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Increased weight impacts safety and comfort aspects such as braking performance, handling characteristics, and vehicle body motion. As a result, stopping distance might increase because the tires carry more vertical load without increasing maximum longitudinal forces by the same rate. The same applies to lateral tire forces so that impeded lateral tire performance limits maximum lateral acceleration and handling qualities. Additionally, a higher body (sprung) mass increases body displacements such as roll, pitch, and heave, which has a negative impact on safety and comfort.

Adapting tires, springs, dampers, and antiroll bars according to the increased vehicle weight can easily mitigate some of those implications; but increased weight cannot be compensated for completely. That is why some compromises in vehicle dynamics are conceptual for a hybrid compared to a conventional vehicle.

There are three main aspects in vehicle dynamics that need to be considered: safety, comfort, and controls. When a HEV is derived through redesign of a conventional vehicle in particular, these aspects need to be regarded carefully:

- Safety—yaw stability, handling, and braking performance should not be affected by the interactions of the hybrid system with powertrain and braking systems
- Comfort—roll, pitch, and vertical motion should not be affected by the changes due to the hybrid system
- Controls—driver/passengers should not notice any changes in steering or braking characteristics when hybrid controls interact with powertrain or braking systems.

As the most important features of a HEV are electric driving, engine start/stop, boost, and regenerative braking, these aspects need to be observed more closely to evaluate their impact on vehicle dynamics. And regenerative braking, in particular, is unprecedented in the field of vehicle dynamics given the characteristic of using two relatively diverse braking options in one vehicle.

To ensure yaw and braking characteristics similar to a conventional vehicle, the respective controller needs to limit regenerative braking to low and moderate lateral acceleration, suspend regenerative braking at the latest upon the intervention of vehicle dynamics control systems, and control the center clutch or variable transmission of an all-wheel-drive system depending on the actual use of regenerative braking.

The implications for safety, comfort, and controls show that a detailed integration of hybrid architecture, driveline concept, vehicle dynamics controls, and suspension is necessary. A decoupled braking system that controls friction and regenerative braking simultaneously is a key component for such a concept.

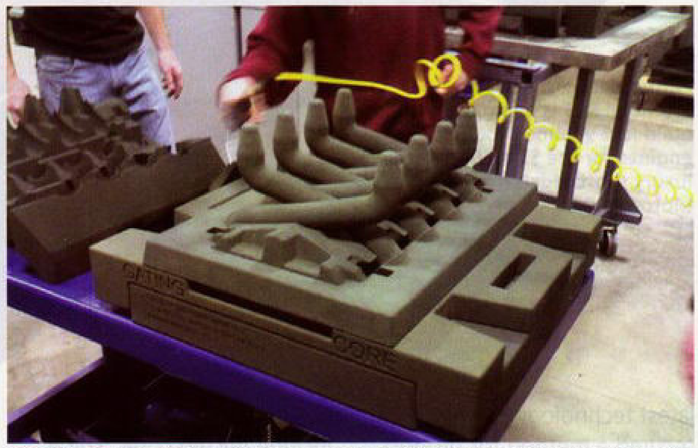
It appears that hybrid and by-wire technologies complement each other perfectly as they use the same electric power architecture and benefit equally from electric chassis systems. Hence, an integrated approach of those two advanced technologies increases powertrain efficiency while maintaining vehicle safety on a high level.

This article is based on SAE technical paper 2009-01-0442 by **Sven A. Beiker**, formerly of BMW Hybrid Technology Corp., and **Renate C. Vachenauer**, BMW Group. The paper will be presented at 11:00 a.m. on Wednesday, April 22, in Room 03-45 of Cobo Center as part of the Vehicle Dynamics and Simulation session at the SAE 2009 World Congress.

Manufacturing

DiMora deploys patternless casting technology

DiMora Motorcar Co. in January took another step toward producing its $2 million sport luxury sedan. By signing **ProMetal RCT** LLC, an **Ex One** company, as its



Like the future DiMora Volcano engine, this Ford manifold casting was produced by ProMetal RCT directly from a CAD file, without patterns or fixturing.

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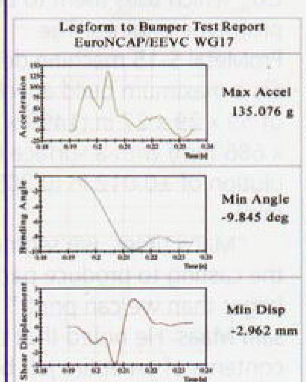
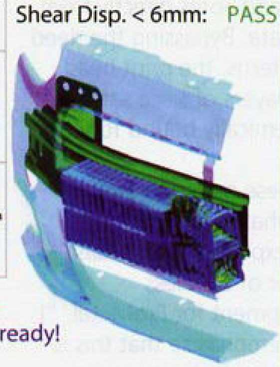


NCAP Requirements
Acceleration < 150 G: PASS
Bending Angle <15°: PASS
Shear Disp. < 6mm: PASS



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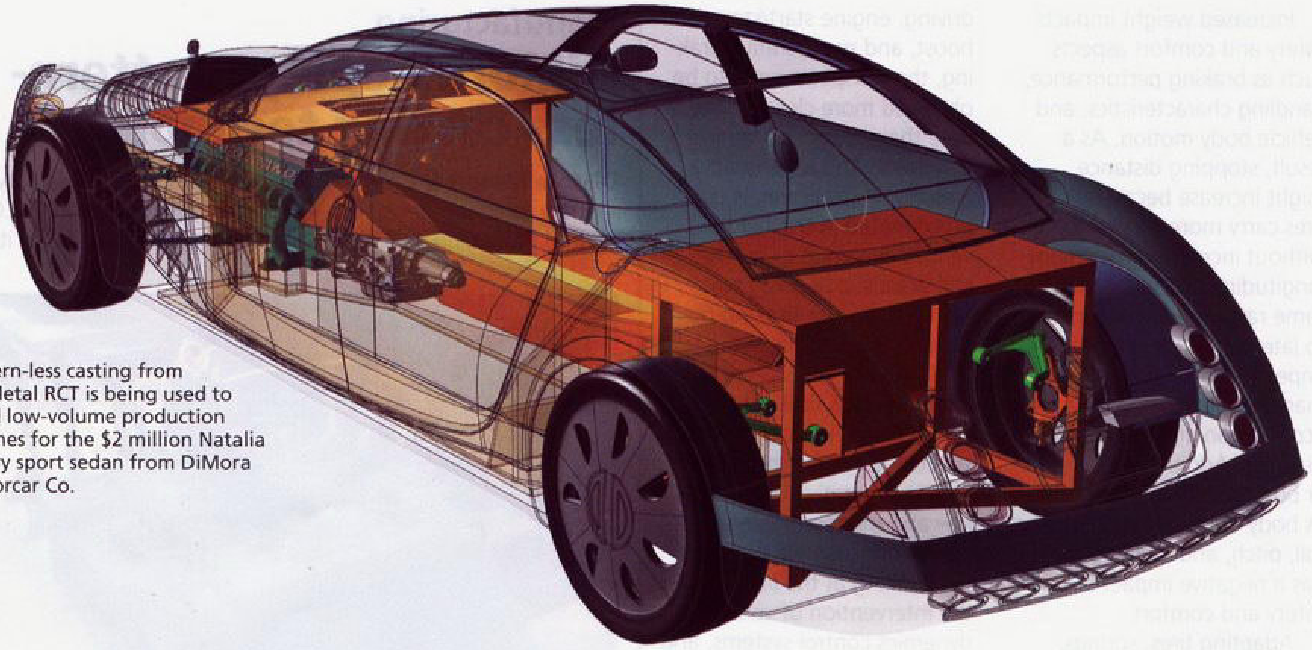

Pattern-less casting from ProMetal RCT is being used to build low-volume production engines for the $2 million Natalia luxury sport sedan from DiMora Motorcar Co.

latest technology partner, it secured a method for producing castings for the 1200-hp (895-kW) Volcano V16 engine that will power the Natalia SLS 2. An integrated product and process team will use the ProMetal digital 3-D printing technology to produce engine castings without the need for patterns or tooling.

ProMetal's rapid casting technology (RCT) is an additive-manufacturing process that automatically builds sand molds and cores directly from CAD data. Bypassing the need for patterns, the print head builds layers of silica sand that are chemically bound for cohesion.

"These materials are exactly what some foundries use," explained Dan Maas, Director of Business Development for ProMetal. "I like to emphasize that this is rapid manufacturing, since the alloys that are poured are exactly the same alloys currently used in foundry processes."

The technology obviates the need for parting lines, draft angles, and undercuts, Maas said. "Design features used today [with this process] include nested cores, spiral vents, volute shapes, and integration of multiple components, in-situ cores, and unique rigging geometry to minimize turbulence."

The DiMora program builds on the success ProMetal has had delivering three S-15 RCT machines to **Ford** Motor Co., which uses them to build prototype engines. The ProMetal S-15 machine delivers a maximum build envelope of 59 x 29 x 27 in (1499 x 737 x 686 mm) with a surface resolution of ±0.012 in (0.305 mm).

"Many times, we segment the casting to produce parts larger than we can print," said Maas. He noted that the contents of an entire job box is produced in about 48 h.

While providing many advantages, the S-15 is currently a low-volume solution. Depending on the application, the break-even point for choosing RCT over a traditional patterned method is a volume of pieces in the hundreds. "Complexity really drives the break-even point," said Maas. More complex parts would be more cost-effective using RCT.

The system seems to be a good fit for the Volcano engine. "This technology is at the forefront of digital additive manufacturing for the production of complex 3D shapes," said DiMora Motorcar Founder Alfred DiMora. "During the design process, being able to accomplish in a few hours what used to take days allows you to refine your design through additional iterations. Eliminating patterns and tooling saves time and reduces waste, making the entire process faster, cheaper, and greener. The size of the casting boxes is another thing that attracted us to their technology." DiMora noted that the company expects to build 75 Volcano engines for the Natalia program and an additional 100 engines for the boat and marine market.

The digital nature of ProMetal RCT's process may be just as important as its other advantages. DiMora, the sole owner of DiMora Motorcar, intends to build a new automotive business model. ProMetal joins more than 50 technology partners that are sharing their technology with DiMora, both to help build the Natalia and expand their own development. The Natalia may only be the first car DiMora produces. Once it proves its basic technology, look for a mass-market car to follow, according to DiMora.

Digital data is a key enabler in this new business model. "[Digital design data] eliminates overhead and allows me to share quickly and easily with my partners," said DiMora. "For example, I just send a CAD file to ProMetal and tell them to build it. We look at any problems over the Internet and over Skype. I am taking Silicon Valley, merging it with Detroit, and calling it the new Detroit."

The company is two and a half years into a five-year development program for the Natalia. It expects to start dynamometer testing of the Volcano in about eight months. Simultaneously, the company will also test four engines on a track in test vehicles.

Bruce Morey