The Chevrolet Z06 Corvette is the fastest, most powerful, and most technologically advanced Corvette in its heritage-rich 55 year history. The Z06 achieves 0 to 60 mph performance in 3.7 seconds, a quarter-mile time of 11.7 seconds at 125 mph, a top speed of 198 mph, and maximum lateral acceleration of 1.04 g. In addition to the Z06’s excellent vehicle performance, the 7.0 L LS7 engine delivers 505 horsepower, while achieving 24 mpg EPA highway mileage rating for 2008. In fact, the Z06 is the first 500+ horsepower vehicle exempt from the gas guzzler tax in the United States. This striking combination of high performance and fuel economy is in no small part attributable to materials and process technologies introduced into the Z06. Many were inspired by products designed and developed for the Corvette C5R road racing program. This article focuses on material and process contributions to the performance of the Z06 Corvette.

**Body and powertrain**

Major modifications had to be made to the

*Member of ASM International*

The Z06 Corvette is a demonstration of how advanced materials and manufacturing processes can be optimized for outstanding performance and fuel economy.

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**Spaceframe architecture**

The standard Corvette has a steel spaceframe consisting mainly of stamped steel components that are joined via welding. To achieve the enhanced Z06 performance and maintain good fuel economy, a substantial spaceframe weight savings was necessary. Therefore, an aluminum spaceframe was designed for the Z06. This spaceframe weighs 126 kg, which is 33% less than the steel frame. To optimize the design of the spaceframe, mass, performance, and cost were carefully balanced. Finite element analysis (FEA) was instrumental to the design of the spaceframe. FEA helped to allocate mass to optimize the structural requirements of the Z06; see Fig. 2. As a result, the Z06 spaceframe includes twenty-one aluminum extrusions selected for their low tooling invest-

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**Fig. 1 — Advanced materials and processes in the Z06 Corvette.**

**Fig. 2 — FEA assessment of Z06 spaceframe.**
ment cost and gauge-optimization potential.

A key enabling technology was a tube hydroforming process. Figure 3 shows a 6063 aluminum frame rail as it is hydroformed. The rail is 4.8 m long and weighs 24 kg, the largest hydroformed aluminum component in the world. The 6063 frame rail is heat treated to the T7 condition, because the resulting excellent combination of strength and elongation provide outstanding crashworthiness.

The remaining components of the spaceframe include eight A356 aluminum castings, a 6061 T6 extruded seatback beam, and several 5754 aluminum stampings. These are joined by a variety of methods optimized for aluminum.

One challenge of the aluminum spaceframe was to manage the stiffness of the aluminum, which has a Young’s modulus only a third that of steel. As a result, the vehicle stiffness goal was set below that of the steel frame. However, through the application of FEA, the team was able to exceed the stiffness goals by transferring loads through to a lightweight magnesium roof frame, as shown in Fig. 4. (Further details on the aluminum spaceframe and magnesium roof frame design are described by Deep et al. in Ref. 3.)

Magnesium engine cradle

The Z06 also has an industry first one-piece magnesium diecast engine cradle, which weighs 10.5 kg, a 35% mass reduction over the aluminum version. The cradle supports the engine as well as the front bumper beam. It also ties the frame rails together, and acts as the mounting point for certain front suspension components, such as the lower control arms.

The interface between these dissimilar metals was a major challenge to the successful integration of this weight savings opportunity. Figure 5 shows the simulation of die fill and solidification for the magnesium cradle. The magnesium engine cradle was in large part selected to improve the front-to-rear weight distribution of the vehicle, which was further enhanced with carbon fiber front fenders and wheel houses, and a floor pan consisting of a balsawood core with a carbon fiber skin. Non-materials-related approaches included moving the battery from the engine compartment into the trunk behind a rear wheel. The Z06, like the standard Corvette, is also balanced by moving...
the transmission toward the rear of the vehicle; a prop shaft connects it with the engine.

**Engine and powertrain**

The remainder of this discussion focuses on key advanced material and process-related contributions to the LS7 engine’s high end performance, as seen in Fig. 6. The LS7 has several racing-inspired components, such as the cranktrain, valvetrain, and exhaust system. Technology advances were instrumental to the engine’s ability to achieve 505 horsepower performance and a 7100 rpm fuel limit shut-off.

The LS7 intake manifold consists of a three-piece friction-welded composite (Fig. 7). It has large straight intake runners optimized for maximum airflow, providing approximately a 20% decrease in flow restriction compared with the Corvette LS2 engine. This is significant, as higher airflow velocity contributes substantially to the level of horsepower that an engine can achieve.

The LS7 has racing-derived CNC ported high flow cylinder heads that are designed to meet the high airflow requirements of the seven-liter engine displacement. To reach this airflow, large 56-mm-diameter titanium intake valves are combined with 41 mm sodium stem-filled exhaust valves; these valves are shown in the CNC ported high flow cylinder head in Fig. 8. Titanium intake and sodium-filled hollow-stemmed exhaust valves were chosen because of their reduced mass in conjunction with their large valve heads. The reduced masses and large valve heads are critical characteristics for the reciprocating valvetrain system to be able to manage the weight of the valves while simultaneously allowing a sufficient cross-sectional area opening to achieve enhanced airflow.

The LS7 intake valve is a Ti6Al2Sn4Zr2Mo alloy. This exotic material was chosen because of its excellent strength and stiffness combined with low density. The exhaust valve consists of a hollow SAE 422 stainless steel upper stem that is friction welded to the SAE J775 stainless steel lower stem and head.

The sodium in the exhaust valve stem contributes to accelerated heat transfer, while the hollow stem contributes to a reduction in the reciprocating mass. The sodium transfers heat from the hottest part of the valve, where the valve head blends into the lower stem, to the upper section of the valve stem where the heat can be transferred through the valve guides.

The large low-mass reciprocating intake and exhaust valves are necessary for the engine to achieve the air flow needed to generate 505 horsepower. In addition, the reduced reciprocating masses of the intake and exhaust valves are necessary for the engine to achieve 7100 rpm. The titanium intake valves are 21 grams lighter than the stainless steel valves in the LS2 Corvette engine, while providing 22% greater surface area.

This advanced valve technology is one of several technologies necessary to reach 7100 rpm. Other high-stiffness, lightweight materials are also necessary for the powertrain to achieve its high performance. These components include the 482-gram flat top aluminum piston shown in Fig. 9. The flat top design allows for enhanced power.
throughput through its 11.0 to 1.0 compression ratio. The piston is coated with an anti-seizure polymer to reduce friction and noise. In addition, the piston assembly contains a shortened, lightweight, high-strength steel full-floating piston pin to improve stiffness and minimize mass. The piston ring lands are anodized for the higher hardness and wear resistance needed for higher performance.

The LS7 has a forged 4140 steel crankshaft that was inspired by the CR5 racing program. The forged steel provides an increased stiffness over the cast crankshaft, as well as the ability to handle higher loads generated by the higher engine RPMs.

Also critical to the ability of the LS7 engine to achieve 7100 rpm and 505 HP are racing-derived forged Ti6Al4V connecting rods, one of which is shown in Fig. 10. The excellent combination of tensile strength, fatigue strength, and stiffness of Ti6Al4V are critical. Each titanium connecting rod weighs only 464 grams, providing ~30% reduction in weight over the ferrous connecting rods, which would have been a modified forged powder metal FC0205. Lighter titanium connecting rods result in reduced loading on the rod-end and main bearings, thereby allowing the bearings to be designed for minimal friction.

**Exhaust manifold**

The Z06 LS7 engine has exhaust manifolds designed with hydroformed 309 stainless steel tubes and 304 stainless steel jackets, whereas the LS2 Corvette engine has more conventional cast iron exhaust manifolds. A CAD rendering of the LS7 exhaust tube and jacket design is shown in Fig. 11.

Each LS7 exhaust manifold consists of four hydroformed tubes and a stamped jacket that are metal inert gas (MIG) welded to the inlet flange. Because the exhaust tubes are welded on only one end, they are free to float inside the jacket. This allows them to expand and contract freely during thermal cycling, which equates to long term durability.

The exhaust tube internal geometry at the inlet starts out with a “D”-shape, after which the inside diameter varies in a complex way to control cylinder-to-cylinder pumping losses and keep restriction to a minimum.

The key to this design is “restriction vs. pumping losses = horsepower/torque,” a relationship that assists the LS7 engine to generate 1.8% more power than the LS2 exhaust manifold, and is a major contributor to its higher horsepower (505 HP vs. 400 HP). Analytical data helped to determine proper sizing and length of the pipes, whose sophisticated internal geometry drives the need for the hydroforming technology. The exhaust tubes come together at a wide-mouth collector that directs the airflow into the catalytic converter.

These material and process technology advances are important not only because they contribute to the Z06 Corvette’s unprecedented combined performance and fuel economy levels, but also because these technology innovations lay the foundation for higher-volume vehicle programs.

**Future developments**

As we approach the end of the first decade of the 21st century, the automotive industry is going through unprecedented technology changes, many of which will be materials and materials-process intensive.

General Motors envisions a transition from the current mechanical linkage and pump designed propulsion systems to electronically driven architectures. New generations of vehicle architectures will be propelled by electricity generated initially from internal combustion engine/battery hybrid systems, and will subsequently transition to fuel cell/battery systems. Undoubtedly many of the component and system innovations in the Z06 will provide a foundation for technologies that will be incorporated into the electronically propelled vehicles of the future.

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