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Motor Trends

Additive manufacturing drives production of race-ready parts.

By Allen Kreemer, Stratasys, Inc.

Additive manufacturing (AM) has been crucial in the motor sports world for years. In the race for speed and performance, it has been a lynchpin for design and testing. Now, race teams are revealing that AM parts will go far beyond review and evaluation. They have found that AM is ready to hit the track and endure the rigors of high-speed racing.

Figure 1 - Interior of the MINI John Cooper Works WRC.

Motor sports are using AM for direct digital manufacturing (DDM) of production parts. In doing so, teams have demonstrated that additively manufactured parts have the quality and durability to meet the demands of racecars of all types. This trend has been developing for years, but until recently, teams have held DDM as a closely guarded secret that gives them a competitive edge.

NASCAR

Stewart-Haas Racing (SHR) uses additive manufacturing to accelerate the rollout of new part designs. According to SHR senior Design Engineer Matt Johnson, the team uses the Stratasys Fused Deposition Modeling (FDM) process to save machine shop time and material expense. "We always find ways to improve our design from our prototypes. We make revised parts without having to take the time to do a new CNC tool-up and procure more material." [Figure 2]

Figure 2 - Ryan Newman (#39) and Tony Stewart (#14) of SHR race for the flag with the aid of FDM parts.

SHR says that within five months of using the FDM machine, its role evolved to race-ready parts for SHR's #39 and #14 cars. Johnson cites two examples: an oversized radio knob and custom hose ducting.

The knob has a D-shaped hole for mounting onto its stem. This simple feature would have been a challenge for CNC. "To machine the small D-shaped hole would have been very time consuming," said Johnson. "Additive manufacturing was an easier solution."

SHR's second application is making custom connections for ducting that direct air to – and carbon monoxide from – the driver. [Figure 3] Considering its options — machining, molding, and composite lay-up — SHR would have opted for less-than-optimal, off-the-shelf connectors if AM was unavailable. Within a few hours of completing a design, SHR produced custom

Figure 3 - Within hours of SHR completing the design, this custom airflow ducting connection was ready for race day.

duct connectors that optimize air routing to improve airflow and driver comfort. [Figure 4]

Figure 4 - SHR drivers Tony Stewart is a bit more comfortable with optimized airflow ducting.

Joe Gibbs Racing (JGR) has been using FDM additive manufacturing for several years, and it shares SHR's experiences. It added AM as a design and evaluation tool but expanded its applications to include pattern making and DDM. The team has just disclosed that it will produce 225 carbon monoxide (CO) filter housings for this race season. According to Design Engineer Brian Levy, six of the two-piece housings will be used each race weekend. [Figure 5]

Figure 5 - JGR drivers Joey Logano (#20) and Michael McDowell (#18) breathe easier with FDM CO filter housings.

Figure 6 - Optimized two-piece CO housing has difficult-to-machine features.

Levy explained that the CO filter housing was additively manufactured with polycarbonate (PC) material [Figure 6], which JGR selected for its ability to withstand 200 °F (93 °C) temperatures over a four-hour race. The optimized housing design leverages FDM's ability to reduce weight to the bare minimum. "It is a design that would be very difficult and time consuming to CNC machine," said Levy.

"We produce 10 a day in one run with our FDM machine. And we make them on demand, which we could never do with our CNCs," said Levy. "The CNC mills always have long queues, so anything that we can offload to FDM is very beneficial, especially when we are ramping up for race season."

WORLD RALLY CHAMPIONSHIP

The FIA World Rally Championship (WRC) pits cars and drivers in a series of two-, three- or four-day events though some of the toughest and most varied conditions on the planet. At top speed, cars race along tree-lined, gravel courses with blind crests and big jumps. Rally cars have hit jumps at 100 mph (160 kph) and have flown over 175 feet (53 meters) for three to four seconds of airtime [Figure 7]. If the crew gets it wrong, the jarring impact on landing can bend the chassis, rip out the suspension, or injure the driver.

UK-based Prodrive is one of the world's largest and most successful motorsport and vehicle technology businesses, with annual sales of

Figure 7 - Bone-jarring jumps batter WRC rally cars.

around £100 million and a staff of 700f in the UK, India, China and Australia. While the company's roots are in motorsports, more than half of its business is now involved in developing niche cars and new technology for road vehicles. The gruling nature of the WRC series does not stop Prodrive from outfitting its car, the MINI John Cooper Works WRC, with up to 15 FDM parts, according to Chief Designer, Paul Doe. [Figure 8]

Figure 8 - Prodrive's MINI John Cooper Works WRC race with 15 FDM parts.

During design and testing of the MINI John Cooper rally car, FDM was vital in design assessment and testing. Now that the car is racing, Prodrive uses its FDM machine nearly full-time for production parts that include gauge pods, wheel arches, and hood vents. Across all Prodrive team cars and customer cars, these parts have endured upwards of 6,000 miles (9,650 kilometers) of abusive rally racing.

Doe cites many advantages to additive manufacturing. Chief among them is cost. "We make only 25 cars per year, so it is hard to justify tooling costs. FDM eliminates tooling, which keeps cost down and shortens response time," he said. As a designer, he also likes that Prodrive can manufacture anything that his crew dreams up, which optimizes performance. "We're not limited by normal constraints, such as how to de-mold a part from a tool. This opens up new directions and new opportunities for our designs."

The MINI's two-piece gauge pod shows what unconstrained design can do for an assembly. [Figure 9] Manufactured from ABS, the pod integrates all mounting features and has channels for electrical components. If made from carbon fiber, these features would have been manually bonded to the pod in secondary operations.

Figure 9 – FDM gauge pod endures five-G impact forces.

Figure 10 – Adding louvers for style posed no challenge since FDM eliminates tooling.

The gauge pod also includes a hollow, yet completely enclosed, mounting brace that maintains strength while minimizing weight. "We couldn't have done that with any other process," said Doe. Although it is a non-structural part, the pod endures five-G impact forces on hard landings.

In another example, the Mini John Cooper WRC's rear wheel arches were conceived and manufactured in 24 hours. On inspection, FIA took issue with the aerodynamic configuration of the rear wheel area. That afternoon, Prodrive designed wheel arches to alleviate FIA's concerns, manufactured them overnight and installed them the next morning. "FIA was very impressed with our response time. They reviewed the solution and signed off on the car," said Doe. "Today, all our MINI's are racing with FDM-made wheel arches."

In spite of the battering the wheel arches take as gravel pummels them when drivers drift around corners, none have failed, Doe said. "During rallies, our only failure has been the bond [between the part and] the car."

A final example of how Prodrive uses additive manufacturing is for the MINI's hood vent, which was produced with FDM. Instead of a simple lip to dress the opening, Prodrive optimized the design for aerodynamics. The shape makes molding or carbon fiber lay-up very difficult, but with AM, production is simple. The vent is stiff, light, and heat resistant; it extracts air passing over the turbo and exhaust, which can run as high as 1,800 °F (980 °C).

But performance was not the only requirement placed on the vent. At the last minute, Mini's manufacturer, BMW stepped in and requested a central hood louver for styling. [Figure 10] Since FDM eliminates tooling, Prodrive had no problems with manufacturing this redesigned part. This is another advantage that Doe welcomes. There is no commitment to a design; Prodrive can alter its parts as needed. Doe noted, "The FDM technology is so easy to use, sometimes I have to rein people in. They are designing wild ideas just because they can." Yet, Doe concluded, "A lot of the time, we can't justify <u>not</u> using FDM."

Although the racing world has revealed DDM's role in reaching peak performance, the general public will only see the tip of the iceberg. Many AM production applications involve innovative designs that teams will not disclose. So, the next time you are watching a race, consider, "Just how many AM parts are on the cars?" There are many more than you know, but unless you're on the team, you will never see the full extent of production AM use.

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