Putting *Simulation Muscle* Be Sporty Concept C

by **Beverly A. Beckert**

Sporting spirit. Performance. Technology. Driving pleasure. Steering wheel feel. Control. That's what Alfa Romeo captures in all of its autos.

The 8c Competizione is no exception. This new sporty concept car, introduced in 2003 at the Frankfurt International Motor Show, features a distinctive Italian style calling to mind two classic powerhouses – the 8c sports cars of the 1930s and 1940s developed by Vittorio Jano, and the 6c 2500 Competizione sports coupe from the 1950 Mille Miglia race.

It is said the 8c Competizione will combine extraordinary handling performance with

Optimization technology delivers **innovative suspension design** for Alfa Romeo's sleek concept car.

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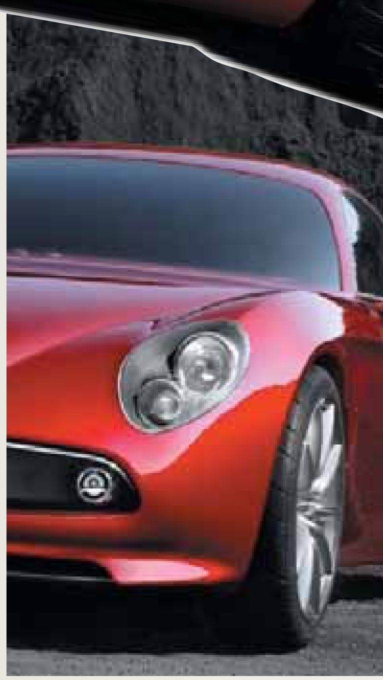

The Alfa Romeo 8c Competizione concept car made its debut at the 2003 Frankfurt International Motor Show.

exceptional comfort. Contributing to its performance is a new double-wishbone front and rear suspension.

But this is no ordinary double-wishbone suspension. It features a distinctive shape, including all new arms and linkages. What's more, Alfa Romeo applied leading-edge optimization technology to fully develop this innovative design.

Close Collaboration

Rocco Longo, manager of Altair Italy's Vehicle System Group, worked closely with Alfa Romeo on the development of the chassis (front and rear suspensions) of the 8c Competizione concept car and, in particular, the new upper control arm (UCA). The entire project involved 16 people and took approximately one year.

Longo explains that Altair Italy created a unique methodology for the project. "We used the optimization, multi-body and finite-element modeling features of HyperWorks," he says, "combining them with packaging check capabilities, which are typically done in a CAD system."

This methodology is new to the industry, according to Longo. He notes that Altair has created a specific environment that automates the process of checking component packaging. It considers the compliance of the elastic parts (i.e. bushings, stabilizer bar, flexible structures) as well as the production tolerances of the assembly. CAD system packaging tools only consider models as rigid under kinematic motion.

"We are providing a richer picture by taking compliance into account, which reduces the margin of design error," he remarks. "The advantage of our approach is that you develop a design closer to reality – and do so in a shorter time frame."

Longo started to consult with Alfa Romeo in 1999, customizing libraries for vehicle dynamics. He then moved to several suspension optimization projects for development vehicles. In 2001 and 2002, he worked in-house at Premium Platform, a joint venture between Alfa Romeo and SAAB based in Sweden.

"In all these years of collaboration, we have built up a good relationship with Alfa Romeo based on trust, mutual knowledge and reliability," says Longo.

Alfa Romeo Director of Handling and Ride Comfort Philippe Krief agrees. He explains that Alfa Romeo selected Altair for this project because Altair understood Alfa Romeo's philosophy with regard to handling, comfort and performance. In addition, Altair provided the capability to design and virtually validate the suspension system from a structural point of view.

"This new approach," says Alfa Romeo Manager of Suspension Development Eugenio Perri, "provided an innovative and light design that allowed us to reach the high level targets in an extremely short amount of time. What's more, we reduced our development and production costs without experiencing any experimental packaging or structural problems."

"Our engineers," Krief concludes, "have confidence that with limited experimental tuning, the car would be ready for production."

In Suspension

The suspension was critical to the success of building the concept car. Double-wishbone suspensions are generally less comfortable than other suspension systems but favored in sports cars because of the handling capabilities they provide. Alfa Romeo's goals were to obtain a level of good comfort and to guarantee the highest level of handling performance.

To develop the front and rear suspensions, the chassis development team had to: 1) identify suspension characteristics and component specifications for optimal performance; 2) develop 3D CAD models and drawings of the suspension components; and 3) virtually validate the structural performance of every suspension component under various linear and non-linear conditions.

Because timing was a critical factor, Alfa Romeo teamed up with Altair Engineering and devised a "multi-body and structural" approach to expedite the project. What's more, the team integrated packaging check capabilities, typically performed in the CAD system, using multi-body dynamics (MBD) analysis and taking component compliances into account. By doing so, they automated the process of importing the component shapes from CAD, assigning their connectivity and identifying any component interferences through the full range of motion of the system (See *Close Collaboration*).

The engineering team initiated the project by performing kinematics and compliance optimization in order to bring the suspension performance in "target." Several analysis events were considered including steering, ride, roll and static loads as well as several controlled variables such as toe, camber and caster. The point coordinates and characteristics of the elastic components (bushings, spring, anti-roll bar, bump and rebound stops) – in addition to packaging limitations due to car body, powertrain, ground clearance, internal suspension packaging and specific requirements for the suspension design – were also taken into consideration.

Altair HyperStudy software was used to optimize the suspension points and parameters to reach the given suspension targets listed in Table 1, where the target value/range, the initial value, the optimized one and the delivery status were reported. Colors display properties that were in target, slightly off target, significantly off target and entirely off target as a consequence of the chosen suspension topology.

In particular, the kinematics and compliance studies of the front suspension system returned a unique optimized solution for the design of the suspension's upper control arm (UCA). According to engineers, the UCA attachment points for the optimized solution showed innovative positioning, with a spring passing on the line connecting two attachment points of the UCA. To develop this completely new UCA design, topology optimization was employed to deliver the lightest design for the desired targets.

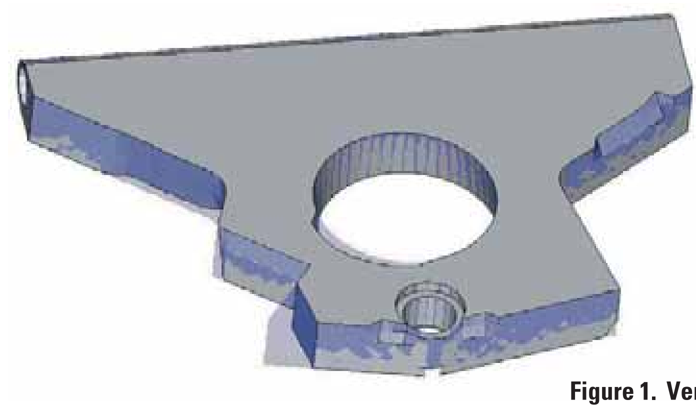

Figure 1. Verified Design Space of the Upper Control Arm overlaid to the approximated one (in transparency).

Room to Maneuver

The design space (DS) is the fundamental input for topology optimization. It represents the volume that material can occupy without interfering with other components. In Alfa Romeo's case, the UCA's design space was not considered a static volume but a dynamic one that moved with the UCA itself and many other components in relative motion.

Engineers started by creating an approximate DS. The DS was generated in the CAD system based on rough estimates, such as maximum steer angle of the tire, rim and caliper and spring positioning. The envelope also included a "must-have-material zone" that took into consideration the bushing and ball joint's housing.

Engineers then conducted an envelope analysis to check the packaging of the DS. It consisted of a discretized sequence of every possible position of the suspension, combining vertical displacement and steer angle.

Then, the UCA DS was meshed and imported into the packaging check environment along with the 3D CAD component models that could interfere with the UCA. Once the component proximity violations were determined, the violating solid elements were removed from the approximated DS.

The resulting DS, carved out during the packaging check operation, was considered a verified DS – a volume within which the UCA structure could be designed with no risk of interference with any other component (Fig. 1).

The Right Material

Topology optimization was used to define the best material distribution for the UCA within the verified DS. The topology optimization analyses focused on reducing structural mass and associated costs for the given targets and constraints.

In general, topology optimization uses a homogenization method to define optimal material distribution. Advanced approximation methods and robust optimization methods aid in finding the optimal load paths within the given DS.

The topology optimization results can be imported into the CAD environment via IGES to serve as the initial concept de-

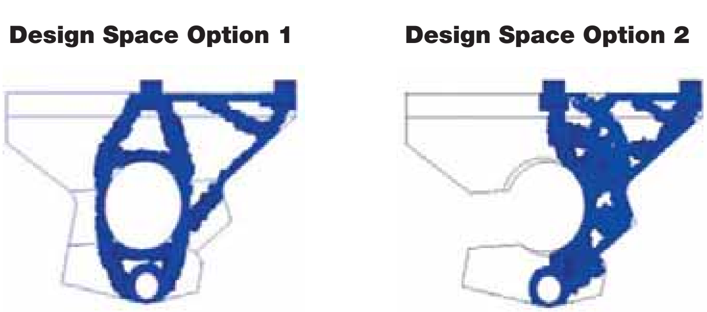

Figure 2. Lateral load case topology optimization results for verified Design Space options.

Property Name	Units	Target	Initial	1st K&C Opt	last K&C Opt
********************	+++	###	y	y	g
********************	+++	###	y	g	g
********************	+++	###	y	g	g
********************	+++	###	y	g	g
********************	+++	###	g	g	g
********************	+++	###	y	g	g
********************	+++	###	v	v	v
********************	+++	###	v	v	v
********************	+++	###	g	g	g
********************	+++	###	r	y	g
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Table 1. Results of the final kinematics and compliance optimization results.

sign with sound engineering feasibility. This approach reduces the number of design cycle iterations and consequent time to market. That is why topology optimization is so beneficial when used early in the concept design stage.

Alfa Romeo identified a welded steel tube construction as a manufacturing constraint for the UCA. In addition, the UCA had to achieve longitudinal and lateral stiffness targets.

The optimization studies returned two possible solutions: one using the entire design space (Fig. 2 – Design Space Option 1), and the second using a reduced design space, forcing the solution to pass by only one side of the spring (Fig. 2 – Design Space Option 2). Only DS Option 1 UCA design was deemed suitable to meet the welded steel tube construction manufacturing constraint while the DS Option 2 design was best-suited for casting.

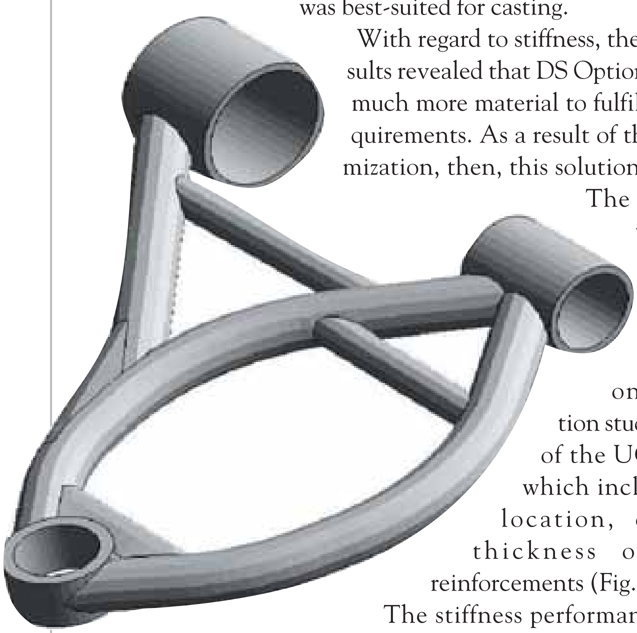

Figure 3. Upper Control Arm CAD design.

With regard to stiffness, the optimization results revealed that DS Option 2 would require much more material to fulfill the stiffness requirements. As a result of the topology optimization, then, this solution was eliminated.

The remaining solution is a symmetric structure around the spring of the UCA. Based on the optimization studies, a first design of the UCA was created which included the initial location, diameter and thickness of tubes and reinforcements (Fig. 3).

The stiffness performance of the newly designed UCA showed that while the longitudinal stiffness was just in target, the lateral one largely exceeded it – indicating a successful design. What's more, linear analyses showed the stress distribution was also in target.

In order to finalize the feasibility of this new UCA design, the engineering team simulated the UCA nonlinear performance for shock loading. The results of lateral impact against a guard rail indicated an optimal deformation characteristic. The UCA experienced a uniform stress distribution during the entire deformation up to collapse – with no premature rupture (Fig. 4). Specifically, the connection between the knuckle and body, under high deformations, is guaranteed by one of the tubes.

In addition, the results of a collapse for longitudinal impact against a sidewalk were comfortably in target. Nonlinear analyses proved that the UCA design was robust while providing the opportunity for weight reduction due to the comfortable performance margins.

Sizing and Shaping Up

Size and shape optimization tries to reach a design objective by varying only some of the characteristic parameters of the initial design, such as thickness, size and type of section. The final shape is derived di-

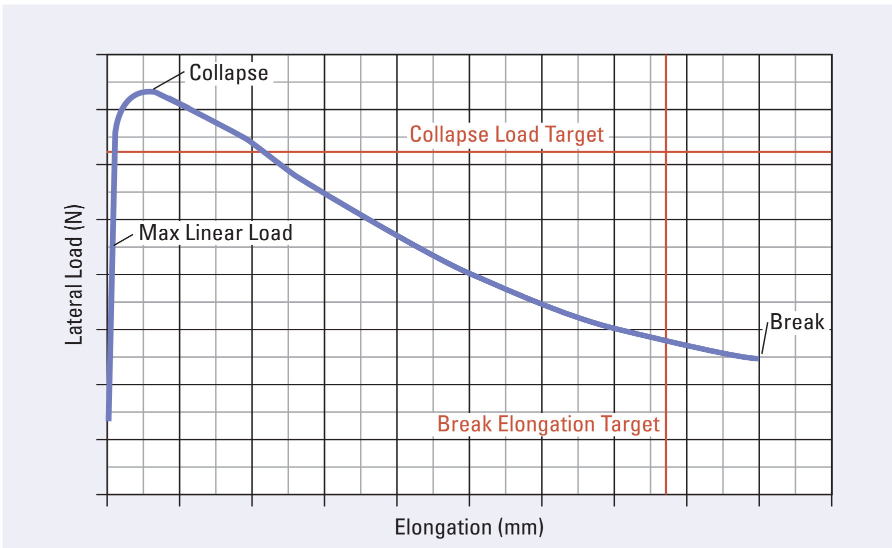

Figure 4. Load vs. elongation diagram of the nonlinear simulation under lateral impact.

rectly from the initial one, with the addition of some specific improvements.

To further refine the design of the UCA, the engineering team evaluated the tube diameter and the thickness of tubes and reinforcements. Targets and constraints were the same as those defined for topology optimization, and the studies provided the necessary information for further UCA enhancements.

Thanks to the use of optimization, the final UCA design reached its target weight – a 20% reduction of the UCA Alfa Romeo used as reference – and complied with the linear and nonlinear FEM requirements. In addition, the design verified the prescribed proximity distance between components and was optimized for kinematics and compliance while addressing all manufacturing considerations.

Other suspension components benefited from this integrated design approach. The engineering team used this approach to refine other suspension linkages and stabilizer bar routing at the front as well as at the rear.

Alfa Romeo officials say that structural optimization, driven by the MBD optimization, resulted in several benefits. The company saved time in developing a quality prototype. In addition, the technology enabled engineers to reach the comfort and handling targets characteristic of Alfa Romeo's sports cars. And, engineers had confidence in the virtual validation, from both packaging and structural points of view. What's more, physical tests highlighted an impressive correlation with the virtual models, citing no critical issues.

Several drivers who tested this concept car straight from the workshop reported that – even without any tuning – it is already well-balanced and provides great comfort. Alfa Romeo will soon decide whether or not to move into production with this vehicle. C2R

Beverly A. Beckert is Editorial Director of *Concept To Reality* magazine.

Tools of the Trade

The Alfa Romeo suspension project was divided into four environments, requiring a collection of application packages:

- **For multi-body analysis, engineers used Altair HyperStudy, Altair MotionView and MSC ADAMS.**
- **CAD models were developed in CATIA.**
- **The packaging check environment used Altair MotionView, Altair MotionSolve and Altair HyperView.**
- **Finite-element analyses and optimization studies were performed using Altair's HyperMesh, HyperView, OptiStruct and HyperStudy products. Nonlinear analyses were solved using ABAQUS developed by ABAQUS Inc.**

CAD and FEA studies were performed on UNIX workstations while PCs were used to perform multi-body dynamics and packaging check studies.

To receive a free copy of the technical paper detailing the suspension approach used by Alfa Romeo, visit *www.altair.com/c2r*