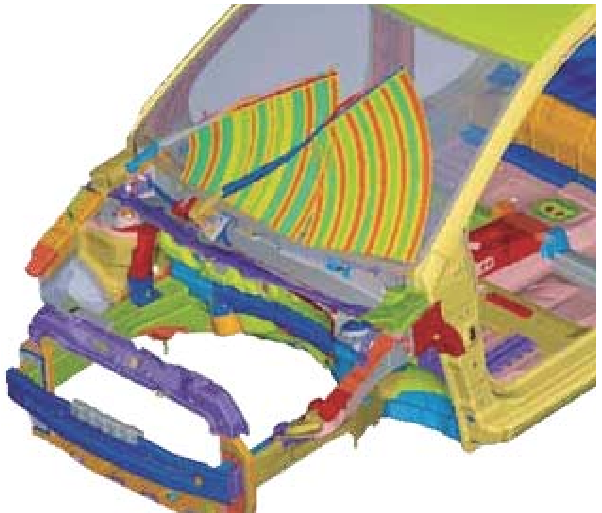
Customer Case Study



Realistic Simulation Saves on the Back-and-Forth of Windshield Wiper Design

Hyundai Motor Company uses Abaqus Unified FEA to perform faster, integrated design simulations

Quick—what's the most important safety device in your car? Did you answer seat belt or airbag? You might be correct on a sunny day. But you can't safely drive a single city block in a rainstorm or blizzard without your windshield wipers. And even when skies are clear you can't see where you're going if your windshield is streaked with mud or smeared with bugs. It's the inexpensive wiper that protects the driver's most important asset: his or her vision.

This fact first became clear when slow-moving horse-drawn carriages were replaced by faster motor vehicles—windshields quickly became necessary to protect people's faces (and hairstyles). But that simple piece of glass didn't solve everything: inventor Mary Anderson watched New York City streetcar operators struggling to see through their windshields during snowstorms and came up with a cleaning brush system, patented in 1903, that had a hand-operated lever that moved a swinging arm device.

Rubber blades soon replaced brushes, and motorized windshield wipers became standard equipment on all American cars by 1917. The current intermittent type didn't arrive until the 1960s and was featured in a 2008 movie about Robert Kearns' battle with major U.S. automakers over patent rights to his invention. Wipers have been added to rear windows and headlights and some are now activated by just the lightest touch of precipitation on the glass.

And they're not only found on cars: planes, trains, boats, off-road vehicles and even space shuttles use windshield wipers. While the blades need periodic replacement, the wiper system itself is considered one of the most reliable of vehicle devices, with a design life average of 1.5 million wipes.

Designing reliability into every vehicle component

Reliability is a key tenet of Hyundai Motor Company, ranked first in a J. D. Power vehicle dependability survey for the third consecutive year in 2010. Founded in 1967 and headquartered in Seoul, Korea, the automaker sold 3.61 million vehicles in the global market last year. Hyundai obviously keeps a very sharp eye on every detail affecting motorist safety, so it comes as no surprise that the windshield wiper has been the focus of considerable attention at the company's R&D center.

"We are looking to optimize both wiping performance and fatigue life of the windshield wipers on every vehicle Hyundai makes," says Sungjin Yoon, research engineer, Hyundai Motor Company. "To achieve that we need to consider all the critical design factors such as blade shape, material, and the structure of the wiper arm and links. Computer-aided engineering (CAE) plays a central role in that process."

Using a variety of CAE tools to evaluate the geometry, kinematics, loads, and stresses on wiper mechanisms during the initial design stages helps the Hyundai engineers meet current wiper performance guidelines. The tools also let them predict the effects of design modifications employing new materials, light-weighting, and/or innovative wiper configurations. Early identification of the most efficient design for each new vehicle concept both speeds up the product development process and reduces prototyping and manufacturing costs downstream.

Abaqus FEA sweeps through the physics of windshield wipers

At the core of the team's CAE work is realistic simulation with Abaqus Unified Finite Element Analysis (FEA). "The physics of windshield wipers are more complex than you might think," says Yoon. "Previously, we'd been performing separate analyses for wiping and durability using two different FEA programs on two different computer models, but we wanted to develop a unified analysis model with which we could study both," he says. "We found that Abaqus has a full range of simulation capabilities that allow us to analyze every aspect of the characteristics we were interested in studying within a single software package."

In addition to its essential back-and-forth behavior, a windshield wiper must, above all else, maintain uniform distribution of pressure between the windshield glass and the wiper blade so the driver's view remains clear (this is known in some engineering circles as "the squeegee effect"). As the blade ages, it must continue to provide a certain level of cleaning ability. And the entire wiper system needs to be strong enough to withstand a variety of loading conditions, from wind-driven rain to heavy snow, and durable to last for many years of operation.

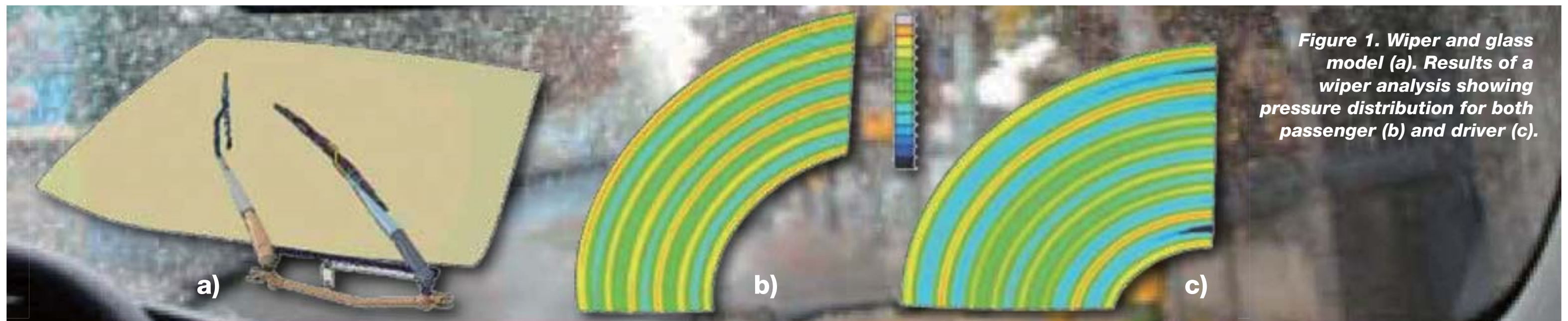


Figure 1. Wiper and glass model (a). Results of a wiper analysis showing pressure distribution for both passenger (b) and driver (c).

Where the rubber meets the glass

To begin their unified FEA inquiries into how wiper design affects both wiping and durability, the Hyundai team starts by looking at the rubber blade alone. Utilizing a material model that fully captures the behavior of the rubber is important in order to accurately predict wiper blade performance. The rubber material exhibits nonlinear elasticity as well as a certain amount of time-dependency in its response. Capturing both these phenomena together is accomplished with a combination of hyperelasticity and viscoelasticity material options available in Abaqus.

Next the engineers model the wiper arm system, a highly interdependent series of links and arms that combine to provide uniform pressure over the full length of the rubber blade (very important for avoiding those annoying streaks on the windshield). To facilitate their FEA modeling the group uses kinematic visualization software with a specific template for each vehicle wiper arm type. A wiper arm assembly is essentially a mechanism, the joints of which are modeled with Abaqus connector elements.

Now the team is ready to run their full Abaqus models to evaluate wiping. The first step is to properly load the wiper blade against the windshield to establish the correct initial contact pressures against the glass. The axial connector element in Abaqus is used to express the behavior of the arm spring. "It's important to establish what the preloading strain is," says Yoon, "because it needs to be taken into account as the wiper moves, when the deformation shape of the blade section on the glass will affect the results over the total wiping area."

A rotational moment is loaded at the base of the wiper arm to replicate the motor torque, at the point where the arm pivots, that causes the arm to slide across the glass with a wiping motion. The analysis can subsequently track the total strain on the blade at specific times and varying temperatures (the latter can particularly affect blade rubber). Final outputs are reported through an in-house post-program that shows the pressure distribution throughout a complete sweep of the windshield glass (see Figure 1). These results can then be compared against established design specifications to determine if the blade is performing as expected.

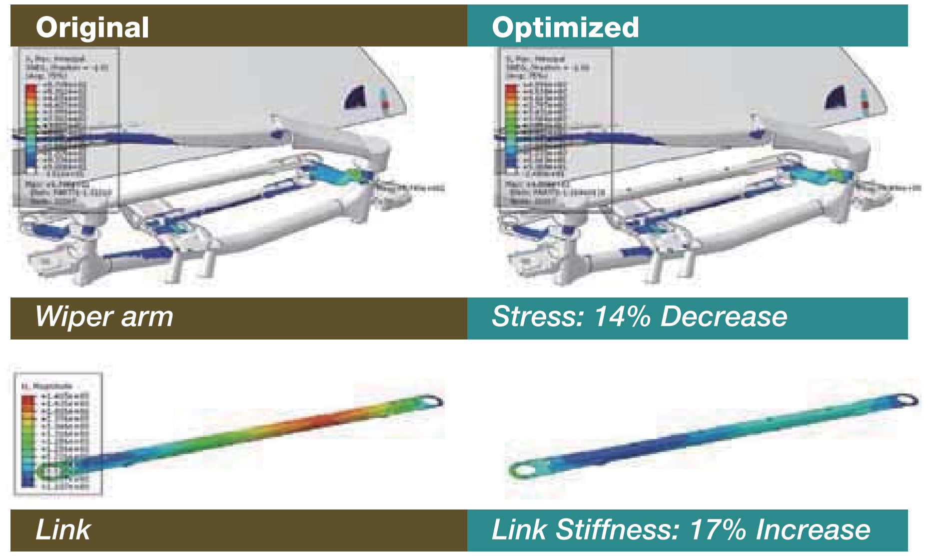


Figure 2. Comparison of FEA results for wiper arm and link before and after optimization.

Seeing multiple analysis results clearly with Abaqus Unified FEA

The second part of the analysis, for durability (fatigue life), can be performed on the same FEA model that was set up for the wiping sequence. "All we need to do is change the boundary and loading conditions in our Abaqus Unified FEA model," says Yoon.

Just as was done with the wiping analysis, a rotational moment is entered as a loading condition. But this time, stationary 'snow blocks' are mounted to halt the wiper blade before the lower and upper extremes of its sweep across the windshield glass model. As the analysis is run, the moving blade arm contacts the snow blocks and the resulting internal forces on the linkage as the blade stops can be determined. Stresses corresponding to these internal forces are used to predict fatigue life during moderate snow conditions or, in the case of heavy snow, plastic deformation or failure within the wiper assembly. These predictions are then validated under real-world conditions that include actual snow deposited on the windshield of a typical mass-produced car in Hyundai's test facilities.

Two for the road: optimizing wiping and durability

With their wiping and durability results in hand, the engineers can then optimize both by varying different design parameters and observing their effect on the overall performance of the wiper system.

"The superiority of the unified analysis model is that it enables us to consider a wide range of design factors affecting both wiping and durability," says Yoon. "With an optimized blade arm and link combination, we can achieve a lighter-weight wiper system while also increasing key link stiffness measures and reducing maximum stresses at the same time (see Figure 2)."

Hyundai's R&D group is continuing to expand their use of templates to speed the windshield wiper design workflow. Their Abaqus analyses are contributing to the buildup of a knowledge base with parameter studies that give them better insight into which design variables have the greatest effect on component operation. They will also be looking at the car-body mounting of wipers. All of which points to their customers' having a very clear view of the road ahead—in any weather.

About Sungjin Yoon

Sungjin Yoon graduated from Hanyang University in 1990 and received a graduate degree in mechanical design engineering in 1992. Since that time he has worked in the CAE department of Hyundai Motor Company. His current interests are rubber analysis and co-simulation in the automotive field.

For More Information
worldwide.hyundai.com/innovation/r-and-d-vision-and-strategy.html
www.3ds.com/SCN-Feb2012