

Global market review of shock absorbers – forecasts to 2013

2008 edition

by Matthew Beecham

October 2007

Published by

Aroq Limited

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Registered in England no: 4307068

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Preface

Research methodology

This report is intended to provide an overview of shock absorbers, providing top-level market fitment, volume and value forecasts through 2013. Our forecasts are not extrapolative but dependent on the underlying drivers of supply and demand. Our forecasts are largely based on interviews with the author's extensive international network of industry contacts. This allows us to consider and explain the meaning and implications of industry events, rather than offer simple description based on incomplete data.

Our approach is divided into two distinct methodologies:

- qualitative interviews – these are generally opinion-based, which aim to build knowledge about future shock absorber market trends and company strategies; and
- quantitative interviews – typically fact-based, focused on establishing market values, shares, and volumes.

Report coverage

In this, the fourth edition of this report, just-auto reviews the key market drivers for shock absorbers, and updates the market analysis. Following our market overview in Chapter 1, just-auto's product fitment forecasts in Chapter 2 predict the market (by volume and value) worldwide (and by major car-producing region) for shock absorbers. This chapter also sets out detailed market share estimates of the OE market for shock absorbers in Western Europe, North America, Japan, China, South Korea, Argentina, Brazil and worldwide. Chapter 3 sets out a review of recent innovations in this arena while Chapter 4 provides profiles of the major manufacturers, namely ArvinMeritor, Delphi, KYB, Showa Corp, Tenneco and ZF Friedrichshafen.

The author

Since 2000, Matthew Beecham has served as an associate editor for just-auto. He authors a range of global auto components' market research reviews, including batteries, braking systems, coatings, clutches, cockpits, driver assistance systems, door modules, electric motors, engine cooling systems,

exhaust systems, front-end modules, fuel injection, fuel tanks, glass, ignition, interiors, lighting, mirrors, roof systems, shock absorbers, spark plugs, rotating electrics, tyre pressure monitoring systems, tyres, wheels and wipers. He has also written a number of features for magazines including *Car Graphic* (Japan), *JAMA* (Japan) and *Automotive Engineer* (UK). He earned his PhD in automotive technology transfer at Cranfield University.

Chapter 1 Introduction

Electronics is now assuming a prominent role in shock absorber (damper) product development. Electronic dampers allow a large range between maximum and minimum damping levels and adjust instantly to ensure ride comfort and firm vehicle control. By integrating mechanical and electronic functions within a vehicle, automakers improve handling and reduce costs. Such technology can also help lift revenues for manufacturers. The main competitors offering such technology include Tenneco (Computerised Electronic Suspension [CES] now supplied to certain Volvo, Ford and Audi models), ZF Sachs (Continuous Damping Control supplied for certain Audi, Opel, Porsche, Bentley and BMW models), Bilstein (DampTronic) and Delphi (MagneRide). For example, Tenneco Inc's CES product increases the company's content revenues seven-fold compared to a standard shock absorber. Tenneco reports that novel valve technologies, anti-roll suspensions and fluid-filled elastomers (rubber bonded to metal) that reduce noise and vibration, are "*highly influential*" in automakers' buying decisions.

Chapter 2 The market

Market trends

Shock absorbers vary widely in their detail design if not in their external appearance. Since any shock absorber is essentially a means of absorbing (and dissipating) the energy of the oscillating spring so as to return it to its static position as quickly as possible, alternatives to the hydraulic type may be conceived. For the last decade or so, the high-end technical emphasis has been on developing shock absorbers in which the damper rate can be varied according to the road conditions, to avoid the compromise in which damping which is soft enough to feel comfortable on rough road can create a nauseous 'floating' sensation on near-smooth but slightly undulating surfaces. Most designs have concentrated on computer-controlling the opening and closing of valves which bring additional damper orifices into operation; thus, the firmest rate exists with all valves closed.

While shock absorber technology is becoming more and more important in the OE world, it is increasingly perceived as a commodity in the aftermarket. Yet the shock absorber continues to play an ever more important role in a new vehicle, especially given the increasing fitment of electronic devices like ABS and ESP. The aftermarket can be counter-cyclical to the OEM market. Demand for aftermarket shocks is determined by a mix of miles driven, number of vehicles in operation and length of vehicle ownership, which now stands at about eight years – within the prime six-to-ten year vehicle age range for replacement parts. Although more vehicles are on the road than ever before, the aftermarket has experienced longer replacement cycles due to the improved quality of OE parts and increases in average useful lives of automotive parts as a result of technological innovation. As a result, the global aftermarket has not grown as fast as the number of vehicles on the road. Consequently, a shock absorber manufacturer's future viability in the aftermarket will depend, in part, on its ability to reduce costs and leverage its advanced technology and recognised brand names in order to maintain or lift sales revenues.

Market players

The following sections set out some thumbnail profiles of the main players.

ArvinMeritor Inc

ArvinMeritor serves light vehicle, commercial truck, trailer and specialty OEMs and certain aftermarkets from 110 manufacturing facilities globally. Headquartered in Troy, Michigan, ArvinMeritor employs 27,500 people in 26 countries. ArvinMeritor's newly-formed global ride-control business involves the integration of design, manufacturing and distribution of light-, medium- and heavy-duty original equipment and replacement shock absorbers and struts. More specifically, this business designs and manufactures a range of twin-tube and monotube shock absorbers and struts.

Q&A with ArvinMeritor

In October 2007, Matthew Beecham talked to Ed Frutig, Vice President and General Manager, Chassis Systems, ArvinMeritor Inc and David Hunt, Senior Director, Global Chassis Systems Engineering, ArvinMeritor Inc.

just-auto: We have all heard how many areas of automotive technology have been revolutionised by the greater use of electronics. What does this mean for dampers?

Dave Hunt: Dampers can have various levels of intelligence both on their own and when incorporated into systems improving ride and managing loads for both chassis and driver direct protection and comfort. Adaptive damping systems can be integrated into other systems such as ESC, ABS, etc, providing improved dynamics in both braking and dynamic handling. This leads to a better-performing vehicle in terms of both safety and ride quality.

j-a: To what extent are you seeing a higher system content on next generation dampers? What are the key elements of that content?

DH: We are seeing integrated systems with controllers, sensors, control software all included into full corner modules. ArvinMeritor is specifying and developing all aspects of the system (controller hardware, sensors and most importantly, control software). The ride and vehicle dynamics will be as much determined by software as physical hardware in the future.

j-a: To what extent are tighter legislative requirements affecting your design of dampers?

DH: There hasn't been direct legislation effecting damper design except for elimination of materials such as lead and HexChrom, however, indirectly the push for improved vehicle stability is pushing us to develop systems more focused toward stability and safety. Dampers can play a greater roll in safety if they are actively controlled with a large enough band width of authority. EU requirements are pushing for 'end of life' recovery and recyclability of automotive components, including oils and any controlled materials. This will be a challenge in the future to find more environmentally friendly fluids to meet environmental standards and still meet performance and durability standards.

j-a: What other trends are you seeing in conventional dampers? What are the drivers behind these innovations?

DH: Vehicles are becoming ever quieter as NVH (noise, vibration and harshness) improvements continue to evolve, dampers are therefore pushed to improve their NVH performance to keep up with the total vehicle NVH. Both transmissibility and audible noise are becoming challenges that damper suppliers need to proactively address for the future. The state-of-the-art even five years ago will not meet requirements for some vehicles launching in two to three years from now.

j-a: Although steel is the preferred choice of material to make dampers, to what extent is aluminium being used in manufacture?

DH: Since aluminium is still significantly more expensive than steel, it is used where weight is a premium. As the push for increased fuel economy continues to increase, the US\$/lbs value of aluminium/weight-saving materials will increase, driving more market penetration.

In other market segments such as high performance and recreational vehicles aluminium plays a dual role of saving weight, performance in the form of heat dissipation and aesthetics (the look of performance).

j-a: As we see it, over the last few years, ArvinMeritor has invested significantly on new suspension module designs, namely active air suspension, active roll control and active damping systems. We would like to get a better understanding for how each system works, its merits and when and where we could expect to see it. In respect of each technology, could you

explain how each works, what makes it unique from competing systems and when will it be ready?

DH: Active Air operates on the principle of a variable geometry air spring piston changing the area on which the air spring sleeve acts. This allows the spring rate to be varied by as much as 300%. We are developing methods of actively controlling this spring rate within the frequency response range of the vehicle's primary bounce, pitch and roll modes. We look for the technology to be application-ready [by the] end of calendar year 2008 with advanced customer development projects currently in progress. The most unique aspect of our Active Roll Control system is its hydraulic power source; we use an electric servo motor pump power pack to meter oil to the actuators. Here the pump doesn't need to be operating during straight line driving eliminating the parasitic power draw from a conventional front end accessory drive (FEAD) mounted hydraulic pump. Our Adaptive Damping system is designed to provide a better vehicle package environment by integrating the hydraulic control valve into the piston rod assembly. This design offers better noise control and flexibility to the OEM customers in addition to a lower system cost compared to the current systems in the market.

j-a: Suspension corner modules include brakes, struts, strut mounts and bearing elements as well as suspension bushings and vibration control elements. How do you see the development of corner modules evolving in North America and Europe?

Ed Frutig: For most customers, corner modules are here to stay. Of course the level of supplier engineering responsibility will vary greatly depending on customer development philosophies. We are involved in projects ranging from assembly and light integration to full coil over module development programs. We also have several cross-car chassis modules in production with several new projects at various stages of development. Our current modules business is North America-based, however many of the new projects are in Europe and China. China, in particular, has some very different market dynamics when compared to Europe, Japan or North America and offers some unique opportunities to chassis suppliers. The more aggressive China-based OEMs are looking for integrated chassis design and production services. This is especially so for the OEMs desiring to export or those planning to rapidly modernise their product lines. They are looking to accelerate their speed-to-market and require a supplier with complete chassis and suspension expertise

that can step in and ensure that their next generation vehicle can meet global safety, reliability and ride performance standards. Through our joint venture with Chery in China, we will have the capability to supply damping technology to the Chinese OEMs as well as expand into complete corner modules and chassis systems.

j-a: What will its success depend on?

EF: Modular supply depends on two main factors: First, manufacturing and assembly excellence and competence. Second, system integration know-how, with technical knowledge of the sub-components and how they interact to affect overall system dynamics. The overall systems knowledge is a competitive advantage for ArvinMeritor as we have integrated our ride-control products with our coil spring, stabiliser bars, and chassis operations into one unified business. We can now deliver complete scaleable chassis solutions to our customer by integrating conventional suspension and ride control technology or integrating some of the advanced technologies we have to offer.

Delphi

In addition to shocks, Delphi's suspension and brake components include callipers, rotors, drums, master cylinders, boosters, drum brake assemblies, friction materials, struts, airlift dampers and levelling height sensors. For the aftermarket, the company offers gas and hydraulic shock absorbers for off-road and high-performance vehicles.

Hitachi

Hitachi¹ designs and manufactures a range of shock absorbers. The company manufactures shock absorbers at its plants in Thailand and China. Tokico (USA) Inc, a subsidiary of Hitachi, distributes and sells shock absorbers and brake hydraulics to high performance and aftermarket customers.

KYB

KYB is one of the world's largest suppliers of shock absorbers to automakers as original equipment. The company produces about 60m shock absorbers

¹ What's in a name? Hitachi is a combination of two Japanese words, 'Hi' meaning 'the sun' and 'tachi' meaning 'rise or stand'. The combination of these two words express a vision of someone looking toward the rising sun and planning a better life.

annually for cars, light trucks and motorcycles. The company supplies shock absorbers to a number of automakers, including Mitsubishi, PSA Peugeot Citroën, Volkswagen, Ford, General Motors, Renault and Toyota. Over the past five years, KYB has been increasing its market presence in overseas markets, especially Europe and North America. The group has manufacturing bases in North America, South America, Europe and Southeast Asia. KYB has expanded its global reach in recent years with new facilities in Europe, serving the OE and aftermarket.

Magneti Marelli

In 2003, Magneti Marelli's shock absorbers and suspensions systems businesses were integrated. As a result, Autocomponents Suspension Srl was merged with Sistemi Sospensioni SpA to form Magneti Marelli Cofap Automotive Suspension. In addition to shocks and springs, this business supplies suspension systems and modules and structural components for suspensions. Cofap Automotive Suspension employs 5,760 people at its plants in Italy, Poland, Brazil and the US. In addition to Fiat (accounting for 72% of turnover), its main customers include DaimlerChrysler, GM, Ford and Renault.

Showa Corp

Showa Corp is organised into three operating divisions: automotive components, motorcycle components and other components. Showa's shock absorber products fall under the auspices of its automotive components business. Headquartered in Gyoda City, Saitama, Japan, Showa operates five manufacturing plants, three R&D centres and two manufacturing operations in Japan. Its global empire spans a network of 30 facilities in 15 countries.

Tenneco Inc

Tenneco Inc is one of the world's largest manufacturers of emission control and ride-control products and systems for the automotive OE and aftermarket. Its ride-control products include shock absorbers, struts, CES, coil and leaf springs, cab shock absorbers, seat shock absorbers, heavy-duty truck and train shocks, top mounts, spring and shock/strut modules, corner modules, axle modules and aftermarket suspension parts. The company is gradually shifting more OE manufacturing to low-cost countries. Today, about 45% of its European ride-control production is based in Eastern Europe. The company attributes winning the high-volume Ford Focus ride-control business to its capacity in Poland and the Czech Republic. In addition, Tenneco supplies

about 60% of Mazda's shock absorber requirements in Japan from its eastern European facilities.

Q&A with Tenneco Europe NV

In September 2007, Matthew Beecham talked to Sandro Paparelli, vice president Sales and Programme Management for Ride Control Europe, Tenneco Europe NV, and Koen Reybrouck, Global Ride Control Technology manager, Tenneco Europe NV.

just-auto: What are the main trends in conventional shock absorber technology that you are seeing and what's driving them?

Koen Reybrouck: There are a number of trends. The biggest driver is the driver's requirement for a quiet cabin in terms of comfort and noise. When we look back to the 1990s, there was a clear trend in the conventional shock absorber arena for better damping performance vehicles. Nowadays, drivers want both. These demands are driving the latest developments in conventional shock absorber technology. There are also things like improved material to reduce friction but also to reduce weight in the light of fuel economy/emission reduction.

j-a: How does Tenneco's Continuously Controlled Electronic Suspension (CES) system work and what makes it unique from some of the competing systems?

KR: Although our technology seems similar to some competing technologies, it performs better because the system allows the damping characteristics to be changed in milliseconds, i.e. ensuring the occupant a smooth transition between comfortable ride and a safe handling. Tuneability is also important. And, of course, driver comfort has improved, too. When we compare our current systems with those we introduced in 2003, then that has also significantly improved. In looking ahead in terms of the pure damping evolution over the next five years, I think we shall see even more tuneability and better damping curves. The electronics behind it is also very important.

j-a: Generally speaking, at an industry-wide level, how do you see the acceptance and growth rate of continuous damping technology by the OEMs?

Sandro Paparelli: We can say that the markets are more than tripling over the next three years. We are also working on system cost reduction in order to make continuous damping technology available for C segment vehicles. That is our objective. If we can achieve that, we expect to see the market further grow considerably. We have already had one or two trials but it is still very confidential.

KR: When we talk about the tripling of the market, that is basically with the current technology. The technologies which are under development focus not only on performance improvement but also on cost reductions which will allow further growth. The trends we see there for those future systems is further application of electronics into the shock absorber itself, allowing the system cost on the vehicle to be dramatically reduced.

j-a: By how much do costs have to decrease?

SP: Costs must be down 50% compared to today [by 2010].

j-a: Could you tell us the ballpark cost of the system today?

SP: This is a little bit confidential.

j-a: What could the size of the market be today and in the future of these continuously-damping systems?

SP: We could say that the market share of cars equipped with electronic suspension in 2006 represents 2% of the passenger car market in Europe and will be around 6% by 2010. At that time the Tenneco market share of such technology will be around 40%. So it is a growing market and indicates how the OEMs are reacting to our technology. If the significant cost can be reduced by 50%, we can easily imagine the penetration of 15% of cars equipped with electronic suspension in Europe [by 2010].

j-a: What does the future growth hinge on?

KR: At the moment, we are only working on future generations of CES. But there is more that can be done with the spring function itself. So as far as damping technologies are concerned, we are not only controlling damping but also controlling position and stiffness on vehicles. We have already developed

a kinetic system – which is an anti-roll system – that has proven itself on the Citroën Xsara WRC over the past few years. That technology keeps the car body very flat but still allows the wheels to follow the road profile. The problem with vehicles with stiff suspension systems which are good for keeping the car body flat while turning is that when the road becomes uneven the contact tyre/road is not homogeneously distributed resulting in loss of handling and comfort. So the kinetic system overcomes that and allows the wheels to move up and down on the road but still keep the car body flat. We can combine Kinetic and CES to introduce the best of both systems but of course at a higher system price. But what we want now is to see CES systems – which are already successful on higher segment vehicles – permeate down to the lower vehicle segments.

j-a: What is Tenneco Europe's involvement in corner modules?

SP: We are involved in that arena but call them suspension modules, not corner modules. Although we built corner modules including the brake system a few years ago in Spain [supplying to SEAT,] we are currently focused on the traditional suspension module, e.g. with strut, coil springs, top mount, compression bumper, etc. It is, let's say, a reduced corner module. About six years ago there was a big push by the OEMs to outsource as much as they could in terms of sub-assemblies, not only suspension sub-assemblies but all kinds of sub-assemblies. Since then, some OEMs realised that they went a little bit too far and took the decision to reverse this trend. We currently supply suspension modules for Peugeot, Volkswagen and Suzuki. We not only assemble the module but carry out the complete system integration, i.e. we don't just assemble parts received from suppliers but we design and perform the concept analysis, testing and validation of the system.

j-a: Could you compare and contrast the European and North American automakers use of corner module technology?

SP: The trend is going in the same direction. The car manufacturers want to have more control of the key functions of the car. The suspension of a car and the tuning of it is the real DNA for them. They prefer to work with us closely but to control the DNA of their product. We can always bring our added value to the car manufacturer's original ideas. This is important and more so than developing the complete suspension. It is about really bringing our knowledge and competence of the suspension.

j-a: How is the European aftermarket for shocks shaping-up? What should the brand 'Monroe' mean to consumers?

SP: The Monroe brand stands for quality products, offering superior handling and safety. We have a very extensive coverage, too. Today, we can offer more than 98% of the [European] market. This is very important for jobbers and distributors.

j-a: How do you go about 'educating the motorist' about the dangers of worn-out shocks?

SP: There are a lot of communication activities which we do. We try to communicate by giving the press an opportunity to drive vehicles with worn-out shock absorbers and compare them to vehicles fitted with new shocks. We also offer a lot of training activities. For example, we have a 'testing van' which travels to European cities which shows consumers how to diagnose a worn-out shock absorber. The van has the latest diagnostic equipment. Its purpose is to educate the market and advise on the dangers of driving on worn-out shocks.

j-a: Is it easier to get that message across to the Germans than it is to, say, the British?

SP: We very often have this discussion about British motorists. Although I feel that the people in the UK are real motorists – they like cars – they don't replace their shocks quite as often as their German counterparts! Vehicle inspections also vary from one country to the next.

ZF Sachs

ZF Sachs' Suspension Components business designs and manufactures shock absorbers and spring struts for passenger cars and commercial vehicles as well as for rail vehicles among other automotive parts. This business produces some 249,000 shock absorbers every working day, which is equivalent to 55m annually. In addition to shocks, this business designs and manufactures a range of tie rods, stabilisers, stabiliser links, control arms, suspension joints, suspension joints, levelling systems, crash absorption parts and chassis mounts. ZF has built up an international network of subsidiaries. Today, the company manufactures chassis components at its sites across

Argentina, Brazil, China, France, Germany, India, Italy, Mexico, South Africa, South Korea, Spain, Turkey, the UK and the US.

Q&A with ZF Sachs

In September 2007, Matthew Beecham talked to Dr Nowak and Dr Eickhoff of ZF Sachs' suspensions systems division.

just-auto: How is your CDC (Continuous Damping Control) business developing²?

Dr Nowak: After successfully establishing CDC in the upper-class segment, more and more cars in the mid-range segment are also relying on continuous damping technology from ZF Sachs.

j-a: What is the rate of acceptance of continuous damping technology by the OEMs?

Nowak: It is estimated that more than half of Europe's new vehicles are now taking advantage of some degree of electronic control system to enhance vehicle stability. The market share at the moment for ESP for example is definitely higher than 50% in Europe. The market proportion across Europe for electronically-controlled suspension systems like our CDC, compared with conventional shocks, is significantly smaller. Passenger cars featuring advanced chassis systems still make up less than 10% in Europe, but a strong increase of the market share in the near future is expected.

j-a: Although ZF has opened the floodgates to CDC, making it more affordable on mid-range cars, how will it affect the aftermarket?

Nowak: The first applications for mid-range vehicles have already been introduced into the aftermarket by ZF Trading, the aftermarket company within the ZF group.

² ZF Sachs' CDC continuously adjusts the suspension damping to the respective driving situation according to the need. The active roll stabilisation (ARS) counteracts the vehicle's roll behaviour when driving into curves. Networked with other control systems in the suspension, ARS and CDC ensures greater controllability of the vehicle.

j-a: What other trends are you seeing in conventional shocks? What are the drivers behind these innovations?

Dr Eickhoff: With conventional shocks, we see an increasing demand for additional features to help OEMs deliver perceivable customer benefits without too much on-cost. For example, ZF Sachs' Sensitive Damping Control system provides greater ride comfort without sacrificing safety. An extra valve in the damper provides exactly the right damping force fitting to the actual driving situation: lower damping forces for minor stimulations, such as road bumps, or higher damping for large stimulations, such as lane-changes or cornering. This simple and inexpensive system without electronics ensures optimal road contact and makes it possible for the driver to enjoy sporty driving with a constantly-high level of ride comfort and safety.

j-a: Although steel is the preferred choice of material to make dampers, to what extent is aluminium being used in manufacture?

Eickhoff: ZF Sachs has a long history of experience with aluminium in shock absorber technology. For shock absorbers, lightweight potentials can be untapped on one hand by means of using lightweight materials such as aluminium or high-strength materials like high-strength steel or, on the other hand, by dimensioning and optimal component design. We have developed lightweight aluminium dampers since the mid 1990s and still have a unique market position. Our light-weight shock absorbers are used in development projects such as the 1-litre car by Volkswagen as well as volume production vehicles, e.g. compact cars up to the luxury segment. In the lightweight damper, up to 4 kg of weight can be saved per car by using hollow piston rods as well as specially-manufactured aluminium reservoir tubes and spring plates.

j-a: To what extent are you seeing a higher system content on next-generation shocks? What are the key elements of that content?

Eickhoff: We see the trend towards enhanced functions by integrating additional features like Sensitive Damping Control. Other features are currently in development, but not to be published yet. In the controlled shocks field, the trend is toward networked systems rather than adding up functions on the individual elements. For example, we have linked ESP and CDC with the benefit of reduced braking distances. Also, ARS and CDC can be linked to generate handling and ride benefits.

j-a: To what extent are tighter legislative requirements affecting your design of dampers?

Eickhoff: We do not see a direct link in this aspect. However, with the required increase in fuel efficiency, the OEMs are currently looking deeper into weight reduction of the entire vehicle as they did before. Thus, our lightweight designs for shocks and struts, is one means of fulfilling these demands. On active systems like ARS, power consumption will be lowered by electric actuators replacing hydraulic actuators.

j-a: How much further could shock absorber design go? What does the future growth hinge on?

Eickhoff: In summary, we see the following major trends for our business growth:

- additional functions on conventional shocks will penetrate the market;
- CDC shocks will penetrate more market segments;
- networking of all active and semi-active systems – like CDC – will be intensified;
- electric actuators will help active systems be applied to a wider extent than currently.

Emerging markets

China

ArvinMeritor recently entered into a joint venture with Chery to design and manufacture chassis systems and parts. The partners reckon that their new joint venture, known as ArvinMeritor Chassis Systems Wuhu Co, will achieve sales revenues of US\$150m by 2010. ArvinMeritor owns 60% of this new venture while Chery owns the remaining 40%. Production of shock absorbers and struts is scheduled to commence in 2008. This new chassis systems joint venture plant in Wuhu will be one of several China-based facilities the company is adding to its network over the next 18 months. Speaking at the Centre for Automotive Research annual Management Briefing Seminars in Traverse City, Michigan on 8 August 2007, Chip McClure, chairman, CEO and president of ArvinMeritor Inc, referred to how the competitive landscape in the global automotive industry is rapidly changing and how more intense competition is coming from new emerging players. He said: *“It won’t be the*

Americans, Europeans and Japanese fighting for a piece of the already crowded marketplace, it's the new players from China, India and Korea that are beginning to give us a run for our money. Some are here, some are coming, but they're all intending to be faster, cheaper and better...It brings not only increased competition, but, to a greater extent, increased growth opportunities.

"Nowhere are those growth opportunities bigger than in China. China has been big news for a while now. And even though ArvinMeritor has been well-established in that region for more than a decade, we still continue to be excited about the ever-emerging opportunities. In China alone – where the GDP grew more than 11% last year – we expect car and heavy truck sales to exceed the rest of the world in the last decade. We believe that by 2010, light vehicle sales could rise to 10m. In 2007, we anticipate China will sell about 300,000 heavy-duty trucks. That means that in 2007 China could sell nearly 100,000 more trucks than we'll sell this year in North America, which has been traditionally been our biggest market.

"We want to be in a good position to leverage those numbers and that requires we get ahead of the curve. The announcement we made a few weeks ago with Chery Motors is a great example of that...Our business with Chery will represent US\$150m in revenue to us by 2010. As part of our global growth strategy, we plan to triple our sales in Asia and with the Asian OEMs within the next five years. That's more than US\$1bn of added sales in Asia-Pacific and it's more than US\$1bn in sourcing from existing and new suppliers and new suppliers in that region. That also includes taking advantage of the phenomenal growth opportunities in India." Indeed, the Indian market is also compelling. It is the second-largest two-wheeler market in the world, fourth-largest commercial-vehicle market, and 11th-largest passenger car market in 2007 (which is expected to be the seventh-largest by 2016).

For its part, Showa Corp is in the process of setting-up a plant to produce shock absorbers and power steering systems in Wuhan, Hubei, China.

Czech Republic

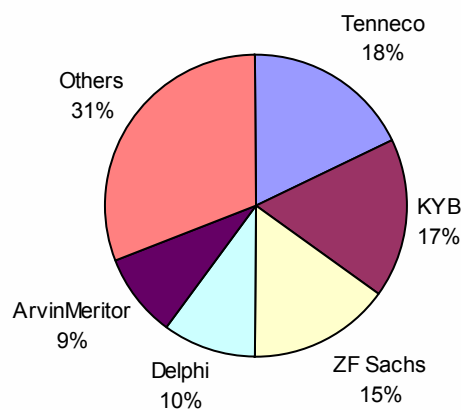
In 2007, KYB opened a new factory in Pardubice in the Czech Republic, creating 200 jobs. A new company, known as KYB Manufacturing Czech sro, has also been established. The new facility produces automotive shock absorbers for the OE market.

Market shares

Global market

Tenneco led the global OE shock absorber market in 2006, followed by KYB, ZF Sachs and Delphi.

Figure 1: Global market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)

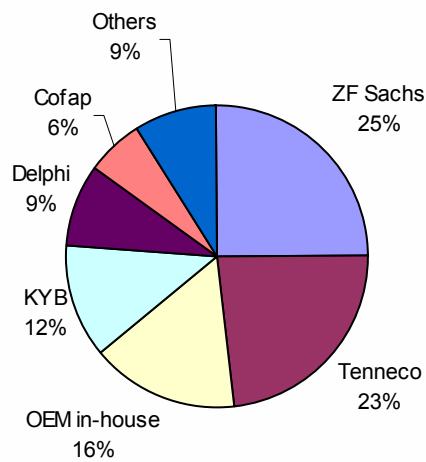


Source: just-auto

Western European market

The main competitors in the European OE ride-control markets are ZF Sachs, Tenneco and KYB. ZF Sachs led the market for passenger cars with a 25% share in 2006, closely followed Tenneco with a 23% share and OEM in-house production (mainly PSA Peugeot Citroën and Volkswagen), KYB and Delphi. Other suppliers of shock absorbers to the European automotive market include Cofap, Bilstein Suspension, Koni and Spax.

Figure 2: Western European market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)



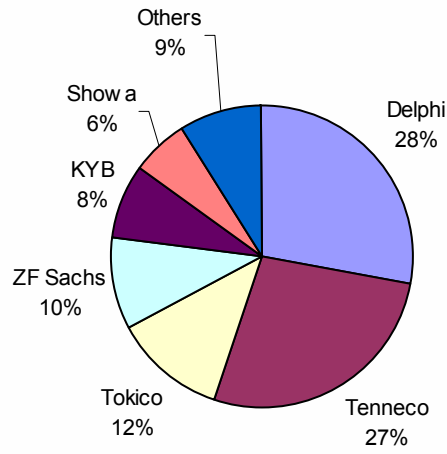
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In Central and Eastern Europe, Tenneco Automotive is a strong player alongside ZF Sachs and KYB. ZF Sachs tends to lead those markets where German models dominate the car parc. In some other markets, such as the Baltics, KYB leads the shocks market thanks to the preponderance of Japanese vehicles.

North American market

Delphi led the North American OE shocks market in 2006, closely followed by Tenneco Automotive, Tokico and ZF Sachs. Over the past few years, KYB has expanded its sales force in North America. Last year, we estimate that the company had an 8% share of the OE shock absorber market in North America.

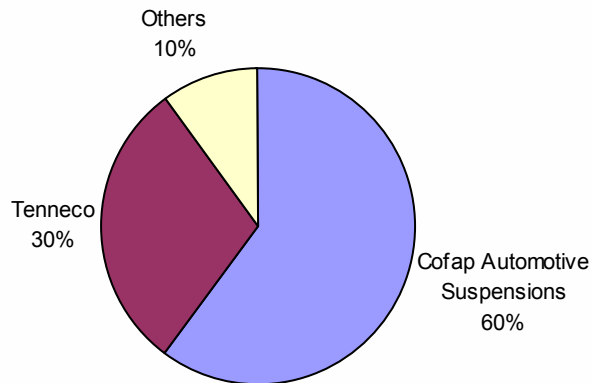
Figure 3: North American market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)



Source: just-auto

Cofap Automotive Suspensions led the Brazilian OE shocks market in 2006, followed by Tenneco. Others include ZF Sachs, KYB and Showa Corp.

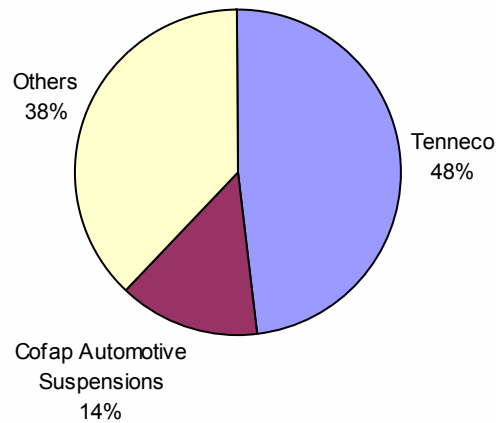
Figure 4: Brazilian market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)



Source: just-auto

In the Argentinean market for OE shocks, the leadership roles are reversed, with Tenneco enjoying a 48% share followed by Cofap with 14%. Others include ZF Sachs, and imports from Tenneco Automotive.

Figure 5: Argentinean market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)

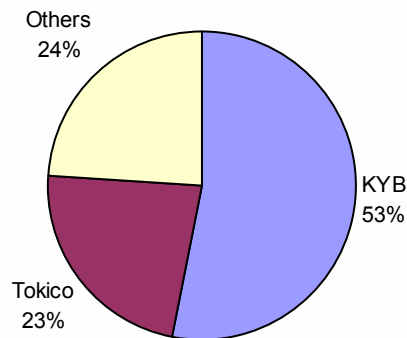


Source: just-auto

Japanese market

KYB was Japan's largest manufacturer of shock absorbing equipment in 2006 with a 53% share, followed by Tokico and Showa Corp. Hitachi-owned Tokico's suspension system product range includes shock absorbers, suspension struts, self-levelling systems, height adjustment systems, and gas springs. In addition to shock absorbers, Tokico designs and produces suspension struts, disc brakes and brake cylinders. Its main customers are Nissan, Ford, and Toyota,

Figure 6: Japanese market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)

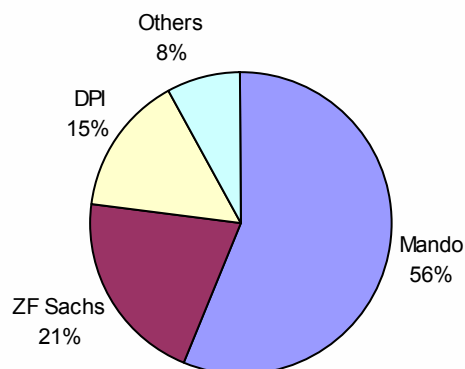


Source: just-auto

South Korean market

The South Korean OE shock absorber market was led by Mando in 2006, followed by ZF Sachs and DPI. In addition to shocks, Mando's product lines include steering systems, brake systems, electronic accessories and electrical parts.

Figure 7: South Korean market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)

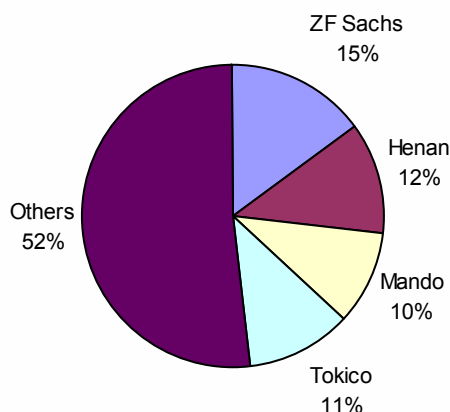


Source: just-auto

Chinese market

ZF Sachs led the fragmented market for automotive shock absorbers in China, followed by Henan, Mando and Tokico.

Figure 8: Chinese market shares for OE shock absorbers for passenger cars and light trucks, 2006 (% of volume)



Source: just-auto

Market forecasts

Table 1 sets out our estimates and forecasts of the market volume of shock absorbers for passenger cars and light trucks for OE applications from 2003 through to 2013. In Western Europe, for example, we estimate that there were about 59.3m shock absorbers produced in 2006 with the market potentially reaching 65.2m units by 2013.

Table 1: OE market volume of shock absorbers for passenger cars and light trucks, Western Europe, North America and Japan, 2003-2013 (Units '000s)

	2003	2004	2005	2006	2007	2008
Western Europe	58,150	59,405	58,941	59,343	61,405	62,836
North America	76,996	78,174	78,158	79,356	80,444	81,557
Japan	22,800	22,921	22,891	23,291	23,673	24,019
Total	157,946	160,500	159,989	161,991	165,522	168,413

Table 1 (continued): OE market volume of shock absorbers for passenger cars and light trucks, Western Europe, North America and Japan, 2003-2013 (Units '000s)

	2009	2010	2011	2012	2013
Western Europe	63,870	64,000	64,400	64,800	65,200
North America	82,628	83,200	84,000	86,000	88,000
Japan	24,292	24,400	24,800	25,200	25,600
Total	170,790	171,600	173,200	176,000	178,800

Note: Figures may not sum due to rounding

Source: just-auto

Table 2 sets out our estimates and forecasts of the market value of shock absorbers for passenger cars and light trucks for OE applications from 2003 through to 2013. We estimate that the Western European market alone for OE shock absorbers was worth about EUR631m in 2006. That value could potentially fall to about EUR602m by 2013, due to continued downward price pressure by the OEMs.

Despite the continual innovation in the shocks market, price pressure from OEMs remains intense, effectively dampening revenue growth. An auto executive told us: *“The OEMs are still looking for more [shock absorber] performance at the same price. So we are having to cut the price [of shocks] to bear bones on current technology and yet offer a bit more technology. They are looking for ‘smarter’ technology even though it is actually mechanical. They also want more durability. In that sense, all of the shock absorber suppliers have the same dilemma of trying to create a high-performance, low-cost device that will last the life of the car. Shock absorbers used to be parts that wore out. That is no longer the case. They are now expected to last the life of the car. But it is extremely irritating for a supplier of good quality shock absorbers to have this important part of car technology become a commodity.”* Faced with diminished profit potential, the major manufacturers continue to educate the motorist about the dangers of using worn-out shock absorbers in an effort to lift sales in an increasingly-competitive aftermarket.

Table 2: OE market value of shock absorbers for passenger cars and light trucks, Western Europe, North America and Japan, 2003-2013 (EUR '000s)

	2003	2004	2005	2006	2007	2008
Western Europe	657,098	657,848	639,658	631,137	640,010	641,824
North America	796,910	792,924	776,898	773,037	767,956	763,017
Japan	279,300	275,167	269,307	268,542	267,480	265,967
Total	1,733,309	1,725,939	1,685,864	1,672,716	1,675,446	1,670,808

	2009	2010	2011	2012	2013
Western Europe	639,341	627,828	619,117	610,503	601,987
North America	757,572	747,560	739,653	742,119	744,190
Japan	263,604	259,483	258,462	257,378	256,234
Total	1,660,517	1,634,871	1,617,232	1,610,000	1,602,411

Note: Figures may not sum due to rounding

Source: just-auto

The clear trend toward integrating more and more electronics into shock absorbers is proving a fertile area for profit for manufacturers. Some manufacturers estimate a typical selling price of an electronic shock of about EUR75 versus a unit value of a standard shock of about EUR11. Overall, we estimate that about 2m electronic shock absorbers were sold in 2006 worldwide. That volume could easily exceed 4.7m by 2013. On that basis, we estimate the electronic shock absorber market could be worth some EUR330m by 2013, up from EUR150m in 2006.

Table 3: OE market volume of electronic shock absorbers for passenger cars and light trucks, worldwide, 2003-2013 (units)

	2003	2004	2005	2006	2007	2008
Worldwide	1,400,000	1,582,000	1,787,660	2,020,056	2,282,663	2,579,409

Table 3 (continued): OE market volume of electronic shock absorbers for passenger cars and light trucks, worldwide, 2003-2013 (units)

	2009	2010	2011	2012	2013
Worldwide	2,914,732	3,293,648	3,721,822	4,205,659	4,752,394

Source: just-auto

Table 4: OE market value of electronic shock absorbers for passenger cars and light trucks, worldwide, 2003-2013 (EUR '000s)

	2003	2004	2005	2006	2007	2008
Worldwide	107,800	120,596	134,911	150,924	168,839	188,880

	2009	2010	2011	2012	2013
Worldwide	211,301	236,382	264,440	295,830	330,944

Source: just-auto

Chapter 3 Technical review

Defining the elements

Ride-control is basically governed by a vehicle's suspension system, including its shock absorbers and struts. Shocks and struts help maintain vertical loads placed on a vehicle's tyres to help keep the tyres in contact with the road. A vehicle's ability to steer, brake and accelerate depends on the contact between the vehicle's tyres and the road. Worn shocks and struts can allow excess weight transfer from side to side (known as 'roll'), from front to rear (known as 'pitch'), and up and down (unsurprisingly called 'bounce'). Variations in tyre-to-road contact can affect a vehicle's handling and braking performance and the safe operation of a vehicle. Shock absorbers are designed to control vertical loads placed on tyres by providing resistance to vehicle roll, pitch and bounce.

The term 'shock absorber' is a misnomer because the device doesn't, in the strictest sense, absorb shock at all. The shock absorber is designed to dampen the movement of the springs – be they coil, leaf or torsion bar – limiting the road shock transmitted through the tyre, wheel, hub and spring mount. Bushings absorb the rest. The spring must also support the weight of the vehicle. The sole purpose, however, of the more accurately-named 'damper' in any suspension system is to control the spring's oscillations. If they are damped, the tyre is able to stay in contact with the road surface. The net result is a more comfortable ride, precise handling, efficient braking and smooth acceleration.

There are many types of shock absorber, but the most commonly used work with hydraulics (oil). There are two absorbers of this type: single-tube and twin-tube.

- Single-tube shocks have a sliding separating piston and a pressurised compensation chamber to receive the piston rod volume that enters the shock absorber during compression. The main advantages of this type of shock are easy adjustment of damping forces and no risk of cavitation due to admission pressure in the damper. The shock can also be installed in any position. On the flipside, the disadvantage of this type is that the outer tube, which acts as a guide for the piston, is prone to damage caused by stone chippings, etc. It cannot be shortened either.

- Twin-tube shock absorbers are available as either an atmospheric or low-pressure twin-tube type. Advantages include a soft response as there is little friction at the seals. Unlike the single tube, the type can be adapted to fit in confined spaces. On the other hand, these shocks are more prone to overload than single-tube shocks.

In any real-world situation a certain amount of damping exists, but with modern suspension systems it is not nearly enough (although inter-leaf friction in multi-leaf spring packages proved sufficient for many pioneer vehicles). Today the telescopic hydraulic damper is almost universally used for the purpose, achieving its damping effect by forcing hydraulic fluid to pass through a restriction from one internal chamber to another.

Shock absorbers vary widely in their detail design if not in their external appearance. Chassis engineers argue the merits of single-tube and twin-tube dampers, and seek to improve performance by filling the chamber voids with pressurised gas. Great care and ingenuity is devoted to the design of the orifices through which the damping fluid passes (these being fundamental to the damper's performance), with different and progressive characteristics in bump (compression) and rebound (extension).

According to Bosch, the damping characteristics are the result of the cumulative function of orifice damping and the valve located at the passage orifice; the spring opens the passage orifice wider in response to mounting pressure. Piston passages and spring diaphragms can be specifically tailored to provide linear to mildly-digressive damping curves. Adaptive dampers support a wide range of characteristics, says Bosch. For dampers with both fixed characteristics and programme-map adjustment, the compression-mode values are 30-50% of those for rebound mode.

Active suspension systems

For the last decade or so, the high-end technical emphasis has been on developing shock absorbers in which the damper rate can be varied according to the road conditions, to avoid the compromise in which damping is soft enough to feel comfortable on rough road can create a nauseous 'floating' sensation on near-smooth but slightly-undulating surfaces. Most designs have concentrated on computer-controlling the opening and closing of valves which bring additional damper orifices into operation – thus the firmest rate exists

with all valves closed – but Delphi has devoted much effort to developing its MagneRide concept in which a magneto-rheological (MR) fluid passes through an orifice which can be ‘restricted’ by applying an electric field across it. The fluid consists of magnetically-soft particles suspended in a synthetic fluid. When current is applied to an electromagnetic coil inside the damper’s piston, the resulting magnetic field changes the rheology (or resistance of flow) of the fluid, which produces a mechanically-simple but very responsive and controllable damping action without any valves. Delphi and Lord Corp³ co-developed the MR fluid. In its ‘off’ state, the MR fluid is not magnetised, and the iron particles are dispersed randomly. However, in the ‘on’ state, the applied magnetic field aligns the metal particles into fibrous structures, changing the fluid rheology and thus regulating the damping properties of the monotube struts. According to Delphi, the MR fluid can change from a mineral-oil-like consistency for low damping forces to a jelly-like one for high damping within a split second. An onboard controller continually adjusts the damping forces up to once every millisecond based on input from four suspension displacement sensors, a lateral accelerometer and a steering wheel angle sensor. MagneRide thus provides continuously-variable characteristics, opening new possibilities. Development has been protracted, apparently mainly because of the need to ensure the special fluid remains viable in extremes of climate, but production applications are expected to appear very soon. MagneRide is currently featured in six premium vehicles in the US with a further five new vehicle applications to be in production by 2007.

The company’s engineers continue to develop MagneRide. *“We are working on a step change in the capability of ride-control systems. Within one vehicle generation we will virtually eliminate the need to choose between ride and handling performance,”* said Dr Alex Alexandridis, Delphi’s Chief Engineer for Chassis Technologies. To increase the performance of the system, Delphi’s engineers are focussing on delivering a higher dynamic range (or as Delphi puts it: *“a softer soft and a harder hard”*) and a faster transient response. The engineering team believes that this will allow MagneRide to take more control of the suspension so that the authority of the roll bar and springs (which create

³ Headquartered in Cary, North Carolina, US, Lord Corp is a privately-held company that designs, manufactures and markets devices and systems to manage mechanical motion and control noise and vibration; formulates, produces and sells general purpose and specialty adhesives and coatings; and develops products and systems using magnetically responsive technologies. The company employs 2,400 workers in factories and offices in nine countries.

ride compromise) can be reduced and transient body motions can be controlled without additional systems. Other mechanical improvements include friction reduction and better seal and bearing designs and materials, plus other modifications to improve resistance to side loads that will push the application possibilities into heavier vehicle sectors such as large SUVs.

In looking beyond the capabilities of MagneRide, Delphi is investigating how vehicle dynamics, particularly response to emergency situations, can be improved by sharing data with other vehicle systems. In a 'global chassis control' system, a supervisory computer would manage an array of sub-system controllers, potentially covering anti-lock braking, electronic stability control, engine torque, roll control, dampers and active steering. *"The main driver to this level of integration is the need for a standard high-speed communications protocol implemented by the manufacturers of each system,"* said Alexandridis. *"We are participating in various consortia, such as FlexRay, to develop the infrastructure that will support a safe and reliable collaboration of the multitude of chassis sub-systems present in today's vehicles."*

In an exclusive interview with just-auto, Oliver Raynauld, Chief Engineer, European Applications for Magneride, Delphi Corp, said: *"Magneride is an extremely fast damper with a wide authority, enabling it to be very soft but also very hard depending in the driving situation. That authority is what you require in order to have the most impact on the vehicle ride and handling. So if we could make that authority even wider then we expect to be able to get the performance improvement. So we are working on changing the characteristics of the damper in terms of its authority in addition to the speed and fidelity of response to the command."* When could we see the results of this development work on the road? *"Some of it will be gradual,"* added Raynauld. *"Things like algorithms and software are relatively easy to change. That's because the verification and validation requirements of software do not require a huge amount of time. So from one application to the next, it is relatively easy to do. Another thing that is going on which will become apparent in the next few years is the fact that our customers are becoming more familiar with the technology and are learning themselves to use it better. Of course, Delphi is the most qualified to use it but it is difficult for Delphi to instil the correct brand of DNA into the tuning of the product. That must come from the OEMs. Of course, they need to become more familiar with the system in order to become more and more competent at expressing their wishes through the system. What we are expecting to see is four or five introductions per year over the*

next three-and-a-half years or so. Now when it comes to more fundamental change affecting the damper or the ECU then that takes a lot longer to develop and validate. So significant change there is expected around the 2010-2012 timeframe.”

Tenneco's so-called Continuously Controlled Electronic Suspension (CES) system continually adjusts damping levels according to road conditions and vehicle dynamics. At the heart of the system is an electronic control unit (ECU) that processes driver inputs and data from sensors placed at key locations on the vehicle. The sensors include three accelerometers mounted on the vehicle body and four suspension position sensors, which provide data on steering wheel angle, vehicle speed, brake pressure and other chassis control factors. The ECU uses control software that processes the sensor information in real-time and sends signals that adjust the damping level of each shock absorber valve independently. The CES shock absorber is a low-pressure three-tube shock absorber. Each shock absorber is equipped with one CES valve. This continuously-variable valve defines the working pressure (and thus the damping forces) in rebounds and in compression. The shock absorber is designed to direct the oil flow in rebound and compression to the CES valve, always in the same direction (uniflow principle). Therefore the shock absorber is fitted with a third tube to guide the oil down from the rod guide to the CES valve and intake valves on the piston and the cylinder end. In rebound the intake on the piston is closed and the intake end is opened. In compression the intake on the piston is opened and the intake on the cylinder end is closed. Tenneco's electronic shock absorbers for this system are manufactured at the company's facility in Ermua, Spain. The company's CES is already being sourced by a number of automakers, including Volvo (for the S60 V70, S60, V70, XC70 and S80 models), Audi (A6, A6 Avant and Allroad), Ford (S-Max, Galaxy and Mondeo) and Mercedes-Benz (C-Class).

In 2005, Opel and Vauxhall began offering ZF Sachs' continuous damping control (CDC) as an option on the new Astra Sport mode (offered in German Opel dealerships for around EUR400). It was the first time that such a system has featured on a mass-market car. The German supplier's solution uses a stepless approach to chassis damping, avoiding the previous compromise between hard and smooth damping. The ECU takes signals from the sensors and interacts with the ABS and Electronic Stability Control system while also taking information from steering wheel angle, brake pressure and engine torque. For the driver, who just has to push a button on the dashboard, CDC

makes the car safer and easier to drive, prevents nose-dive on braking and 'squat' on acceleration and allows driving on 'sport' or 'normal' damper settings. In addition to the Opel Astra, ZF's CDC is also featured on the Opel Signum and Vectra, VW Phaeton and Touareg, BMW 7 Series, Maserati 3200, 4200, Spyder and Quattroporte, Porsche Cayenne, Audi A8, Ferrari 430, Modena, Maranello, Enzo, and Scaglietti, Bentley Continental, Rolls Royce Phantom, SsangYong Chairman, and Lancia Thesis. The CDC is also applied to commercial vehicles.

ZF Sachs' engineers have also recently developed a so-called Sensitive Damping Control system that will go into mass production of an unnamed Asian automaker. In this design, an additional valve is placed on the piston rod which is suspended between springs and, depending on the tuning philosophy, has a certain amount of free play. For minor stimulations, only the standard valve is actuated. For major stimulations, the damping forces of both valves are added. With the additional valve characteristics (pistons with spring-loaded valve disks and bypasses) as well as the definition of the free play. ZF Sachs claims that this situation means that the range, in which the damper switches from soft to hard, is freely adjustable to a very large extent.

For its part, ArvinMeritor's Active Damping System, currently under development on an unnamed European performance coupé, features an electro-magnetically actuated combination spool and poppet valve 'snoopet', replacing a standard piston in either a monotube or twin-tube shock absorber. The company claims that all damping is provided by the valve, which eliminates deflected disks and simplifies the OEM's tuning and development time.

While much of this continuous damping technology is initially only available as optional equipment, it is down to the dealership staff to get the message across to their customers of its benefits. What happens when car dealership sales personnel are unaware of the technology behind these features? In order to avoid this situation occurring with its CDC, ZF Sachs has taken matters into its own hands. The supplier joined forces with Opel to launch a dealership initiative in Germany. During coaching and training sessions, sales teams from German Opel dealerships gained a better idea of how CDC improves driving dynamics and safety.

Q&A with Magna Steyr

In September 2007, Matthew Beecham talked to Robert Scholz, Chief Engineer, Chassis, Walter Rosinger, Engineer, Pre-development Chassis and Dr Werner Kober, Product Manager Global Chassis Controller, Magna Steyr, about the of chassis control systems integrator and continuous damping control technologies.

just-auto: As a supplier of integrated chassis control systems, what does taking on that responsibility actually mean?

Robert Scholz: It depends on the requirements of our customers. In general we have the competence and experience to take full responsibility of integrating chassis systems. That means we do the integration of existing systems in the course of total vehicle development. We also do the final release and validation of these systems. In addition, we are working on our own systems such as active rear steering and torque vectoring systems.

j-a: What are the benefits to carmakers from sub-contracting this integration work?

Walter Rosinger: We can integrate chassis components of different suppliers in order to get the overall performance optimised.

RS: The main benefit is that we are not only a systems supplier but offering engineering services, too. That means we can take over the whole responsibility from the OEM in doing the complete integration.

j-a: What are the main trends in conventional shock absorber technology that you are seeing and, more specifically, what's driving those trends?

Werner Kober: From our perspective, we think that the traditional or passive shocks are particularly-good applications for emerging markets such as India and Russia which need cost-efficient solutions. Meanwhile, the electronic systems and semi-active systems will be integrated first in upper-class cars and then permeate down the segments.

j-a: From Magna Steyr's perspective, how do you see the use of continuous damping control evolving in the automotive industry?

WK: Although we are not developing damping systems, we have the competence to integrate these systems in our global chassis control approach.

RS: We have no product strategy towards damping systems or active dampers. But we have in mind to include it in our global chassis control strategy. Regarding the tendency [toward continuous damping control], I see an increasing proportion of vehicles with continuous damping control on the market due to the benefits of the system against conventional shocks.

j-a: What is Magna Steyr's involvement in corner modules?

RS: We are deeply involved in alternative propulsion systems. That means hybrid systems and this includes electric driving. We have a lot of elements and systems in development now for these alternatively-powered cars. Out of this involvement we are thinking about concepts for corner modules.

Corner modules

Suspension corner modules include brakes, struts, strut mounts and bearing elements as well as suspension bushings and vibration control elements. In summing-up the use of corner modules to date, an auto executive told us: *"Corner modules have been supplied in North America for about 20 years. The European OEMs, however, have been more reluctant to do this because they do not have one single supplier for the whole thing. So putting together a [corner] module in Europe comes with a number of difficulties. One of them is commercial: at what price will they [suppliers] bring in the parts. While the OEMs want to save themselves the hassle by allowing the Tier 1 to sort all those issues out, the sticking point between the OEM and supplier is, of course, price. So that is one thing that has been plaguing the [corner module] concept in Europe. The other thing, of course, is the technical responsibility of the components when there is a quality issue in the field. It also requires a lot of co-operation between suppliers as well as significant 'political' involvement from the OEMs to ensure that those suppliers are walking in the same direction. Ideally, the OEM should remain project leader but that is exactly the job that they no longer wanted to do. So there is a contradiction for the OEM, here, which each one of them is trying to resolve."*

In contrasting the European and North American automakers use of corner module technology, another auto executive told us: *"Basically, this depends on*

the customer's outsourcing strategy. Independent wheel suspensions are also represented, so, basically, there are no fundamental differences. The market potential is increasing along the lines of the vehicle construction figures."

With tomorrow's car in mind, Siemens VDO Automotive's engineers have developed a system to integrate the drivetrain, steering, shock absorbers and brakes directly into the wheels of future vehicles. The company believes that its so-called eCorner will ultimately replace conventional wheel suspensions, along with hydraulic shock absorbers, mechanical steering, hydraulic brakes and conventional internal combustion engines. Siemens VDO reckons we could see its technology on the road in 15 years. Most of the eCorner technology is dependent upon electronic sensors of which Siemens is a major designer and manufacturer.

Other innovations

In the strut suspension system that is used for front wheels of vehicles, the shock absorbers are typically subject to side-forces because the vertical motion axis of tyres cannot be set in complete parallel with the actuation axis of shock absorbers. As this typically interferes with the ideal actual of the shock absorbers, the common solution is to use the 'offset spring system' in which the spring was set slightly off the centre of the axis. In addressing the problem, Showa Corp's engineers have developed a so-called Side Force Cancel (SFC) spring which cancels the side forces by bending the axis of reaction force of the spring itself.

The need to reduce component weight is nothing new in the automotive industry. For its part, ZF Sachs says that shock absorbers can be made lighter by using alternative materials such as aluminium or high-strength steel as well as via dimensioning and optimal component design. The company's lightweight shocks have already been used in development projects such as the Volkswagen 1-litre car as well as volume production vehicles, e.g. compact cars up to the luxury segment. ZF Sachs claims that its lightweight shocks can save up to 4 kg in the total weight of the chassis system by using a hollow piston rod as well as specially-manufactured aluminium reservoir tubes and spring plates.

Chapter 4 Manufacturers

ArvinMeritor

Over the past few years, ArvinMeritor has gradually moved up the food chain, and now concentrates its efforts on designing, engineering and building complete suspension modules although it still designs and makes shocks and struts for the OE and aftermarket. Indeed, in March 2007, ArvinMeritor announced plans to develop its global ride-control businesses as an integral part of the company's overall vehicle strategy. This will involve the integration of design, manufacturing and distribution of light-, medium- and heavy-duty original equipment and replacement shock absorbers and struts. The new organisation will include the Gabriel light vehicle aftermarket business which was previously held in discontinued operations. The newly-combined Ride Control business reports into the company's Light Vehicle Systems (LVS) business group. It includes LVS Ride Control, Gabriel de Venezuela, Gabriel de Columbia, Gabriel India, Gabriel Light Vehicle Aftermarket in North America and Europe, and Commercial Vehicles Systems Ride Control including recreational and industrial applications⁴. *"ArvinMeritor is also implementing an aggressive strategy in Asia which includes responding to an overwhelming demand for ride-control capabilities,"* said Phil Martens, President of ArvinMeritor's LVS business group. In September 2007, the company announced plans to consolidate its three North America ride-control facilities into one, including the closure of one of its Toronto, Ontario OE shock absorber operation, and its Chickasha, Oklahoma packaging and distribution centre. A majority of the shock absorber production will be transferred from Toronto to Queretaro, Mexico by June 2008, with an anticipated closure by June 2009. The Chickasha site will move its packaging and distribution business to a US-based third-party logistics company by April 2008.

Today, ArvinMeritor's chassis system portfolio includes:

- **Air suspension systems:** Currently in development on a European mid-size performance sedan, ArvinMeritor's full system integration approach for air suspension systems improves ride and handling, and allows for load levelling and height adjustability.

⁴ ArvinMeritor completed the sale of its Gabriel South Africa ride control business and North American motion control business in the fourth quarter of its 2006 fiscal year.

- **Active roll control systems:** Currently in development, the company's hydraulically-assisted stabiliser bar system improves ride, handling and safety.
- **Adaptive damping systems:** Currently in development on a North American luxury sedan, this product offers increased safety and comfort by actively adjusting damping forces in the shock or strut.

Figure 9: ArvinMeritor's Adaptive Damping System



Source: ArvinMeritor

Delphi

Delphi has become a leading player in the world's controlled suspension market. Delphi's innovative air suspension technology is helping Land Rover to improve driving dynamics while retaining its legendary off-road performance. The new technology is available on the Discovery 3 (also known as the LR3 in North America). Land Rover's challenge to Delphi was to combine suspension quality normally found on conventional luxury vehicles with the Land Rover's outstanding off-road capability. The solution also offers automatic self-levelling, plus the ability to change ride height and lower the vehicle for ease of loading.

Delphi also provides its fully automatic ride-control system for General Motors' new 'Safe & Secure' package (consisting of four side-impact air bags plus Delphi's Autoride control) offered with Tahoe, Suburban, Yukon and Yukon XL models. Autoride is a fully-automated system that continuously adjusts the

damping level on each absorber to provide improved ride quality and handling. Autoride's 'tow/haul' mode, for example, provides a good level of damping to improve vehicle body control for towing, while automatic rear level-control assists in keeping the vehicle level under extreme load conditions.

In addition to shocks, Delphi's suspension and brake components include callipers, rotors, drums, master cylinders, boosters, drum brake assemblies, friction materials, struts, airlift dampers and levelling height sensors.

For the aftermarket, the company offers gas and hydraulic shock absorbers for off-road and high-performance vehicles.

KYB

KYB's business activities are organised into two divisions: Hydraulic Products, and System Products. Its Hydraulic Products division itself divides into two product groups: shock absorbers, and hydraulic equipment. KYB produces shock absorbers for cars, light trucks and motorcycles. The company produces a range of oil and gas shocks, as well as MacPherson strut replacement cartridges, MacPherson struts, gas replacement struts and steering dampers. KYB's main customers in Japan for automotive shock absorbers include Toyota, Honda and Nissan.

Over the past five years, KYB has been increasing its market presence in overseas markets, especially Europe and North America. The group has manufacturing bases in North America, South America, Europe and Southeast Asia. In China, KYB is in the throes of increasing production of shock absorbers for vehicles.

Headquartered in Tokyo, KYB Industry is one of the world's largest manufacturers of original equipment shock absorbers, supplying around 60m shocks every year to automakers.

Today, the group has operations at the following locations outside Japan:

- The US:
 - KYB Manufacturing North America Inc, Franklin, Indiana;
 - California Representative Office, Cypress, California;
 - Seattle Representative Office, Washington State;
 - KYB America LLC, Addison, Illinois.

- Mexico:
 - KYB Latinoamerica SA de CV, Mexico DF.
- Czech Republic:
 - KYB Manufacturing Czech sro, Pardubice.
- Dubai:
 - KYB Middle East FZE.
- Spain:
 - AP Amortiguadores SA, Ororbia Navarra;
 - KYB Suspensions Europe SA, Orcoyen Navarra;
 - KYB Steering Spain SA, Orcoyen Navarra.
- Germany:
 - KYB Europe GmbH, Krefeld.
- UK:
 - KYB UK, Warrington.
- France:
 - KYB France, Herblay.
- Italy:
 - KYB Italy, Milan;
 - Paioli Meccanica SpA, Minerbio.
- Moscow:
 - KYB Europe GmbH, Vrazhok, Moscow.
- Taiwan:
 - Yung Hwa Machinery Industrial Co Ltd, Tao Yuan Hsien.
- Thailand:
 - KYB (Thailand) Co Ltd, Samut Prakan;
 - KYB Steering (Thailand) Co Ltd, Chonburi.
- Malaysia:
 - KYB-UMW Malaysia Sdn Bhd, Selangor DE;
 - KYB-UMW Steering Malaysia Sdn Bhd, Selangor DE.
- Indonesia:
 - PT Kayaba Indonesia, Jakarta Timur.
- China:
 - Husco-Kayaba Hydraulics (Shanghai) Ltd, Shanghai;
 - KYB Industrial Machinery (Zhenjiang) Ltd, Zhen Jiang Jiang Su.
- Vietnam:
 - KYB Manufacturing Vietnam Co Ltd, Hanoi.

In 2007, KYB increased its OE business with Mitsubishi and PSA Peugeot Citroën by supplying shock absorbers for the Mitsubishi Outlander, Peugeot

4007 and Citroën C-Crosser. During the year, KYB also strengthened its relationship with Toyota by supplying front and rear shock absorbers as OE for the new Auris.

In May 2006, KYB Europe opened a new European logistics and distribution centre at Eragny in northwest Paris. The 10,000-m² site offers a stock capacity twice as large as the company's previous warehouse and provides space for some 20,000 pallets. The new warehouse stores some 5,000 product references, covering more than 98% of the European car parc and includes:

- over 3,500 shock absorber references;
- over 1,000 coil spring references;
- about 100 mounting kit references.

The new site employs 15 people to manage the facility who work alongside KYB's existing 25 workers in France. In addition to the new centre, KYB operates three warehouses across Europe, one located in Germany (which supplies products to eastern and northern Europe), the second in Spain (which covers the Iberian peninsular) and the third located in the UK (covering Great Britain and Northern Ireland).

Over the past year or so, KYB has revealed a number of innovations in the shock absorber area, including:

- Real Sports Damper – an automotive shock absorber that uses piston rods coated with Diamond-Like Carbon (DLC) to reduce low-velocity friction, thereby improving steering stability and overall comfort.
- A front fork shock for motorcycle applications that separates air and oil to prevent aeration and thus enhance responsiveness.
- A hydraulic pump with an electromagnetic proportional pressure-reducing valve and two-speed hydraulic motor for electronically-controlled concrete mixer trucks.

Showa Corp

Showa Corp designs and makes shock absorbers, steering systems and drivetrain parts for cars and motorcycles. The company is one of the world's largest suppliers of shocks. Its shock absorber line-up includes aluminium dampers, self-levelling dampers, oil seals and struts. Honda Motor owns a 33.48% stake in Showa Corp.

Headquartered in Gyoda City, Saltima, Japan, Showa operates five manufacturing plants, three R&D centres and two affiliated manufacturers within Japan. In addition, the company operates an international network of 30 facilities in 15 countries. Its subsidiary companies producing shock absorbers are as follows:

- Nissin Showa UK Ltd;
- Nissin Europe SA;
- Munjal Showa Ltd;
- Summit Showa Manufacturing Co Ltd;
- Armstrong Auto Parts Sdn Bhd;
- Machino Auto Parts Co Ltd;
- Chengdu Ningjiang Showa Autoparts Co Ltd;
- Guangzhou Showa Autoparts Co Ltd;
- Shanghai Showa Auto Parts Co Ltd;
- Kaifa Industry Co Ltd;
- PT Showa Indonesia Manufacturing;
- American Showa Inc;
- Showa Do Brasil Ltda; and
- Showa Industria E Comercio Ltda.

Showa also supplies a range of shock absorbers and drive unit parts for motorcycles, and power units for outboard marine units. For motorcycles, the company produces fork pipes, sheet pipes, rear cushions, springs, rods, damper components and shock absorbers. In addition, the company manufactures parts for outboard marine engines. Showa's shocks business generated sales revenues of US\$474m in the financial year ended 31 March 2006, up 6.3% over the previous fiscal year.

Tenneco

Tenneco Automotive is one of the world's leading manufacturers of emission control, ride-control products and elastomer systems, serving the global automotive OE and aftermarkets. The company markets its ride-control products under the Monroe brand name. In October 2005, Tenneco Automotive changed its name to Tenneco Inc, reflecting the expanding number of markets it serves through its commercial and specialty vehicle businesses.

Tenneco's Monroe ride-control products include:

- Shock absorbers – a range of mechanical shock absorbers and related components for light- and heavy-duty vehicles. The company supplies

both twin-tube and monotube shock absorbers to automakers and the aftermarket.

- Struts – complete line of struts and strut assemblies for light vehicles.
- Vibration control components – generally rubber-to-metal bushings and mountings to reduce vibration between metal parts of a vehicle. Tenneco's products include a broad range of suspension arms, rods and links for light- and heavy-duty vehicles.
- Kinetic roll control – a suite of roll-control, near equal wheel loading systems ranging from simple mechanical systems to complex hydraulic systems featuring proprietary and patented technology. The Kinetic system was first commercialised with Toyota.
- Advanced suspension systems – includes electronically-adjustable shock absorbers and suspension systems that change performance based on vehicle inputs such as steering and braking.
- Other – such as load assist products, springs, steering stabilisers, adjustable suspension systems, suspension kits and modular assemblies.

Tenneco supplies OE ride-control products to 35 automakers for use on over 160 vehicle models. Its five biggest OEM customers are Ford, Volkswagen, GM, DaimlerChrysler and Nissan. It also supplies OE ride-control products and systems to a range of heavy-duty and specialty vehicle manufacturers including Volvo Truck, Scania, International Truck and Engine (Navistar), Freightliner, PACCAR and E-Z Go Car (golf carts).

Tenneco's ride-control products for the aftermarket include Gas Matic Sensa-Trac, Monroe Reflex and Monroe Adventure. Its customers include NAPA, Advance Auto Parts, O'Reilly Auto Parts, Temot Autoteile, and Pep Boys.

Tenneco operates eight ride-control manufacturing facilities in the US and 22 ride-control manufacturing facilities outside the US. Six of these manufacturing facilities are JIT facilities. The company operates two of these international facilities through three joint ventures in which it owns a controlling interest. In addition, it has seven engineering and technical facilities worldwide and shares two other such facilities with Walker, Tenneco Automotive's exhaust systems business. Within each of its ride-control manufacturing facilities, operations are organised by product – shocks, struts and vibration control products.

For the year ended 31 December 2006, Tenneco posted sales of US\$4.68bn, of which its Ride Control Systems business generated sales of over US\$1.7bn.

Table 5: Tenneco Inc's net sales by segment, 2001-2006* (US\$m)

	2001	2002	2003	2004	2005	2006
Emission Control Systems & Products						
Aftermarket	387	359	350	365	368	384
OE market	1,805	1,880	2,037	2,287	2,390	2,592
Ride Control Systems & Products						
Aftermarket	548	549	579	630	653	690
OE market	624	671	800	931	1,029	1,016
Total	3,364	3,459	3,766	4,213	4,440	4,682

* Years ended 31 December
Data may not sum due to rounding

Source: Tenneco Inc

Table 6: Tenneco Inc's percentage of net sales of ride-control equipment for certain geographic areas, 2001-2006* (%)

	2001	2002	2003	2004	2005	2006
The USs						
Aftermarket	45%	45%	43%	47%	46%	53%
OE market	55%	55%	57%	53%	54%	47%
Total	100%	100%	100%	100%	100%	100%
Foreign sales						
Aftermarket	49%	47%	41%	35%	33%	33%
OE market	51%	53%	59%	65%	67%	67%
Total	100%	100%	100%	100%	100%	100%

Table 6 (continued): Tenneco Inc's percentage of net sales of ride-control equipment for certain geographic areas, 2001-2006* (%)

	2001	2002	2003	2004	2005	2006
Total sales by geographical area						
US	50%	52%	47%	43%	42%	38%
European Union	27%	27%	32%	34%	32%	33%
Canada	4%	4%	4%	4%	4%	6%
Other areas	19%	17%	17%	19%	22%	23%
Total	100%	100%	100%	100%	100%	100%

* Years ended 31 December

Source: Tenneco Inc

Tenneco is currently focusing on growth with Japan-based OE customers. Tenneco now serves Japanese customers in 14 countries and the revenue from Japanese OEMs accounted for 10% of Tenneco's 2006 global original equipment revenues and 20% of North American original equipment revenue. The company anticipates this growth will continue with an expected 32% increase in global OE revenue from Japanese customers by 2008. Tenneco has been named a development supplier in Japan on four different platforms with vehicles that are and will be produced in Asia, Europe and North America. For example, Tenneco is currently supplying its ride-control components, front strut module and rear shock for the Suzuki Swift Sport, launched in 2006 in Japan and Europe.

ZF Friedrichshafen AG

ZF Group is organised into five product-oriented divisions:

- Car Driveline Technology;
- Car Chassis Technology;
- Commercial Vehicle and Special Driveline Technology;
- Off-Road Driveline Technology and Axle Systems; and
- Powertrain and Suspension Components (ZF Sachs AG).

ZF generates 87% of its sales revenues in the automotive industry. Half of these sales are in driveline technology and the other half are in chassis technology.

ZF Sachs itself operates two business units: Powertrain Components, and Suspension Components. In 2006, the Suspension Components business unit recorded an increase in sales of 3% to EUR1,219m. The business reported sales increases in all product segments except for the Nivomat suspension level regulating system. More specifically, the positive results for the division were driven by sales of electronic CDC systems. The company also reported that its CDC system is also gaining significance in the truck and bus market. In 2006, the CDC was introduced as a standard in a coach model for the first time.

ZF Sachs employs 16,200 people, of whom about 7,800 work for its Suspension Components business. This business produces shock absorbers and spring struts for passenger cars and commercial vehicles as well as for rail vehicles among other automotive parts. This business produces some 249,000 shock absorbers every working day, which is equivalent to 55m annually. In addition to shocks, this business designs and manufactures a range of tie rods, stabilisers, stabiliser links, control arms, suspension joints, suspension joints, levelling systems, crash absorption parts and chassis mounts.

The aftermarket division is known as ZF Sachs Trading. Its products include clutches and shocks, along with steering, chassis, and rubber-metal components and commercial parts.

ZF has built up an international network of subsidiaries. Today, the company manufactures chassis components at its sites across Germany, Spain, France, the UK, Italy, Turkey, China, India, South Korea, US, Mexico, Argentina, Brazil and South Africa.