Climbing the Winner's Podium with HyperWorks

Overview

To compete within the Formula SAE® contests, a student design competition organized by SAE International, the participating design teams pretend that a fictional manufacturing company has contracted them to develop a small Formula-style race car. Within the competition each student team needs to design, build, test, and finally race its prototype and then gets judged based on a series of rules. By being part of a Formula SAE team the engineering students get out of the class room, gain practical experience in a realistic set-up, and learn all they need to know for a successful career in the automotive industry as well as other engineering fields.

One of the long standing and very successfully competing teams is Cal Poly Pomona Formula SAE (CPPFSAE). As many other teams they apply all their marketing, business, and engineering knowledge to design, develop, build, and promote their race car. This year's competing prototype weighs about 460 pounds, uses a four cylinder motorcycle engine and has achieved excellent results: The 2015 car has been very successful at national and international competitions, including being the second best American team at the German competition in Hockenheim.

Within the development process the students revert to several design (CAD) and engineering (CAE) tools to obtain the best possible results. In the last two seasons, members of the CPPFSAE team have started to apply also Altair's HyperWorks® Suite, especially to design composite structures. This year, the team successfully employed the CAE Suite to design new carbon fiber wheel shells for their car, with the goal to increase wheel stiffness and decrease unsprung mass.

Team

Cal Poly Pomona Formula SAE is a student-run team competing in Formula SAE, an international collegiate design competition. The Formula SAE is one of the largest competitions of its kind worldwide, bringing together students from dozens of countries at competitions spread across the globe. Students in a competing team invest hundreds of hours of hands-on engineering as they design, build, and test their race car from scratch, all while being full-time students at Cal Poly Pomona. To cope with the many tasks and challenges arising in the Formula SAE competition the team does not only interact with industry professionals but also races against top teams internationally. With the experience gained in the team, alumni are highly sought after employees in many of the world's top automotive companies. After over 20 years of competing, CPPFSAE, with more than 30 team members, is one of the top teams in the world. More information at www.cppfsae.com.

Challenge

No matter how long a team has already been participating in the Formula SAE contest, each year it is a new challenge to be among the best in the competition. To reach the winning positions in the design and development categories as well as in the actual races, the teams are always looking to apply new materials and technologies to further improve their race cars. But new materials such as composites also create new requirements and thus new design and development challenges. With the ultimate goal in mind to profit from all the advantages each material offers, i. e. regarding the material's lightweight design or stiffness potential, each material must be designed individually.

For example composites offer many advantages, especially regarding weight and stiffness, but only if the material and the composite components are designed in the right way. Based on the experience from the last designs the CPPFSAE team picked the wheel shells of their 2015 car as components to be built in composites, in this case carbon fiber, as they expected advantages regarding an increase of the wheel's stiffness and a decrease of the unsprung mass.

The CPPFSAE race car 2015.

"The work with HyperWorks has been great so far and we are very happy with the results. It helped us to refine our wheel design and to finally get an improved set of wheels to the car. The main benefit I see for our team is the ability to easily and effectively design and optimize carbon fiber composite materials. During my research I could not find any other tool that had the power and the ability to do what I wanted as effectively."

Christopher Nilsen, Cal Poly Pomona, ME Design Lead of the CPP Formula SAE team.

The new carbon fibre wheel shell offers increased stiffness and less unsprung mass compared to the former component.

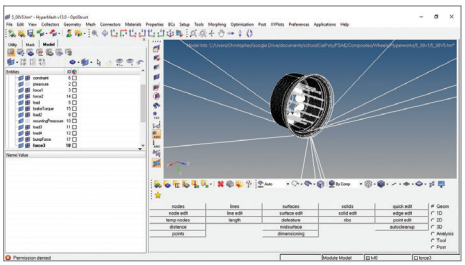
To design and optimize the new wheel shell the engineering students had to find a software tool that would allow them to create a composite laminate design. When they realized that they couldn't get the carbon fiber laminate prepreg to conform to their mold, they solved this problem by increasing the number of debulking cycles and by switching to hot debulk. Finally they had to do a post machining process on the wheel.

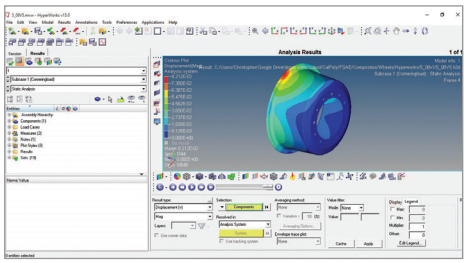
Solution

The team settled on Altair's HyperWorks suite for the design and development of the new wheel shell since the software offers some of the best features to design and analyze laminates. The wheel shell is also a good example to learn to work with carbon fiber as a structural material, going through the entire design process of a structural composite.

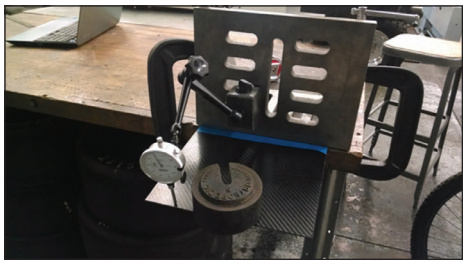
The first step in the design process was the geometry creation in the team's standard CAD system, which was basically a mold. Then they imported the CAD model into HyperWorks and generated a surface mesh of the model including special areas of interest where the students planned to use carbon fiber. In a next step they created the laminate on top of the mesh and used the OptiStruct solver to run a finite element analysis. Finally they varied parameters, layers, and the orientation of the layers based on the results OptiStruct delivered.

The team's design optimizations were based on minimizing the number of layers needed to get an approximately 10 percent increase in stiffness. Thanks to HyperWorks they could go straight into manufacturing a basically final product. They first created a simple virtual deflection test of a flat probe of example material in HyperWorks and applied an appointed load on one end of the piece. The cantilever beam test allowed them to use a simple and reliable method to obtain deflection values from an easy to replicate test. Then they performed the same test in real life to validate the HyperWorks model.





Model setup and finite element analysis results for the carbon fibre wheel shell design. The contour plot (right side) shows a region with higher stresses near the rim.



Physical testing (here static bending test) of the basic carbon fibre material to validate material properties.

Results/Benefits

HyperWorks allows for the option to increase the stiffness of the wheel shell through the use of OptiStruct. By applying HyperWorks to their composite design and development process the team was able to increase the stiffness of the chosen components by 10 percent while learning how to do a structural layout of carbon fiber composites. In detail, using HyperWorks the team could:

- Increase of stiffness by 10 percent
- Decrease the unsprung mass
- Go directly from design and analysis to production
- Learn how to work with state of the art CAE software
- Learn how to apply a streamlined design and development process for composites