JEC magazine

COMPOSITES

113

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Construction

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Mass production

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Marine, Automotive

www.JECcomposites.com

June 2017

Integrating design and costing

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Costing as an innovation driver within product design is mostly underestimated, even though its potential for cost saving is usually well known. Conbility GmbH and the Aachen Center for Integrative Lightweight Production of RWTH Aachen University (AZL) combine expertise in process costing and composite production technology for the development of a new integrated design-to-cost approach considering material and process-related costs within the early product development phase.

The demand for lightweight concepts, and thus the use of composites and multi-material systems, is constantly growing. Today, composites are not only used in high-performance applications, but also widely spread in highly cost-sensitive branches, such as automotive or consumer goods for instance. A core challenge within the growing demand for composite applications is the reduction of the currently high product design costs. To achieve a cost reduction within the design phase of composite parts, tools for comprehensive and early part cost estimations are required and innovation processes need to be accelerated.

The limiting factors of iterative design and cost evaluation

To compete, companies from all industries need to continuously improve their flexibility, as well as their product quality and variety, while consistently maintaining or reducing their costs. Due to the progressive globalization, increasing competition and thus rising speed of innovation, the balancing act between cost efficiency and product performance is challenging. In general, the product development phase itself only accounts for a small share of product costs, but already has significant influence [1]. Consequently, the degree of cost influence is the highest when costing is integrated right from the beginning of the product development process, as shown in Figure 1.

Several different costing approaches can be used, such as target costing, process costing or activity-based costing – principles from business economics.
However, costing is mostly conducted by costing experts, so that development engineers need to provide specific data to costing experts to perform a cost estimation or calculation. Therefore, the challenge for development engineers is to gather cost-relevant product and process information in early stages of the product development process. The demand for creativity is high but the available cost-relevant information is rare, especially regarding the design of new products and production sequences. This separation and the iterative process of product design and costing are often inhibiting the innovation processes within companies.
Due to this iterative process, development engineers often strive to modify a current product for which cost-relevant information is known to satisfy the demand of the costing department, rather than redesigning it holistically. Thus, the level of creativity

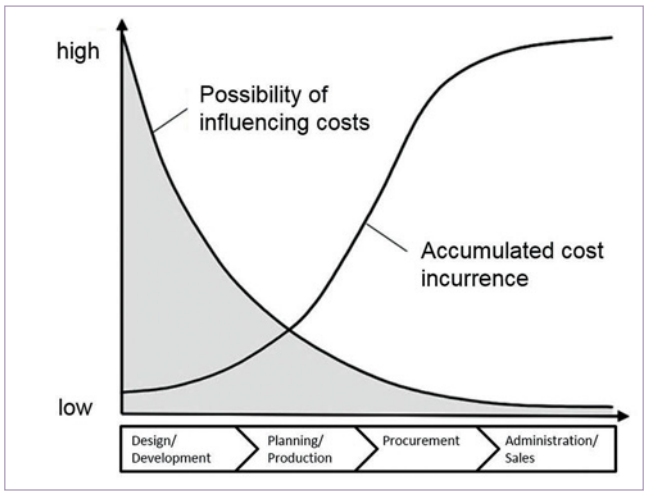

Fig. 1:Degree of cost influence during the product development process [2]

Fig. 2: RTM process model and evaluations

is limited and the products and respective production scenarios are often not designed to their full potential.

In general, tools for composite part and process design are state of the art, while various solutions are available for cost calculation of parts, including material and operating costs. However, the flow of information between the development and costing departments is rarely collaborative due to circumstances such as the high complexity of development processes, time pressure in development processes, different standards of knowledge or the lack of systems and software to enhance communication. Consequently, the direct and early cost estimation of a potential part production is usually not carried out in an optimal way in present composite design processes. However, the combination of these tools holds huge cost saving potential due to early economic evaluations with barely no limitations to creativity in the design phase.

Seamless calculation environment for costing-driven innovations

To enhance cost transparency throughout the product development phase without limiting the creativity and inspiration of part designers, it is necessary to support the responsible engineers and costing experts in their communication and workflow. Good communication between the responsible departments results in shorter processing times for single work packages with decreasing errors due to less misunderstandings and higher motivation of the involved disciplines, finally leading to faster project execution and a high innovation potential.

Part design and costing tools can be combined in a platform software. Conbility GmbH offers a software for process, job and product costing, Oplysis, which was developed in close collaboration with the AZL of RWTH Aachen University to ensure added value for cost estimation and calculation in the composite industry. It is embedded in a platform of engidesk GmbH that helps the user to intuitively set up production processes, allocate resources to specific processes and calculate production cost and capacities in a short time. The platform comes with a drag-and-drop interface to visually support design, production and costing experts when building up production scenarios and adapt changes for product and process variations easily in real-time during team meetings. Advanced features, such as sensitivity analysis or scale-up analysis, identify cost drivers and bottlenecks and outline an existing production scenario to a larger scale with all the necessary investments. An overview of a typical RTM process model and the corresponding evaluation features is shown in Figure 2. A collaborative, cloud-based database is integrated to store, exchange and reuse the users' expertise.

With this unique workflow, costing can be performed in an inspiring, "what you see is what you get" manner, independently of the complexity of the respective product or process and in-depth knowledge of costing.

For example, the cost calculation of parts in the automotive industry in terms of quote generation is often complex due to the high variant diversity, irregularly changing number of parts due to customer requirements, high cost pressure and short time-to-market/customer requirements. The need for flexibility during the quote generation is enormous, not only in the costing department but also in the development, engineering and production departments. Every change of order needs to be discussed, evaluated and recalculated iteratively with all the responsible departments within a short time. Therefore, the same level of understanding of the part, process and customer requirements is necessary. Oplysis encourages not only the costing department to recalculate, but also the development, engineering and production departments to input their expertise into a single holistic system.

Because the costing software can be connected to other calculation tools, Oplysis

offers an appropriate environment to integrate part design and performance information into the cost calculation of the manufacturing processes.

Integrated design-to-cost approach to accelerate innovation

The product innovation process lasts from the product idea to the marketable serial product. To evaluate every stage of the product innovation process to make the market potential quantifiable, it is essential to define certain criteria that can be measured or calculated. In the innovation process for an automotive structural part, for instance, many different performance criteria such as stiffness, strength and crash resistance are considered. Beside these part performance criteria, process-related factors, such as cycle times and resource consumption, are also important to evaluate the potential of the innovation, since the product must be manufactured with current or to-be-developed process technologies. Each of these criteria needs to be considered and continuously evaluated in terms of costs, which substantially determines the product's market price.

Thus, an approach coupling mechanical design and process cost for the development of composites has been developed. This new integrated design-to-cost approach links process chain modelling with the basic analytical mechanical design of composite parts (Figure 3).

The approach consists of three different modules: an economic module based on Oplysis, a mechanical module which was elaborated in cooperation with engidesk GmbH and a coupling module. The calculation is based on the mechanical module, where the part boundary conditions, e.g. dimensions and materials, and the specific load case are defined. This module produces various sets of mechanical parameters to evaluate the part performance. The process chain for the production of the respective part configurations is modelled in the economic module. This way, the part costs are calculated considering the process and material costs.

In the Oplysis calculation environment, this approach was implemented for the first time using a simplified T-beam use case (see Figure 4).

The basic T-beam parameters are defined in the mechanical module, such as the flange and web height, the height of a reinforcement layer on the upper surface, the beam length and, finally, the specific load case. Here, a cantilever beam with one force at the end is considered. The selected material is a standard PA6 and the reinforcement layer is a PA6 laminate. The process chain for the production of the T-beam is defined in the economic module, based on the manufacturing of a tape-based laminate, the forming of the laminate and the part production by injection moulding. The process chain includes secondary process steps for e.g. handling and heating the laminate. Finally, in the coupling module, the part-based information (e.g. part dimensions and material) is linked to the parameters of the process chain, which influence the part costs. For example, the part dimensions automatically influence the selection of an adequate injection moulding machine, taking into consideration the required clamping force. The geometrical values of the part influence the amount of scrap in the laminate production, the thermal material properties affect the injection moulding cycle time based on the automatically calculated cooling time and the tape placement cycle time is calculated by the specific machine throughput.

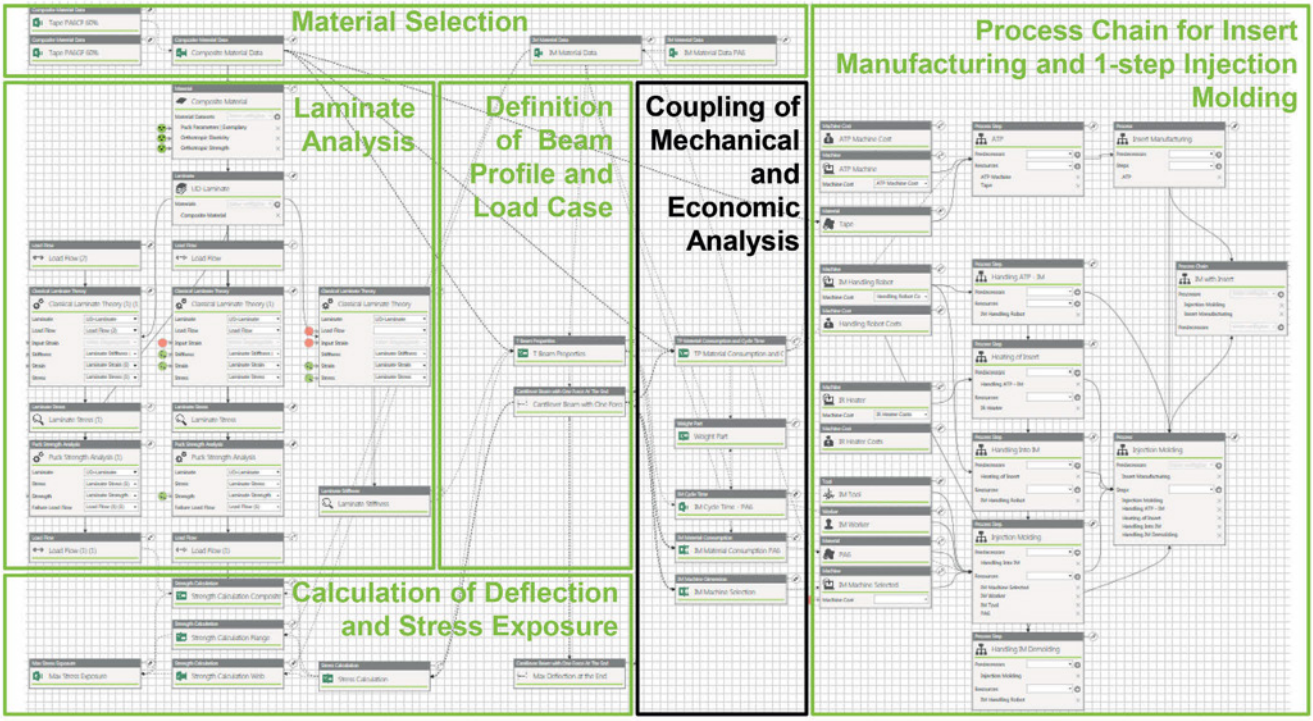

Fig. 3: Integrated design-to-cost approach

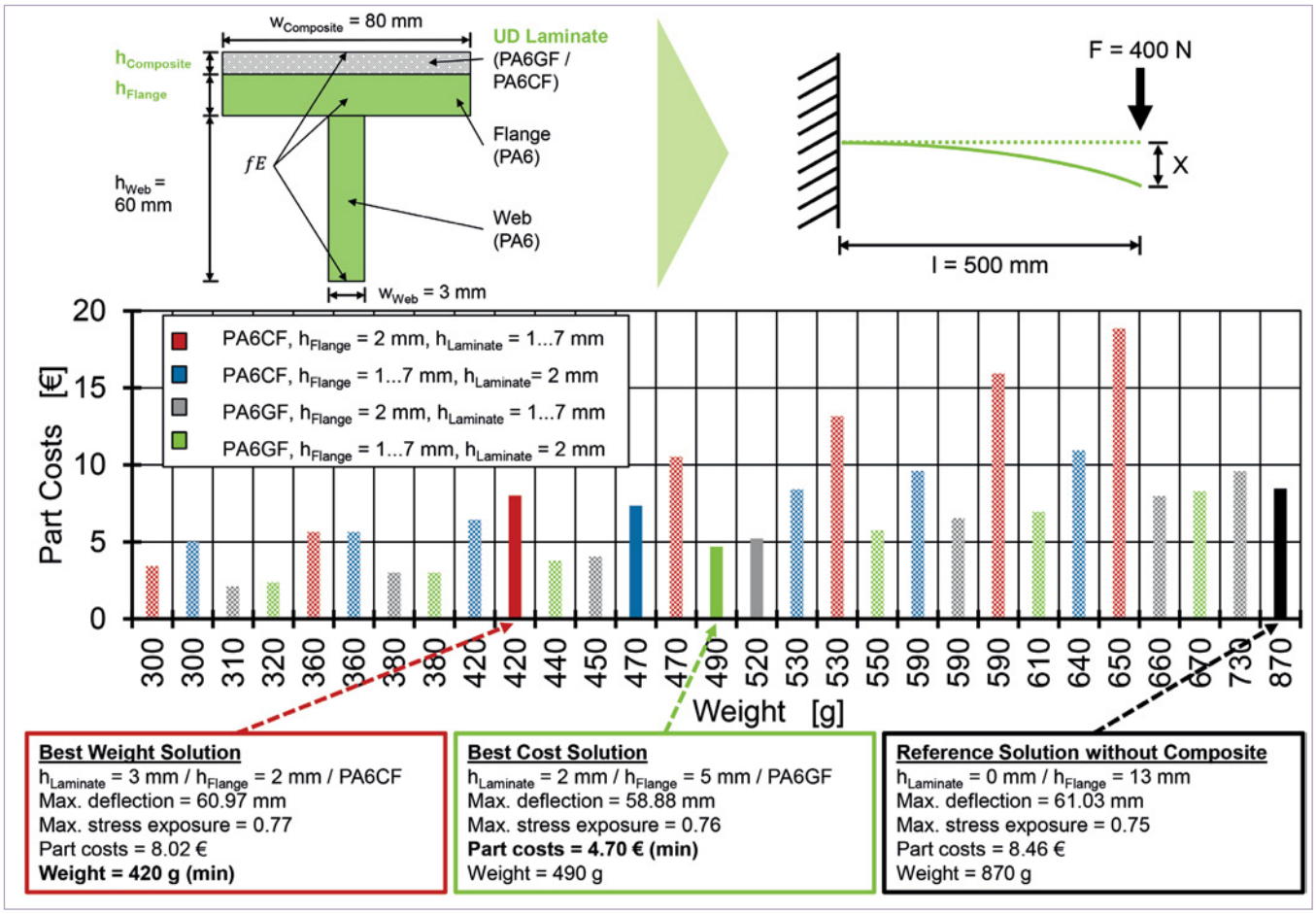

Fig. 4: Use case description and results. The part configurations which are not fulfilling the mechanical requirements or which are over-engineered are crosshatched

Overall, there are various possibilities to automatically couple the calculation modules in this approach, deriving process costs based on the design variants.

In the present use case, three input parameters are varied: composite layer height, flange height and laminate material (PA6/carbon or glass fibre). Here, the approach focuses on the evaluation of four output parameters. On the one hand, the mechanical parameters of maximum deflection and maximum stress exposure are evaluated. On the other hand, part weight and costs are calculated. Within the use case, the variation of the input parameters leads to different part configurations. The cost-efficient solution can be identified easily within these part configurations, in addition to inefficient part configurations (crosshatched bars in Figure 4), which are over-engineered or which are not fulfilling the mechanical requirements. The cost-efficient solution identified achieves the required mechanical properties and provides the best cost-to-weight ratio. As a conclusion, the approach leads to highly efficient design processes.

Overall, the implemented approach is the basis for accelerating the development process. In current developments, the costing models are coupled with numerical FE models to achieve more flexibility in the development of complex part geometries. ▫

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Focus

Conbility GmbH is specialized in solutions and products to support job, process and product costing for manufacturing processes. The company's expertise combines market and technology knowledge with process optimization along the entire value chain, as well as high expertise and a large network in terms of production technologies. One of the key-products is the Oplysis process costing software, which is applied from small companies to TIERs and OEMs especially in the automotive and aerospace industry.

Aachen Center for Integrative Lightweight Production (AZL) of RWTH Aachen University consolidates the lightweight expertise of eight partner institutes with 750 scientists on the RWTH Campus. The AZL of RWTH Aachen University addresses the transformation of lightweight design in mass production with research and development of lightweight products, materials, production processes and systems with access to the latest full-scale machines and automation systems.