GAINING THE COMPETITIVE EDGE

The Formula 1 team for Minardi uses FEA to improve race car structural designs.

Minardi Formula 1 has the drive and motivation to find technologies that give them the edge in making the 'perfect' race car. Founded by Gian Carlo Minardi in 1979, the Minardi Team made its Formula One debut in 1985. Today it is owned by UK-based Australian businessman, Paul Stoddart, who sees his mission as preserving the distinct Minardi character in Formula One. To do this, he is concentrating on a new wave of technical expertise.

Carbon Fibre Monocoque Chassis Design

An important aspect of Minardi's study in how to improve the structural design of its Formula 1 race cars includes a program to enhance the chassis for safety and performance without incurring the massive costs that physical testing imposes. While Minardi had been using Finite Element Analysis (FEA) software they felt they were not getting the full potential from the technology. The team began a six month test with Noran Engineering's NEiNastran in an effort to improve the analysis and simulation of the design and cut down the huge investments they were making in physical prototypes.

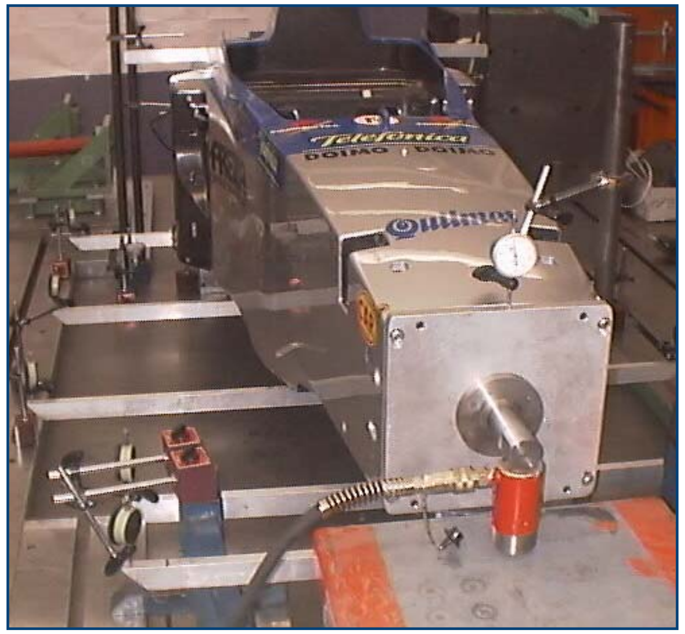
"Minardi needed a much more comprehensive system that combined carbon-fibre design elements with 3D solids, that could be tested accurately and precisely in FEA," said Simone Ragionieri of SmartCAE, an Italian-based systems integrator who worked with Minardi on the project. "We combined NEiNastran with our Smart|Browser and Smart|Laminate technologies so that everything could be created within the digital environment – even down to the smallest fibre in the materials."

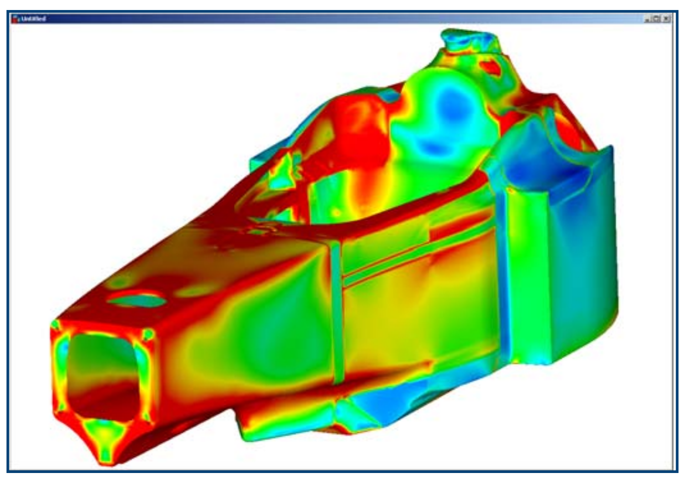
The unique chassis design had to exhibit the smoothest and flattest shape possible within the many engineering constraints that existed. These constraints included the desired wheelbase, engine interface, fuel capacity, aerodynamic requirements, and even the desired driver dimensions.

To complicate matters, the monocoque structure, using high performance carbon-epoxy composites with either an aluminum or aramidic honeycomb core, also affects the chassis design. The fibers within the materials have to be oriented according to the design, and not bend, while the ply overlapping and necessary cuts are minimized. Getting any of these aspects wrong can affect the performance of the chassis.

FEA Simulation and Optimization versus Prototyping and Testing

Once a design concept is in place, modifications and





further evolution continuously interplay with the very stringent safety requirements for the chassis. This is the point at which safety regulations become the main driving force for the chassis design. After testing the 3D model in NEiNastran with more than fifteen impact tests, including side crash, crash cone push-off tests and more, the software Minardi's high expectations (see side bar for data).

All of the tests are simulated in the NEiNastran analysis environment. Some can be replicated very closely while the penetration test uses a simplified correlated calculation validated by years of experimental data fitting within Minardi. The team started using NEiNastran for these tests, checking static analysis, buckling and surface contact. All calculations are corre-

lated with experimental measurements, thus enabling a continuous refinement of methodologies and material data.

During the testing, and in order to achieve the required targets, several optimization routines are executed involving modifications on material choice, layup sequences, local reinforcements, foams, bulkheads, and inserts. The NEiNastran FEA software was flexible enough to manage the existing model, able to solve the problems thrown at it, and able to give accurate and detailed post processing information.

The Finish Line

Minardi worked with SmartCAE thoroughly testing Noran Engineering's analysis and simulation software. By the end of testing, the Minardi Team made the change to NEiNastran official. The team found the following critical benefits were achieved:

- Improved accuracy of results. The Surface Contact features in NEiNastran enabled much more accurate results to regulation tests and simulations. Nonlinear analysis setup and solution finding also proved far more robust than previous.
- Fast implementation. An excellent training program by SmartCAE in Italy combined with timely support from Noran Engineering allowed the new software system, NEiNASTRAN, Smart|Browser, Smart|Laminate to be implemented and used by the Minardi team within a matter of weeks.
- Access and use of legacy data. The system successfully enabled bi-directional access to legacy and new data without compatibility issues.
- Reduced 3D modeling time. The creation of the FE model of the chassis was achieved in about half the time compared to previous software because of the power inherent in the NEiNastran (FEMAP) Pre and Post Processor which includes modules called Smart/Browser and Smart/Laminate.

For information:
Noran Products: http://www.nenastran.com/newnoran/product2.php
NEiNASTRAN: www.nenastran.com
Minardi: www.minardif1.com
SmartCAE: www.smartcae.com

CHASSIS IMPACT AND PERFORMANCE TESTING

Minardi Formula 1 chassis must survive fifteen impact tests. We have described the seven main tests here. We have also described two types of stiffness testing that is done as part of the overall performance testing that each chassis goes through.

Side Crash: This is the most restrictive test performed where a 780Kg cart impacts the side of the chassis at 10 m/s and lateral crash appendices (called Crash Cones) are measured which include maximum deceleration and maximum force on a cone. Each cone has to take from 15-35% of the total energy, and no damage can be found on the chassis.
Crash Cone Push-off:: These are flexural tests on the cones to verify the robustness of the attachments to the chassis.
Front Crash: This test is performed to determine the robustness of the nose design.
Penetration Test: In this test, a square flat plate with the same layout as the chassis's side area is quasi-statically penetrated with an aluminum conical impactor until a penetration of 1500 mm is measured. The model must respond to absorbed energy >6000 J, and reaction load >250kN.
Main Roll Bar Crush: This is where the roll bar is statically pushed with a force of about 120kN via an inclined plate impacting the main roll-bar top. Requirements include deformation of <50mm where the damaged area must be within 100mm from the load application plate.
Front Roll Bar Crush: The front roll bar is a reinforcing structure located just behind the steering wheel. A similar test as above is made with a 75kN vertical force.
Lateral Local Crushes: Several specific locations of the chassis side have to be loaded with forces varying from 12.5kN to 30 kN. Maximum displacements and no damage requirements are prescribed.

Performance Tests

Torsional stiffness: Each team has developed its own tradition for desired torsional stiffness ranging from 15,000 – 40,000 N M/o.
Flexural Stiffness: This includes engineering fittings, local stiffness, which tests to check that the rear wall of the chassis is stiff enough to avoid a 'hinge effect' at the interface with the engine where there is a very high stiffness change.