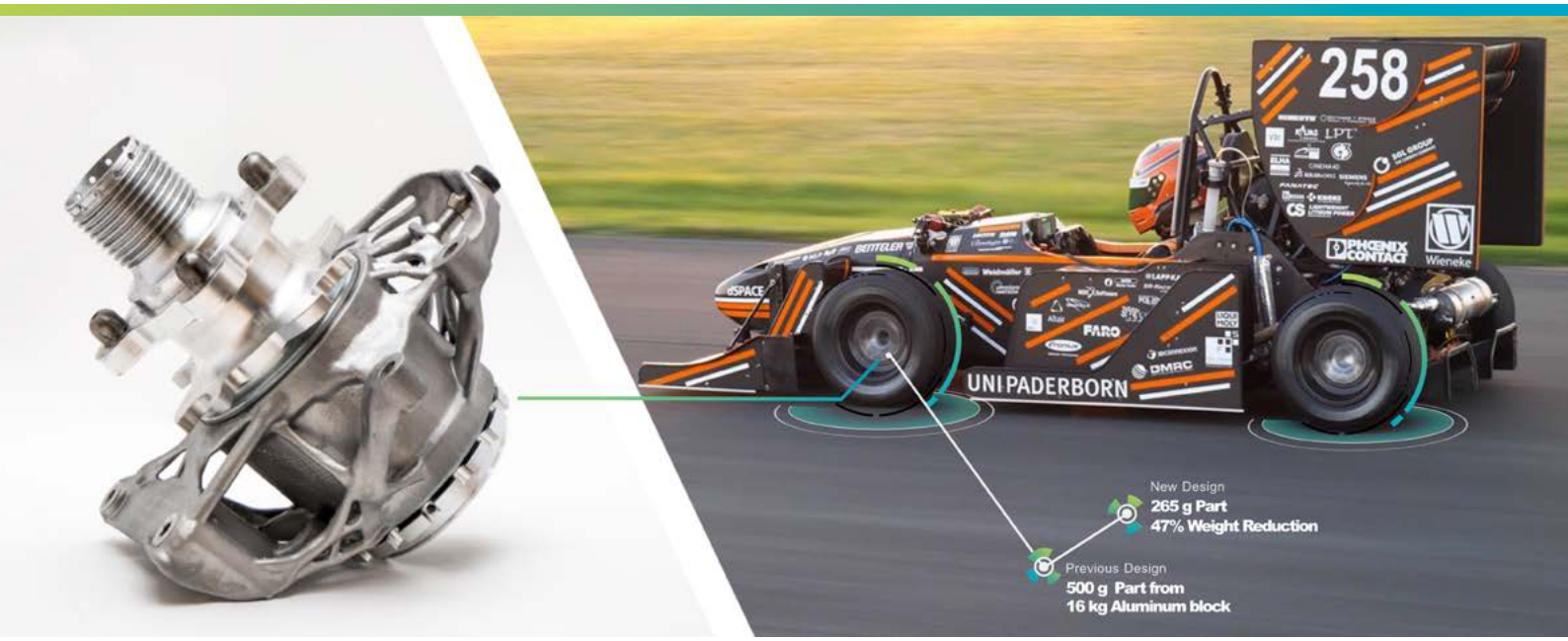
Race sports: Catch the highest performance with lightweight design

From load simulation via generative design to manufacturing and verification – optimisation of a wheel carrier for FormulaStudent with MSC Software



The FormulaStudent Team from Paderborn University utilised various tools from MSC Software to significantly reduce the weight of the wheel carrier by 47 per cent with Generative Design.

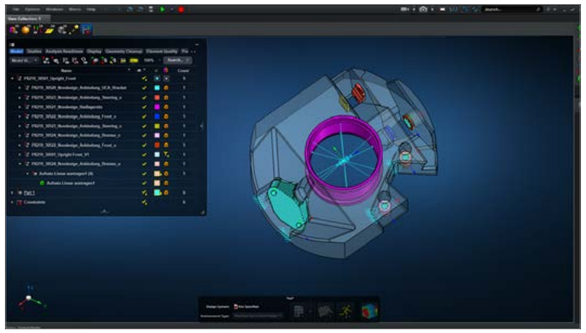
Simulation is a key driver for higher performance, reduced weight and a production process that is right first time. For the racing industry, this is essential in order to be able to develop a new racing car every season. Especially for student teams, simulation saves costs for their highly limited budgets.

Motorsport is always about maximum performance with the least possible weight – a perfect match for Additive Manufacturing and Generative Design! And to maximise the output, simulation is the key driver throughout the whole process from load detection to non-destructive testing.

FormulaStudent is an international design and race competition for University student teams throughout the world. Every year they design a new race car to compete in different categories. The goal for each new car, is to be more lightweight than the previous one. Therefore, with every gram standing in the way of success, it is vital to come up with a design that optimises each component.

Challenge

Due to the unique production, and the drive for highest performance with least weight, Additive Manufacturing is perfectly suited for many applications in this field. However, time is critical, as the teams have to develop a whole new car alongside their normal studies, and have it tested before the competitions start. Weeks of full-time work is often required to optimise complex components such as the wheel carrier, which not only has many different load cases, but is also a good opportunity to reduce weight. An existing complex design from a previous car had produced a 500g component from a 16 kg Aluminum block on a 5-axis milling machine. This process led to 97 per cent of the original raw material being scrapped.



Model set-up with MSC Apex Generative Design for the wheel carrier to start the optimisation of several design candidates

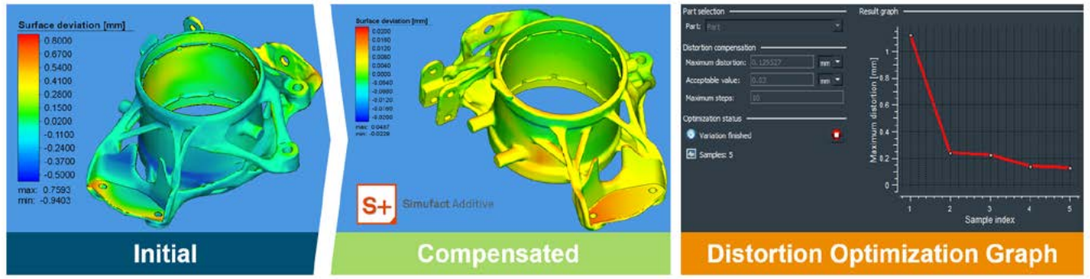
Solution for design

A completely new model was set up to create an optimal design and exploit the benefits of Additive Manufacturing. The earlier car model was used to start an MSC Adams multi-body simulation to identify optimal suspension setup and the resulting load cases. They were then used within MSC Apex Generative Design for the design optimisation. With the strong features of the user-friendly MSC Apex platform, the model set-up proved to be efficient and easy. Both the design and non-design spaces were defined, and the identified loads added to the model. Finally, the maximum stress as the optimisation objective was given as the last input. The software then started the optimisation. Because the smart algorithms can also get the very best out of the graphic cards as a modern computing approach, a feasible design was generated in a few hours for this highly complex model, even though it has about a dozen load cases. This enables the user to generate a number of designs, and choose the most promising. The designs created a component weighing around 265 g, which is 47 per cent lighter than the already optimised traditional milling design.

Identification of best manufacturing

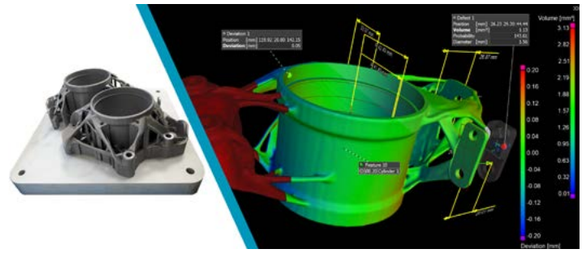
These different design candidates were then further analysed for technical and commercial aspects. Through a simulation with Simufact Additive, the selected candidates were tested for stresses, distortions, cracks and hot spots during manufacturing, as well as how easily they can be removed from the build platform. This was further extended with an economic evaluation, looking at which candidate requires the least amount of support material and which orientation has the lowest price per part. As a result, a design was selected that offered the best trade-off for these analyses.

Furthermore, the manufacturing simulation can be used to gain a predeformed shape for printing, which reduces the final maximum deviation from 0.8mm to 0.02mm.



Manufacturing simulation with Simufact Additive achieves a process that is right first time, with a high-quality result and accuracy through distortion compensation

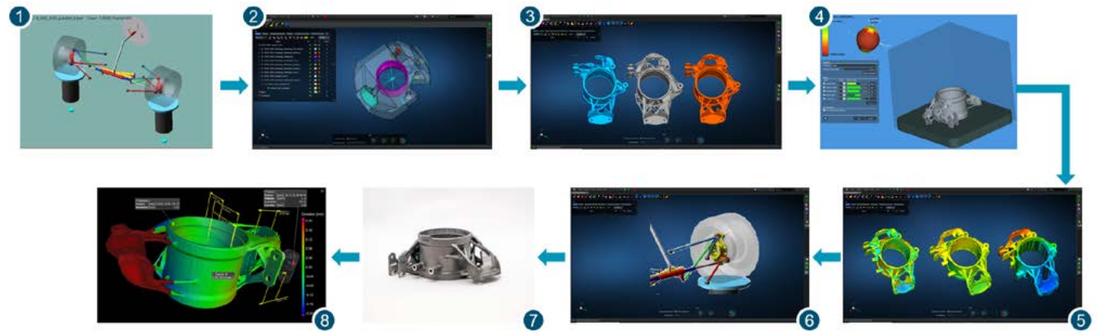
Key highlights:
Product: MSC Apex Generative Design, Simufact Additive
Industry: Industry Racing
Benefits:
Reduced weight and optimized production process
Tailored design for additive manufacturing
Verification of the part's integrity by non-destructive testing



CT scan of the manufactured parts (bottom left) and digital analysis using Volume Graphics VGSTUDIO: Illustration of the real geometry as a mesh (left), variance comparison between CAD, simulation and reality (middle), measurement of the components (arrows) and pore analysis

Virtual validation and manufacturing

After the final, robust part geometry had been chosen, MSC Adams was applied to validate that the design meets all input requirements. Therefore, the design was added to the initial MSC Adams model and the structural simulation conducted again. No failure could be detected, so that the FormulaStudent team went on to manufacture the part. To ensure that the produced parts were of a high quality, CT scanning as non-destructive testing was applied. The CT scan was then analysed with Volume Graphics' VGSTUDIO, and overall, the results were good: the distortions were higher than simulated but within a good range, and the dimensional accuracy was fine. One manufacturing induced bigger pore could be found within the tie rod connection but as that is not highly critical loaded this is acceptable, although it needs to be observed for any obvious defects.



Workflow for the wheel carrier with MSC Software tools: (1) MSC Adams load case identification, (2) model set-up with MSC Apex Generative Design and (3) few design candidates after optimisation, (4) Simufact Additive manufacturing simulation, (5) verification with MSC Nastran and (6) with MSC Adams, (7) manufacturing through service provider and (8) final analysis with Volume Graphics after CT Scan

Conclusion

Simulation is a key driver for higher performance, reduced weight and a production process that is right first time. MSC Software has all required tools to make this process fast and successful. A weight reduction of 47 per cent was achieved with MSC Apex Generative Design. Manufacturing induced distortions could be significantly reduced through Simufact Additive, and the manufacturing result was analysed by Volume Graphics non-destructively. Here, the different solutions worked hand-in-hand to deliver the best possible outcome for this high-demanding sport and design competition. What previously took weeks to achieve, is now possible within a few days, coping with the high demands of the race team.

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