Reworking crash protection

on the 2021 Mustang Mach-E

A recent Ford presentation in the USA on how it adjusted structural crash protection for the 2021 Mustang Mach-E's fully electric powertrain provides collision repairers with a sense of changes they may well see on other vehicle bodies.

Unlike a traditional internal combustion engine (ICE) powertrain, the gigantic battery at the heart of a battery electric vehicle (BEV) is often housed beneath the floor, between the rockers. It's a heavy, expensive part that, while normally perfectly safe, can pose a risk to the occupants if damaged in a serious crash. Therefore, you've got to protect it as well as the occupants above it.

At the recent Great Designs in Steel Symposium, Mark Mikolaiczik, Ford vehicle hardware modules integration chief engineer, explained how Ford addressed this problem on the 2021 Mustang Mach-E. "We faced many challenges related to energy management as we moved from the ICE to the BEV, as it meant we had to deal with a 36% increase in test mass and energy input during a crash. That's primarily due to the weight of the battery."

But Ford also faced a 10% reduction in the crush space available in the front of the vehicle compared to an ICE vehicle, which meant the front rails had to handle a 53% increase in crash load. "We therefore increased the rail section, boosting the front rail gauges to 1.9 mm and strengthened the upper load path, the shotgun to the hinge pillar. We also made sure the vehicle had no 'stress risers' related to tyre clearances."

Normally, Ford would send frontal crash energy through the front rails and into the torque box and sled runners. However, Mikolaiczik pointed out that they did not have that luxury due to the package of the battery pack. They had to change their load path strategy. "We therefore had to rely solely on the torque box and send energy into the rockers, which meant we needed a 'very robust dash crossmember' to manage the rails' compressive loads and the powertrain's bending loads. We did a tremendous amount of work incorporating the battery into the structure," he said.

Originally, Ford sought a rectangular battery for maximum energy density, according to Mikolaiczik, but this meant the torque box would need 90-degree square corners to handle the crash energy, which also meant high mass and high cost. "'Well, we knew that wasn't going to work and that we had to make changes." Instead, Ford chamfered the front of the pack, allowing the torque box to have a "smoother transition" between the front rails and the rocker panels and boosting structural efficiency.

Mikolaiczik added that moving up through the floor, repairers would find a lateral crossmember that Ford installed to help handle the compressive load. He described it as a balance between giving customers as flat a floor as possible but handling severe loads from a crash. According to Ford, the extra vehicle mass meant more energy reached the body in white during the Insurance Institute for Highway Safety (IIHS) small-overlap crash test. The test involves the outer 25% of the vehicle's front end hitting a barrier at 40 mph.

Ford "extended the shotgun" to send the load to the upper structure and added crush cans to get the crash energy to the shotgun sooner, according to Mikolaiczik. It also extended the aluminium bumper beam "to engage the barrier" and bolted on a reinforcement to toughen

2021 Mustang Mach-E GT.

The global electrified platform.

the hinge pillar. Through-bolted joints also kept the hinge pillar from separating. "That all worked fantastically," said Mikolaiczik.

Side-impact crashes with the battery-electric Mach-E also presented a challenge to Ford. In an ICE vehicle, you just need to keep the crash forces away from the occupants. But in a skateboard BEV like the Mach-E, the battery needs to be protected as well. Mikolaiczik said Ford needed work out how to absorb the crash energy before intrusion into the battery case occurred. He added that they had lost available crush space "by a factor of 2" compared to an ICE vehicle.

In addition, the battery's mass meant the collision between the vehicle and side-impact test pole now carried a load of 350 Kilonewtons, so Ford decided to beef up the floor pan. Mikolaiczik presented an illustration of the press-hardened steel side sills and crossmembers and Martensitic roll-formed rockers.

Mikolaiczik described the rocker as a three-piece Martensitic roll-formed setup with steel strengths ranging from 1,500–1,700 MPa, which he said permitted smaller sections. He described the overall structure as "tuned to handle BEV loads". He added that through-bolts unite components to achieve a "solid node" for the IIHS' small-overlap crash test.

The rocker extends to the leading edge of the hinge pillar to engage with the small-overlap collision early. According to Mikolaiczik, this allowed Ford to "rigidise" backup structure for that crash energy. The rockers were designed for both side-impact and small-overlap crashes, and he said the ultimate design saved $50 per vehicle compared to the company's early plans, which may have been extruded aluminium. He added that using the multiple steel parts allowed Ford to use traditional welding techniques but still accommodate the bolt-on battery tray and optimise energy path.

The three-piece design allows "B-pillar pass-through," and the split geometry collapses together in side impacts to "maximize energy absorption", and the back of the crossover featured "clever energy management", according to Mikolaiczik.

The electric crossover presented Ford with a 23% rear overhang reduction, and therefore less room to deal with the energy of getting rear-ended compared to an ICE model, and the battery's location also meant the rear rails would need to handle higher loads. Mikolaiczik said Ford built its rear rails from press hardened steel "with a soft zone". The area behind the battery pack was "fantastic for absorbing energy" and was followed by a stiffer region. Thus, both the occupants and battery are protected.

Ford's work has clearly paid off as the 2021 Mustang Mach-E is an IIHS Top Safety Pick and scored "good" ratings on all the IIHS' crash tests. It hasn't yet received ratings from the National Highway Traffic Safety Administration, whose testing includes a side-impact pole strike not featured in the IIHS' regimen.

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