Rainwater Collection by an Automotive Air Scoop

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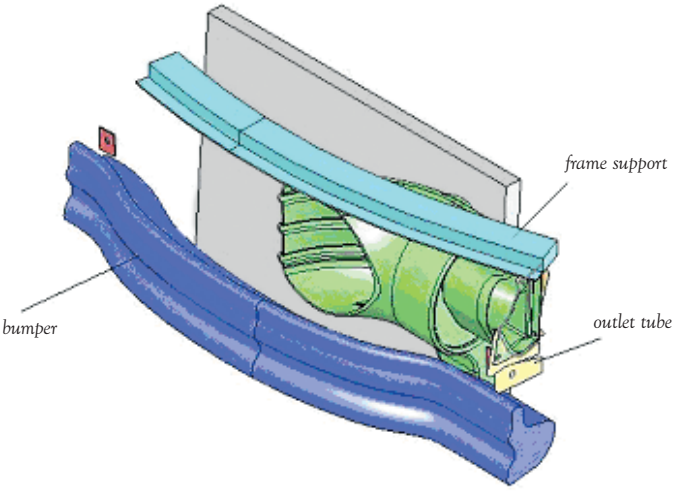
SPORTY NEW CARS MAY LOOK GOOD on the outside, but for many car enthusiasts, it is what lies beneath that counts. To be considered a true high performance vehicle, a car must have a high power-to-weight ratio, which translates into more rapid acceleration, and optimized cornering and stopping capabilities. After-market components that are used to enhance performance must be tested thoroughly, however, so that their operation will not be compromised under any potential driving conditions.

While stock BMWs are considered by most to be high performance cars, Dinan offers a broad range of products and services to enhance the performance of this line of vehicles. Their product line includes engine, driveline, and chassis tuning components, but they also offer complete Dinan Signature BMW Vehicles. For the BMW Z4 for example, one modification is to replace the standard shielded air intake with a ram air scoop. In addition, the standard air filter and housing are replaced with less restrictive units. The new air filter housing is injected molded plastic that resists underhood heat.



The original after-market air scoop (green) is designed with groves to collect rainwater before the air enters the air box

The upgrade provides the engine with a greater volume of air at higher velocity, enabling the engine to produce additional power for faster acceleration. Fully-matched engine software ensures that the increased airflow is accompanied by the appropriate ignition timing and air/fuel ratios for maximum power gains and BMW-like drivability.

The air scoop, which is mounted behind the front grill and in front of the radiator, is designed with groves to collect rainwater before the air enters the air box. When this particular scoop was originally designed, it was noticed during heavy rain that water was entering the air-mass meters and damaging the sensors. To determine the ability of the groves to remove rainwater from the incoming air, a series of CFD analyses of the scoop were performed.

The volume of fluid (VOF) model in FLUENT was used for the simulations. This model is designed to track the motion of two or more fluids (in this case, air and water), as well as the interface between them. The transient 3D simulations were turbulent and isothermal, and employed a user-defined function (UDF) for the inlet boundary condition to account for the raindrops entering the system. The raindrops are simulated as spheres entering the system at equally spaced points. The time interval between drops entering the system was chosen to give the required water inflow.

The simulation showed some problems with the original design. When the car moves at high speed through heavy rain, the inertial forces in the curved air scoop are large. The scoop is quickly filled with an air/water mixture, but the gravitational force is not strong enough to divert the water downwards and out of the scoop. In addition, the opening on the bottom was found to be too small, so that the rainwater could not flow out as fast as it was coming in. A significant amount of water was therefore found to enter the air box in the original design.

Engineers at Fluent and Dinan worked together to redesign the scoop. Rather than make use of grooves and a water outlet at the bottom, the new design does not rely on grooves, and makes use of a water exit on the outer sidewall of the scoop. The new design with the side exit has been found to perform much better than the original one. In addition, the new design is much simpler and more cost effective to manufacture. When the inertial forces are large, most of the water hits the back wall of the scoop and exits, leaving a more purified stream of air to pass into the air box. ■

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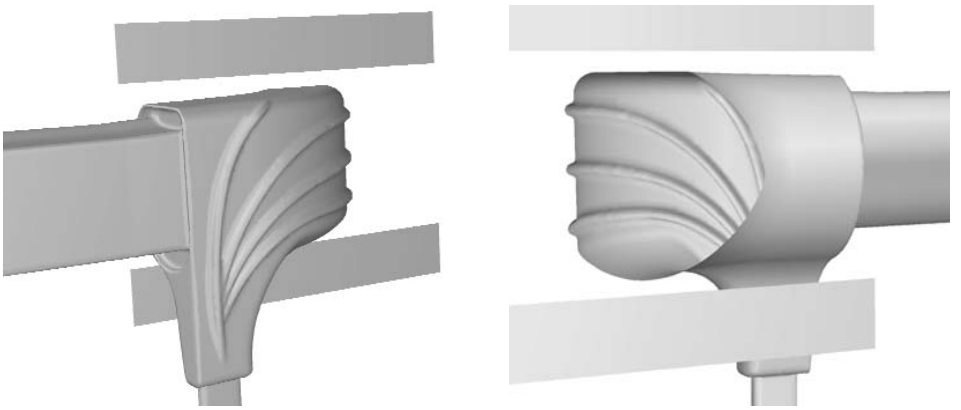
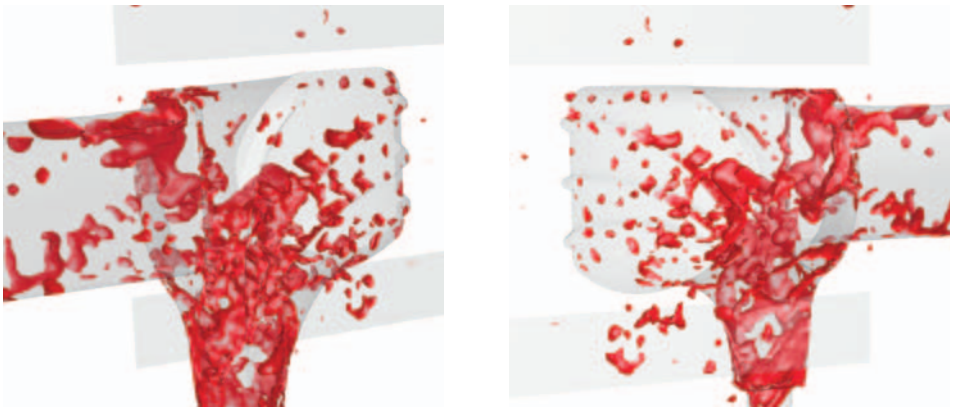
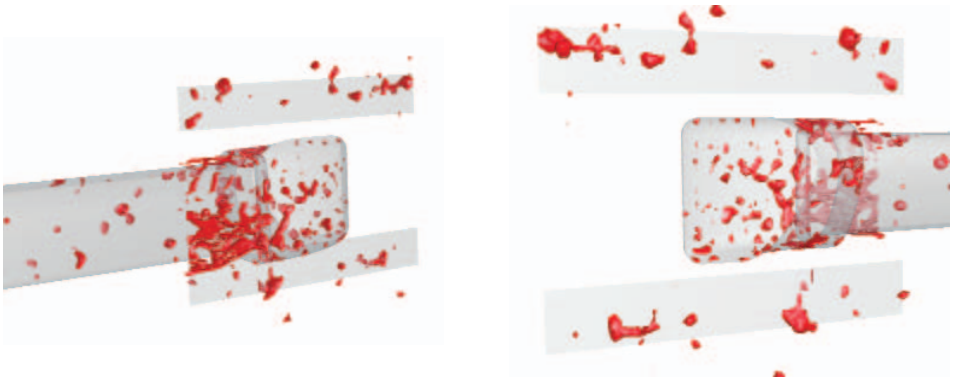


Groves in the original design bend in order to deflect water into the drain pipe; the rectangular surfaces are part of the bumpers



Iso-surfaces of volume fraction show the water distribution for the original scoop design

The modified air scoop design does not employ grooves; instead, the water escapes through an opening in the outer wall



The water distribution for the modified scoop design shows that less water is directed into the air box