Taking the Metal Out of the PEDAL

Traditional optimization methods are limited in the weight savings that can be achieved; they change dimensions but not the overall shape of the part. Topology optimization, on the other hand, redesigns a part to minimize its weight while meeting loading and other requirements specified by design engineers. KSR International used this new approach to reduce the weight of an automotive brake pedal by 21 percent and decrease structural optimization time from 7 to 2 days.

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The automotive industry is continuing its efforts to reduce average vehicle fuel consumption and emissions. The most effective way to achieve both goals is to decrease vehicle weight. A 25 percent reduction in vehicle weight lessens fuel consumption by approximately 10 percent, while a 25 percent decrease in aerodynamic drag yields only about a 5 percent reduction in fuel consumption.

Early efforts at cutting weight focused on the largest and heaviest assemblies, such as changing from cast iron to aluminium engine blocks. With such large weight reductions already accomplished, automobile original equipment manufacturers (OEMs) and suppliers now focus on squeezing every last unnecessary ounce out of smaller parts. KSR International engineers used ANSYS topology optimization to largely automate the process of redesigning a brake pedal. Compared to conventional design methods, digital exploration using topology optimization reduced structural optimization time from 7 to 2 days while achieving a 21 percent weight savings, which is considerably more than could have been accomplished using conventional methods.

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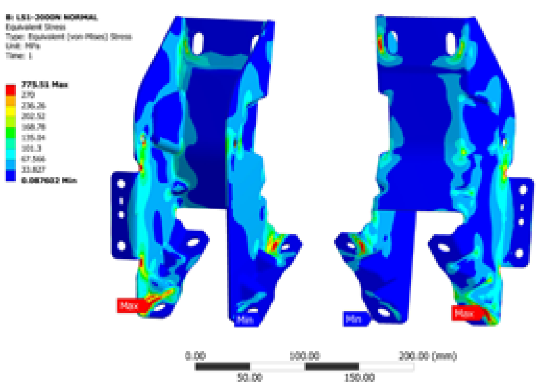
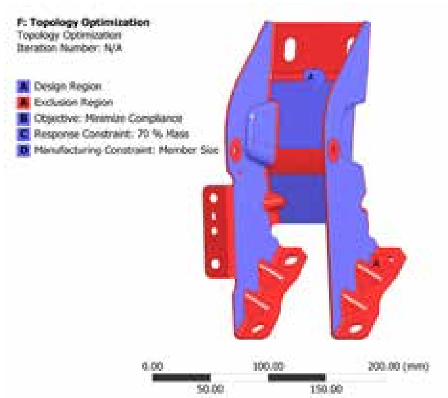
ROLE OF THE BRAKE PEDAL

KSR International is an industry leader in the design, engineering and manufacture of numerous automotive sensors, including accelerator pedal modules, electronic throttle control sensors, adjustable and fixed pedals, electric steering control units, and power modules for automobiles, light trucks and all-terrain vehicles (ATVs). The company makes more than 14 million fixed brake and clutch pedal modules a year. The brake pedal is the primary driver interaction point with the braking system and must transfer all normal and abnormal loading that can occur in panic situations while remaining fully functional.

The brake pedal optimized in this project is designed to withstand a pushing force exerted by the driver of more than 2,000 Newtons and significant lateral and reverse loads. Finite element analysis with ANSYS Mechanical showed low stresses in many areas of the pedal under all four load cases, which indicated the potential for weight removal. The traditional approach to reduce the weight of the pedal was to develop new designs for simulation, either one at a time by manually defining their geometry or dozens at a time by parametrically varying their dimensions. It would take an engineer using this approach about 1.5 weeks to achieve substantial weight savings by decreasing material in low stress areas, rerunning the simulation, then modifying the design based on the simulation results. For this application, conventional methods would have been likely to achieve significant weight savings, but the final design would not be fully optimized from a weight standpoint.



Stress analysis of original design with pushing load shows that stresses are low (blue areas) in most of the part.



Areas marked in red must be maintained during topological optimization.

REDESIGNING THE PART

The ANSYS topology optimizer goes beyond incremental changes, such as adjusting the size or thickness of individual features, by essentially starting with a blank sheet of paper and designing the part from the beginning to meet objectives specified by the engineering team. The topology optimizer is integrated with ANSYS Mechanical within ANSYS Workbench. KSR engineers defined the features that must be maintained in the final design as the outer boundaries and mounting surfaces (where the pedal is attached to other parts) of the initial design. They set up the simulation so that the thickness throughout the part was the same as the previous design, which was required to meet

ANSYS in Action: Topology Optimization
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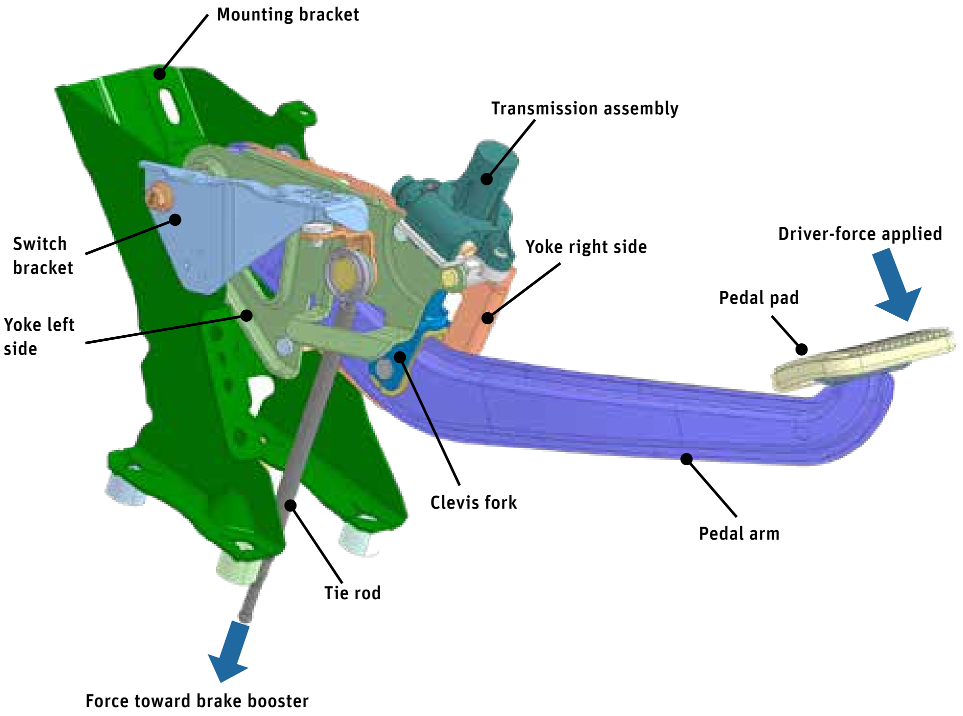
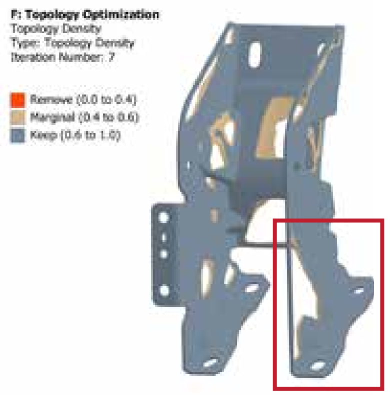


When the driver presses the brake pedal, force transfers from pedal pad to tie rod and activates the brake boosters. The transmission assembly shown is part of an adjustable pedal system used on higher-end large vehicles so that the driver can adjust the brake pad positions (in combination with the accelerator pedal) within the vehicle to the driver's comfort level.

manufacturability constraints of the stamping operation used to produce the pedal. Engineers defined the optimization objective as minimizing the weight of the part while holding stress to a specified maximum value based on the material properties.

The ANSYS topology optimizer defined a geometry for all four load cases that met the design requirements at the lowest possible weight. KSR engineers performed another structural analysis of the new design. They determined that stresses were at acceptable levels throughout the part. They also observed that stresses were very low along one edge of the part, indicating the potential for additional weight savings. Because these low stresses were caused by maintaining the entire outer boundary in the final part, they achieved additional weight savings by removing this boundary.



Initial optimized design provided significant weight savings by removing materials where they were not required. Further weight savings were achieved by removing thin boundary highlighted in red.

SAVING WEIGHT AND ENGINEERING TIME

The optimized design weighs 694 grams, a reduction of 192 grams from the 886-gram original design. The new design can be implemented at no additional cost because a new stamping die must be built whenever a pedal is designed for a new model vehicle. These improvements were achieved in only one and half days, far less than would have been required to optimize the design using traditional methods. It should be noted that this figure refers to the time required to meet structural requirements for a specific configuration of a pedal. Additional time is required to package a pedal for a specific vehicle configuration. The weight savings that were achieved by using topology optimization were much greater than what could be achieved by changing design parameters with either manual or automated optimization. The automotive OEM that buys the brake pedals from KSR is very pleased with the weight savings. KSR plans to use topology optimization in the future to achieve substantial weight savings without having to invest significant engineering resources.