HEXAGON

Case study

Generative design provides and easy ride for e-Bike manufacturer with 55% lighter design for additive manufacturing

Lightweight design for bikes: torsion-resistant, robust, and lighter design for motor connections

More range, more comfortable handling and easier riding: Lightweight construction is also highly important for electrically powered bicycles. Krause DiMaTec and Hexagon joined forces to take on optimisation, validation, and production for bike manufacturer Xplorcycles.

In light of the electrification of bikes bringing extraordinary attention and expansion to cycling, the bicycle market expects high growth rates in the coming years. A desire for more outdoor activities, caused in part by the coronavirus pandemic, and a trend toward more sustainability are prompting the transition and demand for ecologically friendly alternatives to the car.

At the same time, specialized bicycle concepts are becoming more popular, such as three and four-wheeled recumbent bicycles, also known as trikes or quads. Among advantages is the more comfortable sitting/lying position, which offers better ergonomics and is much easier on the back. This is an ideal alternative not only for people with disabilities, but also for those who enjoy riding in comfort.

New manufacturing technology for a new generation of bicycles

Bicycle manufacturer Xplorcycles is committed to producing recumbent bicycles and has forged a plan to equip the next generation of bicycles with electric motors. While the company had an existing design used to connect the 3.2 kg electric motor to the bike structure using conventional manufacturing processes, the design was not suitable for small-series production and added extra weight.

With this in mind, Xplorcycles asked industrial 3D printing expert Krause DiMaTec to look into additive manufacturing options. Because the existing component design did not allow for cost-effective, high-quality additive manufacturing, Krause DiMaTec focused on optimising parts geometry using MSC Apex Generative Design software to develop a design suited for additive processes. This innovative optimisation technology generates bionic structures that are optimally adapted to the performance requirements of the component and are particularly lightweight. The component was thus redesigned from scratch to reconcile good manufacturability with the engineering requirements of the component.

Tour de France stage as basis for optimization

To prepare the model for redesign, the engine, as well as its interfaces, connection points to the bike, and original adapters, were imported into MSC Apex Generative Design software. From there, a design space was derived in which the algorithm was allowed to place material in the simulation. Similarly, tools provided by the software were used to define non-design spaces, including fixed connection points on the bicycle and the engine. To define load cases, it was necessary to determine the forces that act on the motor, bracket, and bicycle connections as a result of the pedals being used.

To determine these forces, Krause DiMaTec engineers used the load profile of cyclist Andre Greipel during the 2014 Tour de France to provide a realistic high-end load for the design. Using this data, the forces for pedals and chain force on the gear were calculated from the torque of the shaft and adopted for the optimisation model. In addition, Krause DiMaTec accounted for potential special cases, such as the effects of an assembly or load on both sides of the pedals in the event of a crash. This resulted in a total of 17 load cases, which ensured that the optimised design was robust and could withstand everyday demands.

From 0 to 55: high-speed weight reduction

In the first optimisation, only the upper part of the mount and the mount for the bike connection were optimised. Here, the original adapter plates for the motor were intended to be part of the assembly; this approach reduced weight by 13%.

For further weight reduction, the adapters were included in the next step of the optimisation, resulting in less assembly and, potentially, additional lightweighting. With this new approach, the design resulted in a 55% weight reduction compared to the original design using 316L / 1.4404 stainless steel, and deformation under load was reduced by 90%. The stress-based optimisation produced homogeneous stress distribution with significantly higher mechanical reliability than the original design. As a result, the assembly and adjustment of the additional adapters could be eliminated.

Figure 1: The simulation result shows homogeneous stress distribution in the entire component with very uniform colour distribution (blue/turquoise) and few critical areas (red).

Assembly without detours through spot-on production

With just a few mouse clicks, optimisation results were fed back into a standard CAD (computer-aided design) exchange format (based on NURBS) for CAD/CAM (computer-aided manufacturing) processing using parameterised functional surfaces. A final check of the entire assembly was performed in MSC Apex Generative Design before moving on to production preparation with the definition of the orientation alignment and support structure generation.

Thanks to the high process accuracy of Krause DiMaTec, no allowances for functional surfaces and no post-processing were necessary. As a result, the manufactured component could be installed immediately after the removal of process-related support structures. Without further adjustment, bicycle manufacturer Xplorcycles was able to attach the motor to the bicycle with the motor mount. The first test rides were flawless, and the bionic design and workmanship were of high quality.

Dr.-Ing. Johannes Tominski, Managing Director of Krause DiMaTec GmbH, is also extremely satisfied with the overall project and performance of the generative design software: “This development project impressively demonstrates the added value that can be generated by the close integration of topology optimisation and 3D printing. In addition to the improved mechanical properties, the optimisation also enabled us to improve the visual appearance of the engine mount and realise an additional eye-catcher for the trike.” According to the two project partners, series production is scheduled to start in the first half of 2022.

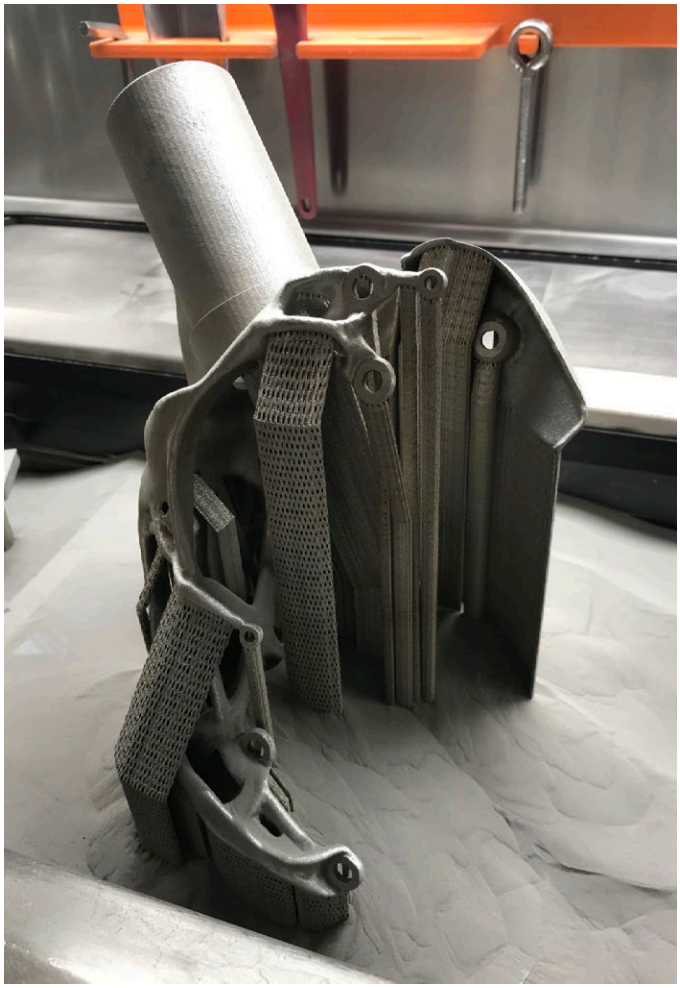

Figure 2: The motor mount was manufactured using the powder based SLM (selective laser melting) process. The support structures required for the process can be easily removed so that the ready-to-install solution is immediately available.

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