

By Andrew Halonen, Mayflower Consulting, LLC

OBSERVATIONS ON LIGHTWEIGHTING AT GREAT DESIGNS IN STEEL



[Focusing on innovations]

As a lightweighting consultant in automotive, defense and commercial trucking, I follow the information flow. A great place to do that is at the annual Great Designs in Steel (GDIS). Its focus is on steel and the innovations in material development, processing, applications and vehicle performance. This mid-May event is well-organized and extremely well-attended. The host is the Steel Market Development Institute, an organization made up of four steel producers, ArcelorMittal, Nucor, AK Steel and Algoma Steel.

I am always looking for the best material for the application. Nov-

ices think it is about density—steel is heavier than aluminum, which is heavier than plastic. In reality, the material-selection process considers many factors at the same time—material cost, processing cost, capital expenditure, stiffness, fatigue, the ability to integrate to adjacent components, robustness of the supply chain, vehicle safety and the ability to achieve the lowest system cost and weight. Sustainability is often discussed, as in a life-cycle analysis. Yet I do not understand how it comes into the material specification and purchasing criteria.

The presentations at GDIS range from micro-alloying elements to cor-

rosion resistance, from welding to industry outlooks, from new applications to keynotes by vehicle OEMs. So much to learn, so many people to connect with—all in one day. Barely time to eat lunch.

Kicking off the event with OEM presentations is an excellent way to begin because it puts into perspective the value of innovation and that the efforts of the engineering community are critical to produce great vehicles that consumers want to buy. Each presentation was unique—one on global development and production, the other on meeting needs of a passionate customer base dating back to the early 1940s.



2020 Ford Escape

Mike Kozak of Ford presented the 2020 Escape crossover, a vehicle that appeals to those who may have purchased cars in the past, yet want to sit higher in the vehicle and carry more stuff. The Escape structure was well-thought-out such that it incorporates four different powertrain packages—two internal combustion (IC) engines, a hybrid and a plug-in hybrid.

The vehicle was launched in four regions of the world at the same time, each having unique safety-test requirements. Ford strives for a 5-star safety rating in each region. A crash test that is growing in popularity is the IIHS small overlap crash barrier, or SORB¹. This is a crash test that does not impact the highly engineered crash-management system. Rather, all the energy absorption must come

in the quarter panel, the wheel end and throughout the load path extending into the safety cage. Check out this video to see the 2018 Escape in the SORB test, www.youtube.com/watch?v=35W1itsUIP4.

A few noted innovations in the development of the latest Escape include premium steels, boron steel and Smart Steel by MSC. Smart Steel is a layered material composition of a polymeric material sandwiched between steel skins.

Ford noted that both boron steel and Smart Steel met the target of less than \$3/kilogram (\$1.36/pound) weight savings multiplier, which is not a very high value in the world of lightweighting. The integration of these materials is easy, just a spot weld to adjacent steel structure. On the system cost perspective, they met cost targets by reusing past tooling.

Ford is confident that the latest body structure will accommodate revisions over the next five years, not needing a Body-in-White (BIW) revision. Some models offer a panoramic roof window. There is a slight weight increase, yet the upper body structure can accommodate the glass roof without modifications.

In total, Ford was able to shave 5 kilograms (11 pounds) of weight from the BIW by using advanced steels, and overall, the vehicle weighs 90 kilograms (198 pounds) less than its predecessor.

2019 Jeep Wrangler

Every vehicle has an identity, and with the Jeep Wrangler, it's its tough, versatile, off-road capabilities. The Jeep team needs to strike the balance with the realities of the automotive market,



2019 Jeep Wrangler

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maximizing fuel economy, improving ride quality and delivering innovative designs that capture more market share. However, they have a market need that is unique from many vehicles.

One, it has a storied history dating back to World War II, and its loyal followers are passionate about the Jeep and what it is and what it is not. Second, the Jeep Wrangler is often modified in the aftermarket for climbing mountains, as in the Easter Jeep Safari in Moab, Utah. FCA engineering takes these extreme load cases into its computer-aided engineering (CAE) modeling to ensure the vehicle is structurally sound.

The vehicle structure needs to accommodate any of the product options, and perhaps the Jeep Wrangler has more than any other vehicle: the 2-door comes in hard top or soft top; the 4-door in hard top, soft top and a power top that removes the soft top with the push of a button.

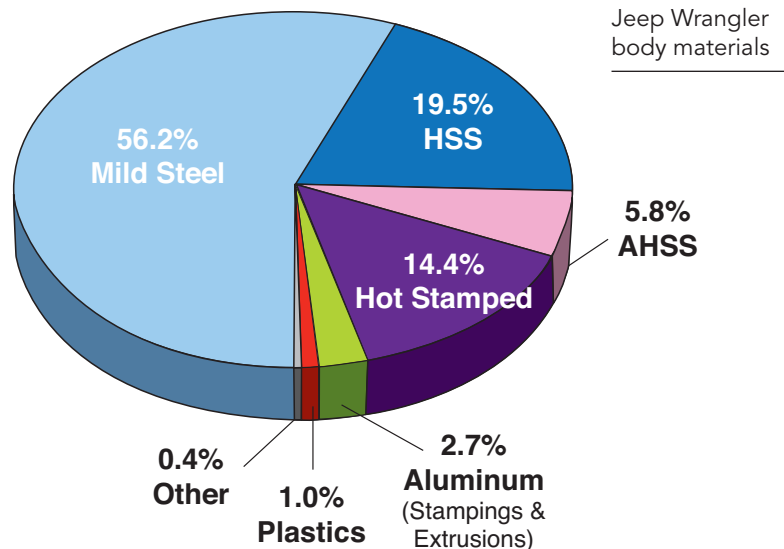
Ms. April Bagley, manager of body engineering, Jeep Wrangler, FCA, delivered a solid message by first identifying the Wrangler market, then a

deep dive into load cases, Body-in-White performance relative to lateral and torsional stiffness. She highlighted a number of areas where bolted joints were minimized to improve torsional stiffness and noise, vibration and harshness (NVH).

One balancing act is on aerodynamics, which is one of the biggest levers to improving the fuel economy. The balance is relative to appearance, and Jeep owners are paying close attention.

The Jeep engineering team was able to reduce the coefficient of drag (Cd) by 9.4 percent with subtle changes on the front, rear and the side mirrors.

From the 2017 JK body, Jeep engineers were able to achieve 66 kilograms (145 pounds) of lightweighting, and in the end, the body is 51 kilograms (112 pounds) lighter. The Body-in-White construction is dominated by steel:



One particular lightweighting innovation is the hot blow-formed sport bar, which extends from the bottom of the A-pillar to the bottom of the C-pillar. The partners were Multi-matic on the forming, using an ultra high-strength steel shaped tube supplied by AK Tube. During the process, after hot blow forming the steel tube, it is immediately quenched in the die to form the martensitic structure and lock in the ultra high-strength mechanical properties. The key to this technology is the ability to produce complex sections with a martensitic steel, avoiding welds and wrinkles for better aesthetics.

Material Innovations

NIOBIUM GRAIN REFINEMENT

Dr. Matt Enloe was formerly a body-structure materials engineer at General Motors and is now a senior technical market-development manager at CBMM. CBMM is the global leader in production of niobium and niobium-products. When we design with metals, there is the typical trade-off between strength and elongation.

Element 41, niobium, as earlier presented by Dr. Curt Horvath of GM, is a micro-alloying element that refines the grain size. A small grain size means improved mechanical properties. Here, using very small amount of niobium in steel, such as 0.05 wt% Nb, both the strength and the elongation increase. In addition, niobium reduces

the tendency for hydrogen embrittlement in press-hardened steels.

New Applications

ENGINE CRADLES

Paul McKune, technical specialist, Martinrea, did a phenomenal job in presenting engine cradles and very low-cost means to achieve weight savings. First, the cradles come in three sizes—small, medium and large. Two vehicles side by side, the 2015 Nissan Murano and 2017 Kia Sorento, are near-identical weight vehicles. Yet one, the Murano, has a large cradle and the Sorento a small cradle.

Different OEM design approaches, yet McKune noted that the ride quality with the large cradle was much better. The Murano floated over bumps and Michigan potholes like a luxury vehicle. The large cradle also offers better crash protection. He said the Kia Sorento likely had to add 5 to 10 kilograms (11 to 22 pounds) to another part of the vehicle since the cradle did not offer crash protection.

Martinrea used a multi-material approach, all steel, yet with selective use of 1180 Mpa-tailored blanks of high-strength steel, and was able to achieve a 15-percent weight reduction for less than \$3.36/kilogram (\$1.52/pound). The general allowable on weight savings is \$2/pound.

What about the 15-year life, and how does a multi-material steel solution compare to aluminum?

Certainly, the OEM customer will decide. Yet if you consider these points, most cradles are steel today and likely will remain steel.

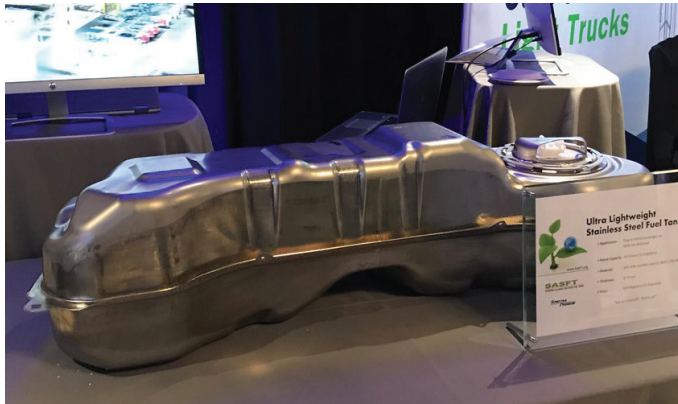
1. Steel cradles have a 15-year corrosion life solution with zinc-rich coatings.
2. A heavier engine cradle like the Nissan Murano not only provides more front-crash protection than an aluminum cradle, it also provides a smoother ride and thus has functional advantages.
3. As shown in the presentation, an engine cradle can go on a 9-kilogram (20 pound) diet, just by switching to a medium footprint steel-cradle design from the large size.
4. Lightweighting with steel can be done below \$2/pound. Aluminum would be more than \$4/pound saved.

FUEL TANKS ON HYBRIDS

Nothing gets me more excited than new applications where a material or a process innovation brings about a disruptive change, an improved product. I mentioned material density, and I will say that it is often difficult to move from a low-density material to a high-density one. However, this is happening now.

Fuel tanks are made of blow-molded plastic because the processing allows it to be shaped to fit the allow-

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Ultra Lightweight Stainless-Steel Fuel Tank for PHEV.
Photo by Mayflower Consulting LLC



able package space under the vehicle. This worked for a long time. However, the onset of hybrid vehicles is driving up the pressure in the tank². This led to thicker plastic walls, increasing the weight. Protective shields are added to polymer tanks to guard from penetration by road debris and from the heat of the exhaust pipe.

Taking the system into consideration, it was time to assess the total package for the best material solution. The new Chrysler Pacifica hybrid, which incorporates many lightweighting innovations, has a steel fuel tank.

The ultra-lightweight stainless-steel fuel tanks are advertised to have cost, mass and capacity advantages.

VERSASTYLE WHEELS ARE LIGHTER THAN ALUMINUM

Today, about 75 percent of the light-duty automotive wheels are alumi-

num castings, when the spares (i.e., donut tire in trunk) are included. Not including spares, more like nine of 10 wheels are aluminum. When aluminum first came onto the scene, they were a mass-add, meaning heavier than steel. Yet because designers discovered a whole new palette of design flexibility, they were accepted anyway. They have since been optimized to reduce mass compared to steel.

Maxion is setting out to prove that steel is back as a lightweighting option. The new VersaStyle wheel advertises an 8-percent weight reduction from cast aluminum and a cost savings, as well. The innovation is one where a robust, low-cost steel wheel design can be decorated by a large variety of injection molded polymer covers displaying exciting aesthetics for a broad customer appeal.

Ironically, while the designers brought in aluminum because of improved design, they just might bring back steel with this design improvement and versatility. In light of the expensive electrification systems, the market appreciates wheels that look good and at the same time, provide cost-effective weight savings.

FORMING EXTREMELY HIGH-STRENGTH STEEL FOR BUMPERS

I was amazed by the formed martensitic steel-crash management products (i.e., bumpers) from Shape Corporation. Forming 1700 Mpa steel, then combining multiple roll-formed products makes for a very competitive bumper system. They also displayed a tubular roof rail, a seat cross member and a cross car heelboard for a battery electric vehicle (BEV)—all using 1700 Mpa steel. Certainly, Shape has pro-

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Maxion wheels. Photo courtesy of Maxion

2013 vs. 2018 Average Net Change in Steel Content by Grade in Pounds / Vehicle

Mild Steel	BH	AHSS (DP)	UHSS/3 rd Gen. AHSS
▼ Decline	▼ Decline	▲ 70.0	▲ 19.9

Changes in Steel Content
Source: DuckerFrontier

cess secrets and well-trained staff to be able to deliver this innovation.

Market Outlook

The easiest means to achieve vehicle lightweighting is via material substitution, especially if the improved material can be processed much the same as the incumbent. DuckerFrontier always does a fine job in laying out the market drivers, in this case the weight reduction needed to reach the fuel-economy regulations. Over five years, from 2013 to 2018, there was a noticeable reduction in the lower strength steels, and corresponding increase in the use of high-strength steels.

There has been so much news on aluminum for closures that I had the impression that aluminum dominated over steel. The opposite is true for most closures, including front and rear doors, fenders, trunk/gate and the roof. In the hoods, aluminum has a 57-to-43-percent edge in applications. **LW**

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