BMW Simulates the Durability Impact of Door Slam Sequences

LMS International, working in conjunction with BMW, FH Aachen and MAKROSS, has developed an analytical process that allows predicting the durability performance of vehicle doors. The scope of this project comprises the use of virtual simulation to predict the ability of components to withstand door slams. It combines explicit Finite-Element (FE) analyses using modal superposition techniques, and durability simulations to convert the obtained local stress histories into fatigue-life predictions. When further elaborated and optimized, this approach has the capacity to provide reliable insights in the durability performance of body and door components, before physical prototypes become available. In the future, this way of working may potentially replace or complement BMW's current approach, which includes performing physical tests on vehicle prototypes.

Tight vehicle crash regulations and high quality and comfort standards continuously raise the bar in vehicle-body and door design. The inclusion of additional crash safety structures as well as the usage of softer rubber elements increase the loading of components when doors are being closed. Also changes made to trim packages for increased passenger comfort, such as integrating new acoustic isolation materials, potentially impact the durability of doors and associated body components. When these components are not properly designed for durability, intensive use of the doors may cause obstructions when they are opened or closed. Such occurrences may generate undesired noise and rust, and may even lead to malfunctioning of the door lock mechanism. In order to avoid these problems and maintain reputation for extremely high quality, BMW performs tests on physical prototypes to guarantee that the durability performance of door and body components is sufficient. This test approach delivers reliable results, although a number of disadvantages are associated with it. Expensive prototypes are required to perform the verification tests, and the evaluation of numerous door slam events consumes a considerable amount of time. And when discovering durability problems, the design needs to be adapted, prototypes modified, and tests rerun, adding both time and cost to the vehicle development process.

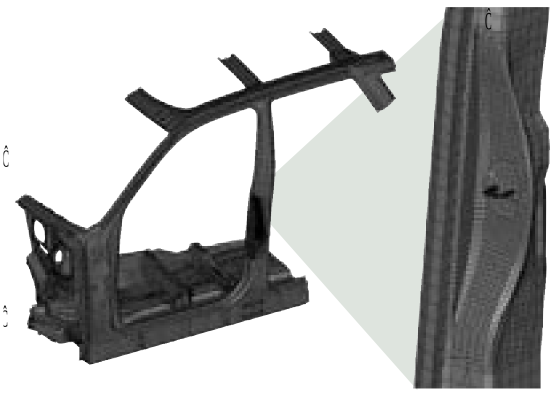
When the door hits the closing hook ...

BMW's goal was to explore the possibility to evaluate the durability of door and body components in relation to door slam events by means of virtual durability simulation. The durability test that was simulated consists of repeated door slam events with a predefined mixture of three different door-closing velocities. The simulations and physical tests involved were carried out on two different designs. The first design exhibited early failures in the metal sheets close to the reinforcement spot welds. In the second design, the reinforcement was revisited to obtain a more satisfactory load distribution.

When studying a door slam sequence in greater detail, three phases can be distinguished. First, the door contacts the rubber grommet on the body, which undergoes large deformations. The kinetic energy absorbed by the rubber is converted into heat and elastic energy. Then, the door hits the closing hook and is completely stopped. In the final phase, the previously stored elastic energy tries to swing back the door, but is stopped by the hook. The precise capturing of the time-dependent contact conditions between the different components of the closing mechanism is essential in simulating the load transfer between the door and the frame. The body-door contact sequence brings about a variable deformation of the rubber grommet, due to the curbed movement of the door and the resulting modal oscillations of the door itself.

Starting from advanced FE modeling and analysis

The FE model that was used to simulate the door slam sequences consists of the door, body frame, grommet and lock. The basic FE mesh of the body frame components was taken from an existing full-vehicle model that was previously used for stiffness calculations. The engineers cut out the area around the front-left front door to reduce the number of elements, and refined the mesh density in the critical area around the lock hook.



Cut-out and refined mesh in the critical area around the lock hook.

Detailed door model from previous side impact simulation.

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