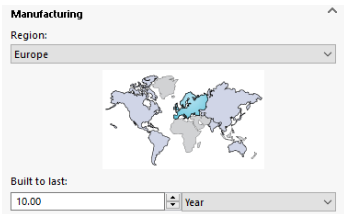

Figure 5. Manufacturing tab

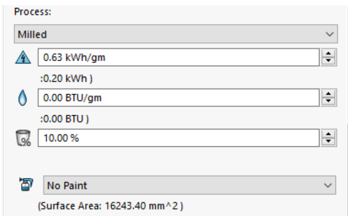

Figure 6. Process menu

Figure 7. Use tab

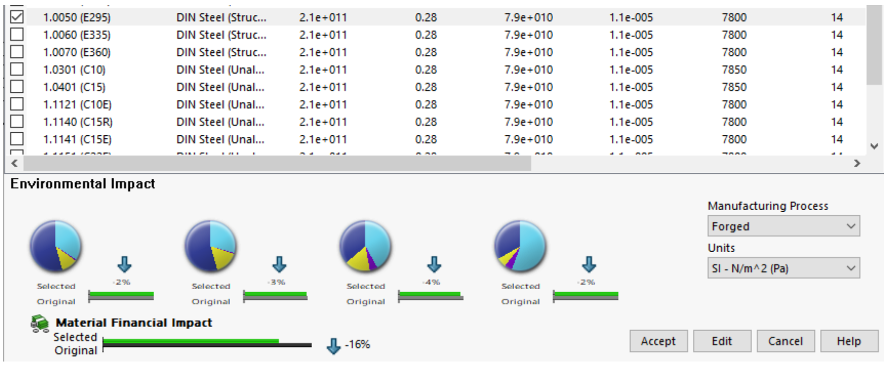

Figure 8. After changing the material and processing process

As can be seen in Figure 8, after changing cutting manufacturing process in hot forging and changing the material with similar characteristics, were obtained:

- A decrease in *carbon footprint* by 2%. If the final product is used in a region other than the one mentioned above, for example in Europe, this factor will shrink by another 6 percent, and if North America chooses, the factor will decrease by another 12 percent from South America.
- A decrease in *total energy consumption* by 3%. If the final product is to be used in a region other than the one mentioned above, for example across Europe, this factor will shrink by 8 percent, and if North America chooses, the factor will decrease by another 9 percent from South America.

- A decrease in *air acidification* by 4%. If the final product is to be used in a region other than the one mentioned above, for example in Europe, this factor will shrink by 16 percent, and if North America chooses, the factor will decrease by another 14 percent from South America.
- A decrease in *water eutrophication* by 2%. If the final product is used in a region other than the one mentioned above, for example in Europe, this factor will shrink by 16 percent, and if North America chooses, the factor will decrease by another 19 percent from South America.
- A decrease in the *cost of material* by 16%.

After such a sustainability analysis conducted by the Design Department, designers can get various reports with the results tested in the CAD environment, then they can be analyzed in a meeting with the other departments and using, for example, the brainstorming technique to choose the best option from an ecological and economic point of view.

4. Conclusion

New trends in manufacturing organizations focus on developing an organic product.

Sustainability analysis was performed for a single product, and the result was obviously diminishing environmental impact factors, and if the analysis is made across the whole and taking into account a small series production of approximately 1000 pcs / month, shrinking percentages for factors that impact on the environment will increase.

After such an analysis, the enterprise can decide which regions can export and sell the products, which would be the cheapest way of transport, etc.

Many organizations that do not have product execution capabilities but are highly focused on design and because the region where the company's headquarters is located has some sustainability legislation they can delegate for manufacturing elsewhere and later, to sell the products in another region.

In parallel with this analysis, design engineers can also approach the DFMA redesign method, from which you can get a reduction in material requirements, machining operations, lower assembly costs, and a lower production cost.

I believe that in the near future, because a company/enterprise that has a design department and wants to keep up the market and face the competition, you need to use this sustainability module provided by CAD software or to have dedicated software for these analyzes.

In the following papers, several sustainability case studies from several organizations will be dealt with for various parts made from both ferrous and non-ferrous materials in order to reduce the impact on the environment.

References

[1] Elkington, J., "Cannibals with Forks: the Triple Bottom Line of 21st Century Business," New Society Publishers, 1997.

[2] Sustainability of Products, Processes and Supply Chains Theory and Applications, 36, Elsevier, 2015 Accessed on 10 April 2019

[3] A. Jula, E. Chisu, Gh. Moldovean, D. Velicu, D. Savescu, Gh. Mogan, R. Velicu, E. Eftimie, Cl. Pozna, D. Oprean, M. Lates, " Screw Mechanisms, Design Guidelines" ("*Mecanisme Surub-Piulita, Indrumar de proiectare")*, Editura Lux Libris, 1976)

[4] A. D. Patel, et al, ESI or Energy & Environmental Science, (2012) Accessed on 15 March 2019

[5] Chowdary, B.V. and Phillips, C.M. (2014), "*Integration of computer-aided design and DFE principles for the development of a tennis ball retriever concept: A case study*", Asian Journal of Management Science and Applications, Vol. 1, No.4, pp.333-354

[6] Mutingi, M., Dube, P. and Mbohwa, C. (2017), "*A modular product design approach for sustainable manufacturing in a fuzzy environment*", Procedia Manufacturing, Vol.8, pp.471 478.

[7] "Introducing Sustainability in Value Models to Support Design Decision Making", Marco Bertoni, Vol. 9, Issue 6, 2017 Accessed on 25 March 2019

[8] Sustainable Design Guide in SolidWorks Accessed on 10 April 2019