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PRODTECT AUTOMOTIVE – MEETING THE REQUIREMENTS OF ELV

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ABSTRACT
With the implementation of the European directive 2000/53/EG on end-of life vehicles and 2005/64/EG on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability car manufacturers are obliged as part of the car type-approval to meet a recycling rate of at least 85% and a recovery rate of 95% . The calculation method for the recycling rate is defined in ISO 22628. For the EU type-approval, information regarding material (type and mass), parts to be disassembled, as well as a complete documentation of the recycling and recovery processes of all materials is needed along with the calculated recycling rate[1][2][3]. This paper presents a method of assuring the achievement of the required rates, integrated in the software tool ProdTect. The software module is developed by KERP together with MAGNA STEYR and IWF, TU Braunschweig. The DfR tool evaluates the vehicle end-of-life from the early concepts of the new vehicle as changes are more easily applied in this phase. This method starts with the definition of the minimal set of data that a vehicle model in the DfR software should have to be able to be assessed. This method also proposes an adaptive algorithm that allows an incremental product model definition in the DfR tool that follows the vehicle concepts definition levels from the first concepts to the detailed design. Product developers are flooded by an amount of new regulations that is difficult to handle. ProdTect allows producers to keep these requirements under control by providing a holistic overview. It turns product developers into product architects and helps realizing End-of-Life cost savings and legal compliance. Once passed on to the market, implemented cost savings measures will help increasing customer satisfaction and market share, thus turning regulatory challenges in competitive advantages.

Keywords: Design for Recycling, ISO 22628, Product improvement

1 INTRODUCTION
The design for recycling activities arise from the legislative requirements as well as from the ever increasing recognition of the need for sustainable economy and use of resources. Considering the large amount of materials contained in a car, and their complexity it is very important to be able to perform an efficient recycling.
In the context of modern car design it is very important to allow the integration of design for recycling in the earliest stages where the ability to influence product end of life performance is high. Design for recycling, plays an important role in the design for X concept. Missing information concerning the end of life performance of the vehicle have to be provided, along with expert knowledge to allow an efficient product improvement. The concept is presented in Figure 1.

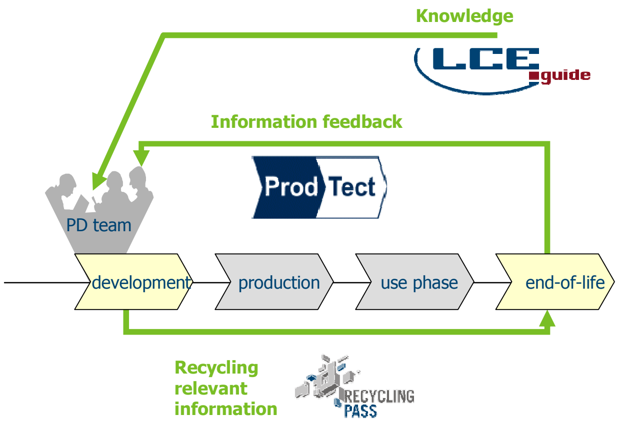


Figure 1. The development cycle

The assessment flow follows the scheme described in Figure 2. It starts with a model definition that is integrated in the data landscape of a typical automotive OEM. Existing data can be imported in different quality stages to allow incremental product assessment. Data describing the recycling processes in terms of technical capabilities, ecological impact and economical performance have to be available to perform the calculation. At the calculation stage end of life parameter such as recycling rate, pre-treatment steps, disassembly time and cost are calculated. If the end of life performance does not fulfil the requirements, a product optimizing can be performed. Recycling relevant design aspects of the vehicle are analysed and improvement potentials are identified.

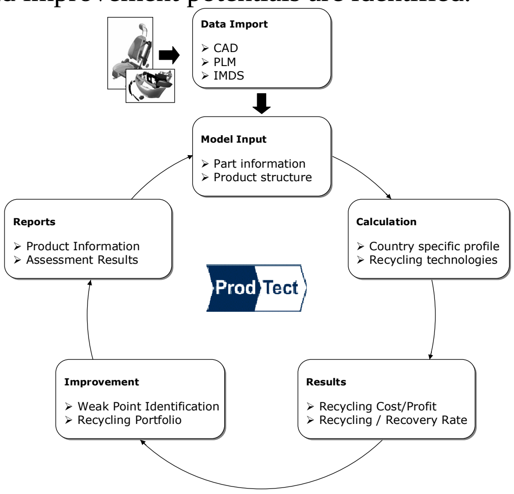


Figure 2. The assessment flow

Each module is described in the presented paper.

2 MODEL DEFINITION – INTEGRATION IN VIRTUAL PRODUCT DESIGN

Due to ever shorter product development cycles, the complexity of the system and the high number of requirements to be taken into account, the optimisation task a designer has to perform is extensive. A lot of requirements must be tackled simultaneously under time pressure. The environmental legislative requirements add an additional challenge to the design phase. Virtual car development is a very important aspect in automotive design. All development targets are checked virtually before the validation of physical prototype cars starts. An intense use of the existing internal and external information systems is a precondition for efficient virtual development. An analysis of complex product models regarding their environmental impact is possible only through extensive data availability

2.1 Model definition

The vehicle is defined in ProdTect as a parametric product model which incorporates a set of data needed to deliver maximum assessment accuracy of the end-of-life phase. The vehicle is modeled using three interconnected sub-models: structure model, joining techniques model, and priorities model. The structural model is defined as a tree of assemblies, sub-assemblies and parts where assemblies and sub-assemblies define the structure of the vehicle and parts define the materials and geometry assessment relevant parameters. The second model is a graph with parts as vertexes and the joining technologies connecting them as edges. The priorities model is also a directed acyclic graph defining the relative positioning the parts.

Key point of the product model is its granularity level allowed by the group/ungroup concept. Many parts and assemblies can be grouped together and therefore their parameters merged to a single part. The three vehicle models will be adapted accordingly; the grouped parts and assemblies will be treated as a single one in the three vehicle sub-models. A typical need of this concept is the evaluation the vehicle in a scenario where a complete assembly (i.e. engine) can be reused on the end-of-life phase or in the case some parameters are missing about some parts of an assembly because the vehicle is still in the early development phase. The goal of the group/ungroup concept is to permit different granularity levels of the vehicle modeling according to the assessment needs and available data. Thus allowing the evaluation of the vehicle from an early stage of the development process where changes in the design are still less expensive than in later stages. It also allows keeping control over the increasing number of the complex parts design forming the vehicle along the development process.

Another key point of the product modeling is the definition of part types. Parts can be assigned to types defined in a library in the software. These types can be seen as labels that mark the parts that have more relevance for the end-of-life evaluation. In this way, fluids and parts containing hazardous materials or valuable materials with good accessibility can be treated particularly by the software. This allows a specific assessment of the vehicle.

2.2 Data exchange and integration in the virtual product design

A road vehicle is composed of a big number of complex components. Manually defining a vehicle product model would be a hard and time intensive task. The need for an interface with the digital vehicle defined in the PDM and CAD systems is ineluctable. Such an interface may be based on a direct integration policy in the PDM/CAD systems or may use a data transfer policy as for ProdTect. Many data transfer open formats and standards are available and could be used such as The STEP standard and especially its part AP214 [4] or PDTnet [5]. The problem with the actual data transfer standards and open formats is that they still don’t satisfy the need of DfR software or they are still not widely adopted by the PDM/CAD systems.

The key data needed by the software for the end-of-life assessment are the materials, the used joining techniques and the positioning of the parts in the vehicle. Therefore, ProdTect implements a proprietary data exchange interface based on XML (Figure 3). The vehicle data can be imported from the PDM/CAD and the IMDS systems from the early development process. In the case data is still missing after the import, especially in the early design stages, the user can edit and enhance it manually using the materials and joining techniques databases. In addition, using the group/ungroup concept, the user will not be constrained to supplement the missing information for all the parts but only for the relevant ones to the evaluation, the rest can be grouped together and considered as a single part. Using the data exchange interface, the vehicle data can be also updated along development process.

This systematic method of import/update and the different available modeling concepts and facilities help to reduce the complexity of the vehicle modeling allowing assessment results in short times without reducing their accuracy.

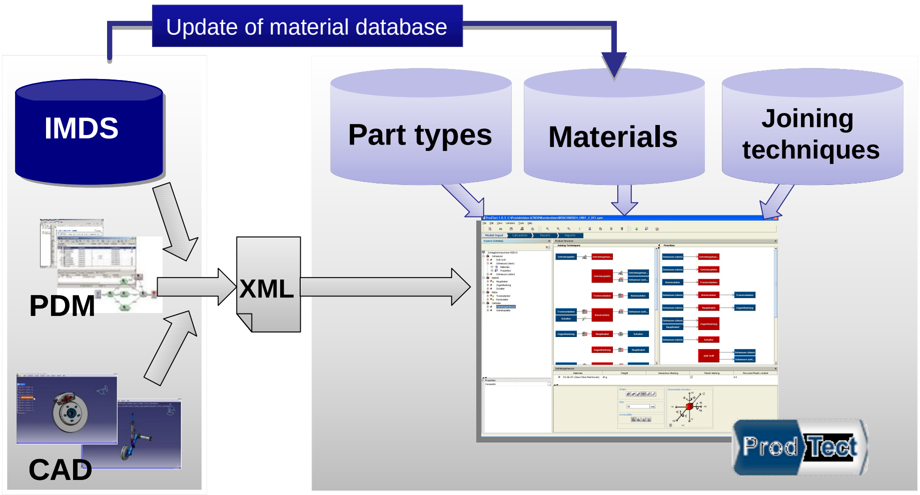


Figure 3. ProdTect Data import interface

3 CALCULATION OF END OF LIFE VALUES

The main purpose of the calculation is the determination of the recycling rate according to ISO 22628, for the EU type approval. Information regarding recycling processes and material compatibility as well as disassembly times and sequences are needed to be able to perform the calculation.
Pre-treatment is the first step of the recycling process. A series of parts (all fluids, batteries, oil filters, liquefied petroleum gas tanks, compressed natural gas tanks, tyres, and catalytic converters) have to be disassembled and treated separately. In a further step, reusable parts can be disassembled, if the process is economically feasible. Large parts with high material purity can also be disassembled assuring a high quality recycling. The times for the required pre-treatment and other disassembly operations are calculated using the defined product joining techniques, and the ProdTect library. Using the labour cost, the disassembly effort can be monetarily quantified.
When considering the separate treatment of disassembly parts the optimal disassembly depth has to be determined. The disassembly is not a reversed assembly. One important difference is related to the objects of disassembly. Due to the labour costs which increase with each additional disassembly step, components of the product will not have to be removed since they consist of the same material or can be processed for recycling together. Disassembly objects have to be determined by forming major units of parts and subassemblies which are called recycling segments. Recycling segments consist of one or several parts which are joined which each other and which can be recycled in the same way or where the separation is not linked with a benefit. The calculation module determines the optimal disassembly depth for a product and the related recycling rates and costs. The remaining vehicle materials are treated by the shredder process and proven post-shredder recycling processes (e.g. VW-Sicon).
A product assessment is based on a 'Calculation Scenario' that defines the function to be optimized: cost or rate. The assessment uses also a recycling library, which is a set of 'End-of-Life profiles', every profile holds disassembly labour costs and recycling processes information.

3.1 End-of-Life Profile library

The profile library contains data on economic background of product recycling such as Labour cost, cost/profit for certain material fractions, available proven recycling processes, their relations and recycling performance (destinations). The recycling library is composed of a set of Profiles that simulate a set of recycling facilities that the producer can use. Every Profile can be seen as a black box that accepts a segment of parts resulting of a disassembly step as input and gives the resulting disassembly cost and the recycling rate as output. Defined processes range from metallurgical ones to shredding and material sorting. ProdTect uses the recycling library to simulate the end of life of the product.
This allows ProdTect to evaluate the product using different regional conditions or market profiles. It gives an overview of the End-of-Life performance of the product on all markets without further modelling effort. The figure 4 gives an overview of the recycling processes model in ProdTect.

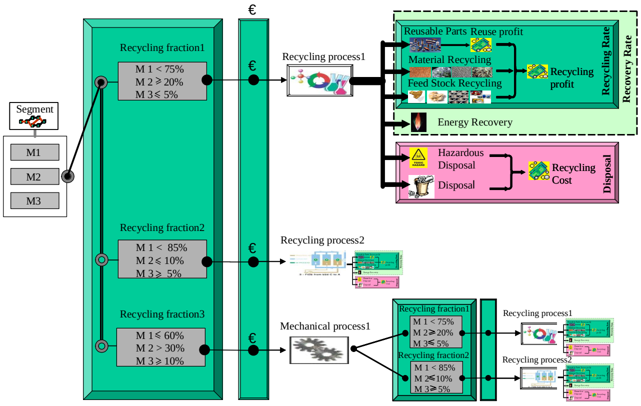


Figure 4: Recycling processes model in ProdTect

A special profile was defined for the calculation of ISO 22628 recycling rate. Automotive specific recycling processes are included and modelled according to the ISO specifications.

3.2 Calculation Scenario

A calculation scenario specifies the function to be optimized during product assessment. Product developers can choose which End-of-Life target to take into account during the assessment of the product. The main available scenarios are:

- End-of-Life value optimization - minimization of the of the treatment cost resp. maximization of recycling profit
- Recycling rate optimization - a maximization of the recycling rate to achieve some strategic goals, such as legislation conformance
- Rate threshold scenario – end of life value optimization by a given rate threshold

Further parameters such as pre-treatment and disassembly parts can be used. All relevant parts are identified and treated accordingly. Together with the defined recycling profiles, a large variety of recycling strategies can be simulated.

4 RESULTS

Key results are recycling and recovery rates for the total reference vehicle depending on available proven recycling technologies (calculation method and data presentation acc. to ISO 22628), a listing of the dismantled component parts (dismantling stage, treatment process), a breakdown of all vehicle materials and the documentation of conformity regarding declarable and restricted substances acc. to Annex II, Directive 2000/53/EC. [6]

Beside the vehicle recycling and recovery rate additional information is presented, to allow a detailed analysis of the end of life performance of the vehicle. All formed segments are shown, together with the calculated disassembly times and the end of life destination. Recycling relevant information can be seen on part or assembly level as well as on vehicle level. Increased disassembly times or end of life costs can be localized, in order to create the precondition for product improvement. Picture 6 gives an overview of the results screen

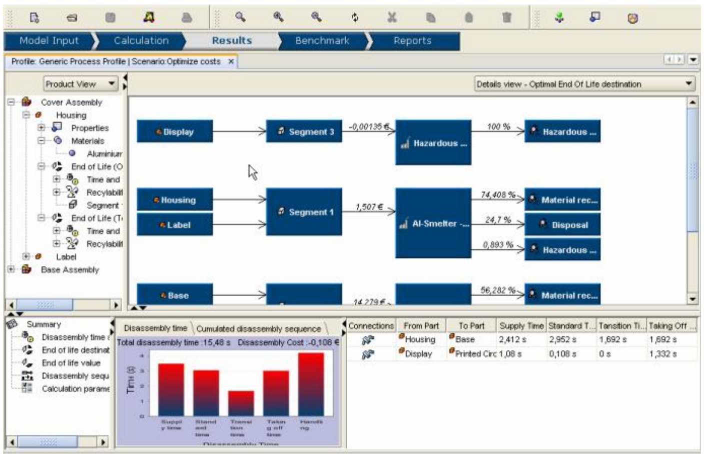


Figure 5: Calculation results

The main end of life values are:

- Recycling and recovery rate
- End of life destination (material flow per process)
- End of life costs
- Optimal disassembly depth and optimal disassembly sequence
- Disassembly times

5 IMPROVEMENT POTENTIAL

To achieve cost saving advantages regarding the competition, the enhancement of the recycling rate and the decrease of the incurred recycling costs represent a strategic product development goal for the producer. In addition to the product structure, the available recycling processes and their abilities determine the recycling rate for a product. Therefore the cost saving potentials can be achieved with good product design as well as efficient recycling processes. With the benchmarking module, ProdTect allows the product developer to deeply investigate the improvement potential of the product. The values exposed by the benchmarking module indicate whether the improvement should go in the direction of the product structure or the available product recycling processes.

5.1 Product Potential

The product based evaluation considers the disassembly and recycling relevant product qualities. In a first step, problem-oriented ratings are determined, which describe the disassembly and recycling orientation concerning a specific aspect [4]. In a second step the actual evaluation takes place. Criteria points are determined for this via evaluation functions or value scales by means of the ratings. These represent the actual evaluation results.
Starting point of the evaluation is the definition of suitable criteria. For each criterion, a characteristic rating describes the product features to be evaluated quantitatively. The evaluation of the product is based on its parts, their material composition, arrangement and the connections joining them.
To prepare the product for future optimum recyclability, the aim of the evaluation criteria is to direct to a ‘Recycling Potential’ as high as possible by considering only properties of the parts which are independent of the current recycling situation. Therefore the product potential is *product structure dependent*.
All these criteria can be seen in the recycling potential window showed in the figure 6.

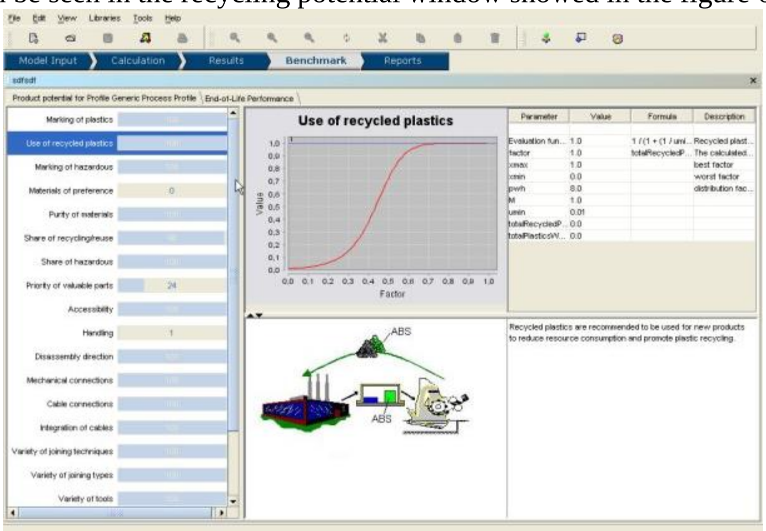


Figure 6: Product Potential

5.2 End-of-Life Performance (Product Portfolio)

The Product Portfolio brings together all the different evaluation views of the product to a complete End-of-Life value. This value is a vector of two coordinates, one is the recycling potential and the second is the recycling rate of the product. The figure 7 shows the representation of the product portfolio.

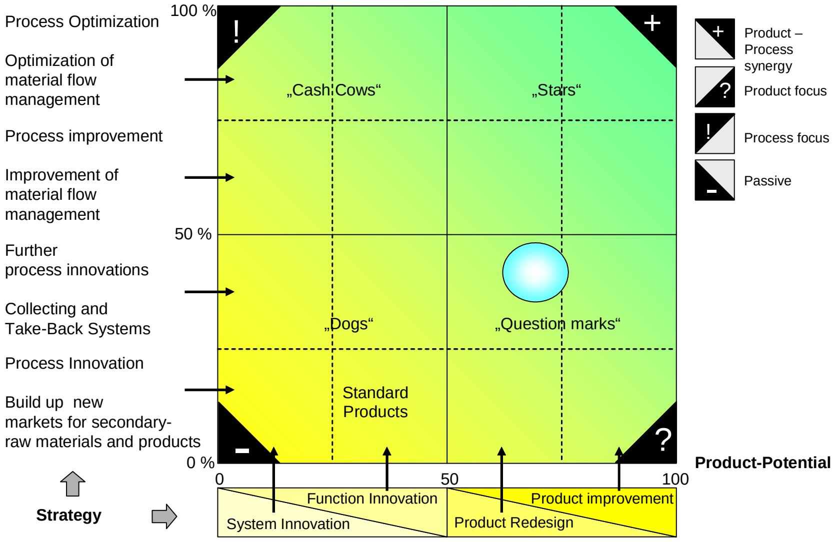
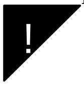


Figure 7: Product Portfolio

Basically, during the product development, a company can decide to follow one of two types of strategies. Active strategy, in witch a company decides to fulfil recycling rates without having to be legal compliant, for marketing goals for example. And another, in witch a company has to put this in its development goals for legal compliance. By means of these two strategies four types of product development basic strategies can be ordered in the topology of the product Portfolio [7].

Product/Process synergy

Products in this category have a product structure that allows a good recyclablity taking into account the existing recycling processes. These products can be defined as the best available techniques. Therefore the Product/Process synergy should be considered as a goal during the product design for future products.

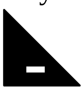


Process focus

In this category the product has a high recycling rate but a lower potential. The companies with this kind of products focused only on the recycling processes. They should also try to enhance the structure of their products.

Product focus

The recycling potential of the product belonging to this category is classified as high. The company follows a recyclabilty enhancement strategy during the product development. However, the available recycling processes don’t allow reaching high recycling rate of the product.



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A product belonging to this category has a low Potential as well as low recycling rate. The company hasn’t undertaken a product enhancement strategy yet.

The product portfolio helps then correction of the product development strategy, if it should focus in the product structure enhancement or more in the available recycling processes.

6. PRODTECT BENEFITS

ProdTect allows producers to keep development strategy requirements under control by providing a holistic overview. It turns product developers into product architects and helps realizing End-of-Life cost savings and legal compliance. Once passed on to the market, realized cost savings potential will help increasing customer satisfaction and market share, thus turning regulatory challenges in competitional advantages.

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