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EXTENDED TARGET WEIGHING APPROACH – A SYSTEM LIGTHWEIGHT DESIGN APPROACH FOR NEW PRODUCT GENERATIONS

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1. EXTENDED TARGET WEIGHING APPROACH (ETWA)

The "Extended Target Weighing Approach" (ETWA) [1] describes a holistic, cross-subsystem, function-based lightweight design method – in the context of system lightweight design – to identify and evaluate lightweight design potentials in the concept phase of product development. It systematically extends the existing "Target Weighing Approach" (TWA) as introduced by Albers [2] and Wagner [3] in order to balance the crucial factors for lightweight design: mass, CO2-emission and cost. Fig. 1 shows the workflow of the ETWA.

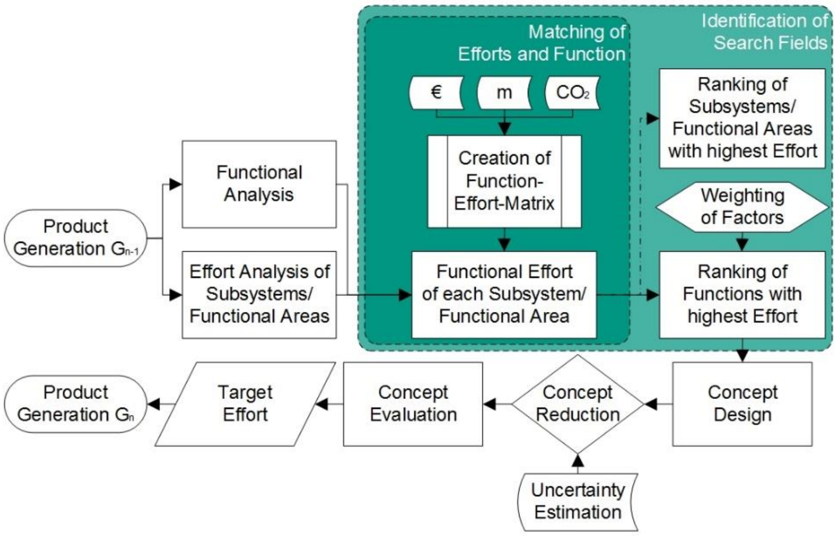

Fig. 1: Workflow of the Extended Target Weighing Approach

Ideally, the starting point for ETWA is a reference product whose mass has to be optimized. Afterwards a functional analysis is conducted and the functions fulfilled by the reference product are determined. Perpendicular to that, the effort of each subsystem meaning its mass, CO2-emissions and costs is gathered. Thereafter, the percentage contribution of each subsystem to the fulfilment of the functions is quantified in the so called Function-Effort-Matrix (see Fig. 2).

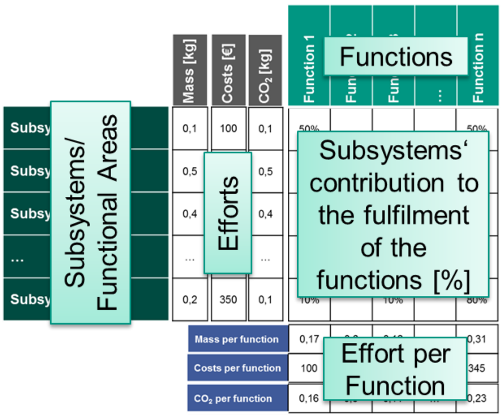

Fig. 2: Function-Effort-Matrix [4]

The identified functions are plotted on the horizontal axis, while each of the subsystems and its effort is listed on the vertical axis. This results in the effort per function and is used to identify "heavy" functions with lightweight design potential by means of evaluation methods such as function portfolio (see Fig. 3). In order to be able to take the strategic orientation of a company into account, the ETWA allows the factors mass, CO2-emissions and costs to be weighted with business specific weighting factors.

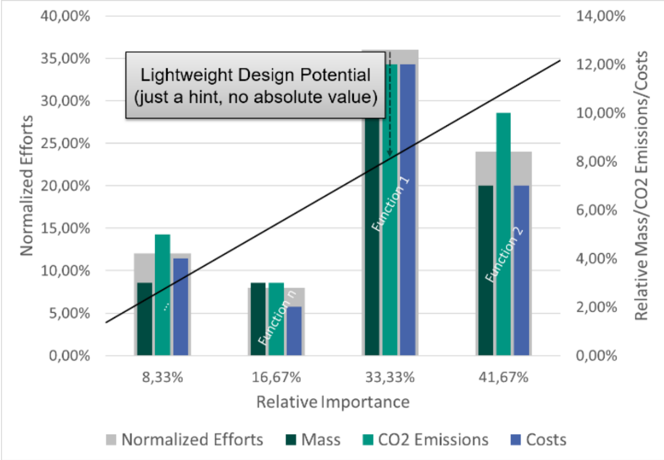

Fig. 3: Function portfolio [3]

For each of these identified functions, new concept ideas are generated using different lightweight design strategies. To evaluate the new concept ideas, a sensitivity analysis is performed by using the Function-Effort-Matrix in the opposite direction. As a result, it is possible to determine the influence on the weight, CO2-emissions and costs directly in the Function-Effort-Matrix.

In addition, new concept ideas are evaluated with regard to technological uncertainties due to a company-internal lack of information when using new technologies. Therefore, the influencing factors Impact, Carryover Variation Share, Reference Product – Technology and Reference Product – Application Scenario are examined and visualized in a spider diagram.

The following paragraph describes the determination of each effort (mass, CO2-emissions and costs) of a subsystem. Furthermore, the business specific weighting factors that allow strategic positioning when developing new concept ideas are discussed.

2. WEIGHTING OF FACTORS MASS, CO2-EMISSIONS AND COSTS

In order to generate the Function-Effort-Matrix, the effort of each subsystem must be identified. To determine the mass, either each subsystem can be weighed or its CAD data can be used. Since new concept ideas are initially designed on the computer, their mass cannot be assessed by weighing. For this reason and to ensure comparability of the new concept ideas with the reference product, the mass is determined using CAD data. Therefore, the volume is specified and multiplied by its density. This results in the mass in kilograms for each subsystem.

The CO2-emissions are determined with the aid of a life cycle assessment (LCA). The LCA is an iterative analysis method for the assessment and modelling of the environmental impacts of products and materials over their entire life cycle ("cradle to grave"). Therefore, the LCA takes the production, the use phase and the recycling/disposal into account. The workflow of the LCA consists of the following four steps: Goal and Scope, Inventory, Impact assessment and Interpretation. First, the system boundary including the functional unit, the goal and the purpose of the LCA are defined. The functional unit describes the reference value to which the results of the impact assessment are related. ETWA uses the CO2-emission in $kg_{CO2\text{-}eq}$ for this purpose. Afterwards, all input and output flows must be recorded within the defined system boundary. This results in the complete mass and energy balances describing discharges from the environment as well as emissions and waste into the environment. Then, possible environmental impacts are quantified on the basis of the inventory. The impact-oriented CML2001 method is used for this purpose. This method summarizes the potential environmental impacts of certain substances in so called impact categories (e.g. human toxicity, acidification, resource consumption or GWP). Since ETWA examines the impact on global warming, only the impact category GWP is required. The result of the impact assessment is a value in $kg_{CO2\text{-}eq}$ that includes all emissions that contribute to global warming. Finally, the results are interpreted. To do so, in addition to drawing conclusions, the following questions need to be clarified: Which life cycle phase has the greatest impact on the GWP? Which flows are the most important? [5]

The costs of each subsystem are calculated based on the guidelines of the purchased subsystems according to the greenfield approach taking the current economics and commercials into account. This so called bottom-up calculation is based on the design of an existing product but with an independent vertical integration. In order to avoid competitive conflicts, this confidential data is standardized in percentages. In comparison to the LCA, the greenfield approach only considers the production phase, as this has the greatest influence on costs.

After the effort of each subsystem has been determined, the question is, how to evaluate the generated data. At this point it is remarked that the mass is included both in the calculation of costs and in the calculation of CO2-emissions. However, the description of the underlying calculation models for costs and the LCA in the paragraph above has shown that the mass only partly contributes to the other factors. Both in the costs and in the CO2-emissions, many other mass independent influencing variables are considered, which is why the authors assume three independent factors, that can be weighted among themselves. In order to allow business specific trade-offs as well as strategic positioning a weighting of factors is introduced in the ETWA before ranking the functions with the highest effort. Different approaches are conceivable for this. However, in order to ensure intuitive applicability, a linear approach was chosen, as for example proposed by Ashby [6] in his material selection in order to minimize mass while taking costs and CO2-emissions into account.

Equation 1 shows the chosen linear approach. The effort (mass, CO2-emissions and costs) of each subsystem are represented by m, $CO2$ and $€$. The corresponding weighting factors are illustrated by w_m, w_{CO2} and $w_€$. Equation 2 applies to the summation of the weighting factors.

$$E = w_m \cdot m + w_{CO2} \cdot CO2 + w_€ \cdot € \tag{1}$$

$$w_m + w_{CO2} + w_€ = 1 \tag{2}$$

3. CONCLUSION

In order to respect economic and ecological aspects in lightweight design, the lightweight design method "Extended Target Weighing Approach" (ETWA) has been developed. It systematically takes the factors mass, CO2-emissions and costs into account. When having a closer look at the calculation of these factors, it has been shown that they can be considered as independent for the method. This allows a business specific weighting of factors so that methodological supported, individual designs can be created. Choosing a linear approach helps using the weighting intuitively.

4. ACKNOWLEDGMENTS

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