Life Cycle Analysis Principles and Automotive Case Studies

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The use of Life Cycle Engineering/ Life Cycle Assessment within the design process of production facilities – A business case: Different options of handling overspray

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Executive summary

DaimlerChrysler plans to replace the current paint shop of the rear axles by a new one. It is the goal to design the new paint shop representing the latest technology for paint shops and overspray handling and to consider ecological, technical and economic aspects from a life cycle perspective during the design process. Therefore the Life Cycle Engineering approach (LCE) has been chosen to give a broad view and compare the different options. The application of LCE within the design phase has shown that the reaction time for feedback is reasonable for designers and therefore it can be applied within the planning of new production facilities.

The LCE study showed that there is no direct relation between the economic cost and the ecological performance of a design option. While all considered recycling systems have better economics than the options considered at the present time that allow energy recovery of the collected overspray, there is no general preference regarding pro/contra recycling from an ecological point of view.

Life Cycle Engineering (LCE) integrated in the design Process

The LCE methodology is evaluating ecological, technical and economic aspects considering the total life cycle of processes/products. LCE studies are based on material and energy flow information obtained during the operation of the facilities. LCE is a simulation tool analyzing weak points and show optimization potentials as well as supporting the decision making process within the design phase. As various databases hold information on ecological impacts of material- and energy production, so called ecoprofiles, and information of the economic values is available from the participating companies, the time consuming research on how to obtain life cycle information for materials is not necessary anymore. As a result first order estimations for different scenarios can be made within days to support the decision process not causing any time delay of the process.

LCE studies can be conducted within the design process and on existing facilities/products. If LCE is used within the design process optimization potentials can be shown in early stages of the design phase of facilities/products. Integration of LCE within the early stages of the design ensures an efficient way of improving the ecological profile of processes and products and reducing the overall costs considering the total life cycle.

Life Cycle Assessments using the software tool GaBi4[1]

The software tool GaBi4 is developed and designed to support LCE efficiently and in a transparent way. The design of the facilities can be modeled according to the material and energy flow. All boundary conditions, e.g. efficiencies, time of operation, climatic boundary conditions, emissions to air, water and soil etc., can be modeled as parameters. This enables the user to run simulations within different boundary conditions using the base model for all scenarios of interest.

The business case - Goal and scope

It is planned to replace the current paint shop for painting the rear axles at the DaimlerChrysler facilities in Mettingen by a new one. The new facilities should contain the latest technology for paint shops and overspray handling. Currently, the rear axles are painted with a solvent based paint for corrosion protection. Due to several reasons, e.g. direct VOC emissions of the paint shop, new concepts for corrosion protection have been analyzed. The new concept consists of a layer of water based paint and a layer of conservation material.

During the design phase different options for the overspray handling and for the layer of water based paint have been analyzed considering technical, ecological and economic aspects.

The goal of this study is to gain knowledge on the environmental effects associated with the different concepts for handling the overspray and the different water-based paint options considering the total life cycle (from the production of the paint system through the application and the handling of the overspray). Additional focus has been set on the economic differences of the different design option considering also the total life cycle.

The study has been conducted to meet the goal of considering the three dimensions, **technology**, **ecology** and **economy**, during the decision making process.

Boundary conditions - description of design option for handling the overspray

The functional unit of the study of the ecological part has been the paint process of the rear axle with water based paint including handling of overspray, thermal post combustion (TNV) and the conditioning of supplied air etc. The boundary conditions are shown within Figure 1.

[1] GaBi4 – software and database for Life Cycle Engineering (www.gabi-software.com)

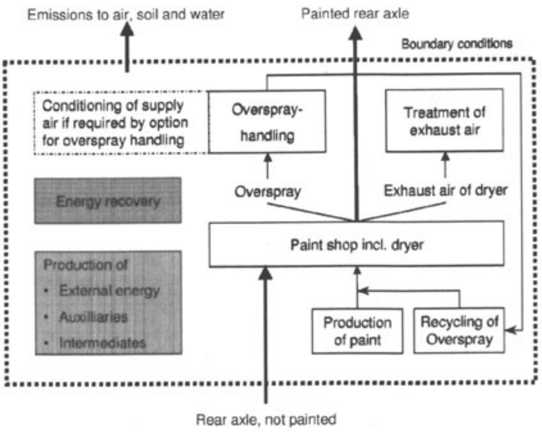

Figure 1: Boundary conditions

The economic analysis is focusing on the differences of the different design options and 20 years of operation. The focus of the economic part has been in the following issues:

- Investment costs
- Cost of operation (e.g. power, water, natural gas, wear parts etc.)
- Material costs
- Logistic- and storage costs
- Labor costs (e.g. operation, maintenance, training etc.)
- Labor specific equipment (e.g. protection clothes etc.)
- Controlling and quality assurance
- Transport- and storage packaging
- Reporting (e.g. audits etc.)
- Waste treatment (e.g. landfill, recycling)
- Waste water treatment
- Emissions to air (e.g. filter, TNV etc.)
- Area related costs (e.g. rent, overhead etc.)

The paint shop has been modeled based on information provided by Sturm[2] and Dürr[3]. Information on the water based paint has been provided by Schramm coatings[4].

[2] http://www.sturm-gmbh.de
[3] http://www.durr.com
[4] http://www.schramm-coatings.de

The following different options for handling the overspray have been considered and analyzed:

a)	ULF –circulating filter	Brainflash
b)	Relac/ULF	Brainflash[5]
c)	Relas	Reiter[6]
d)	Turbo Coolac	Range & Heine[7]

ULF – circulating filter

ULF consists of a housing of galvanized sheet steel with integrated filter and extractor boxes, endless circulation filter fleece, drive system and "dust collector" unit. Plastic laminated strips are used to pre-filter and dry the paint mist. The core of the ULF technology is a circulating filter fleece which does not absorb the paint overspray but only catches it and conveys it to the extractor point. In the ULF a special fleece performs this task very efficiently. The relatively thin, air-permeable filter is only a transport medium; air handling capacity and air speed remain constant. The dry material is collected in a replaceable container and can be disposed of easily. Paint which adheres to the plastic laminated strips is simply peeled off like a skin. Subsequent filtering with a so-called "police filter" is often superfluous, as up to 99% of the overspray can be extracted and collected dry in one cleaning process.[8]

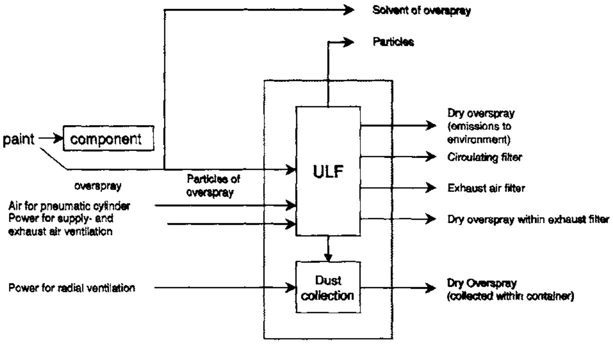

Figure 2: ULF system

Relac/ULF

The Relac /ULF option is a combination of the Relac- and a ULF system. The overspray which is not collected by the Relac system is handled by the ULF system.

[5] http://www.brainflash.at
[6] http://www.reiter-oft.de
[7] http://www.range-heine.de
[8] http://www.brainflash.at/Webseiten/0231funktione.html

The technical heart of the RELAC® recycling system is a conveyor belt behind the workpiece. It catches the paint overspray, and deflector blades strip off the material before it dries. More than 90% of the overspray can be reclaimed immediately. Adjustment of the viscosity and addition of volatile components can be carried out during the reclamation process. The reclaimed material is filtered and blended with new paint or passed directly to the coating process. A multistage dry separation system is used to clean the exhaust air. In enclosed cabin systems, sensors monitor and control the air intake for optimum coating conditions. In the case of water-based paint systems, the plant can be operated in 90% recirculating air. When solvents are being used, the exhaust air heat can be recycled by means of plate heat exchangers.[9]

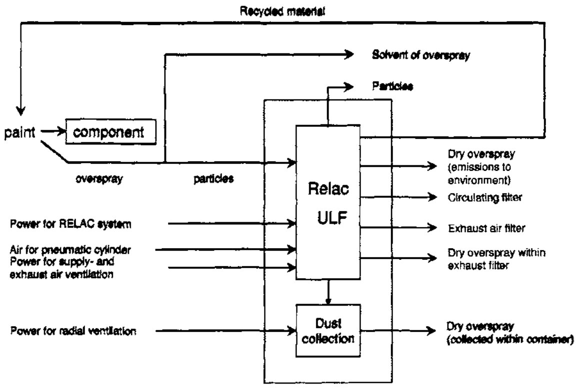

Figure 3: Relac/ULF system

Relas

The Relas system is, like the ULF system, a system for dry deposition and placed also behind the component which is painted. Between 70 % and 80 % of the overspray is collected by the “lamellar curtain” and will be scraped of by a metal blade. The recovered material can be either landfilled, send to energy recovery or send back to the material producer. The overspray which is not collected by the Relas system will be filtered by exhaust air filters.

Turbo Coolac

Turbo Coolac is a wet separation system with the goal to recycle the collected overspray. The system is illustrated within Figure 4 and consists of a separation surface, a cyclone, a cold water production device, collection containers and a exhaust air ventilator (not illustrated within Figure 4).

[9] http://www.brainflash.at/Webseiten/0211funktione.html

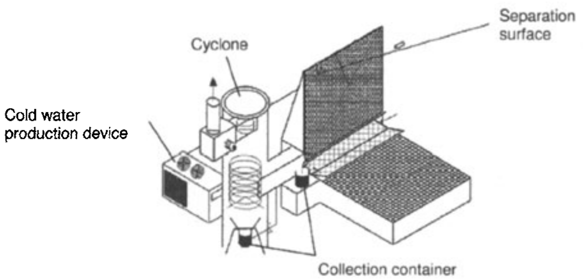

Figure 4: Turbo Coolac

To avoid that the material is drying on the separation surface, the temperature of the surface is cooled below the dew point of the cabin. This condition is created by conditioning of the cabin and cooling of the surfaces. Due to the cooling the humidity is condensing at the collection surface and the overspray reaching it stays liquid and is pouring into the collection container. The part of the overspray which is not collected by the separation surface will be handled by the cyclone. The air stream containing the overspray is aspirated by the cyclone and the particles are separated using the centrifugal force. Due to the fact that the surface of the cyclone is also cooled, the overspray condensates at the surface and can be collected by the collection containers.

The collected material can be either recycled by the material producer or mixed to virgin material (adding volatile components to meet the viscose requirements).

Execution of study

This section emphasizes the information flow within the project, effort assigned to each participant involved and challenges within the project.

To perform an evaluation of new design production facilities considering the ecological and economic impacts based on total life cycle, the following parties have to be involved:

a) Customer, e.g. DaimlerChrysler
   - Planning department of production facilities
   - Environmental department
   - Technical staff, e.g. testing if recycled material meets technical specification
   - Purchasing

b) Developing companies of different design options:
   - Designer
   - Sales

c) Material supplier
   - Technical staff, e.g. testing if recovered material can be recycled
   - Sales

d) LCE consultant
   - Technical staff to conduct the study, e.g. modeling with LCE software, analysis of results, trustee of confidential information of participating companies etc.

LCE studies highly depend on the cooperation of the different participating companies. Most of the participants are concerned regarding confidential information and the effort they have to put in to make the analysis successful. During the course of the project the concerns mostly disappeared due to the fact that the project partners realize that most of the information needed is not confidential. No confidential information on the different technologies was needed to perform this study. In case confidential information on material composition was needed to perform the study, e.g. composition of paint, the LCE consultant acted as a kind of trustee. No confidential data on recipes of the paint is needed to be displayed to the other project partners, due to the fact that the ecological profile of the used material, e.g. paint, will be only one part of the overall environmental profile of a specific option. Within this study the corporation of each project partner and the willingness to provide information has been really good. The effort everybody had to put in had been hold to a minimum as no extensive investigation to gather the information needed for creating the LCA. The cost model had to be done by the participating companies. Most information was already available. The information only had to be collected from internal sources within the companies and provided to the consultant[10].

The following list represents the most relevant information the analysis is based on:

- Amount and composition of paint needed
- Amount and specification of energy need for running the process
- Percentage of overspray
- Life time of wear parts / paint shop
- Efforts/benefits of scenarios handling the overspray, e.g. recycling, energy recovery
- Assessment of direct process emissions to environment

RESULTS AND DISCUSSION

This section discusses the results in a qualitative way. (Options 1 to 4 do not necessarily follow the order of the description of the systems.)

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[10] PE Europe GmbH; www.pe-europe.com

The analysis of the results has shown, that the impact of the different life cycle stages to different impact categories vary. It is therefore important to analyze the whole life cycle and more than one impact category.

As shown in Figure 5, the operation phase of option 4 has a significant influence on the overall primary energy demand (approximately 25 %) while the operation of option 1 and 2 are negligible.

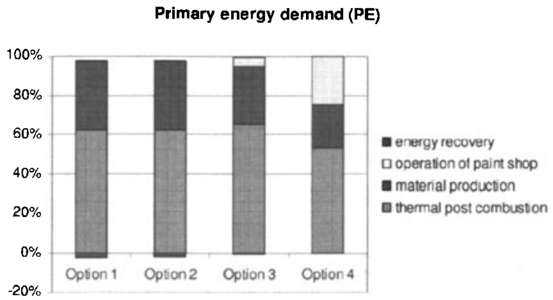

Figure 5: Primary energy demand of selected options

Figure 6 shows the different contributions to the GWP. By comparing Figure 5 and Figure 6 one can observe, that the contribution of the material to the overall results are significantly different analyzing option 1 and 2. While the contribution to the overall PE of the material is approximately 35 % the share of the GWP is only approximately 25 %. Also it can be seen, that there is a benefit assigned to the energy recovery looking at PE. This is due to the fact, that the thermal efficiency of the energy recovery options is less than the production of thermal energy and electricity not by energy recovery.

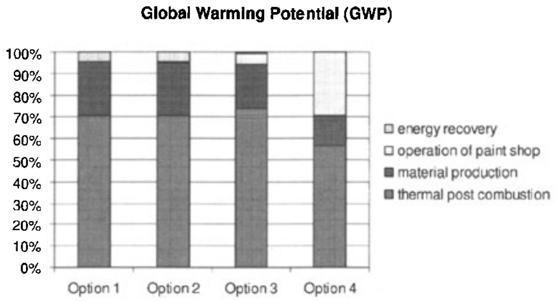

Figure 6: Global Warming Potential of selected options