Getting Out All the Breaks

Pratt & Miller get ahead of the race by redesigning a brake pedal using ANSYS with fe-safe fatigue analysis software.

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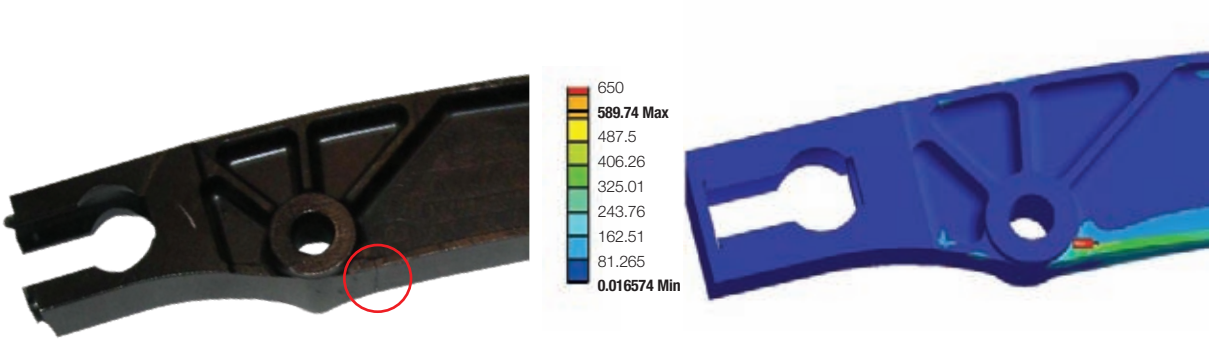
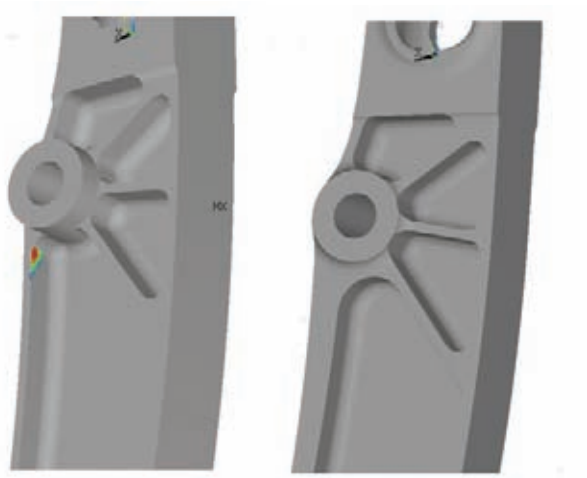
In world-class auto racing, mechanics often reposition the brake pedal face to comply with driver preference. But moving the pedal off center introduces a significant twisting moment — a situation that increases stresses which can lead to metal fatigue.

Pratt & Miller Engineering is recognized around the world as a formidable force in both motorsports and high-level engineering. The Pratt & Miller team discovered that one of its race cars prematurely demonstrated small cracks on its brake pedal faces. Their initial investigation showed that the cracks started near the pivot pin, which led the team to realize that mechanics were repositioning the pedal face. As the pedal face was moved farther and farther off center, the resulting twisting moment resulted in a crack at the high-stress location. Fortunately, engineers discovered the problem before any accidents occurred.

Because the original pedal design had not taken into account any aftermarket modifications, Pratt & Miller engineers set out to redesign the critical component. The goal was to greatly increase the fatigue life without compromising race performance. Simply overengineering any part is not an option in motorsports, as weight is such a vital consideration. Race car engineers have to skirt the limit on parts: Weight costs speed, lap times and, ultimately, the race. With the next race scheduled just three days away, the part had to be designed, verified and machined quickly. To get an optimal redesign in the shortest amount of time, the Pratt & Miller engineering team employed structural mechanics simulation using the ANSYS Mechanical product together with fe-safe™ fatigue analysis software from Safe Technology Limited.



Brake pedal crack with simulation of equivalent stresses



Original design in fe-safe (left) and redesigned component (right)

The original pedal part was used as a benchmark against which to compare various design alternatives. The team set up and evaluated the various options within the ANSYS Workbench environment, which allows users to very quickly set up structural mechanics models — as much as three times faster than with other FEA software. This platform made it especially easy to create the revolute joint at the pivot point on the pedal, then apply a remote constraint to resist rotation where the balance bar connects to the master cylinders. Finally, a remote force was applied to represent the applied pedal force.

The team then parameterized the pedal in the NX™ CAD package with the rib thickness and fillet size as variables. ANSYS DesignXplorer software performed automated iterations with ANSYS Mechanical simulation and the CAD package to determine the lightest possible design without exceeding the material limits. The integration among the various ANSYS packages and fe-safe made the process seamless, and the design team had a great deal of confidence that the redesign would meet the new load requirements.

The fe-safe analysis clearly showed where the component needed to be strengthened in order to reduce the stresses. The simulation also determined how much the stresses must be changed by adding more material, and where the material must be added, to achieve the target design life of more than 1 million cycles. The engineering team chose fe-safe because they felt it offered increased confidence in getting the design right the first time — in effect, outpacing the competition by designing a lightweight part with a lower target fatigue life factor.

Pedal failure corresponding to the ANSYS stress plot, showing how the model was restrained and loaded: loads and constraints (left), original design (middle) and optimized design (right)

The pedal is constructed from normalized 4340 billet and machined with pockets and ribs to produce a light, stiff part. The loading was an assumed worst case, and the fatigue was a simple 0 to full load over 1 million cycles minimum required. The pedal design was improved by thickening the flange near the pivot to resist the twisting moment. The engineering team checked the redesign using fe-safe and found it to have a greatly improved fatigue life, well over the 1 million minimum load cycles. The original design predicted a life of 16,567 cycles, while the redesigned pedal has a predicted life of more than 10 million cycles. The new design is now in production and on the race track.

Pratt & Miller uses fe-safe in conjunction with ANSYS Mechanical software to optimize design, identify stress factors, and determine where unnecessary material can be safely reduced to save weight, and where parts should be strengthened to prevent failure before the target fatigue life. ■