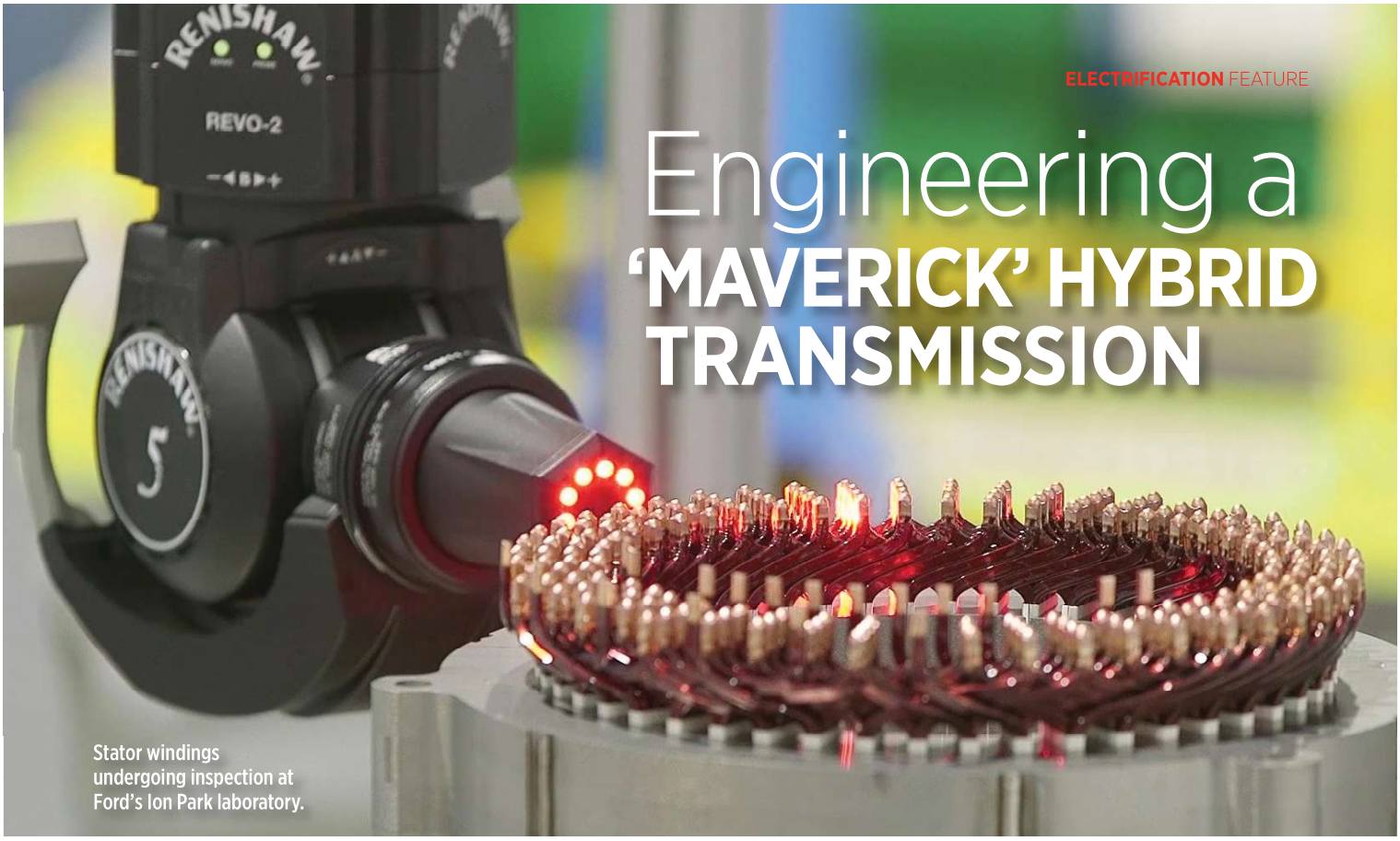
Engineering a ‘MAVERICK’ HYBRID TRANSMISSION



Stator windings undergoing inspection at Ford’s Ion Park laboratory.

FORD

Ford Powertrain engineers marry their new in-house electric machine with the proven HF45 transmission — under aggressive vehicle program timing.

by Lindsay Brooke

Ford’s 2022 Maverick combines many practical attributes that earned the new compact pick-up its North American Truck of the Year title, among them a standard hybrid powertrain which delivers a 42-mpg city (37 mpg combined) EPA fuel economy rating. MCA (Maverick) program chief Chris Mazur called the truck’s aggressive $20,000 base price “a rallying cry” and a “wildly audacious goal” for the development team. Their work included integrating and validating a new **Ford**-designed electric machine into the two-motor HF45 hybrid transmission, on what engineers describe as “a dramatically accelerated” timetable.

“The biggest challenge for us was time,” Manny Barberena, the hybrid powertrain supervisor, told SAE Media. “Go-fast programs make engineers nervous, but we were able to overcome it by being efficient” – taking the learnings, development and base calibration from the Escape Hybrid powertrain that was basically carried over and applying it to Maverick. “It really minimized the amount of re-development,” he said. “We did have to do some tuning to make things work properly with this new transmission but it sure saved a lot of time in going from Escape to this program on the common C2 architecture. It enabled us to hit the ground running.”

Working on the vehicle-development critical path, the powertrain engineers set up two teams to optimize efficiency. Barbarena’s team focused on the vehicle level, encompassing emissions, on-board diagnostics (OBD) and driveability, particularly the NVH transitions from when the 2.5-L IC engine is running to when it’s off. “The transition should be invisible to the customer,” he noted, “but NVH with electrified vehicles is a challenge because the IC engine masks certain noises, some of them rather quiet.” A second team, led by Abdul Hajiabdi, the E-drive system and applications supervisor, focused on the Maverick’s powertrain from a component and systems level.

In addition to the new e-motor - the first of its kind developed in house by Ford — Hajiabdi’s team also juiced up the power electronics for higher voltage and current, and upgraded the other e-machine that serves as the HF45’s generator, “pushing its boundaries” he said.

“We were able to design the in-house motor [which Ford engineering sources said is currently manufactured by Toshiba] in such a way that it shares the footprint and all the transmission interfaces with the machine that’s used in Escape,” Hajiabdi said. “That was one of the major enablers, the synergies, in keeping the cost down without affecting other components.”

The team also revised both the rotor and stator, changing from round distributed winding to flat-wire, hairpin-type windings on the stator. The hairpin design resulted in an e-machine with higher current density and higher torque density, paving the way for a slightly smaller overall motor with about a 20% mass savings. On the rotor side, magnet orientation and tension were re-engineered with innovation: The magnets are molded into rotor core, rather than adhesively bonded.

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Hybrid-powertrain engineer Manny Barbarena's team focused on the revised HF45's vehicle-level functionality.

The collaboration between Design and Manufacturing engineering to support the Maverick HF45 was an engineer's ideal, said Abdul Hajiabdi.

Close collaboration between the Design and Manufacturing engineering groups made it happen.

"Until the in-house motor and Maverick program came along, the relationship between the Design team that I represent and the Manufacturing team at Van Dyke [Ford's Electric Powertrain Center factory] was typically a three-way conversation that included suppliers," Hajiabdi noted. "That changed with the introduction of the in-house program, because now the full design ownership is with Ford. The full manufacturing ownership is still with Ford. So now we have a full in-house team that works with what we call PTME, the manufacturing-engineering team, producing the parts together.

"We were able to come up with the design, take it to the shop, prototype build it, check it for process and quality prove-out," he continued. "In doing so, we noticed that there are certain design criteria that looked good on paper but were not manufacturable." The result was "what the true engineer looks for," he said: the 'sweet spot' between the high function sought by the designers, and manufacturability at scale, with high quality and low cost. "It's the start of in-house electric machines to come, including F-150 Lightning," he asserted.

The Maverick hybrid's 2,000-lb (907-kg) trailer-tow capability put transmission thermal management into focus. Initially this presented a challenge, the engineers recalled, because taking an all-new electric machine with its own heat-rejection signature and cooling it in the carryover HF45 "was not a straight plug-and-play," Barbarena noted. Clever internal "tuning" and attention to lubricant flow ensured the hybrid pickup withstands SAE J2807 tow testing and has helped the powertrain team close the tow-capacity gap with Maverick turbo gas-engine models, which is 4,000 lb. (1814 kg). ■

HF45's Ford-Aisin-TRW heritage

The HF45 has an interesting heritage, according to Craig Renneker, VP product engineering at **American Axle & Manufacturing**. Its predecessor HF35 was one of 18 transmissions launched by Ford between 2000 and 2018, when Renneker was a chief engineer in the company's Transmission & Driveline Engineering.

"The HF35 was one of the great successes," he said proudly. It was based on the Aisin AW PowerSplit architecture (itself inspired by early-1970s TRW technology) enabled by an agreement between Ford and **Toyota**. The deal allowed Ford to use the powerflow of the first-generation **Aisin AW** models HD-10 and HD-20 for their own product. According to Renneker, the powerflow of the Aisin and Ford HF35 "are nearly identical, as are the motors and Denso inverter architecture."

Ford Escape taxi cabs operating in New York City proved the basic design's durability. Renneker recalled getting a hybrid Escape cab back from the field with 450,000 miles (724,205 km) on it that "was still running fine with the original battery." A full teardown revealed transmission internal parts that looked perfect, "good for many more miles," he said.

Renneker points out that contrary to some media articles, the HF35/HF45 design is "not a typical CVT in which the torque multiplication ratio between the engine and the wheels can be varied continuously." He noted that with the Toyota/Aisin PowerSplit concept, the ratios themselves are fixed, but in Ford's unit, one of the electric motors is used to control engine speed to optimize best-fuel-economy or best-power conditions. All of this is managed by the software, with no driver input required. "This speed control is continuously variable, so the 'CVT' terminology is still okay," he said.

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