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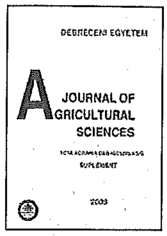

Life Cycle Assessment of the Denso VCT product

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SUMMARY

Life Cycle Assessment (LCA) is a relatively new and very promising method of environmental management. LCA is an investigation and valuation of the environmental impacts in a life cycle of the product or service from the cradle to grave. LCA enables to the companies to recognize the environmental impacts of their products, hereby to optimize their environmental performance.

Denso Corporation is one of the biggest automotive supplier of the word and the company is always committed to operate in the most environment-friendly way.

In our research we have analyzed the VCT product of Denso with the new manner of LCA. The goal of our study was to determine the eco-friendliness of the product in numerical terms, identifying the most significant environmental effects related to the life cycle of the VCT. Our aim was also to point out the most harmful parts and processes of the VCT in order to recommend possible improvements.

Our research work was supported by the ISO 14040 environmental management standard and by one widely used life cycle assessment software.

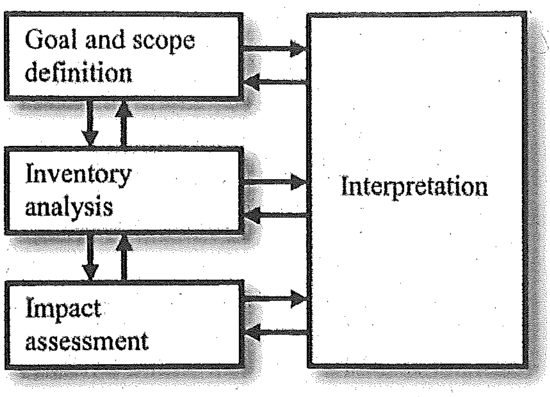
INTRODUCTION

Nowadays the environmental awareness of the companies is growing constantly. The annually increasing number of the published sustainability and environmental reports, and also the growing number of audited ISO 14001 or EMAS standards prove this development. In accordance with the principle of sustainable development - *as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs* - more and more companies raise the question of how to operate in less impact on the environment in order to manufacture more ecological products, to follow environmental regulations and to establish a competitive advantage. (Buday-Sántha, 2002) The latter can be created by capital savings or by fulfilling customers' demand for environmentally friendly goods. Furthermore, in the recent years the environmental regulations – passed by national governments or by the European Union - oblige the corporations to pay more attention to their actions and to improve their processes continuously.(Hendrickson et al.,2006)

One potential tool assisting in identifying problematical spots and implementing improvements is the Life Cycle Assessment (LCA). As the name implies it is an examination of the entire life of a product, process or activity, also referred "from cradle to grave" or "from cradle to cradle" by many practitioners. (Kerekes and Kinler, 1997) Thus the LCA is a tool for the analysis of environmental burden of the product at all stages in their life cycle: from the extraction of raw materials, through the production of materials, product parts or products itself, the use of the product, and the waste management (reuse, recycling or final disposal) finally the transportation as well. (Schaltegger and Braunschweig, 1997) Therefore the product is considered regarding to its inputs and outputs at every stage of its life. The aim is to determine the eco-friendliness in numerical terms for each material and process involved in the manufacturing of the product and to take corresponding corrections and changes in the production process. (Curan, 1996) Haes (2004) claims, that the LCA can be used very well also in the European Union Eco-labeling program.

The first approaches in analyzing the life cycle of a product go back to 1960, at that time the energy consumption was of the major interest. Nowadays, also the used raw materials and their environmental friendliness, the emissions related with the production come to the fore. (Guido et al., 2003) The first basic framework about how to conduct a LCA was designed at a workshop of the Society of Environmental Toxicology and Chemistry (SETAC) in 1990. This structure served as a basis of the international standard ISO14040 – Life Cycle Assessment principles and framework - which was initiated in 1997, and modified in 2006. Thus a LCA study pursues the following structure (Szita, 2002): goal and scope definition, inventory analysis, impact assessment and improvement assessment. This structure is shown in *Figure 1*. In the next paragraph each stage will be described in more details.

Figure 1: **Life Cycle Assessment framework**



The goal of an LCA study shall clearly state the reasons for carrying out the analysis, the intended application and audience. At the definition of the scope it has to be defined if the assessment contains the whole or just the partial life of the product. Furthermore the scope of the study should contain the followings: the system boundaries, which describe what kind of processes is considered in the conducted investigation of the product; the functional unit for which data will be presented; data requirements; assumptions, gaps; the timeframe and the place of the research. (Guinée,2002)

Inventory analysis is the stage in which data are collected and where any calculations are performed in order to quantify the relevant inputs (used raw materials, energy and water, packaging, transportation) and outputs (solid wastes, releases to air, water, and soil) of the system as a whole. (DMHU, 2007)

In the impact assessment the data collected in the inventory stage is examined concerning on its environmental impacts on human health and ecosystems. That is, it is ascertain which factor causes what kind of environmental effect (like acidification, greenhouse effect, smog or ozone layer depletion) and what extent. Moreover a statement is done regarding the significance of the determined problems.

The final step is the improvement assessment where recommendations are given how to reduce and to avoid the environmental problems identified in the impact analysis. Furthermore the data used in the research is evaluated regard to the completeness and accuracy in order to make an overall statement about the reliability of the results of the LCA study. (Hennig, 2005)

MATERIALS AND METHODS

In our research we have examined the VCT product of the Denso Manufacturing Hungary Ltd (DMHU) in regards to its environmental friendliness by means of Life Cycle Assessment.

DMHU is a subsidiary company of the Denso Corporation which is one of the biggest automotive suppliers of the world. The company started its operation in Székesfehérvár in July 1997, and manufactures system control components and diesel products to the automobile market. DMHU believes that the company is responsible for minimizing the environmental effects of cars and for developing vehicles for the future, which can satisfy the needs of society without any harmful effects to the direct and indirect environment. This philosophy is integrated in every activity of DMHU, including planning, development, production and commerce. (Vizy et al., 2006)

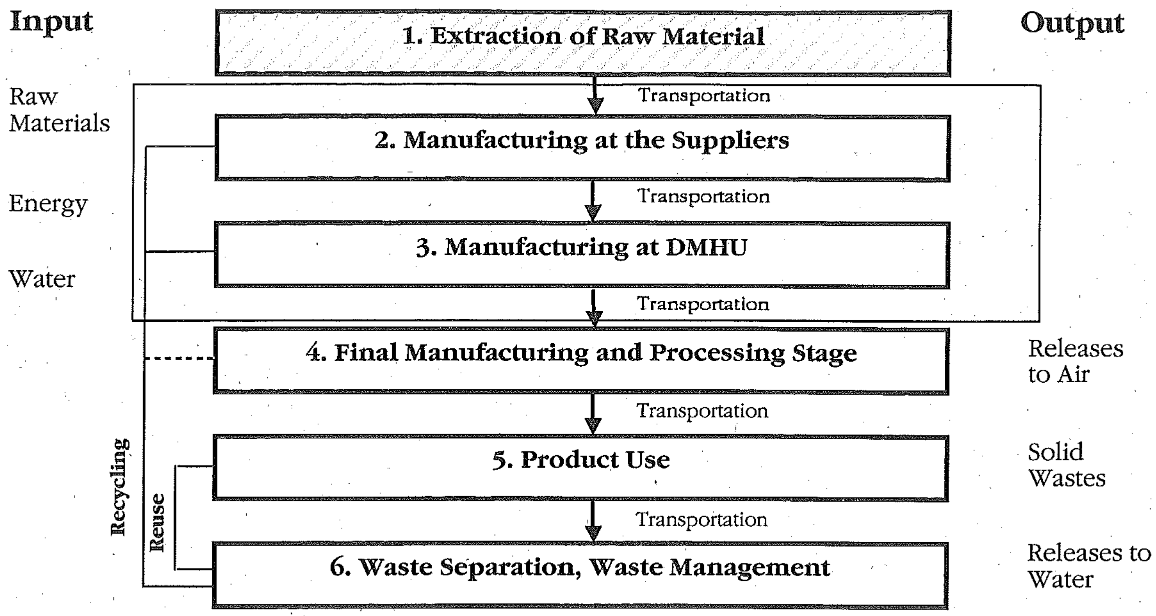
One of the DMHU products is the VCT that is a Variable Camshaft Timing, which has been developed for the mostly environmental-friendly European market. This product regulates the timing of valve operation, thus providing proper engine power and optimum fuel consumption by this means VCT reduce the harmful effects of the engine.

Goal and scope of the study

The goal of the analysis was to identify the environmental impacts of the Variable Camshaft Timing, and also to point out the most environmental harmful parts and processes of the product. We want to identify the environmental impacts linked with the manufacturing of the VCT, and the factors that initiated them in order to find if there are possible improvements. This is prime importance since Denso is committed to manufacture its products in the most environmentally acceptable way.

Defining the scope, the research does not involve the whole life cycle of the product but only a part: the extraction of the raw materials, manufacturing at the suppliers and manufacturing and assembly at DMHU. We have also calculated the environmental impact caused by transportation as well. The limitation of the scope is due to the fact that we have been lacking the data concerning the other stages of the product's life cycle. Therefore to conduct a reliable and significant LCA we had to focus on these stages. The functional unit was one piece of VCT manufactured in DMHU. In *Figure 2* the life cycle of VCT is illustrated. The shaded field and the hatching represent our scope.

Figure 2: **VCT life cycle flow chart**



Inventory assessment

The next step in our LCA is the inventory assessment. This stage is prime importance, because it is the base of the following two steps of the Life Cycle Assessment. Therefore the aim should be gather data as closely as possible, but actually that was the most difficult task while doing the LCA.

First we have determined of how many parts the VCT consists of and how many suppliers are involved in its production. VCT consist of 7 main parts (Sprocket, Bushing, Spring Vane Seal, Rotor Vane, Housing, Bolt, Chip Vane), and 11 suppliers are involved in the production. After identifying the relevant parts, we had to collect all information about these components that is all the inputs and outputs of the system. Starting the data collection we created a questionnaire which was sent to all the suppliers of the VCT. In this questionnaire the suppliers were asked to give all information about their inputs (raw material, energy and water usage, transportation and packaging) and outputs (wastes) of the production process. The received questionnaires differ in their completeness and accuracy. The most of the suppliers have been very cooperative however some of them caused difficulties to perform this analysis. In total, using questionnaires in different quality can influence the informational value of the conducted study, and we had to rely on the precision of data provided by the suppliers. We have also conducted an inventory assessment at the DMHU plant. It was based on the structure of the questionnaires we gave to the suppliers. Thus we gathered data regarding:

- The energy consumption for each part,
- The weight of every component,
- The used material,
- The operated process,
- The transportation of the products,
- The used packaging materials.

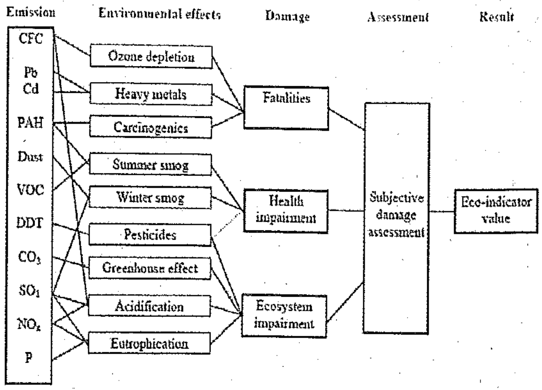
Impact assessment

The impact assessment is based on the SimaPro LCA software developed by the Dutch PréConsultants B.V. This software translates all the data collected for every component in environmental impacts affecting human health and ecosystems. The databases of this software contain information generated by several institutions by analyzing real products. The obtained data serves as a sample for future examined products, for example the VCT. (Hennig, 2005) First of all we had to enter the collected data into the SimaPro software. This software enables us to determine the impacts in the VCT life cycle and to identify the environmental effects caused by those impacts. For this purpose SimaPro provides histograms and impact tables as analytical tools.

In the histograms you can specify which part of the product causes the most harm and which environmental effect is dominating associated with the manufacturing of one unit of VCT. Using this kind of evaluation tool enables to identify on which of the parts the improvement process should be focused on. Four types of histograms are existing: the characterization, the normalization, the evaluation and the total indicator graph.

The other analytical tool of the software is the impact table, which shows the basic raw materials and emissions associated with the materials and processes used in the assembly. Thus air, water and solid emissions ant their amounts can be determined. By means of the impact table you can identify where specific substances come from in the manufacture and assembly.

Figure 3: **Concept of the eco-indicator method**

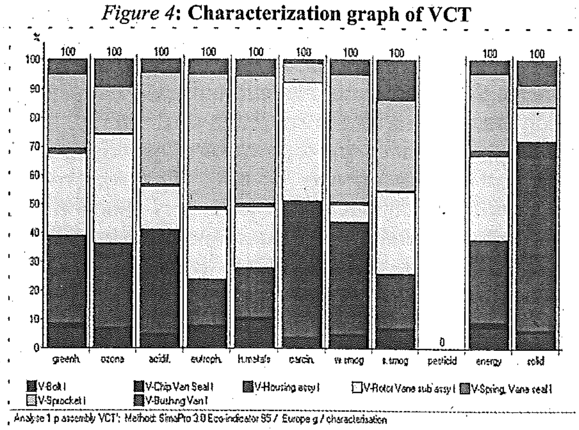


In order to ascertain the extent of the impact and the environmental effects produced by those impacts, SimaPro includes the eco-indicator method (*sown in Figure 3*). Starting from the emissions like SO_2, NO_2 or CO_2 produced by the VCT, the environmental effects (acidification, ozone depletion, smog etc.) are identified. After this, it is assessed how grave, how serious these damages are. The result is the eco-indicator point, the higher the point the grater the environmental impact. (Lewis et al., 2001)

RESULTS

As we already mentioned we used 4 types of histograms to evaluate the collected data. The first is characterization graph (*shown in Figure 4*). In this bar chart the impacts of the 7 main parts of VCT are compared in the scale of 100 percent. It is like a comparison of the 7 independent products based on various environmental effects. It is visible, that in terms of percentages the Housing, the Sprocket and the Rotor causing the main environmental impacts. Besides it can be noticed that no pesticides are used in the life cycle of VCT, hence the value is 0%. All other environmental effects are occurred in the life cycle, but with this graph we cannot make a statement about the relative contribution of each environmental effect.

Figure 4: **Characterization graph of VCT**



The next histogram is the normalization graph (*shown in Figure 5*) where the impacts of the parts are compared on a scale of inhabitant equivalent. That is, the data is normalized to the effects of an average European inhabitant over one year. Now, the carcinogen substances, acidification, energy usage, and heavy metals have the highest value. The score of heavy metals can be interpreted as follows: the production of the VCT causes 0.00047 part of heavy metals that one European inhabitant causes in one year. There is even no contribution to the solid waste anymore.

Figure 5: **Normalization graph of VCT**

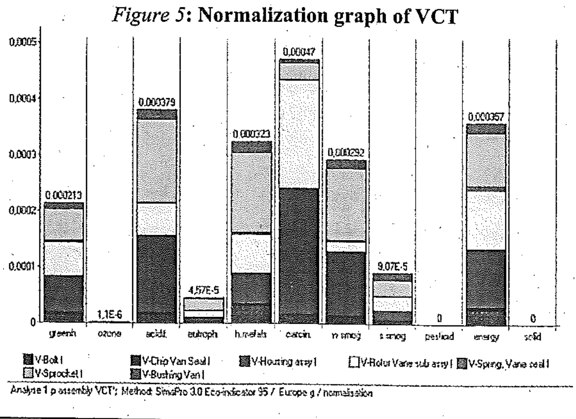
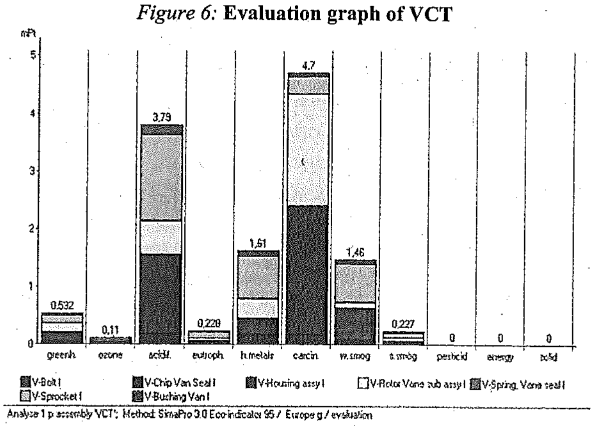


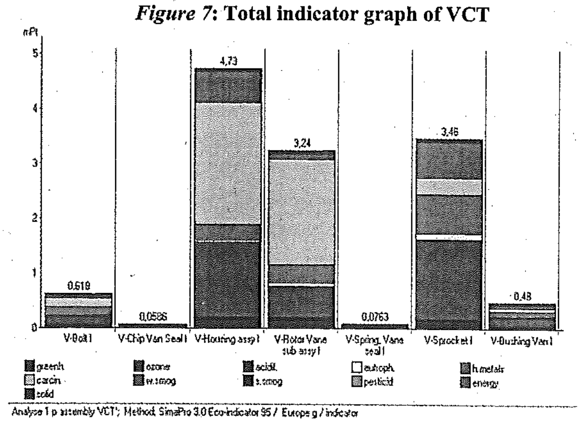
Figure 6 is the evaluation graph, which is the most interesting to our assessment. The difference to the normalization chart is that the evaluation graph applies the above mentioned eco-indicator method as a weighting factor, scaling the results to the certain level of seriousness. That is the evaluation is not only regarding the quantity but also how significant one environmental effect is in comparison with the other effects. Therefore it is possible to make a statement about the seriousness of each environmental effect. There the carcinogen substances and acidification obtained the highest values, followed by heavy metals and winter smog. That is they are the most important now. Besides, the weighing factor of energy usage considered to be less serious that is why the energy is completely disappeared for now.

Figure 6: **Evaluation graph of VCT**



Our last graph is the Total indicator histogram (shown in Figure 7), where all different environmental effects are added together to give a total impact for each part. Hence for each part it can be identified which environmental effect it generates and what extent. Adding up all environmental effect the indicator graph shows that the Housing, the Sprocket and the Rotor have the highest impact and almost entirely responsible for the environmental problems. It can be noticed, that all of the histograms include the same data, they are just illustrate the environmental effects from different perspectives.

***Figure 7*: Total indicator graph of VCT**



After identifying the main environmental effects we have to determine the emissions hat caused them, as well as which part of the product emitted them by applying the impact tables. Hence we will able to recognize at which point of the production of the VCT improvements have to and could be done respectively.

After we have considered the above mentioned impact tables we could establish the followings: the substances with the highest indicator point causing environmental effect carcinogen substances are: PAH's, Nickel, Fluoranthene and Benzo(a)pyrene emission to the air. In the impact tables is also illustrated which part of the VCT and which materials/processes produced which of the substances mentioned above. In this case the ADC12 material, the Aluminium-A6061-T6, the Cloyes steel and the transportation is responsible for the substances. ADC12 is a material containing 83%aluminium and 17%heavy metals (copper, nickel, zinc, tin and iron). Its huge impact is due to two facts: first, the extraction of aluminum is associated with high energy consumption. Secondly, during the processing of this material a huge amount of heavy metals are released to the air. The substances with the highest indicator score in the case of acidification are SO_2, SO_x, and NO2, NO_x emissions to the air. The materials induced this emissions are ADC12, Aluminium-A6061-T6 and Cloyes steal again, and the processes both side cutting and transportation. In respect of heavy metals the substances with the highest indicator score are cadmium and lead emission to the air, and lead, nickel, chrome emission to the water. The same materials/processes are responsible for these emissions as in the case of acidification. As it can be noticed, the same parts and almost the same processes and materials raise the problems, because one material/process can release different emissions, which can initiate several environmental effects.

CONCLUSIONS, RECOMMENDATIONS

After the examination of the Life Cycle Assessment of the Variable Camshaft Timing we could verify that the most important environmental effects occurring in the life cycle are carcinogen substances and acidification followed by heavy metals and winter smog, when producing one unit of VCT. Carcinogen substances are caused by the parts Housing Assy and Rotor Vane Sub Assy. Acidification is caused by the parts Sprocket, Housing Assy and Rotor Vane Sub Assy. Heavy metals are produced by Sprocket, Rotor Vane Sub Assy and Housing Asssy. Based on the results of the impact tables of the most important environmental effects (carcinogen substances, acidification, heavy metals and winter smog) and the most harmful components (Sprocket, Rotor Vane Sub Assy and Housing Assy) we could determine that the main materials/processes generating carcinogen substances are ADC12, Aluminium A6061-T6. Concerning acidification and heavy metals the ADC12, Aluminium A6061-T6 and Cloyes (steel) are responsible for the high values.

At the end of the research we would like to recommend to the Denso Manufacturing Hungary Ltd. the followings:

- DMHU should consider the most environmentally harmful components of VCT.
- Of all the materials ADC12 and Aluminium A6061-T6 was the most ecologically damaging. Hence another material should be used instead of them, if procurable without losses in quality and functions.
- DMHU should consider the further co-operation with the suppliers who was not able to help our LCA study.
- In several processes the indicator result was caused by high electricity consumption. A revision of comparable machines which requires less electricity would be recommendable.
- In total the factor transportation has not a huge impact, but the main use of van (<3.5t) has a high environmental impact. Therefore we suggest shift to bigger trucks or train as means of transport.
- Based on the results of this survey, DMHU should take environmental aspects into consideration when designing the products, the components and processes.

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