V-Process Aluminum Decreases Machining for Mustang Manifold from 150 to 90 Minutes

By using V-Process aluminum casting on the air intake manifold of the new Stage 3 Mustang, Roush Performance Products reduced machining time for the part from 150 to 90 minutes. The recently released Stage 3 Mustang, a high-performance version of Ford's Mustang GT, includes a custom air intake manifold. When Roush tried traditional aluminum casting for the manifold, they found that the parts lacked dimensional stability, increasing machining time and adding to the cost. Manifolds produced by TPI Arcade, Inc., Arcade , New York, using V-Process technology are so accurate that one machining setup works for all parts, reducing machining time by almost half and ultimately reducing the cost of the part. In addition, the smooth finish of the V-Process produces an attractive surface. "The parts produced by TPI Arcade Inc. are so consistent that the machinists just set them up and let them run," says Mark Yagelo, design engineer at Roush Performance Products.

Roush Performance Products is a division of Roush Industries, a full-service engineering company, headquartered in the Detroit suburb of Livonia, Michigan. Although primarily known for providing engineering, management, and prototype services to the transportation industry, Roush has developed a significant role in providing engineering and manufacturing for the electronics, sports equipment, and motor sports industries. Roush Performance Products, a maker of high-performance road cars, upgrades commercially available vehicles, both appearance and handling, with track-proven race technologies backed by advanced automotive engineering. Roush Performance Products offers customized versions of a number of vehicles including the Mustang, Cougar, Expedition, and Ford F-150 pickup truck. Its cars are available through a national network of some 200 Ford dealers who sell Roush Performance Products vehicles.

Roush has been selling Stage 1 and Stage 2 Mustangs, based on the Ford Mustang GT, for a number of years. These vehicles have body, tire, and suspension upgrades that change the look of the vehicle but no changes to the powertrain. With the introduction of its Stage 3 Mustang, Roush offers a version of the Mustang that combines carefully engineered changes to suspension, braking, and body systems with changes to the powertrain that greatly increase horsepower and torque. Roush re-engineered the 4.6-liter single overhead cam V-8 engine that comes from Ford, boosting horsepower from 260 hp to 360 hp and leading one automotive writer to call the Stage 3 Mustang "one of the strongest street Mustangs ever offered for sale to the public." In recent testing, a manual transmission Stage 3 Mustang accelerated from 0 to 60 mph in 4.3 seconds. The automatic version reached 60 in 5.3 seconds. Yagelo describes it as "an awesome driving car, running with a Corvette Z06 and close to a Viper."

Engine enhancement

In modifying the Mustang engine, Roush replaced the standard induction system with an Eaton Roots-type belt-driven supercharger. Instead of the Ford intake manifold, they use a new one designed in-house that that incorporates an Allied-Signal dual-core air-to-water heat exchanger or intercooler with electric water pump. They also equipped the engine with a modified mass airflow sensor with a greater range, special Bosch fuel injectors, and a BBK throttle body. "Our approach is unique in that we are the only vehicle modifier that puts a blower on a Mustang and uses a second drive belt to spin the supercharger and the alternator," explains Yagelo. "Everyone else runs them off the one existing belt. Our design takes the load off the other front end accessory drive components and the front main bearing in the engine, dramatically improving durability." Other changes to the Stage 3 Mustang engine include proprietary calibration for the spark and fuel systems that eliminate what Yagelo refers to as "flat spots in the drive that you see in other modified vehicles."

The intake manifold that Roush designed for this engine is a critical component from both an aesthetic and a geometric standpoint. As the first thing the eye sees when the hood is opened, Roush wanted it completely smooth and free of flecks of sand and other debris. The manifold also needs to be geometrically precise because it mates with the supercharger, the cylinder heads, and the intercooler. It also includes a number of mounting holes for rails and coil packs. "Dimensional stability in the casting is critical because it affects the machining we do to create the mating surfaces and the mounting holes," Yagelo explains. "When a part comes from foundry as a rough-cast piece, it includes additional material where you will be cutting so that when you set the part up and make the initial cut to establish the '0 line,' there is material you can machine away. On a part that is not tightly dimensionally controlled, you might machine one surface then go to the next feature and the cutter won't even touch the part. You waste a lot of time moving the part around, or balancing it, to get a consistent zero point for each surface." Dimensionally stable parts, in contrast, eliminate this additional setup time, reducing machining and cycle time and allowing the part to be produced at a lower cost.

When Roush was building the prototype engine, they hired a traditional sand caster to produce several dozen test pieces of the air intake manifold. This was the largest and most complex aluminum casting Roush needed for this project and while the prototyping foundry wanted the job, Roush soon learned that the traditional sand casting process couldn't deliver the dimensional stability they needed. "It took a lot of work to get one of the prototype parts set up and balanced for machining," says Tim Kilgore, director of the machining center at Roush Performance Products. "Then we'd take the next one out of the box and it would balance totally differently. Where we had machine stock on one part there was virtually none on the next part, so we had to go through the entire setup process again, balancing it out with shims." Machining the prototype manifolds took about 150 minutes per part.

More accurate manifolds

Then Roush asked TPI Arcade, Inc. about producing the air intake manifold. "They were the only one who had confidence that they could control the part consistently," says Yagelo. "They use the new V-Process sand casting technology that was developed specially for producing aluminum castings with thin walls and close tolerances." V-Process is a form of sand casting that uses dry unbonded sand that is finer in grain size than that used in a traditional sand casting. The process is accomplished in the following steps. A pattern, a "positive" of the part to be cast, that has vent holes is placed on a hollow carrier plate. A heater softens a sheet of thermoplastic film 3 to 7 mils thick that has good elasticity and a high deformation ratio. The softened film drapes over the pattern. A vacuum draws the film skin-tight over the pattern surfaces and assures precise reproduction in the mold. The mold flask is placed on the film-coated pattern. The walls of the flask constitute a vacuum chamber and the flask is filled with fine-grained sand. No binders are used. Vibration is applied to compact the sand and maximize its bulk density. This avoids the need for jolting or ramming.

The sand is then leveled and a sprue cup formed for the pour. The top of the mold surface is covered with unheated plastic film. Vacuum is applied to the flask to create negative pressure and harden the sand. When the vacuum is released on the pattern, the mold strips easily off the pattern. The drag half of the mold is similarly formed and the cope and drag halves are assembled to form a plastic-lined cavity with the exact shape of the casting. Still under vacuum, the mold receives the molten aluminum. After cooling, the vacuum is released and the free-flowing sand drops away leaving a clean casting. Sand is then cooled for re-use.

One benefit of having the air intake manifolds produced this way is that they cost less per piece. As Yagelo explains, the vendor that produced the prototype parts charged much less for tooling because they were working with plaster. But the per piece cost was quite high. With TPI , the higher tooling cost was balanced out by a lower cost for the 1,000 part run." When the entire fee is converted into a per-piece cost, TPI’s costs less than half as much," says Yagelo. The cost of TPI manifolds is an even better bargain because machining time for these parts is only 90 minutes, compared with 150 minutes for the prototypes. This is due to the accuracy of the V-Process pieces. "The parts are very consistent, so it takes less time to set them up on the machine," says Kilgore. "Basically, the same setup works for all the parts. Also, because each piece is identical, the machining itself is now completely unattended."

The other advantage of having the manifolds produced by the V-Process is a nicer appearance. Parts produced with traditional sand casting have a porous finish because of the grain size of the sand. The sand used in the V-Process is one-third that size, giving the finished product a smoother appearance. Also, the sand used in the V-Process does not contain other materials such as binding clay that can show up in the finished part. "The manifold sits on top of engine so when you pick up the hood it is the focal point," explains Yagelo. "The overall appearance of the part produced by TPI Arcade,Inc is very clean and pleasing to the eye."

The Stage 3 Mustang went into production in March 2001. Prices range from about $39,000 to just shy of $50,000. For Roush Performance Products, having the air intake manifold produced by TPI Arcade using V-Process casting technology has had two key benefits. The part costs less than one produced with traditional aluminum casting methods, yet its appearance is excellent, in keeping with the look of the Stage 3 Mustang.

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