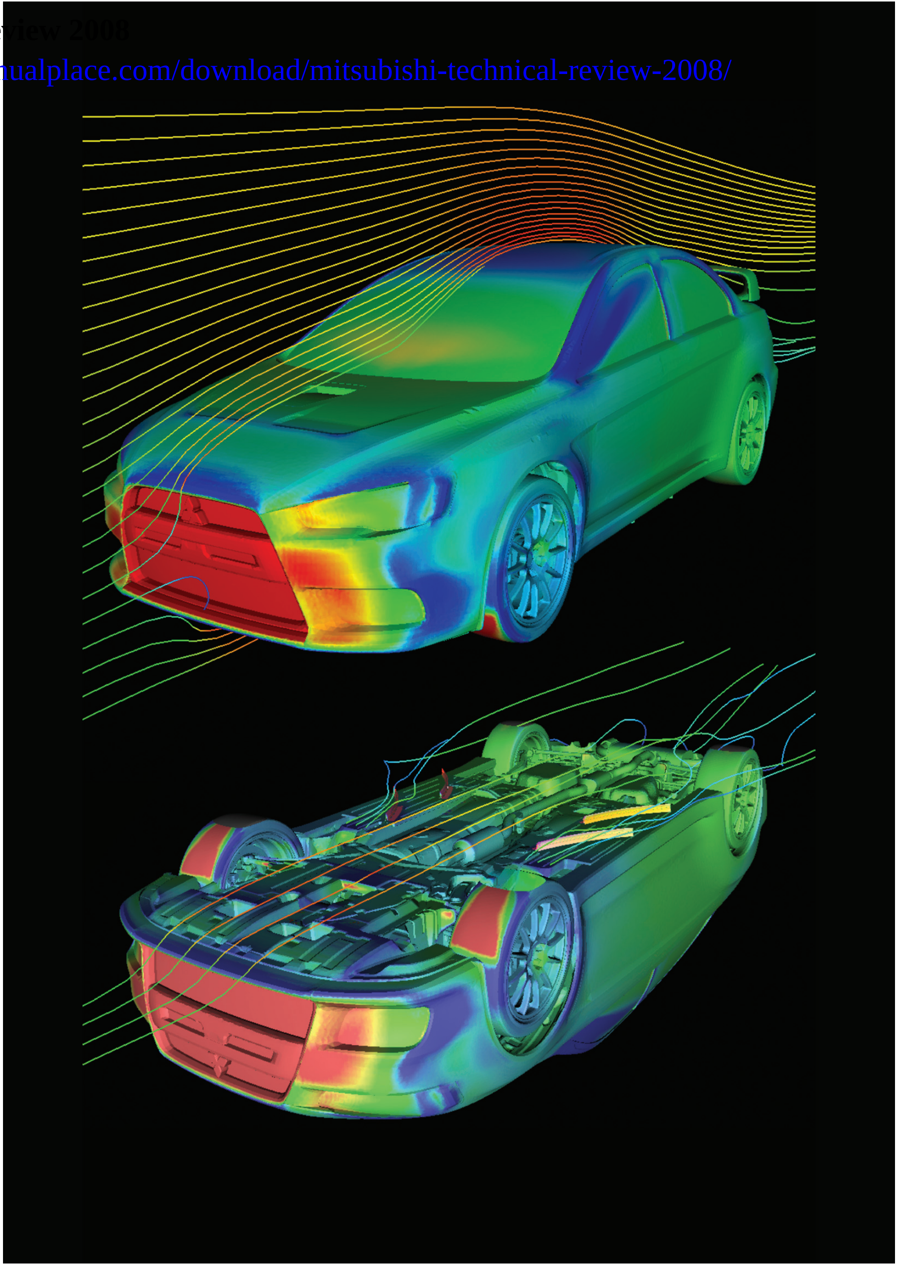
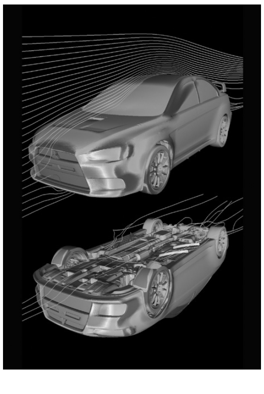


TECHNICAL REVIEW

2008 NO. 20

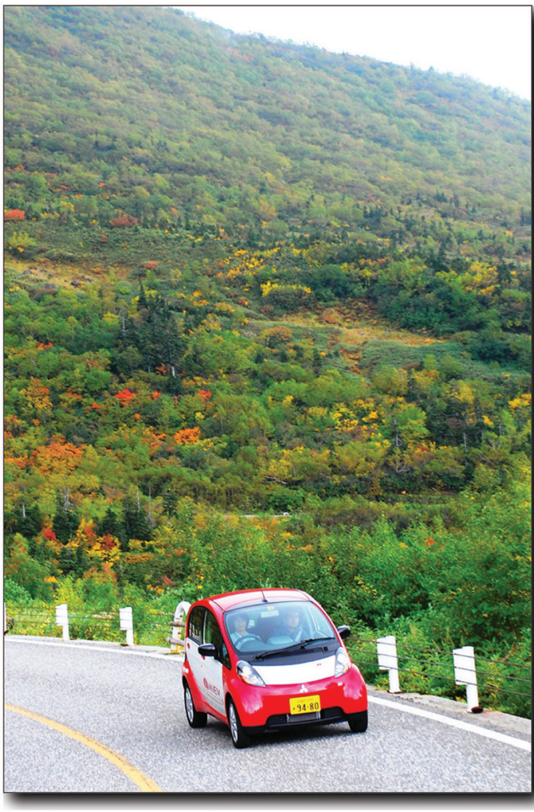
MITSUBISHI MOTORS



- **Cover Photograph**

The photograph shows the CFD (Computational Fluid Dynamics) analysis results of the LANCER EVOLUTION X. Its massive body design incorporated aerodynamics, in combination with the newly-developed rear air spoiler and floor air guides, delivers superior aerodynamic performance far surpassing that of the previous EVOLUTION models, in terms of not only air resistance but also lift, which is extremely important for steering stability. The floor air guides direct the under floor airflow to the outside of the vehicle to increase the flow velocity at the center area under the floor, and also reduce the pressure under the floor by vortices generated downstream of the air guides, thus effectively reducing the lift.

i MiEV, Mitsubishi's next-generation electric vehicle starring in various events



i MiEV being test-driven on the Tateyama Kurobe Alpine Route, which is normally closed to private cars

i MiEV being used as the chief judge's support car in the 2008 Lake Biwa Mainichi Marathon

i MiEV demonstration drive in a motorsport event at Odaiba

i MiEV pacing the field in a minicar endurance race

MITSUBISHI MOTORS TECHNICAL REVIEW

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The i MiEV (Mitsubishi innovative Electric Vehicle) is a next-generation electric car that's based on the Mitsubishi "i" and incorporates high-capacity lithium-ion batteries, compact, high-performance motors, and other innovative technologies from Mitsubishi Motors Corporation.
This zero-emission vehicle recently proved its superior running performance and environmental performance on hilly roads at high elevations in a specially permitted test on Japan's Tateyama Kurobe Alpine Route, which is normally closed to private cars to protect the environment.
Thanks to its clean, quiet operation, the i MiEV is popular as a support car for marathons. It's also used as a pace car for motor races and is featured at a wide range of other events.

New Technologies

Awards

New Products

A 20-Year History of New Models and Major Technologies at Mitsubishi Motors Corporation

Customer Satisfaction is Our Satisfaction

Osamu MASUKO
President

I'm always delighted when customers get in touch to say how pleased and satisfied they are with Mitsubishi vehicles. Here's a selection of comments we've recently received at our customer affairs center:

"The i is a really good car! Driving it felt great. It actually relieves stress."

(from a male i purchaser in his sixties)

"It's easy to drive, and I can cover long distances in it without getting tired. I love it!"

(from a male OUTLANDER purchaser in his forties)

"I never get tired of the design. I suspect I'll keep this vehicle for 10 years or even longer."

(from a male DELICA D:5 purchaser in his forties)

Complimentary comments like these give me tremendous pleasure. They show that everyone at Mitsubishi Motors is working harder than ever to deliver customer satisfaction and to be genuinely useful to society, in line with the company motto:

"We are committed to providing the utmost driving pleasure and safety for our valued customers and our community. On these commitments we will never compromise. This is the Mitsubishi Motors way."

This motto, which we adopted in January 2005, represents a pledge to make customer satisfaction our highest priority. And in addition to the promise to deliver driving pleasure (the fundamental attraction of our vehicles) and long-term user confidence, it reflects our determination to offer new forms of value in the vehicles we make.

This thinking shows in the OUTLANDER, which we launched in October 2005, and in all subsequent new models such as the i, the new eK WAGON, the new PAJERO, the DELICA D:5, the GALANT FORTIS, and the LANCER EVOLUTION X.

It's embodied (among many innovations) by the rear-midship layout of the i, with which we swept away conventional thinking about minicars, and by the S-AWC (Super All Wheel Control) vehicle dynamics control system, which puts intuitive control of the vehicle in the driver's hands. Innovations like these add to customer satisfaction in ways that are unique to Mitsubishi Motors.

A particularly outstanding example of our dedication to customer satisfaction is the LANCER EVOLUTION X, which we launched in October 2007. Incorporating our very latest technologies, this new model shows our passion to provide a confident, high performance driving experience to customers of all skill levels. Since we launched the LANCER EVOLUTION series in 1992, we've continually enhanced its technologies, feeding know-how gained through motorsport participation into each successive competition model and its marketplace iteration in line with a consistent policy of pushing the limits of performance. In the LANCER EVOLUTION X – the 10th model in the series – we adopted the newly developed TC-SST (Twin Clutch Sport Shift Transmission) and S-AWC to realize a new form of driving pleasure: confidence and comfort in addition to speed.

The enjoyment that the LANCER EVOLUTION X has delivered to many drivers prompted the Japan Car of the Year judges to give the car a special "Most Fun" award.

This 20th edition of the MITSUBISHI MOTORS TECHNICAL REVIEW describes the LANCER EVOLUTION X's new technologies in a feature about driving pleasure.

In April this year, Mitsubishi Motors launched a new mid-term business plan called Step Up 2010, which is aimed at realizing sustainable growth as we strive to deliver satisfaction to even more people.

We're keenly aware that automobiles, while convenient and valuable on one hand, play a role with respect to traffic accidents and environmental problems such as global warming on the other. So, the Step Up 2010 plan includes stepped-up production of vehicles with fuel-sipping engines and high-efficiency transmissions, plus accelerated efforts to bring clean diesel engines and our MiEV next-generation electric vehicle to market.

At Mitsubishi Motors, we are determined to continue developing products and technologies that boost customer satisfaction and help to build a sustainable society that harmonizes vehicles with the needs of people and the environment.

TECHNICAL PERSPECTIVE

"Vehicle Dynamics Technologies to Provide Driving Pleasure" Round-Table Discussion

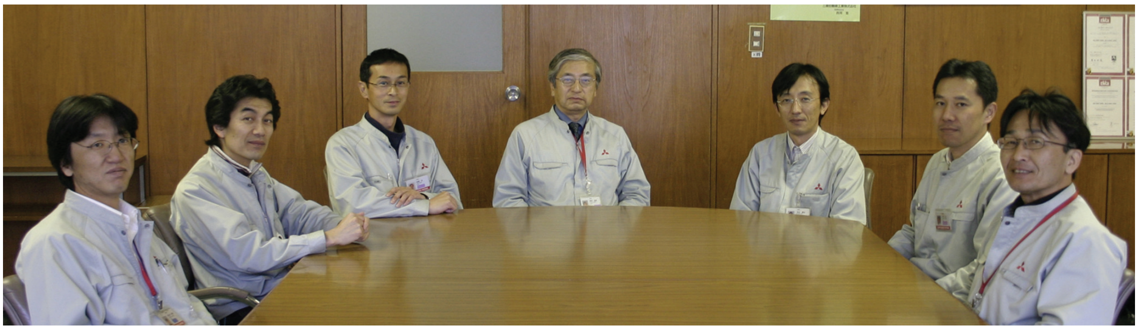
Abstract

Mitsubishi Motors' corporate philosophy is encapsulated in the following motto:

"We are committed to providing the utmost driving pleasure and safety for our valued customers and our community. On these commitments we will never compromise. This is the Mitsubishi Motors Way."

In this issue focusing on driving pleasure, we hear from the engineers in charge of developing the technologies for enhanced vehicle dynamics and 4WD systems, which provide the core support for driving pleasure.

Key words: *Driving Pleasure, Vehicle Dynamics, 4WD System*



From left to right
Advanced Chassis Engineering, Advanced Vehicle Engineering Dept., Development Engineering Office
Hiroyuki SUNOUCHI
Drivetrain Design, Drivetrain Engineering Dept., Development Engineering Office
Kaoru SAWASE
Master Evaluation, Testing Control Dept., Development Engineering Office
Hiroshi FUNO
Vehicle Dynamics Testing Dept., Development Engineering Office
Tsuneaki NISHIDA (Chairman)
Vehicle Control Engineering, Advanced Vehicle Engineering Dept., Development Engineering Office
Sumio MOTOYAMA
Ride & Handling Testing, Vehicle Dynamics Testing Dept., Development Engineering Office
Hiroshi SUGIMOTO
Advanced Vehicle Engineering Dept., Development Engineering Office
Yusuke KONDO

1. Introduction

Nishida: In recent years, we have seen remarkable progress in vehicle dynamics control technologies. These technologies have the possibilities of allowing drivers to operate a vehicle more safely and comfortably, even in difficult conditions or even if they are unskilled. As you know, Mitsubishi Motors Corporation (MMC) has adopted "utmost driving pleasure" as a key phrase expressing the driveability and roadability that is the fundamental attraction of our vehicles, aimed at producing exciting vehicles. These dynamic control technologies are incorporated in the LANCER EVOLUTION and other MMC vehicles and now support driving pleasure as well as "toughness and safety", which is another of our key phrases. On the other hand, vehicle systems that work on these control technologies do not necessarily meet the driver's expectation, sometimes leading to the driver feeling that this spoils the fun of driving the vehicle. This suggests that electronic control is not always welcome and there are areas where intrinsic performance of the vehicle reigns. I think that achieving an optimum combination of the two is an ultimate goal as we strive to offer driving pleasure to our customers. Needless to say, the application of latest testing and analysis technologies, extensive field trials, and stringent and accurate evaluation are all indispensable to achieving the goal.

With this in mind, it is worth reviewing to what point our vehicle manufacturing has advanced in the field of vehicle dynamics technology. Today, we have attending engineers who are involved in vehicle dynamics technology development, from the control technology, basic technology and testing and evaluation sections. Please share your thoughts with everyone freely, including any difficulties you experienced.

2. Chassis control technology

Nishida: In the 1980s, vehicles incorporating dynamics control technologies were launched at MMC. These included the antilock brake system (ABS), traction control system (TCL), four-wheel steering system (4WS), variable-characteristic shock absorbers, height control system on air suspended vehicles, roll angle reduction control, and stabilizer-bar on-off control. And also the electronic control of the steering reaction force was applied to the power steering system. Today, some of these are installed as standard, while others do not appear to be as popular as they once were.

Motoyama: The categories that went through the most fluctuations were the 4WS and so-called variable characteristics suspension technologies, including damping-force-switching shock absorbers, air suspension and hydraulic suspensions. They boomed in the late 1980s, but did not gain long-term popularity. In the 1990s, there were no significant developments in their application. Recently, variable characteristics suspension technologies have regained popularity, mostly in Europe, especially with shock absorbers that have the capability of continuously varying rather than switching damping force characteristics. The temporary decline they experienced earlier was due to the immaturity of the systems, in both the hardware and software. Another reason appears to be the immaturity of the envisioned goals of these systems.

Funo: As a specific case, the 4WS was a system that was developed to focus on a single area of a vehicle's functions. In fact, it displayed remarkable performance in this area, but the driver sometimes had difficulty in using it.

Motoyama: Back then, the Japanese automakers were ahead of competitors in other countries in developing these technologies. Both the manufacturers and the market here found value in something new that these systems offered. However, the market did not fully appreciate the functions that the new technologies offered, partly because most of them remained immature, even after being developed as products, due to a lack of refinement. For example, the market appreciated the 4WS for its ability to help in tight turns but not for its other abilities. Customers generally did not fully realize what benefits the 4WS could provide in what scenarios. Enhanced controllability and stability of a vehicle is difficult to feel as it is present or absent, depending on the driving environment, unlike significantly-improved ride comfort, which customers can easily perceive.

Sunouchi: A changing economic background has also influenced the popularity of these technologies. During the bubble years in Japan, people avidly looked for something technologically advanced and novel. After the bubble burst, people focused on value for money. Additional vehicle functions only work fully when the vehicle's performance itself is sound. European manufacturers continued refining the vehicle's basic performance over the years, and today, with a strong economic background, they have advanced to the point of adding value to the equipment. Japanese vehicle manufacturers, on the other hand, are now focusing on enhancing basic vehicle performance from the step they reached during the bubble years.

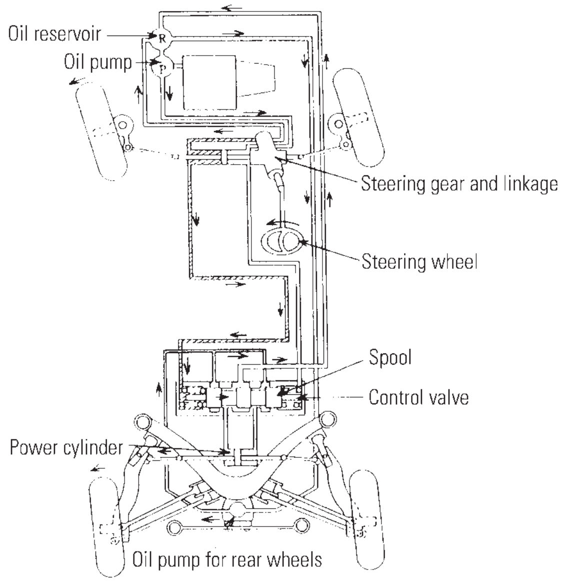


Fig. 1 4WS system (1987 GALANT VR4)

Sugimoto: The 4WS was not optimized for all speed ranges. Actually, the systems on the models for the European market were tuned to specifications different from Japanese market models.

Motoyama: Unpleasant feel, by its nature, is an unavoidable problem with the 4WS. A steering system completely devoid from such unpleasant feel is only the conventional front wheel steering system. It is also true that, no matter how well you familiarize yourself with the system, unpleasant feel will never become familiar and comfortable. To enjoy the full benefit of 4WS, maybe you must think, "the 4WS steers my car better than I can" just before driving the vehicle.

Funo: For a vehicle to be stable and controllable, the rear wheels must remain firmly in position. This is a basic rule. Therefore, there is inevitably argument regarding the 4WS as to whether a system that involves positional movement of the rear wheels can be said to be beneficial. Finding an optimal method of controlling its positional movement will pave the way to progress of the 4WS.

Motoyama: The 4WS has the potential to substantially expand the degree of freedom in toe control. Today's technology is still not that advanced. Perhaps, chassis control developments, assuming a 4WS-based platform, would drastically increase the possibilities.

Nishida: That is the active steering control working on the four wheels, including the front wheels. Front steering systems with variable gear ratio control have been introduced and some of them are combined with rear wheel steering control. MMC has also made its own technology relating with this control public. As with the steering system, development of the suspension system to enhance its variable characteristics by such means as controlling the damping force has become increasingly active today. Do you have any thoughts on this?

Motoyama: Technologies for selecting suspension characteristics were predominant in development in this field, but the trend has now shifted toward technologies for varying them continuously. The former technologies aimed at selecting the best characteristics, but actually selected characteristics might be neither better nor worse, while the latter aims at continually adjusting the system to optimum characteristics. Today, variable characteristics suspension systems are mostly employed on high-end luxury cars, but they will become popular with lower-priced vehicles. The key factor that decides whether the systems on high-end cars will evolve further will be the energy they consume. The weight of the additional control system for the drivetrain or steering system is greater than that of the braking system. The additional system for the suspension system is heavier than that of the drivetrain or steering system. As the weight increases, more power is consumed. An active steering system, for example, requires a maximum current of 10 A, approximately the same current as that of brake lamps, but an extra control system added to the suspension system weighs more and therefore consumes more current.

Sunouchi: Currently, air suspension systems are employed in some high-end sedans and sport utility vehicles (SUV). Hydraulically operated fully active suspensions were used in the past, but what we have today is classified as a semi-active type of suspension.

Motoyama: Hydraulic systems consume sufficient power to change the result of emissions test cycle driving. In this sense, electric active suspensions will be more feasible than hydraulic systems. Electric systems allow energy to be regenerated. Another merit is a much larger range of control.

Nishida: The conversion of various chassis systems into electrically operated systems is now advancing. The most important of these is electric power steering (EPS).

Sunouchi: EPS has had a issue in its steering feel. However, it can now give almost the same level of feeling as a hydraulic system. Nevertheless, friction and motor inertia remain an EPS challenge to be addressed. Besides the hardware, the approach may include enhancing the software.

Funo: EPS control technology may have the potential to give the driver a sporty feel.

Motoyama: The increased worm gear friction with the EPS is caused by road surface inputs. It is possible to solve this problem by developing the control technology, but this requires tremendous skill. Even with the best EPS today, the steering feel it provides is not as good as that with the best hydraulic power steering system in particular aspects.

Nishida: The EPS reduces fuel consumption. How about its contribution to the vehicle's dynamic performance?

Motoyama: We are going to expand the application of the stability control and brake-related control systems under the key theme of safety. The systems that follow these will be steering-related control systems because they have the potential to offer a high degree of freedom. Of course, one option is a system that combines these. The largest benefit of the EPS is a high degree of freedom of control. Its control is so free that we can even generate steering torque in the opposite direction to that of the driver's input.

Sunouchi: The EPS contributes less to the reduction of fuel consumption on larger vehicles. For these vehicles, the EPS will find its application in added functions, such as lane keeping and parking-assist systems, to assist the driver rather than to reduce the fuel consumption. The EPS will offer more potential in this area where the capabilities offered by hydraulic means have reached a limit.

Motoyama: I think another key point for success in the EPS is the embodiment of steering feel that is available only with an electric system control. The target is not something on a par with, but rather that exceeds hydraulic systems. Steering feel adds "flavor" to the vehicle.

Nishida: On a different topic, electric systems remind me of MMC's MiEV electric vehicle.

Funo: The MiEV has a low center of gravity, which means good stability in vehicle control. It sways little and only has a small load transfer in cornering, so you feel like the center of gravity is near the wheel axis. The location of the battery has been optimized, so the distribution of the vehicle mass is well controlled. Because the electric motor responds much better to accelerator operation than a mechanical engine, I think it is reasonable to design the response rather conservatively to prevent the driver from perceiving a surprising difference from gasoline engine vehicles when using the accelerator, although suppressing a good response is wasteful. What is important is a good-feeling response, low electricity consumption and problem-free running distances. The i MiEV runs really well. It is definitely a next-generation electric car.

3. Drivetrain control technology

Nishida: How about drivetrain control? Electronics have been applied to 4WD and other drivetrain controls to enhance the vehicle's dynamic performance.

Sawase: Electronic traction control technologies intended to enhance cornering performance, in addition to traction, are becoming the mainstream. Early electronic control applied to the 4WD system was an on-demand system that allowed high-speed on-road driving and distributed more torque to the rear wheels as lateral acceleration increased. At MMC, the first drivetrain control introduced as a means of enhancing the vehicle's dynamic performance was the system employed in the 1992 GALANT. This is the first fully-fledged system that controls the distribution of traction between the front and rear wheels by using the center differential full-time 4WD as a base system. Few people will know about this system because it was only produced in small volumes (laughter). Today, electronic