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Advanced Optimization Methods for CFRP Components in the Motorcycle Industry

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Micro Abstract
Carbon fiber reinforced plastics (CFRP) are increasingly used in the motorcycle industry due to their good weight specific mechanical properties. Complex geometries, mechanical requirements as well as cost issues and manufacturing influences are the main design challenges here. Therefore, advanced optimization techniques have been developed for CFRP components in order to find an optimum between costs, weight and manufacturing robustness. This approach is shown using selected case studies.

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Introduction

Weight is a key element for achieving good handling and driving behavior of a motorcycle. Although there are already a couple of electronic assistance systems available for two wheelers, it still requires active movements of the driver as well as weight shifting to ride a motorcycle. Furthermore, the increasing number of comfort features such as grip and seat heating, navigation and communication elements or multimedia systems present on motorcycles nowadays, add even more weight to it, making it even harder for the driver to handle. Therefore, it is important to reduce the weight of the structural components dramatically in order to keep the weight constant with regards to the predecessor or even to reduce it.

Carbon fiber reinforce plastics play an important role here due to their good weight specific properties [5]. Regardless of this advantage in comparison with metallic structures, there is a high number of challenges to face in order to guarantee not only a light, but also a robust design. A part from the material properties of the fiber and matrix themselves and the wrought material [1], there are further parameters to take into account in the development of lightweight structures, such as laminate lay-up, stacking sequence, fiber orientation, fabrication process and parameters, draping strategies and many more. These parameters show in most cases a nonlinear behavior, are highly connected and interfere with each other, requiring appropriate optimization techniques to handle them. In addition to this technical consideration, these optimization methods also have to address parameters such as costs and manufacturability. Within this work, the approach of KTM Technologies is shown using two representative case studies.

1 Optimization method

Similar to the automotive industry, a large number of load cases have to be addressed in the motorcycle development. Therefore, in order to get a first idea of the load paths, a topology optimization is done, which is exemplarily shown in Figure 1 left.

Based on this information a transformation is done towards a surface dominated carbon reinforced design taking into account the boundary conditions of the desired fabrication process. Thereafter, a definition of appropriate fiber directions is done representing not only technical considerations, but also cost and manufacturing parameters. As a next step a thickness optimization of the defined accumulated layers with different fiber directions is done. A shuffle optimization

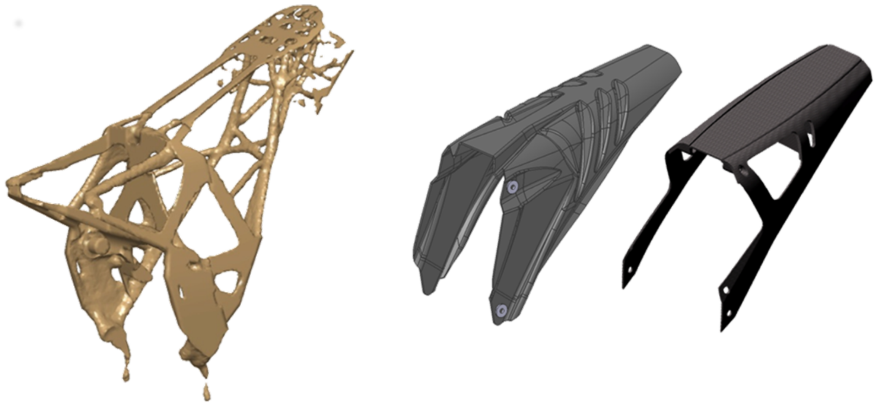

Figure 1. Motorcycle rear frame: Results of a topology optimization (left) and robust composite designs (right) [4]

represents the next step in the development of a lightweight and cost efficient layup, taking into account available wrought materials, their draping behavior, appropriate layer overlaps, fiber patches as well as their costs.

Additionally, manufacturing costs are respected using an empirically developed function, where main parameters are the part geometry/complexity, wrought materials, fiber patches and lay-up. Finally, a sensitivity study is performed in order to prove, whether the present design is robust to variations in material properties and of the manufacturing process. If the design is not robust enough a parameter variation is performed and the previously explained steps are performed again until the design is robust. Figure 1 right shows exemplarily the results for two different materials and manufacturing processes for a motorcycle rear frame.

2 Case Study KTM 450 Rallye Tower

Especially in off-road racing, lightweight and robust structures are essential. The first case study illustrates one part of the above described optimization strategy, the robust design optimization with scattering material and manufacturing parameters using degradation fields [2]. Figure 2 top left shows the front structure of the current KTM Rally 450 motorcycle together with all functional components and fittings.

The structural components are made of fiber reinforced plastics. The roadbook base carrier is the main load carrying element and is used to attach the IriTrack, a GPS emergency transmitter, as well as the roadbook and the light carrier. Due to the high geometric complexity of this structure and the manually dominated prepreg autoclave process [1] the local fiber orientation may differ within certain boundaries from the theoretical fiber orientation. Due to the fact that this is not a one-dimensional scatter problem, a new degradation field approach was developed by Kellermeyer M., Perterer M. and Wartzack S. [2]. A part from the fiber orientation, the layer thickness, material properties and failure detection probabilities are taken into account. Figure 2 top right shows three exemplary artificial created degradation fields that are used to develop and validate the approach.

Figure 2 buttom shows exemplary results of the robustness analyses for a specific failure point. Three main influence factors out of a high number of design parameters are identified. The correlated scatter shapes are shown on the right side. Those scatter shapes indicate the areas of the structure where these specific parameters are of high relevance. With other words, this new approach not only helps to identify the critical design parameters but also helps to understand the behavior of them for the whole structure.

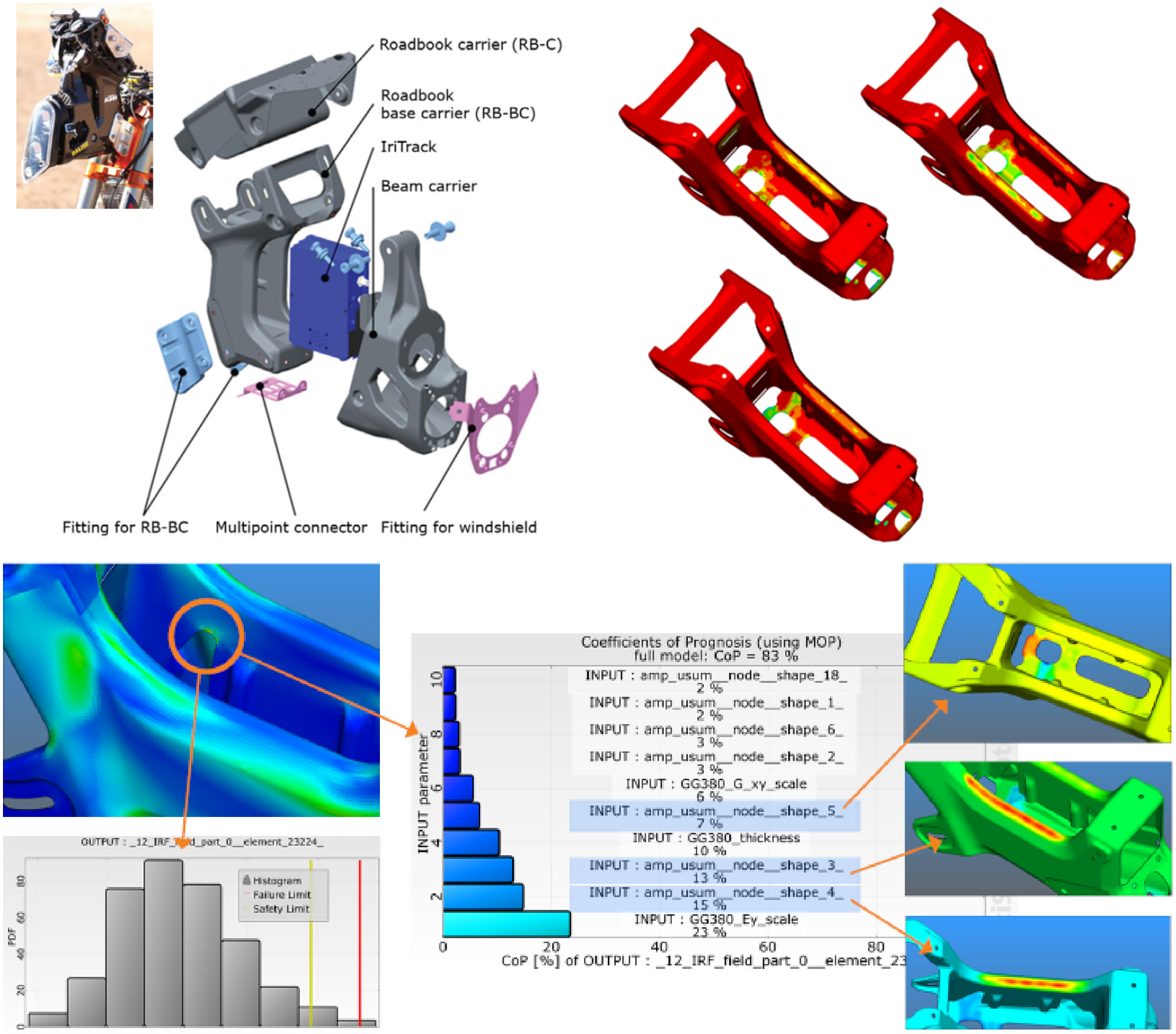

Figure 2. Front structure of the KTM Rally 450 motorcycle: assembly and exploded view with all functional components and fittings (top left), exemplary artificially created degradation fields (top right), Scatter influences on a specific failure point - distribution curve of the failure criterion, influence on the most important input scatterings, translation of the most important amplitudes into degradation regions (bottom) [2]

3 Case Study Fiber Reinforced Motorcycle Rearframe

Due to the high costs of fiber reinforced structures using endless fibers compared to metals, there is only a small range of parts where this material can be used in series production. Therefore, other carbon fiber wrought materials and processes such as fiber reinforced injection molding and C-SMC (Carbon Sheet Molding Compound) are investigated here [3].

Although, these materials have lower weight specific properties compared to endless fibers, they offer a significant weight saving potential with comparable or only slightly increased costs compared to metallic structures. The above described optimization method is also applicable for these kind of structures where the parts dedicated to the definition of the layers, their orientation and shuffling are replaced by an optimization of the fiber orientation, which is connected to the fabrication process, either injection molding or C-SMC.

Figure 3 shows the development process of a motorcycle rearframe using fiber reinforced injection molding material. Figure 3a) shows the results of the topology optimization, figure 3b) the final 3D geometry of the structure which is divided in three parts due to manufacturing and

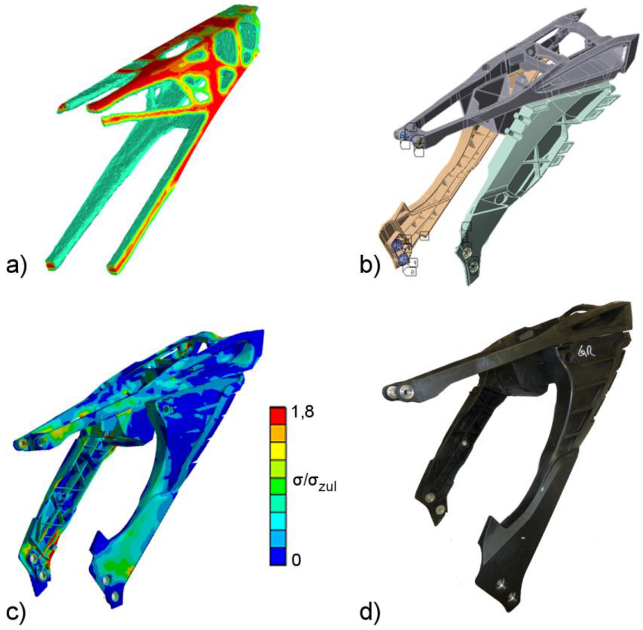

Figure 3. Development process of a short-fiber reinforced motorcycle rearframe [3]

assembly issues. Figure 3 c) shows a static simulation result during the process of evaluating the robustness of the structure itself. Figure 3 d) shows the first prototype.

Conclusions

Fiber reinforced materials have become an important lightweight material in nearly all industrial areas, although their potential is in most cases not used completely due to engineering and manufacturing challenges. The fast progress in computing performance and optimization techniques are a key contribution to increase the understanding of fiber reinforced structures by using these methods also for serial development. In this contribution, the approach of KTM Technologies to develop light and cost efficient motorcycle structures was explained and shown using two case studies. Mechanical properties, costs, manufacturing issues and robustness, which are main drivers during the development of structural components, were addressed together in a combined way. The optimization methods here are continuously further developed as new materials and processes for fiber reinforced plastics are coming up.

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