The Lotus Elise: *A Technological Tour de Force*

By Gary S. Vasilash, Editor-In-Chief

Although the Elise is not available in the U.S.—it doesn't come equipped with airbags—the car, which was introduced in Europe last year, has stirred up a sensation. Key to the car's looks and driveability: the clever use of materials, including plenty of aluminum.

Car magazine, a British publication, held its second annual Design and Technology Awards last October. The vehicle named "The Most Innovative New Car in Production": the Lotus Elise. It received the nod over the BMW 5-series, the Renault Scenic minivan, the Mercedes SLK, and the Porsche Boxster. The chassis and brakes on the Elise also picked up the "Best Innovation in Production Award." Meanwhile, in another section of the same issue of the magazine in which the awards are detailed (December `96), results of a road test of 20 different cars on a British race course are presented. The lineup includes the Lamborghini Diablo SV, the Porsche 911, the Honda NSX, and the Jaguar XK8—many of your not-so-basic, stratospherically priced vehicles. The car that was judged to be the best-handling: the Lotus Elise. If the car was available in the U.S.—and it's not (no airbags)—the price would be on the order of $30,000 to $32,000.

Car magazine is not alone in hailing this vehicle, which is quite evidently a technological and driving tour de force from Lotus Cars Ltd. (Norwich, England), the company established in 1955 by racing great Colin Chapman. Chapman may have died comparatively young—in 1982 at age 54—and the company he founded may now be owned by a Malaysian automaker, Proton (which acquired Lotus Group International on 30 October 1996), but his philosophy lives on at the car maker/consultancy. As Kenneth Sears, head of Vehicle Engineering, Lotus Engineering, Lotus Cars, puts it, "One of the things that people identify with the company is gaining some performance advantage through the development of new technology. That's the constant theme of all Lotus cars. We've always come out with performance in a vehicle sector, and that's been associated with new technology." That's the strategic approach taken. On a more tactical level, there's this from Tim Holland, the executive engineer at Lotus Engineering's Detroit office (Walled Lake, MI): Lotus' philosophy for years has been to make each component do as many tasks as possible. Every design feature has to carry out as many functions as possible."

The Car Makers' Engineer. There are a few things that are useful to know about Lotus before getting into the Elise. First off, it is a company that is primarily an aid to other auto manufacturers. Each year, some 500,000 vehicles are produced with Lotus-designed engines (sometimes credited, sometimes not). In all, about one million vehicles per year are produced that are equipped with Lotus-designed systems; the company is especially noted for its suspension work. On the engineering side of the business, which represents about 80% of the firm's revenue, approximately 800 people do the contract engineering and development. On the car-making side, there are 300 people. Engineers are assigned to the car side for a finite period of time: they do their jobs and then get back to contract engineering. In the case of the Elise, the whole project went rather quickly: from clean sheet to production in 27 months. That timing was not a fluke. According to Sears: "We've always been able to do very short programs because we work with lean teams and highly motivated people. We've got fast response throughout the whole company." Lotus engineers also fully developed the Lotus Type 918 V8 engine, which was introduced in March, 1996, in 27 months. It is the first new Lotus engine since 1972—and it is anticipated that the engine will have a product life of 20 years. Still, of the Elise, Sears says, "This particular car is the most-efficient design program we've ever undertaken."

Getting the Right Price & Performance. One of the primary objectives of the Elise program was not just to make a high-performance vehicle, but to make one that was affordable. This had two ramifications. One was that the performance was not going to affordable. This had two ramifications. One was that the performance was not going to be achieved through the use of a powerful engine. In fact, the engine that powers the Elise isn't actually built by Lotus: it's a 1,796-cc, 118-hp four-cylinder Rover K-series engine. So this means that key to achieving performance would be through the production of a light-weight vehicle. Still, there is the over-riding caveat: "From a business point of view," Sears says, "it needed to be a low-investment program."

First off, there's the body. Lotus has been using glass-reinforced composites for body structures since 1957, so there is extensive in-house familiarity with the material. Holland points out that whereas some people might assume that the rationalization for the use of plastic body panels goes to the point of achieving low mass, that's not it: "If you made an Elise out of steel, there wouldn't be much in it. The advantage of the material to a company like Lotus, which is quite small, is in the investment cost." The company produces soft tools—plastic-faced tooling—which allow the economical, though slow, production of body panels. Given that initial plans called for the production of just 700 Elises per year (a number which has been pushed up to 2,500 because there is a year's waiting list that involves a non-refundable deposit: this car is sought!), the slow rate is not a problem.

"The big car makers are looking at composites bodies," Holland observes, "but what always scares them is the processing time. If you stamp out a panel in steel, *whomp!*, it's there. It takes a lot of investment to get there"—consider the price of the press, the tooling and the auxiliaries—"but once set up, you can get the steel panels quickly." Sears thinks the cross-over point at which the economies of scale make stamping steel the right choice is at from 20,000 to 30,000 units per year.

Not only does the use of composites suit the Lotus production methods but, Sears notes, "They can be engineered to have some very advantageous features. Composites can have very high specific energy absorption, and we rely on carefully designed composite components in the front of the car for crash-energy management." The front of the car, beneath the skin, features a series of horizontally oriented cones. Holland describes the arrangement as being akin to an egg carton on its side. This structure has been designed so that it has a known deformation pattern. Energy absorption is critical because the chassis is tremendously stiff—better that the car body should absorb the energy than the bodies of the driver and passenger.

Advancing Aluminum. The key factor in creating the light-weight vehicle is the extensive use of aluminum extrusions to produce the frame. "We wanted to absolutely optimize the use of extrusions," Sears says. "We wanted to make the frame out of as small a number of components as possible. We didn't want to introduce additional pieces on the joints. We wanted to join each piece directly to the next piece."

The chassis is actually produced for Lotus by Hydro Aluminum in a facility in Denmark. Hydro Aluminum produces the extrusions, then assembles the chassis, which are then shipped to the Lotus plant in England.

Extruding aluminum is a known process. It helps address the low-investment target for the vehicle: the total number of dies used to produce the extrusions for the Elise is 27.

The real issue—the area where Lotus engineers had to develop technical expertise, which Sears thinks can be satisfactorily utilized by more-mainstream auto makers—was in designing the elements so that (1) each would perform as many functions as possible while (2) each would be as light as possible. In addition, the aluminum bonding method had to be developed.

Although aluminum structural elements can be welded, the engineers opted not to use welding for a number of reasons. For example, because welding can cause heat-induced distortions, it would have been necessary to beef up the areas on the components where the welding would occur. Since extruding materials results in uniform sections, that would have meant adding additional pieces, which, as Sears uniform sections, that would have meant adding additional pieces, which, as Sears comments, was not part of the plan. Another consideration: welding results in the modification of the material properties at the weld site, so there was a concern that corrosion might be a problem down the road.

The extrusions are designed so that they have, in effect, tongue-and-groove mating. The pieces interlock. The interlocking is such that it helps assure the assembly process (the chassis is hand-built in a single fixture by as few as three people) and it controls the thickness of the adhesive in the joint.

According to Sears, when the decision was made that bonding was the correct technical choice, Lotus engineers couldn't find anyone with the expertise necessary. So they worked with Hydro Aluminum and engineers from Ciba (the adhesives supplier) to develop the methods, materials and testing for the bonding. (It should be noted that rivets are also used, but as a secondary element: the rivets stop the onset of peeling that can occur when the adhesive joints are in a high bending mode.)

"We believe that you should design the structure to be very efficient. That sounds obvious," Sears says, "but for most cars, the structure tends to be what's left after everything else has been put in place." It is an after thought; this sort of thinking leads to things like diagonal structures beneath the hood to help provide additional rigidity. "Normal structures work well at the end of the day, but there are penalties in mass, cost, and usually in performance." None of these penalties were acceptable for the Elise. The resulting structure weighs just 154 lb., yet it meets safety regulations and provides durability and torsional rigidity.

A Technical Material. Beyond the chassis, aluminum is used extensively. For example, the 11.1-in. diameter brake discs are an aluminum metal matrix composite, which is thought to be the first use of such brakes on a production vehicle. The engine cover (the Elise has a rear-engine configuration) is stamped aluminum: "It' partly because we wanted to get some experience with the technology," explains Sears, "and because we felt that it reflected the theme of aluminum in the car, the technical aspects." The technical aspects includes aesthetics: there are wide areas of unadorned anodized aluminum in the interior. When you get behind the wheel, the car, with stark simplicity (even the radio is an option), seems to be very much a well-built machine.

(Sears notes that the type of buyer of an Elise tends to appreciate the technology represented by things like stamped aluminum engine covers and the sizable extrusions used for the door hinges. So attention is drawn to things like that.)

"We're amazed at how well the Elise has been received," admits Sears. Given what they've accomplished, they shouldn't be.