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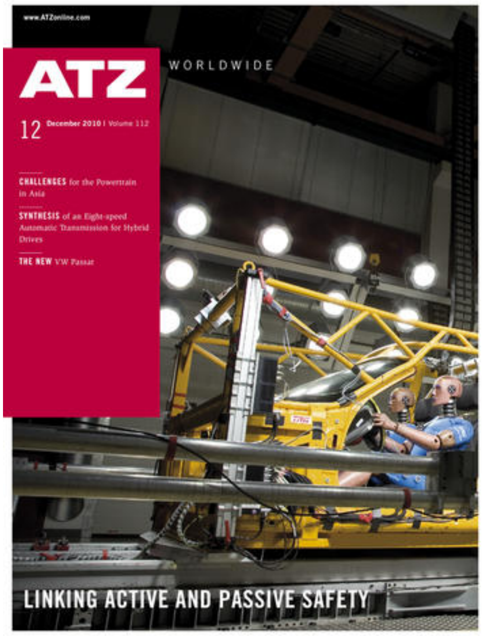

ATZ .worldwide 12/2010, as epaper released on 25.11.2010
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12 December 2010 | Volume 112

CHALLENGES for the Powertrain in Asia

SYNTHESIS of an Eight-speed Automatic Transmission for Hybrid Drives

THE NEW VW Passat

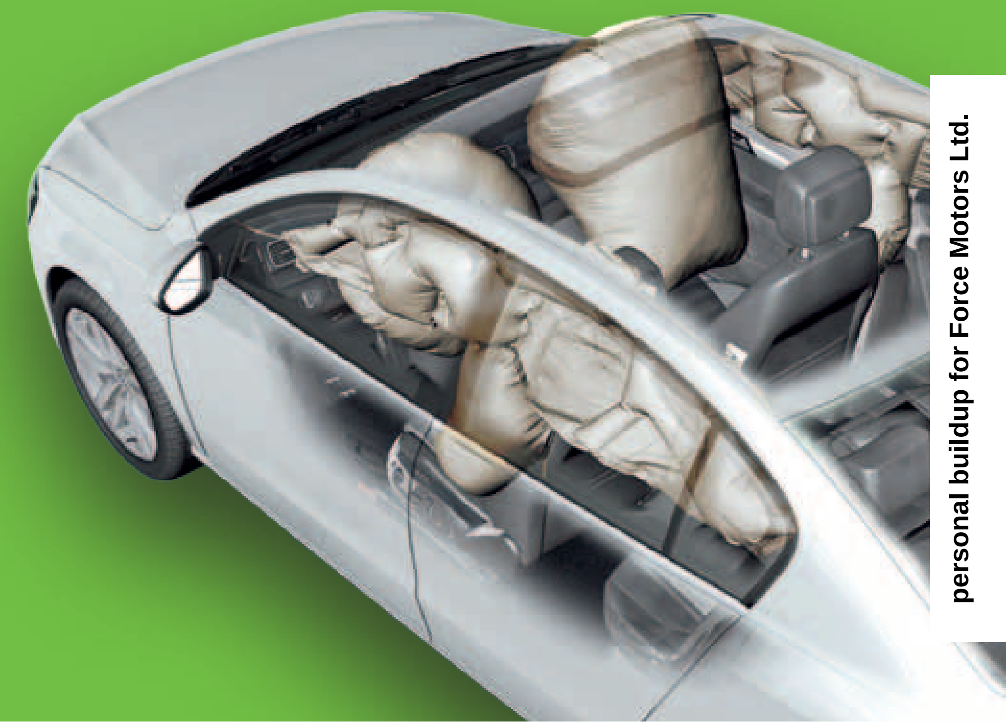
LINKING ACTIVE AND PASSIVE SAFETY

CONTENTS

COVER STORY

LINKING ACTIVE AND PASSIVE SAFETY

4, 10 I Accident-free driving must always be seen as the result of both active and passive safety. At the same time, the borderline between the two types is becoming less distinct, as restraint systems and assistance systems are being increasingly interlinked. ATZ describes how Continental has developed cooperative sensor technology as part of its Ko-FAS research initiative in order to increase road safety by using transponders. TRW is using an innovative snake-like plastic piston to transfer the tensioning torque in a belt pretensioner.



COVER FIGURE TRW
FIGURE ABOVE Volkswagen

FAREWELL

Dear Reader,

Most of us find it difficult to say goodbye. Certainly when changing jobs or even when leaving our favourite holiday resort. But saying “farewell” to a person we like and respect is a much harder task.

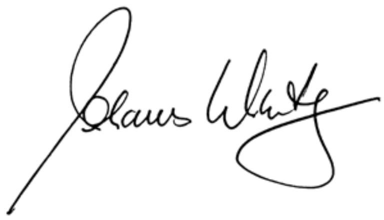
At the end of the year, our publisher Dr. Richard van Basshuysen, who has accompanied the development of ATZ and MTZ for two decades, will be leaving. During this time, his achievements in advancing technical progress in our field have been extraordinary.

It is, of course, quite impossible in these few lines to give a comprehensive appreciation of the life work of this exceptional engineer, journalist and author. Therefore, I would simply like to recall two points from his time as Head of Development at Audi that made a lasting impression on the German automotive industry. As a pioneer of TDI technology, it was he who first launched the direct-injection turbocharged diesel engine into series production. As a result, it was Dr. van Basshuysen who laid the foundation stone for the overwhelming success of the diesel engine in passenger cars, even in the luxury class. What is more, as Head of Development for premium class vehicles, he went on to conquer this class with the predecessor to the A8, the V8, which was an important milestone on Audi’s long journey into the premium segment.

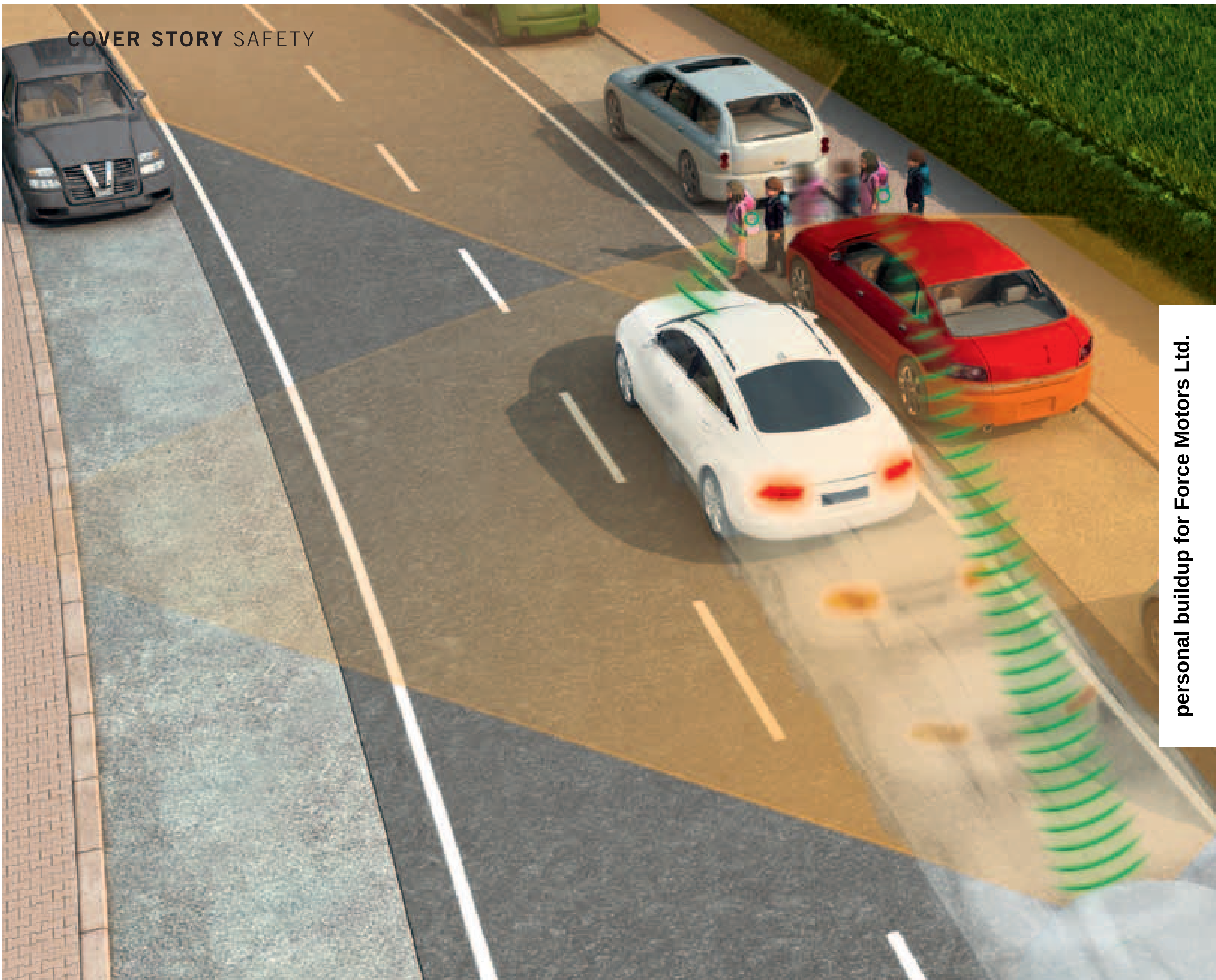
Dr. van Basshuysen brought his expertise and contacts from his time in industry with him when he joined ATZ and MTZ. Benefiting from his untiring support, my predecessor Wolfgang Siebenpfeiffer succeeded in turning these magazines into a modern technical media family, including what has since become an extensive range of books published by us.

As a young man, having just joined ATZ and MTZ in the early 1990s, Richard van Basshuysen impressed me above all by the way in which he was not only open to new ideas – and surprised us with many of his own – but also insisted on absolute perfection when it came to putting these ideas into practice. His boundless energy motivated us, and perhaps even overstretched us occasionally. In short: He was a good mentor to us.

Now, as our paths go separate ways, we not only give him our heartfelt thanks but also bid him “farewell”, in the truest sense of the word.

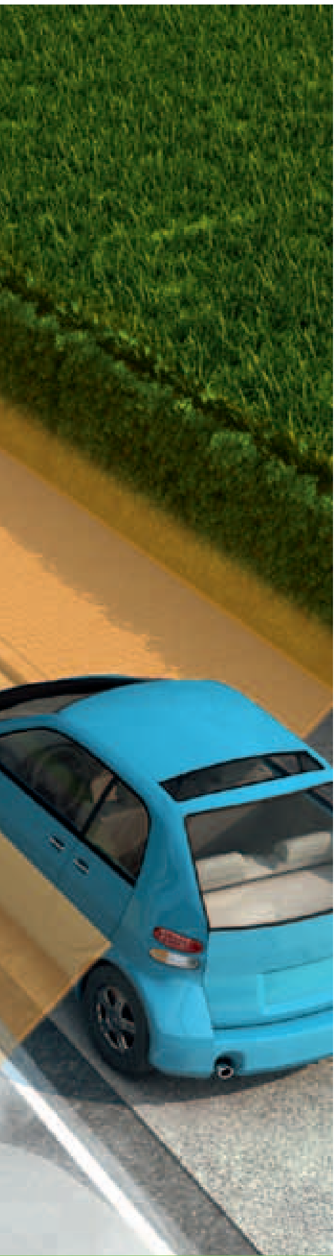


JOHANNES WINTERHAGEN, Editor-in-Chief
Stuttgart, 19 October 2010



PREDICTIVE VEHICLE SAFETY USING COOPERATIVE SENSORY SYSTEMS

Continental as the coordinator of the research initiative Ko-FAS shows together with 17 partners which potential cooperative sensory systems have to increase traffic safety. The introduction of transponders into the traffic infrastructure can increase the safety of participants in road traffic. Integration of these transponders into clothing objects, satchels or even mobile phones is quite conceivable. But also track guidance of vehicles could be supported substantially.



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WHEN SENSORS COMMUNICATE WITH ONE ANOTHER

The European Union‘s target of halving the number of deaths on the roads in the period between 2001 and 2010 will unfortunately be missed in many countries despite the introduction of numerous measures. The EU has already announced its intention to abide by its commitment to halve the number of motoring fatalities in the decade ahead [1]. So further possibilities must be examined which will enable a substantial improvement in road traffic safety for all road users.

A clear safety advantage is to be gained by preventive intervention in driving situations before a collision occurs. However, preventive intervention in a traffic situation calls for very reliable observation and assessment of the current traffic situation. Therefore, the use of cooperative sensory systems and cooperatively networked sensors is ideally suited. Cooperative sensors supply extended information about the driving environment. This allows critical road traffic situations to be identified as they arise and then remedied effectively using situation-dependent measures ranging from targeted driver warnings through to autonomous driving maneuvers.

Cooperative sensory systems can be implemented in accordance with two different procedures: In the first of these, ”sensors“ carried by the road users determine their positions relative to one another. This enables the movement path of nearby road users to be tracked chronologically and critical situations to be identified at an early stage. In the second procedure, the information gathered from locally distributed sensors in the vehicles or the infrastructure is exchanged via suitable communication networks. Both methods are being researched as part of a research initiative called Ko-FAS (which stands for Cooperative Sensory Systems and Cooperative Perception for Preventive Safety in Road Traffic).

TARGETS OF THE KO-FAS RESEARCH INITIATIVE

Ko-FAS is a research initiative promoted by the Federal Ministry of Economics and Technology which focuses on cooperative technologies. The project is costing some 25 million Euros and involves 17 partners; it is one of the biggest national research initiatives in the field of vehicle safety.

With its extensive expertise in the development of vehicle safety engineering, Continental has been entrusted with the technical coordination of the overall initiative, and will be undertaking research tasks in all sub-projects of the research initiative. Other partners in the project include BMW Forschung and Daimler representing vehicle manufacturers, and Delphi, Magna and Sick from the supplier side, as well as renowned universities, research institutes and technical colleges.

The technical focal points of this initiative are the research into cooperative transponder systems, as well as methods of cooperative perception and the linking of these cooperative sensor procedures with effective protective measures on the vehicle. The comprehensive, chronologically available information about the driving environment gained from the cooperative sensors is used to recognize at an early stage the potential risk of a collision.

FUNCTIONAL PRINCIPLE OF COOPERATIVE TRANSPONDERS

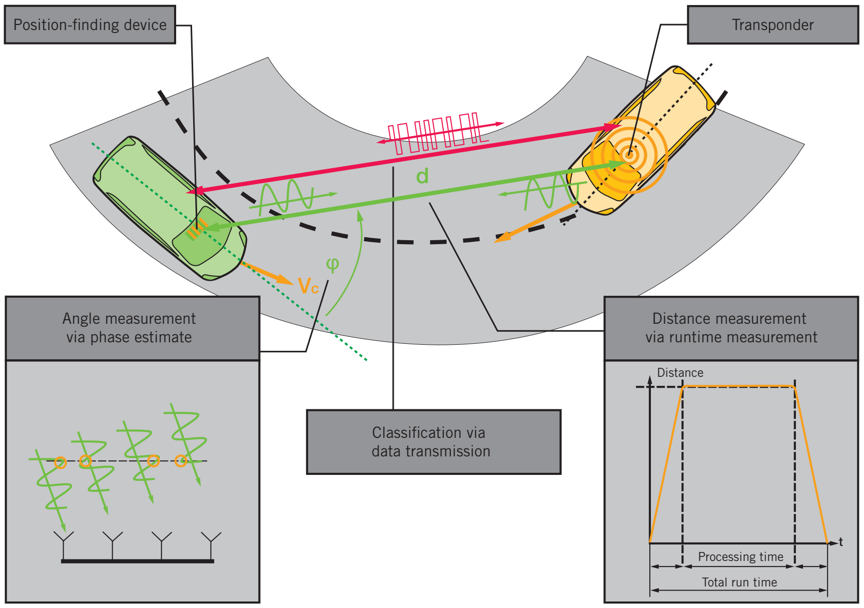
A method using cooperative transponders is a promising procedure for determining the relative positions of road users. This method is derived from the secondary surveillance radar method used for air traffic control; it has been further developed and adapted for use in road traffic. In this procedure, a position-finding device located in the vehicle transmits a coded signal into the traffic environment. The signal is picked up by the transponders which are carried by other road users and then sent back to the position-finding device after a prescribed processing time. The transponder's unique identification number (ID) is attached to the response signal. Further information about the road user's driving situation can also be appended to this signal and can then be applied to assess the driving situation.

The relative position is determined via two synchronized evaluation processes to work out the relative distance and estimate the azimuth angle. The functional principle is illustrated in ❶.

The distance is measured using the classic radar principle via round trip time of flight measurement. By using a correlation procedure in the position-finding device, the total run time of the signal can be determined precisely. As the processing time in the transponder is known, the distance can be determined from the measured run time less the processing time. The azimuth angle is determined by estimating the phase shift of the returning "wave front". If there is an angle misalignment between the position-finding device and the transponder, as illustrated in ①, then the wave front occurs at the adjacent antenna "patches" in different phases. This phase shift – and therefore also the incidence angle of the "wave" – can be estimated by scanning the arriving signals at the individual antennae and the use of an approximation algorithm. This method of measurement enables the position of other road users to be recorded to within a few centimeters. The key data of the cooperative transponder system trialled as part of the Amulett project [2] is summarized in ❷.

However, other road users can be detected and tracked chronologically not just when line of sight is available. Even concealed road users, for example pedestrians moving between parked vehicles on the road, can be recognized and tracked. In these cases, the deflection characteristics of the existing electromagnetic wave are utilized.

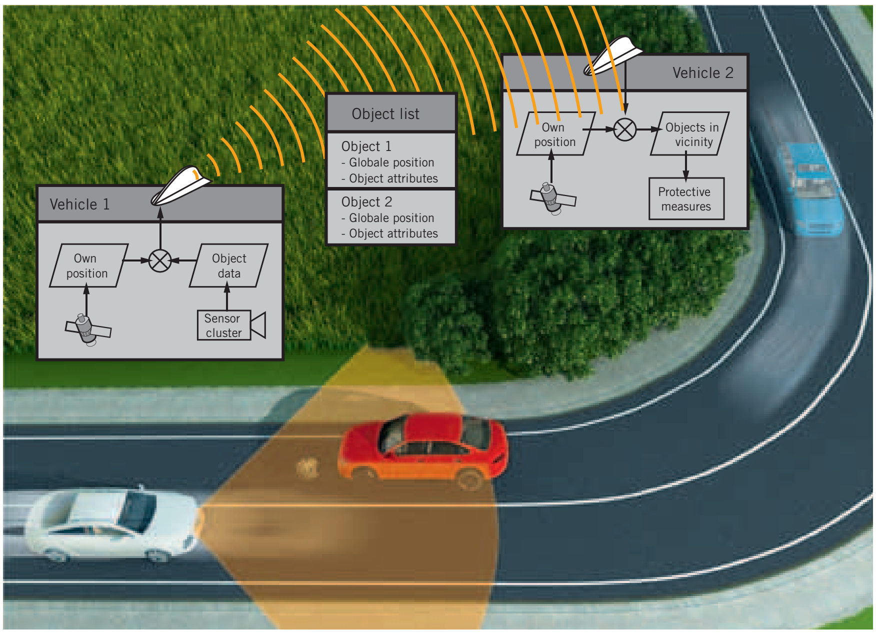
In order to use a transponder system in a more complex driving environment, the system must be able to identify and track a minimum number of road users in parallel. This multi-user system is achieved in two ways: firstly the individual road user can be identified by its unique ID, and secondly an adapted time slot procedure is used which enables systematic



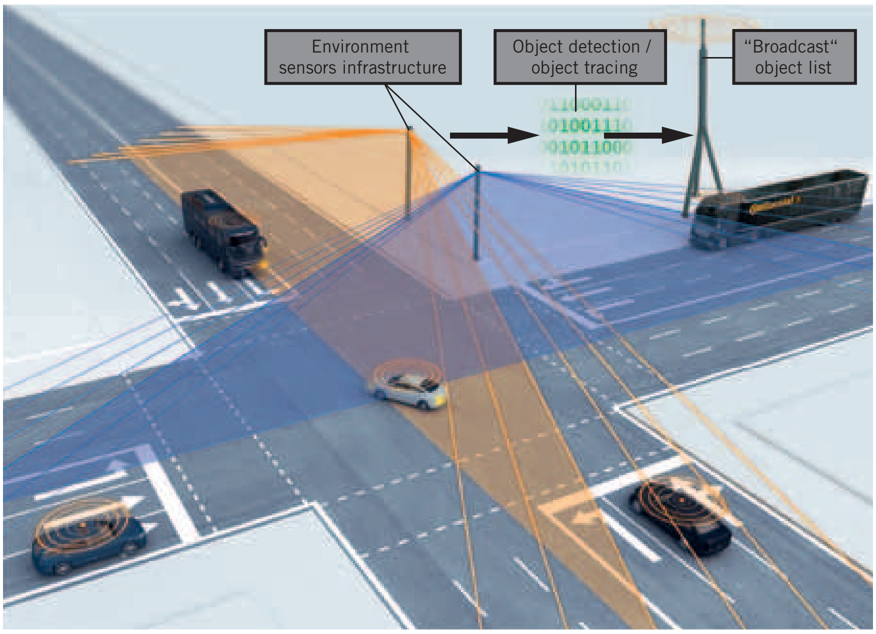
❶ Functionality of the cooperative transponders

❷ Amulett transponder system performance data

AMULETT PROTOTYPE 2009	VALUE
Frequency range	ISM band with 2.4 GHz
Frequency bandwidth	70 MHz
Update rate	> 50 Hz
Open air range	Approximately 400 m
Deviation in distance measured (1 σ)	< 8 cm
Multi-user application	TDMA



❸ Principle of the cooperative perception



❹ Cooperative perception in a crossroads area

interrogation of the transponder units in a traffic environment. Ko-FAS makes provision for simultaneous management of several hundred road users who, according to their priority, can be interrogated at different cycle rates. In order to ensure the anonymity of individual road users, the code of the transponders is changed erratically, which means that misuse can be ruled out.

COOPERATIVE ENVIRONMENTAL RECORDING VIA NETWORKED SENSORS

A further method of the cooperative sensory systems is the bringing together of locally distributed traffic environment information via communication networks to form comprehensive environmental information. The basic method consists in exchanging object information from the environment sensors of the vehicles via communication links. The functional principle is explained in ❸.

In ③, an occlusion situation is shown in connection with a breakdown vehicle which can lead to a critical situation. The situation can be detected by vehicle 1, but not by the cornering vehicle 2. Vehicle 1 identifies the traffic obstacles with its environment sensors and can determine their position and further object attributes. In order to be able to pass this object information on to other road users, the position of the identified objects must be transferred to a global coordinates system. To do this, the detected relative object position is combined with precise information about the vehicle's own position and orientation. This global object information can now be passed on to other vehicles in the traffic environment via a suitable communications link. In this case, the communicated data is received by road user 2. Before this information can be utilized, the "global" object information must be linked again to vehicle 2's own position information. Road user 2 is then able to identify the critical traffic situation hidden from it and to react to it with preventive measures.

The challenge in this method, in addition to ensuring reliable communication, lies in determining the vehicles' own positions and orientation. To this end, high-quality position determination procedures are being researched as part of Ko-FAS. In addition to various GPS-based methods, promising procedures for determining position are being looked at using landmarks. Distinctive environmental points detected by the environment sensors are compared with mapped information about landmarks which allows the calculation of the "global" position.

An extension of the method of cooperative environment recording is achieved by adding information from infrastructure-bound sensors. In crossroads areas in particular the complementary use of infrastructure sensors affords a considerable information gain in order to be able to identify the traffic situation at crossroads, ❹. In the infrastructure-bound cooperative perception, environment sensors are distributed in such a way that seamless recording of the traffic situation in the area under observation is ensured.


❺ Predictive pedestrian protection with cooperative transponders

❻ Prototype of a transponder from the Ko-FAS project (source: Technology University of Munich, Fraunhofer IIS)

The object data thus determined is brought together via suitable merge algorithms so that a comprehensive ”object list“ of road users can be put together in the observed area. This object list is distributed to road users in the vicinity at an adequately high update rate via a ”broadcast“ procedure.

AREAS OF APPLICATION OF COOPERATIVE SENSORS

Cooperative sensor systems have some outstanding unique selling points that are of central importance for vehicle safety applications. A major advantage is unique object identification and classification without costly identification algorithms. At the same time, the information exists at an early stage and in almost uninterrupted chronological sequence, which enables a far more reliable assessment of the situation. In addition, the systems enable precise position determination of other road users and, associated with this, the possibility of comprehensive observation of the traffic environment.

Based on these properties, cooperative systems can be used for manifold traffic safety applications. In particular, use of these systematic advantages is particularly well suited to the areas of predictive pedestrian protection and the all-round safety of vehicles.

Pedestrian groups that are in particular danger, such as senior citizens and children, could be equipped with special pedestrian transponders. Pedestrians who, because of their specific motion capabilities, are in particular danger would be detected early in critical traffic situations. Pedestrians as depicted in ❺ could also be identified and tracked in occlusion situations. Preventive protective measures are activated in this way in good time and the accident is avoided, or at least the consequences reduced considerably. Current variants of such transponders are depicted in ❻ which, however, will also be realizable in a later chip-based series solution as an integral component. Integration into clothing objects, satchels or even mobile phones is quite conceivable. The possibility of detecting pedestrians in occlusion situations was proven as part of the Amulett project [3].

NECESSARY STEPS

Cooperative sensory systems have the potential to increase road safety considerably. This technology could therefore provide substantial assistance in the quest to achieve the demanding targets set by the European Union.

A precondition for the rapid achievement of a high level of effectiveness is a broad-based market launch of such cooperative systems. The introduction of other expensive vehicle safety systems such as the provision of airbags in vehicles as standard equipment has proved that such comprehensive market penetration can indeed be realized. Another important factor is the provision of intelligent aftermarket solutions for existing vehicle inventories so that they can be retrofitted, for example, with transponders. Added value could be made available to users of cooperative systems at an early stage by providing a correspondingly equipped ”cooperative infrastructure“.

The introduction of transponders into the traffic infrastructure could make a major contribution to track guidance of vehicles. Transponder installations at unclear bends in roads provide an opportunity for guiding vehicles safely through this traffic environment and, for example, avoiding the vehicle coming off the road. In addition, environment sensors could be attached near complex traffic areas and their traffic information passed on to suitably equipped vehicles.

However, the crucial driving force behind the introduction of cooperative sensors should be their outstanding features which allow them to identify the traffic environment in detail. Early identification of situations – including hidden road users – and activation of measures to avoid accidents before a potential collision occurs would afford an entirely new level of quality of road traffic safety.

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Founded 1898 as „Der Motorwagen“

Organ of the VDI-Gesellschaft Fahrzeug- und Verkehrstechnik (FVT)

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12 I 2010 _ December 2010 _ Volume 112

Springer Automotive Media I Springer Fachmedien Wiesbaden GmbH
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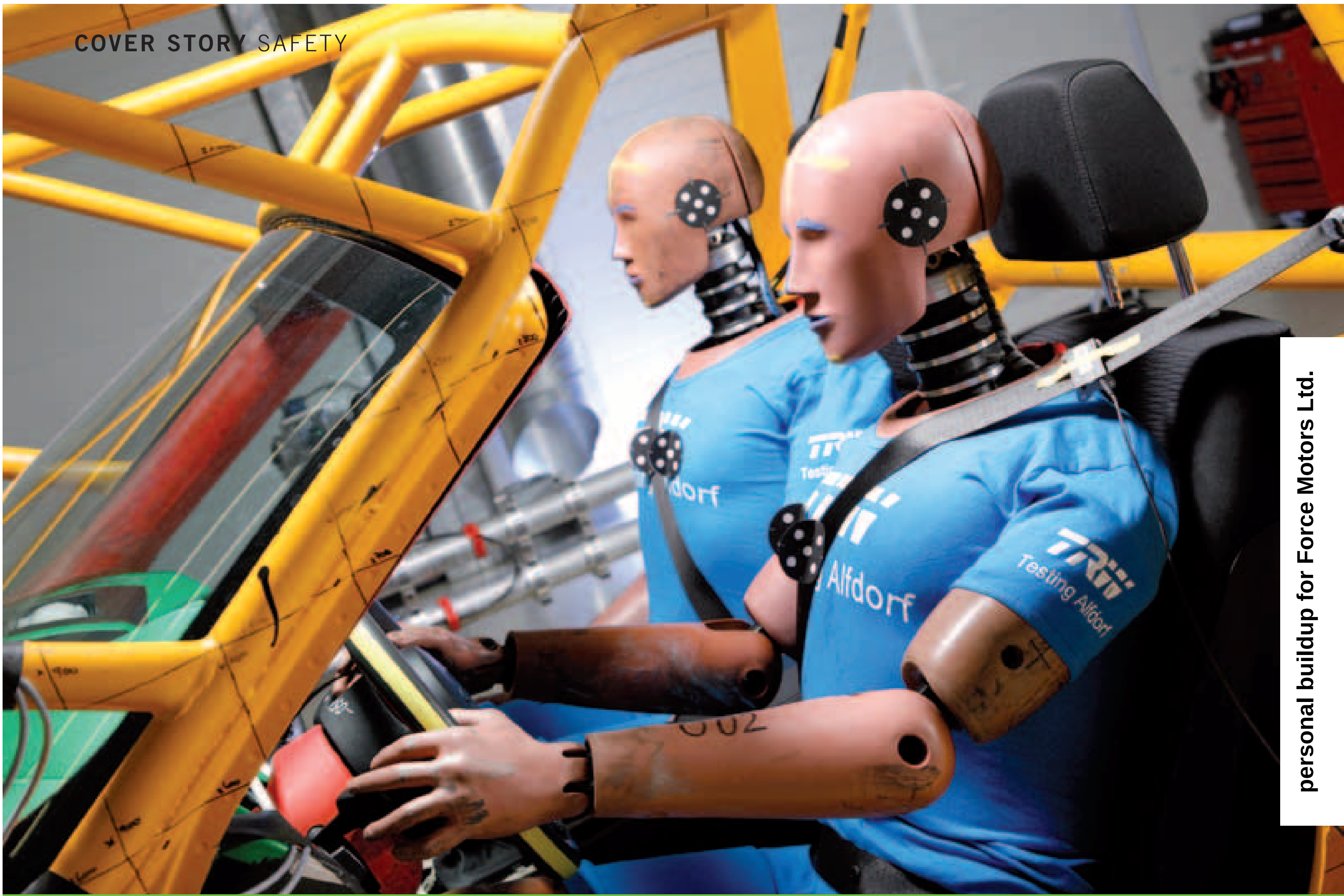

SPR4 – THE NEXT GENERATION OF SEAT BELT PRE-TENSIONERS

A newly developed seat belt pre-tensioner from TRW uses a snake-like plastic piston instead of metal components to transfer tensioning torque. The plastic piston is propelled through a tube by a propellant made of green gas and then drives the spool via a pinion. The new concept allows a simpler yet very robust design as well as compact packaging and is lighter in weight.

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INITIAL SITUATION

The first pyrotechnical seat belt pre-tensioner was launched in 1981 at the Geneva Motor Show and has since become an established part of modern restraint systems. TRW first offered its own version of this seat belt pre-tensioner as an optional feature on the W126 model of the Mercedes-Benz S-Class. Triggered by a control unit, the new type of safety system was able to tighten the seat belt to allow the passengers to be fastened more securely in the vehicle and to be decelerated sooner during a crash.

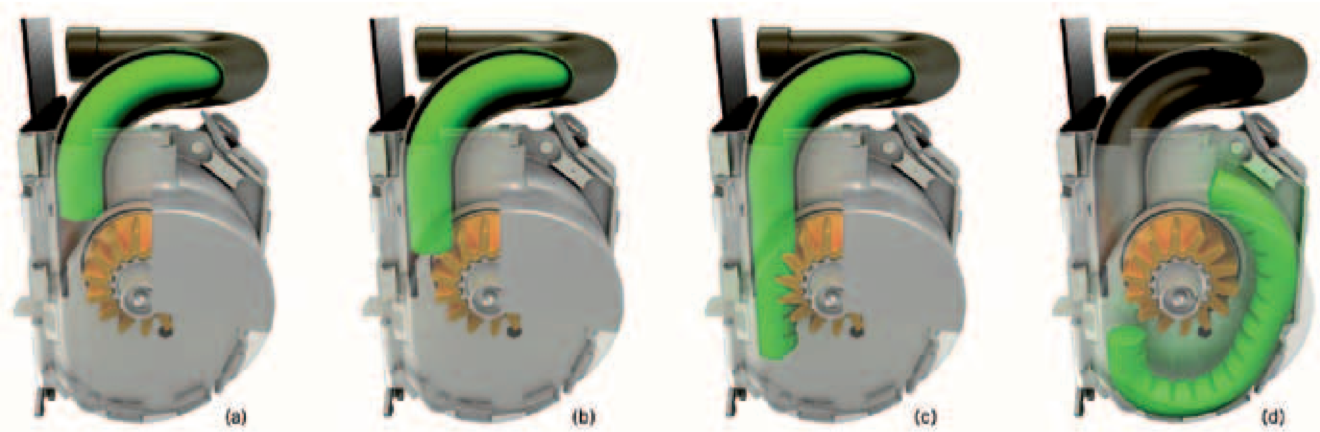
In 2002, TRW introduced the world's first reversible belt pre-tensioner with an electric motor that was also fitted into a Mercedes-Benz S-Class. By pre-tensioning the seat belt in critical situations, for example during a sudden manoeuvre, emergency braking or when the vehicle skids, the electric seat belt pre-tensioner activates the restraint system to pull the passenger into an improved seating position in the event of an accident. At the same time, drivers are given feedback about the driving conditions to enable them to adapt their driving behaviour accordingly.

The latest advancement of the pyrotechnical seat belt pre-tensioner, for which a patent has been applied for, is a simplification of the design to transfer power without limiting its functionality. In the "Snake Pretensioner Retractor Generation 4" (SPR4), a polyamide plastic piston is used instead of metal bearings and toothed racks used in conventional models. The name comes from the snake-like design of the piston. By using plastic materials, TRW has been able to increase tolerance insensitivity, which can also offer significant benefits for component procurement and assembly.

DESIGN AND FUNCTIONALITY

Based on TRW's ESA 4.0 retractor technology, the SPR4 uses the housing, retractor spool and spool bearing concept of the existing model. The locking side and sensor mechanisms are also almost unchanged. The key to the new development is the tensioning concept, in which a plastic piston transfers a pyrotechnically generated thrust onto a pinion which is connected directly to the retractor spool, ❶. The plastic piston is pressed into a tube, the top end of which contains the gas generator. To minimise installation space, the tube is bent into the dimensions of the retractor without constraining the seat belt webbing. The modified pre-tensioner housing guides the plastic piston and acts as a storage chamber. It also houses the components of the main drive spring system. Apart from modifying the pre-tensioning housing, the SPR4 consists of only four new main components: the single-piece thrust medium (piston), the gas generator, the tube and the pinion.

❶ TRW snake pre-tensioner retractor: simplified design with a snake-like plastic piston



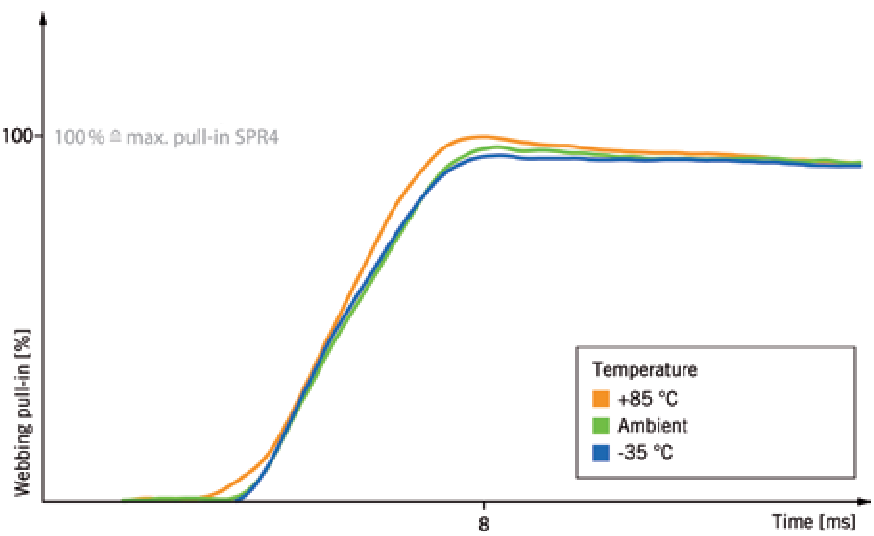
❷ The seat belt pre-tensioning process in detail

Additionally, all of the existing supplementary equipment for the basic ESA 4.0 unit can be used such as different torsion bars for constant load limiting, switchable, declining or progressive load limiters as well as child safety systems.

SEAT BELT PRE-TENSIONING PROCESS

As soon as the vehicle's sensor technology triggers the belt pre-tensioner, a pyrotechnical gas generator is ignited. The controlled combustion builds up pressure in the tube, ❷ (a). This pressure acts on the first end of the plastic piston facing the gas generator and causes it to first leave its guiding tube and then to engage with the pinion's teeth, ② (b). During the tensioning phase, the plastic piston acts like a toothed rack. The material is exposed to highly dynamic conditions and reveals a number of benefits.

Right from the initial contact, the pinion generates a counter-gearing to produce a synchronised gear system that effectively transmits power. The pushed plastic piston is cogged along its entire length and ensures efficient belt webbing pull-in by transferring a significant torque to the retractor spool, ② (c). After leaving the contact area, the plastic piston is guided by the housing into the final storage position, ② (d). The single-sided cogging of the plastic piston forced by the pinion favours this operation as it brings about a corresponding pre-curvature of the plastic line. As soon as the end of the plastic piston approaches the tube opening, the gas is fed out of the pre-tensioning tube through defined outlets and the pressure is released. The entire tensioning operation takes only 10 ms.

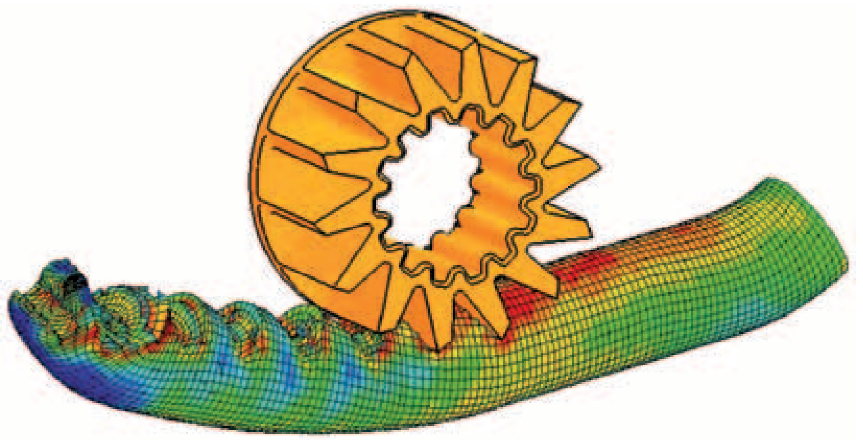


❸ Stability of the webbing pull-in characteristics with changes in the ambient temperature

BENEFITS OF THE NEW CONCEPT

Seat belt pre-tensioners have to generate the tensioning torque quickly and reliably with a stable level of force. The SPR4 is particularly reliable due to the quick and stable conversion of the applied green gas even with fluctuations in temperature and differences in the gas load. ❸ shows the measurement results of the webbing pull-in curves at various external temperatures. The quick generation of the tensioning force in the SPR4 is related to the use of a plastic piston instead of steel balls, with the result that the gas has to accelerate only half of the dynamic mass.

One of the greatest innovative steps of the SPR4 concept is the simplicity of its design. As the pre-tensioning unit is made up of a total of only four major additional components, the system is insensitive to tolerances. The steel tube and the pressed-in single-piece plastic piston are easy to install, as the manufacturing tolerances (component and joint tolerances) and ambient tolerances (temperature fluctuations) balance each other out due to the elasticity of the snake plastic piston without affecting the seat belt pre-tensioner's function. This compensation enables higher component and assembly tolerances, thus facilitating the worldwide procurement and assembly of the individual components.



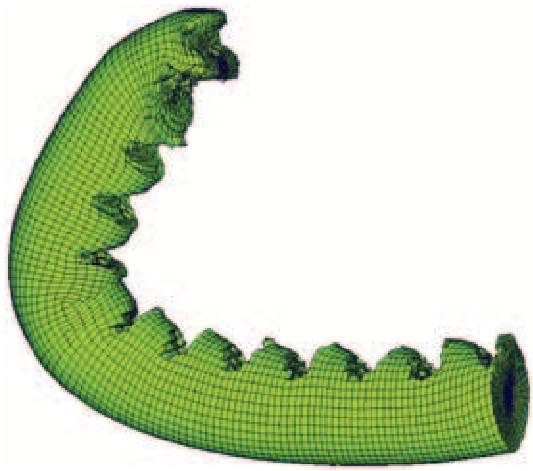
❹ Example of the definition of the pinion tooth geometry

One important aspect of seat belt pre-tensioners is the dynamic threading engagement of the drive element (balls, toothed rack or plastic piston) into the power transmission element (pinion) that transfers the feed torque onto the belt retractor. In conventional retractor systems, it is known that lack of accuracy with this threading process may result in reduced tightening performance. Such a problem does not exist in the SPR4 concept, as the pinion teeth intersect exactly into the elastic plastic pistons. One further benefit of plastic is its damping behaviour: upon initial contact with the pinion, it allows the peak of the impact to be significantly lower when compared with the conventional systems in which two rigid steel elements impact on each other. This results in less wear on the components overall, which can be considered in their design.

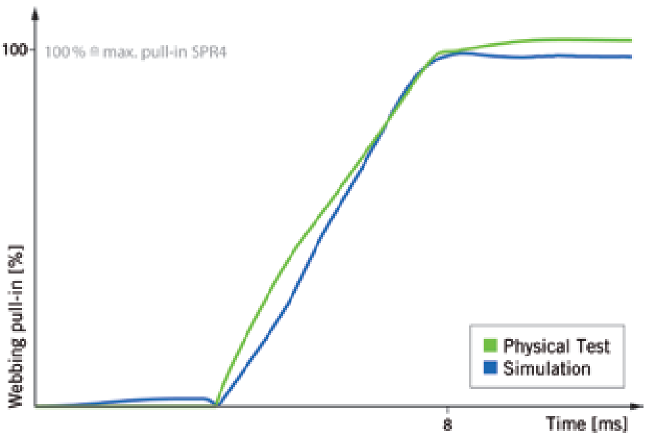
The new SPR4 from TRW is lighter than conventional systems as a plastic piston is used instead of metal drive components. As the design of the guiding tube for the plastic piston is fairly flexible, TRW has been able to make significant improvements in terms of space and packaging compared with conventional concepts with a toothed rack. The pretensioning tube is curved into the dimensions of the ESA 4.0 basic unit, thus simplifying the installation of the SPR4 even for more demanding package situations in a vehicle.

A further positive aspect is the fact that the plastic piston is securely accommodated within the geometrically rigid housing lid after having passed the pinion. On the one hand, there is a smaller mass to decelerate during this operation compared with conventional systems due to the design. On the other hand, the piston's kinetic energy is deflected in a rotational movement, which is easier to absorb in the compact rigid housing cover. The impermeability of the housing cover also facilitates the controlled ventilation of the hot propellant gas that is effectively diverted away via the inward facing holes.

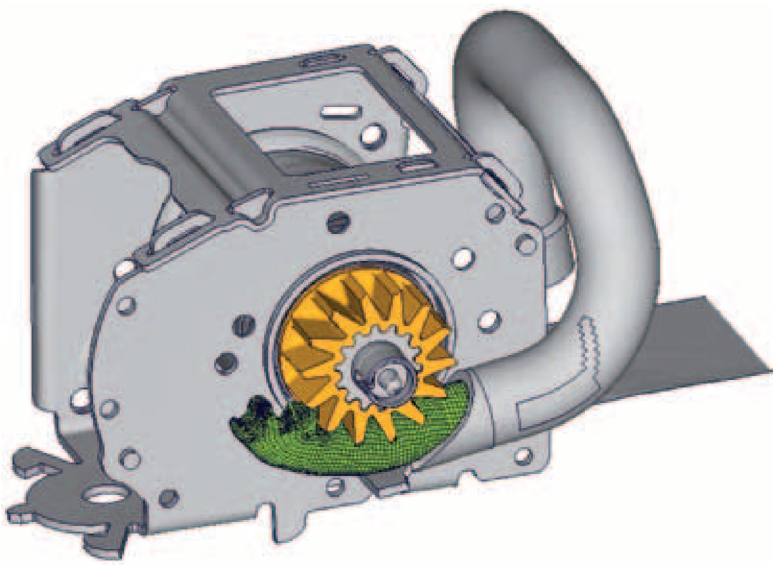
Noise robustness has also been improved. The simple design with just a few components eliminates any rattling noise. This feature is becoming more and more important for passenger comfort in an environment that is increasingly sensitive to noise. Due to the design, the pressed-in and therefore reliably tensioned plastic piston and the low number of individual fixed components have a lower tendency to produce rattling noise than steel elements inside a tube, for example, especially when subject to high vibrations.



❺ Qualitative comparison of simulated (above) and actually generated plastic deformation (below) of the polymer piston



❻ Comparison of simulated (blue) and actual measured (green) webbing pull-in characteristics



❼ Total component model

VIRTUAL PRODUCT DEVELOPMENT

The appropriate sizing of the diameter, length and material of the plastic snake, the geometric design of the teeth of the driving pinion and the overlap between the pinion and plastic piston were milestones in the implementation of the SPR4 concept. The challenge lay particularly in designing and matching the individual components to transfer energy efficiently for many different load cases. Capturing these complex, dynamic operations required the development of models for computer simulation and their validation in a comprehensive series of measurements. One particular challenge was in describing the material behaviour of the plastic piston, the load on which is at a maximum when it passes over the pinion subject to dynamic deformation. Teeth are produced at high strain rates that transfer a considerable torque to the retractor spool when interacting with the pinion, ❹.

This can have a number of effects depending on the load and on the selected design – from elasto-plastic deformation to material abrasions right through to teeth that are already formed being pulled out and peak loads on the pinion. TRW has been able to make a qualitative prediction of these effects with the aid of proper modelling of the piston material. The material model was validated during extensive measurements (tensile testing at different strain rates, quasi-static tensile tests with loading and unloading cycles, pressure and shear tests) at different temperatures (–35, +23 and +85 °C). During the tests, any local elongation was measured visually with the aid of an "Aramis" system and the resulting flow curves were then used as input variables for the "SAMP-1" (Semi-Analytical Model for Polymers) material model employed [1]. ❺ shows the qualitative comparison of the calculated (above) and the actual plastic deformation (below) of the tested plastic piston. A comparable formation of the teeth can be observed for the pre-tensioning operation, where it is possible to predict the partial tearing of the first tooth in the calculations. The quality of the simulated and actual webbing pull-in characteristics is shown in ❻ as an example of the correlation at the level of the full assembly, ❼. The validated simulation model has therefore made a valuable contribution to the design and further enhancement of the new SPR4 concept.

SUMMARY

With its new SPR4 seat belt pre-tensioner, TRW has managed to greatly simplify the conventional belt pre-tensioner while maintaining its functionality by using a plastic polyamide body. In the newly developed concept, the belt is pre-tensioned by a pyrotechnically driven snake-like plastic piston that is propelled onto a pinion instead of the usual steel balls or rigid toothed racks. The elasticity of the plastic material that occurs under the high dynamics of the pretensioning operation and which has high rigidity in a quiescent state compared to conventional systems using ball or rigid toothed racks offers significant benefits The physical properties of the chosen plastic enable fewer and simpler components to be used, make their procurement and assembly easier and improve the SPR4's functionality compared to conventional systems. The development of the SPR4 required comprehensive computer simulations and test series before individual parts could be adjusted in terms of material and geometry and their functional properties.

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[1] Kolling, S.; Haufe, A.; Feucht, M. Du Bois, P.A.: SAMP-1 A Semi-Analytical Model for the Simulation of Polymers. 4. LS-Dyna Anwenderforum [Dyna User Forum], Bamberg: 2005, p. A-II-27-53

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DEVELOPMENT OF MARKET-SPECIFIC CONCEPTS

GKN Driveline takes China and India as examples in this paper for the new situation that these automotive engineers are now focussing on the new concepts. What is an issue here in the emerging countries is not so much competition with existing systems, but the development of market-specific concepts that do not exist in the developed automotive world.

These new concepts occupy successful market segments which are due for further development to meet evolving consumer demand. While today everyone in Europe and USA is focussed on electrification, large-volume markets in alternative vehicles are growing almost unnoticed in emerging countries.

INDIA

The first example is India where there is a large market in small three-wheeled, and increasingly, four-wheeled vehicles. ❶ shows the size of this market segment. These are small delivery vans, taxis and small passenger cars.

In line with the car market in India as a whole, the demand for basic transportation, now amounting to approximately 650,000 vehicles, is growing at a significant rate. A production volume of over one million vehicles is expected by 2014. This makes this vehicle segment, representing about 25 % of the total market in passenger cars and light commercial vehicles, an important opportunity for any manufacturer of driveline components.

Driveline technology has traditionally concentrated on rear-wheel drive with independent rear suspension. An integrated power set consisting of combustion engine and manual transmission fits compactly in the rear of the vehicle. Sideshafts power the rear wheels directly. A typical vehicle specification for a small delivery van is shown in ❷.

Obviously, this is a vehicle designed for local conditions in India. It is intended to provide transport over short distances at moderate speed. The technology used is tailored to the local context and to workshop facilities for repair and maintenance. The cost/benefit ratio dominates all these requirements. Here, however, a change is taking place

CHALLENGES FOR THE POWERTRAIN IN ASIA

In Asia, the second stage of powertrain development is now underway. After first adopting, and then localising existing systems from the developed automotive world, automotive engineers are now focussing on new concepts. Using the example jointed shafts for Indian small delivery vans and Chinese mini buses, GKN Driveline shows here how the internationally set-up supplier solves the challenges in emerging countries.

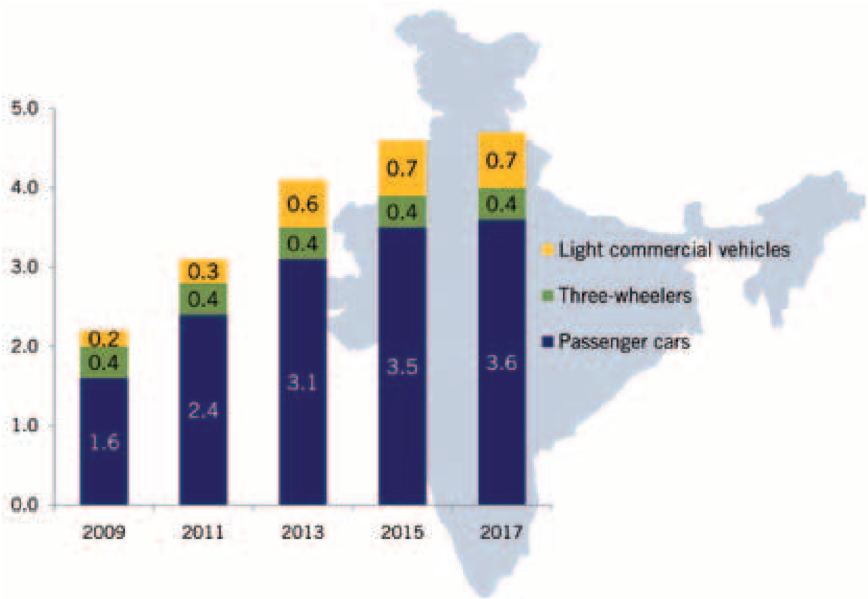
because of increased maintenance requirements, improvements in reliability and the convenience of transport. The need for frequent repairs is viewed as a major drawback for today's vehicles.

Although the technical divide with respect to modern passenger cars has widened, even in the small vehicles segment, maintenance-free technology is widely expected nowadays. In addition, demand for lower noise and vibration levels is increasing with improved infrastructure and better roads. All these changes have led to new developments encompassing engines, transmissions and sideshafts.

The primary focus in the sphere of jointed shafts is on improved kinematics and low-vibration transmission as well as reliable sealing to minimise lubricant loss or the ingress of dust and water. ❸ shows a comparison for sideshafts between conventional technology and the newly-introduced technology with constant velocity.

The traditional system uses bipode joints and sliding blocks, which results in significant non-uniformity of the transmission movement. This means that power transmission is affected by vibration. The sliding-block solution works with high sliding friction, leading to heating and losses. Sealing by bellows with snap connections allows for easy maintenance, but also leads to regular seal failures in operation.

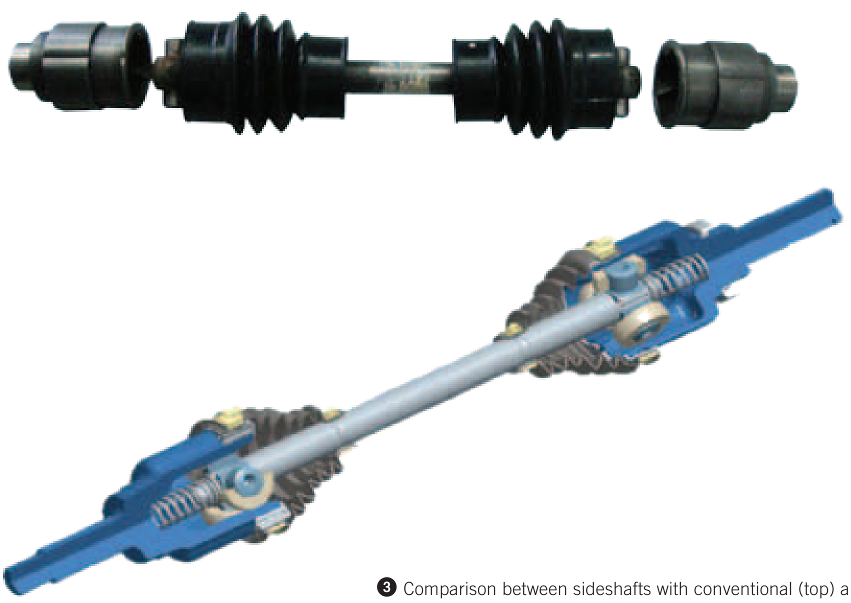
The new tripod system overcomes all the above disadvantages and represents a maintenance-free drive solution giving a high level of comfort. Of course, this solution is designed for the specification of vehicles in this segment, as shown in ②.



❶ Size and growth in million units in the small vehicles segment in India (source: AMP, October 2000)

FEATURE	VALUE
Engine type	Diesel, single cylinder, water cooled
Engine displacement	611 cm^3
Maximum Power	11 hp
Maximum Torque	31 Nm
Top Speed	55 kph
Transmission	Four forward speeds and one reverse (synchro mesh with cable shift)
Brakes	Hydraulic drum type
Front suspension	Independent McPherson strut
Rear suspension	Independent coil spring with semi-trailing arm and hydraulic shock absorber
Steering	Mechanical rack and pinion
Tyres	12-inch radial
Seating	Driver plus four passengers
Fuel tank capacity	10 l

❷ Vehicle specification of a typical Indian small delivery van



❸ Comparison between sideshafts with conventional (top) and modern constant velocity technology (bottom)

CHINA

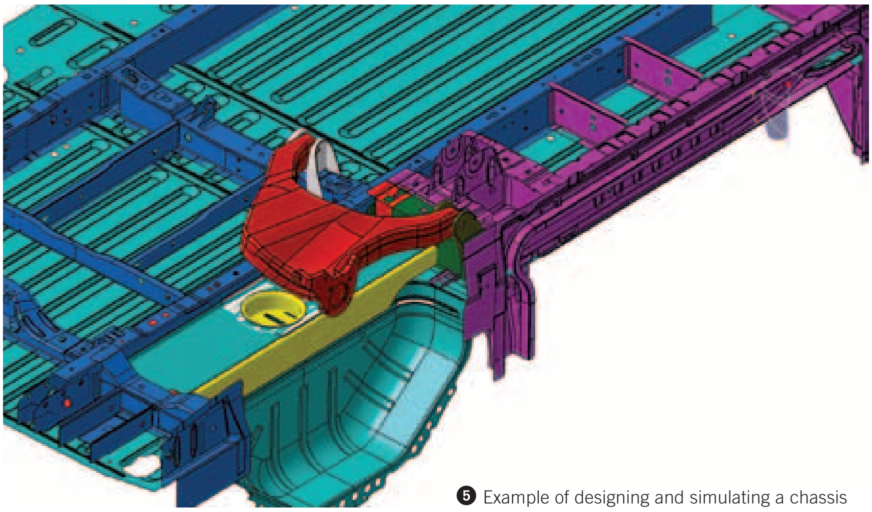
The second example is the Chinese market, and in particular the mini bus segment. This is growing at an astonishing speed and is not merely the best-seller among passenger vehicles and light trucks, it represents one third of this segment. A typical example of this is shown in ❹ as a mini bus. About 800,000 vehicles in this segment were built in 2009.

This vehicle concept uses very simple drive technology with the engine at the front and the rear-wheels driven through a rigid axle. It was widely used as the standard drive approach in the Western world until the 70s of the last century. The change expected here will be triggered by higher standards of ride comfort, safety and vehicle handling. Such a change has already been observed in the developed markets. Especially in Japan, several manufacturers have successfully completed the transition to independent wheel suspension, even in mini buses.

Higher expectations of ride comfort are caused by the rapid improvement of roads and the development of infrastructure in rural areas. The challenge for engineers due to the complexity of the elements involved is to convert drive systems from rigid axle to independent wheel suspension. Not only does the drive train have to be renewed, such a conversion affects the entire system from bodyshell assembly through to suspension and axle and sideshafts.

GKN Driveline has many years' experience in the areas concerned and has worked on reference projects involving such a switch. ❺, for example, shows the depth of calculation and simulation of forces exerted on the vehicle cell. To prepare for market launch, extensive studies are currently being carried out including the construction of demonstration vehicles. The concept is based on existing versions in the market. It draws on the rich portfolio of drives with cardan shaft, axle and jointed shafts. The geometry of the

❹ Chinese mini bus
(photo: Uwe Paksa, GKN Driveline)



❺ Example of designing and simulating a chassis

❻ Wheel suspension and sideshafts for a Chinese mini bus

body, however, requires extensive new designs for the chassis parts.

The example shows that the powertrain can no longer be considered as an isolated issue and new limits have long since been established in subsystems capabilities. As changes to the suspension system are involved here, optimisation of vehicle dynamics also has a special role to play. The demonstration model is then used in customer projects and for further development of components, ❻.

DISTRIBUTION OF TASKS

Here, GKN Driveline presented two examples of drive technology challenges in Asia. These are very specific market segments in India and China. Their size demands the attention of manufacturers of components and systems. Since the lowest possible costs are a requirement in both examples, production in the appropriate country is essential. A viable solution for the local production environment requires close cooperation between development and production. Therefore, all development tasks are carried out as far as possible in the countries in which production takes place. This accelerates the development of local specialists and a dynamic learning curve.

Overall, it is clear that the successful development of new powertrain variants still holds sufficient challenges, even in the non-electric sector, for high-volume business.

EVOLUTION TO THE SEVEN-SPEED AUTOMATIC TRANSMISSION 7G-TRONIC PLUS

Daimler finalized the advanced development of the sixth generation of its seven-speed automatic transmission for more comfort, less fuel consumption and more driving pleasure. Assembled in E-, R-, S- and CL-Class, the 7G-Tronic Plus has a new fuel efficient torque converter with centrifugal pendulum damper and regulated zero slip at the torque converter lock-up clutch as well as a new automatic transmission lubricant (FE-ATF).

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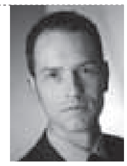

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TRANSMISSION EVOLUTION

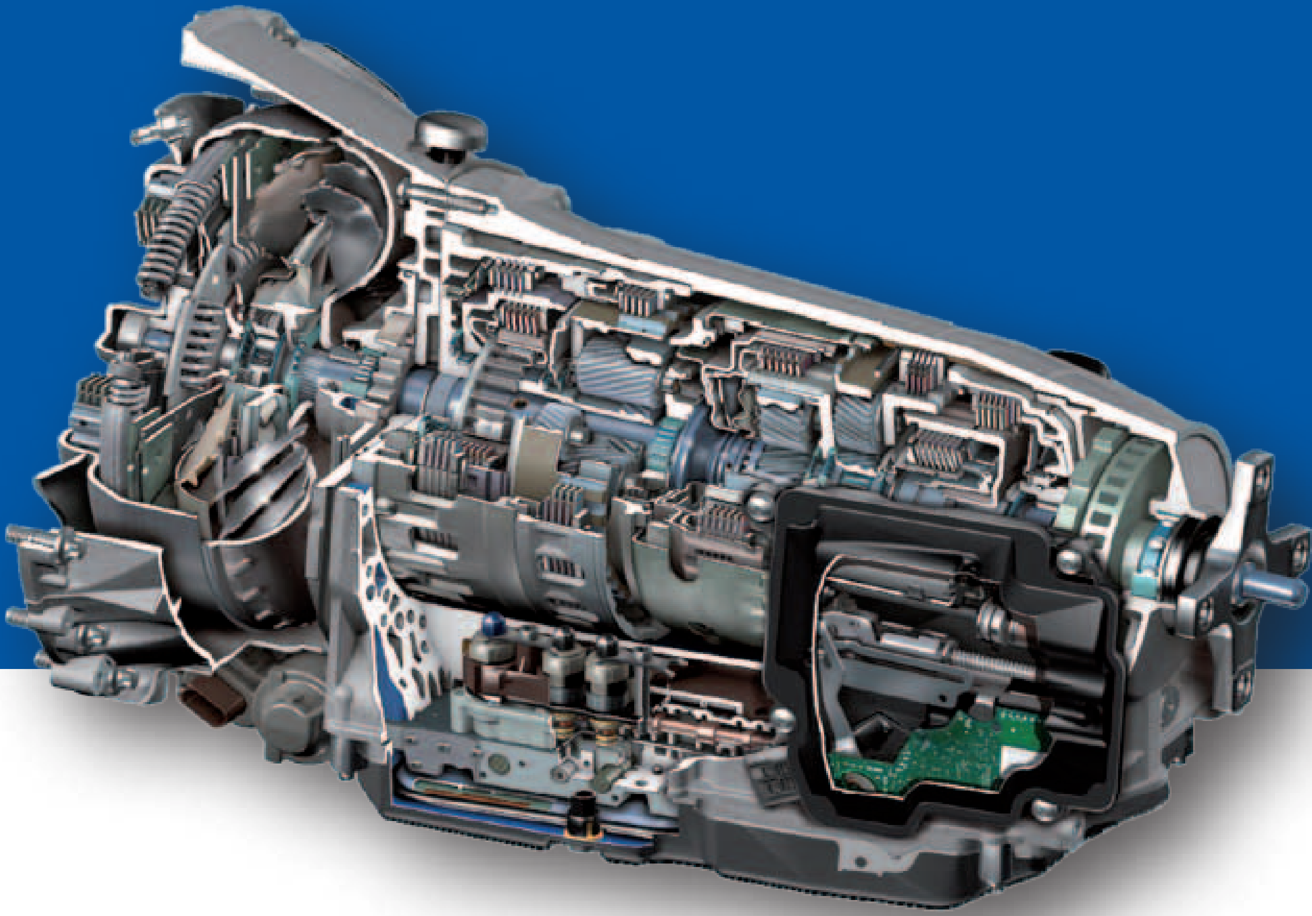
In the fall of 2010, Mercedes-Benz Cars launched the latest version of its seven-speed automatic transmission 7G-Tronic [1] called 7G-Tronic Plus for passenger cars in the S-Class, R-Class, and E-Class with the V6 diesel engine and in the CL-Class with the new V8 gasoline engine. The S-Class will also be offered with the four-cylinder inline diesel engine and with the new V6 and V8 gasoline engines from the start of 2011 with this new transmission.

With this transmission evolution, the five-speed automatic transmissions W5A330 and W5A580 currently available will likewise be discontinued, albeit successively, for passenger cars and vans with a four-cylinder engine but also from 2012 the reinforced five-speed automatic transmission W5A900 in conection with twelve-cylinder gasoline engines. The new, sixth generation automatic transmission 7G-Tronic Plus, which dates back to 1960 and has been continually developed and manufactured by the company ever since, is internally designated the W7C700 and W7X700 (for the integrated all-wheel-drive version 4Matic and W7C1000 for the reinforced transmission version [2]). This automatic transmission delivers approximately 7 % better overall fuel economy than the predecessor transmissions W7B700 and W7X550 (as tested in the NEDC cycle) while making a significant contribution to reducing the CO_2 emissions of the Mercedes-Benz fleet. Using the six-cylinder diesel engine in the S-Class as an example, this equates to 17 g of CO_2 per km or 0.64 l per 100 km [3].

DEVELOPMENT OBJECTIVES

Further improving the energy efficiency (fuel economy, FE) of the current transmission 7G-Tronic [1] was one of the main development objectives, ❶. The transmission design incorporated a wide variety of measures designed to lower fuel consumption:

: an extreme reduction in torque converter slip thanks to a new converter generation
: new FE low-friction automatic transmission fluid with accompanying changes to the geometry and materials selected for the transmission
: an improved Eco shift program that considerably reduces engine speed in conjunction with optimal damping systems in the converter



: friction-reducing measures for bearings and disks.

Compared to other measures for reducing individual vehicle consumption as required by the markets and international legislation, the new transmission provides exceptional performance and value when it comes to reducing CO_2 emissions in line with target objectives. This could only be achieved by leveraging available technologies and processes as far as possible. Additional improvements and functions that the customer will experience were also realized, ❷:

: improved dynamic response to movements of the accelerator pedal as a result of a more direct connection to the engine

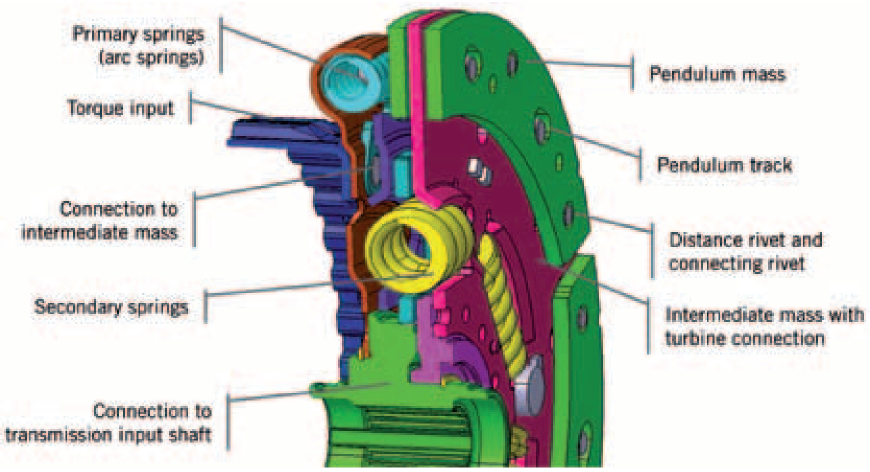
: better shift quality thanks to improvements made to the electro-hydraulic control

FEATURE	VALUE	UNIT
Maximum sustainable transfer capacity of transmission input coupling downstream of converter	700 / 1000	Nm
Maximum permissible output torque	2700	Nm
Diameter of converter	270	mm
Total length (depending on joint flange and converter)	619 – 640	mm
Weight (including converter and fluid; depending on the engine, the optional shift-by-wire system, and optional start-stop system with auxiliary oil pump)	83 – 93	kg

❶ Technical data of the automatic transmission 7G-Tronic Plus

LOCK-UP CLUTCH	VIBRATION DAMPER	HYDRAULICS
: Optimized engine launch behavior under cold conditions and low barometric pressures : Improved clutch cooling	: Opportunity of “zero slip” lock-up clutch and lower enginespeeds (eco-shifting), reducedfuel consumption : Improvement NVH	: Better launch and driving performance : Higher efficiency, reduced fuel consumption, more comfort in lock-up clutch control
Surface pressure –15 %	Torsional angle 42° (currently 17°)	Efficiency 90 % (currently 85 %)

❷ Basical new design of the torque converter enables improvements in fuel consumption, NVH und cooling



❸ New speed adaptive twin-turbine torsional vibration damper with centrifugal force pendulum

- lower levels of noise, vibration, and harshness (NVH) and lower engine speeds via Eco shift programs
- start-stop capability by way of an additional electric pump
- extended service life of transmission fluid due to reduced friction and optimized formulation.

TORQUE CONVERTER

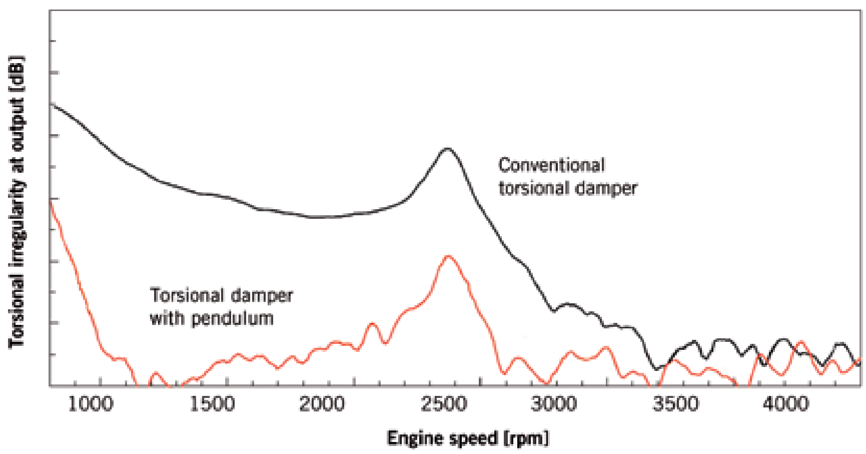
A modular, next-generation torque converter was designed with an improved hydraulic circuit, torque converter lock-up clutch, and dampers to accommodate, in particular, the dramatic increase in torque generated by the new V8 gasoline engine and the torque increase of the four and six-cylinder diesel engines. This corresponds also with increased demands on damping the imbalances and on aggravated consumption targets with minimum frictional loss.

The torque converter, ❸, assumes many functions in modern automatic transmissions. When the vehicle accelerates from a stop, for example, the engine must be smoothly connected to the drive line and output efficiently transferred to ensure high performance. Both tasks are carried out exceptionally well due to the hydraulic power delivery, which also bumps torque. An output unit, the torque converter must likewise convert power with as little frictional loss as possible. This is managed by a torque converter lock-up clutch, which splits the power as per the hydraulic characteristic curve. Efficient delivery via the lock-up clutch also means that imbalances created by the combustion engine are channelled directly into the drive line. In order to provide a high level of comfort here as well, a performance torsional damper is required.

The development goal in defining the hydraulic characteristic curves was to find the ideal balance between a suitably high stall torque ratio and a high level of efficiency. Since the two variables cannot be optimized independently of the other, achieving this balance was key to ensuring good start-off performance. Realizing very high efficiency also facilitates a comfortable transition between the hydraulic characteristic curve and the torque converter lock-up clutch within the power split. The power curve was defined using turbocharged engines, which resulted in flat to slightly upward sloping curves.

The torque converter lock-up clutch continues to utilize the proven three-channel system, which has since been improved in key areas. The path that the cooling oil takes to the clutch plate set, for example, has been redesigned to flow directly toward the coupling package. This provides for especially effective and efficient cooling. Another change was to increase the gap between the clutch disks so that the clearance of the coupling package could be optimally used and drag torque significantly reduced. The result is much improved performance, especially under cold-starting conditions, when engaging a gear typically reduces the rotating speed of the engine.

Damper development was mainly influenced by three factors with respect to the torque converter, all of which target a reduction in CO_2 emissions. First, the trend in engine design is toward increasing output and torque with ever-smaller engines (less displacement). This can only be achieved through heavy turbocharging or supercharging, which further increases rotational imbalance. This imbalance, in turn, is channelled directly into the drive line. Second, the good power delivery of the engines at low speed, in conjunction with today's typically wide gearbox ratio, makes it possible to introduce an exceptionally low-speed drive program, whereby the engine is principally driven at higher excitation levels. Last but not least, developers wanted to eliminate slippage of the torque converter lock-up clutch in order to promote efficient power delivery, which would be impossible using the damping characteristics of this setup. The answer to these



❹ Torsional de-coupling to a six-cylinder diesel engine three challenges came in the form of a centrifugal pendulum damper, ③, designed in conjunction with the company LuK.

This damper initially comprises a conventional twin-turbine damper. Its distinctive characteristic, however, is the fact that a pendulum mass is connected to an intermediate damper mass and functions as an additional damper. A standard damper comprises a spring mass oscillator that responds to a specific excitation frequency, which is determined by spring stiffness and mass. With a pendulum, however, the natural frequency depends on gravitational acceleration and the length of the pendulum. Since gravitational acceleration in the rotating reference system of the torsional damper can be replaced with centrifugal force, the natural frequency fluctuates with the speed of the engine. Designed appropriately, the natural frequency is always in line with the engine order, allowing the main excitation frequency to be almost fully compensated (dampened). This damper design makes it possible to operate the torque converter lock-up clutch without slip – while ensuring maximum comfort with respect to the drive line noise caused by torsional excitation.

The only way to realize a similar outcome using conventional technology would inherently require more space and significantly increase the weight of the drive line, ❹. Another advantage of the pendulum approach and the regulated zero slip associated with it is a more direct connection between the engine and the drive line, which increases driving pleasure while reducing CO_2 emissions.

TRANSMISSION MECHANICALS

The basic transmission 7G-Tronic [1] was systematically refined to further reduce frictional loss. This was achieved by using the world‘s lowest-viscosity automatic transmission fluid (ATF), which was formulated in close collaboration with Shell, Afton, and Fuchs.

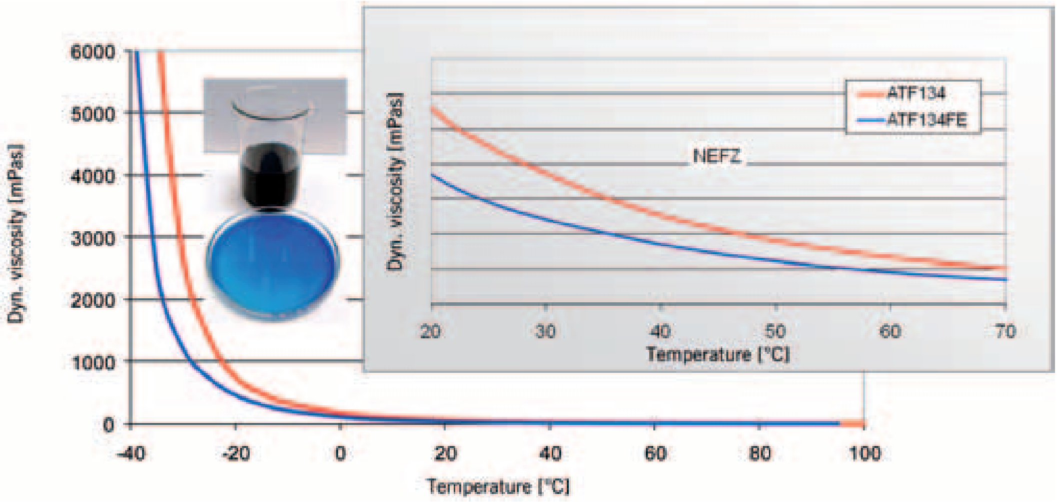
In particular, the new ATF134FE had to provide an optimum balance between reduced dynamic viscosity, temperature, friction level, and volumetric and mechanical efficiency, ❺. Internal leakage and seals, foaming, lubrication properties, and bearing construction were therefore key design challenges. These problems were solved by harmonizing the base oil, viscosity and friction characteristics (viscosity index), and lubrication and pressure-transfer additives in the fluid with tribological and anti-leak adaptations made to various transmission components (for example planetary gear set materials, seals, transmission oil pan) and temperature-related improvements to the control software. The new transmission oil is not backwards compatible due to the target-oriented optimization measures implemented for all tribological systems, which encompass the oil itself and the bearings, seals, gearing, and friction plates. To visually reinforce this, the transmission fluid has been dyed blue instead of the previous red to prevent confusion during maintenance. Optimized vehicle cooling, an improved fluid formula, and reduced friction throughout the transmission translate into extended service intervals, whereby the fluid no longer must be replaced the first 50,000 km, but every 125,000 km only.

TRANSMISSION MECHATRONICS

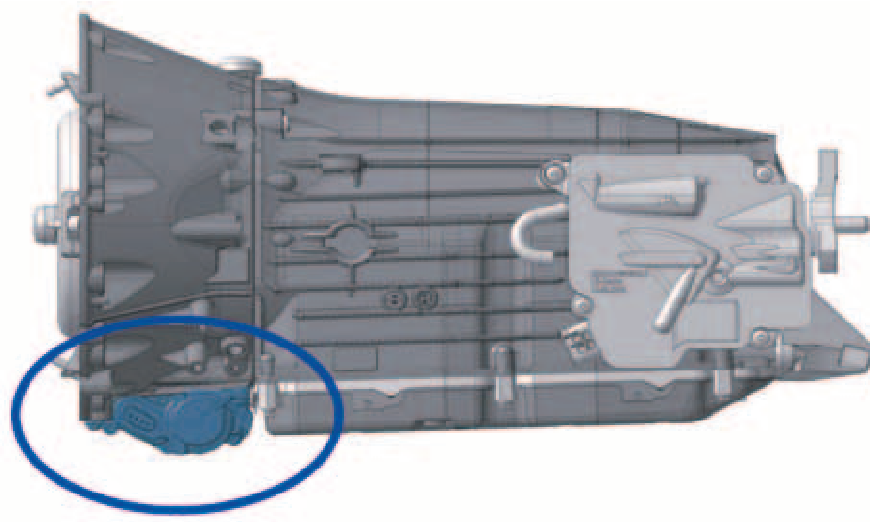
Detailed improvements to the electrohydraulic control unit, integrated in the transmission, and reduced friction in conjunction with optimized engine and transmission software, likewise better shifting dynamics and shifting quality. The focus of development work was on more effectively leveraging the volumetric oil flow rate available by lowering engine speed at idle and using a low-viscosity transmission fluid to minimize the hydraulic loss associated with the transmission controller. To this end, the hydraulic channels in the shifting plates were optimally positioned and arranged to reduce such loss.

The new seven-speed automatic transmission is equipped with a start-stop system for the first time. This makes possible with the addition of an electric auxiliary transmission oil pump, ❻, that safeguards the pressure supply when the mechanical transmission oil pump is not running (engine off). When the driver comes to a stop at a red light, for example, the engine switches itself off. As soon as the foot brake is released or the accelerator pedal pressed, the engine starts as if it were running the entire time.

Intelligent technology provides for comfortable, instantaneous engine starts. A crankshaft rotation sensor detects the resting position of the pistons. The electric auxiliary transmission oil pump, mounted externally to the converter housing for the transmission with start-stop system, maintains the minimum level of pressure required in the transmission when the engine is switched off. The shift elements remain filled and the transmission can be



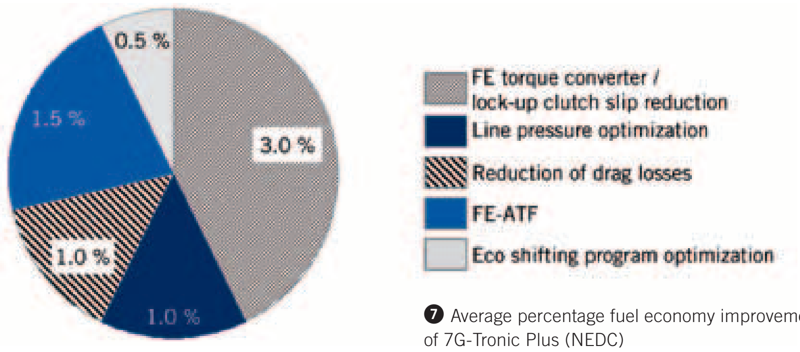
❺ Comparison of viscosity of the old transmission fluid ATF134 versus the new one ATF134FE



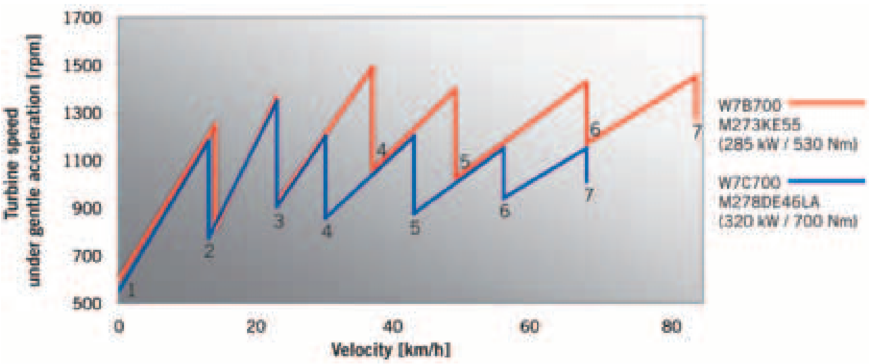
: Shifting elements of the transmission remain oil-filled with stopped transmission constant pump because of engine-off during start-stop mode
: Opportunity of a quick relaunch of the vehicle after engine start
: Electric pressure supply, comfort-oriented and reproducible

HYDRAULIC PRESSURE	Max. 2.5 bar at 6 l/min
ATF TEMPERATURE (WORKING)	10 – 125 °C
BATTERY VOLTAGE	9 – 16 V
POWER ELECTRONICS	Integrated
CONTROLLED BY CAN	Motor current controlled
CURRENT CONSUMPTION	Max. 8.5 A
MAX. OSCILLATION	Up to 50 *g*

❻ Auxiliary electro-hydraulic pump for start-stop operation



❼ Average percentage fuel economy improvement of 7G-Tronic Plus (NEDC)



❽ Comparison of shifting programs for an eight-cylinder gasoline engine (blue: improvements by W7C700 transmission)

smoothly engaged immediately after the combustion engine has started. This process can be repeated in shortest time. It is realized by a G-rotor pump (crescentless internal gear pump) powered by a direct current motor with integrated electronics, which are controlled by the transmission controller via CAN.

The starter then simply has to provide the initial impulse to automatically start the engine. The engine control unit only switches the engine off if critical predefined criteria have been met. These encompass the starter battery, which must have a sufficient charge, and the engine, which must be warm enough for the exhaust gases to be optimally treated upon start-up. The same applies to the interior temperature set by the driver. If this temperature has not yet been reached, the engine will not be switched off at a standstill. The on-board management system ensures that any active audio, telephone, or video signals are not interrupted by the Eco start-stop function. A yellow ”Eco“ icon indicates to the driver that the Eco start-stop function is enabled but has been temporarily overridden because of a conflict with one of the mentioned criteria. When all criteria for switching the engine off have been met, the ”Eco“ icon turns to green.

The average percentage fuel economy improvement by the improved transmission is shown in ❼ with 7 % in total. Using start-stop further 4 % are possible due to shut-down of the combustion engine in idle of the consumption cycle.

SUMMARY

Finally, the new seven-speed automatic transmission from Daimler is equipped with a start-stop system for the first time, made possible with the addition of an electric auxiliary transmission oil pump that safeguards the pressure supply when the constant-flow pump is not running (engine off). The vehicle can start off again without delay following a brief stop.

A next-generation torque converter optimizes NVH levels thanks to more advanced dampers, which also noticeably reduce fuel consumption. This is achieved by greatly reducing the slip of the lock-up clutch (actively regulated zero slip) in conjunction with better mechanical damper insulation from very low engine speeds and during gear shifts, despite the fact that the nominal and reaction torque of the engines has increased. The gear shift program has also been modified to reduce engine speed in Eco mode, ❽. In addition, the new FE converter provides for optimal acceleration from a stop, smoother operation of the torque converter lock-up clutch, and better response to movements of the accelerator pedal.

Consumption-reducing measures were implemented for the transmission as well and include new automatic transmission fluid (ATF134FE) with reduced viscosity in conjunction with an optimized additives package, redesigned internal componentry for the transmission, with new materials, bearings, disk linings, and geometric enhancements, and adapted software, lower service pressure at many operating points, and better internal seals. The reworked electronic control unit for the transmission, together with improved software, make shifting smoother.

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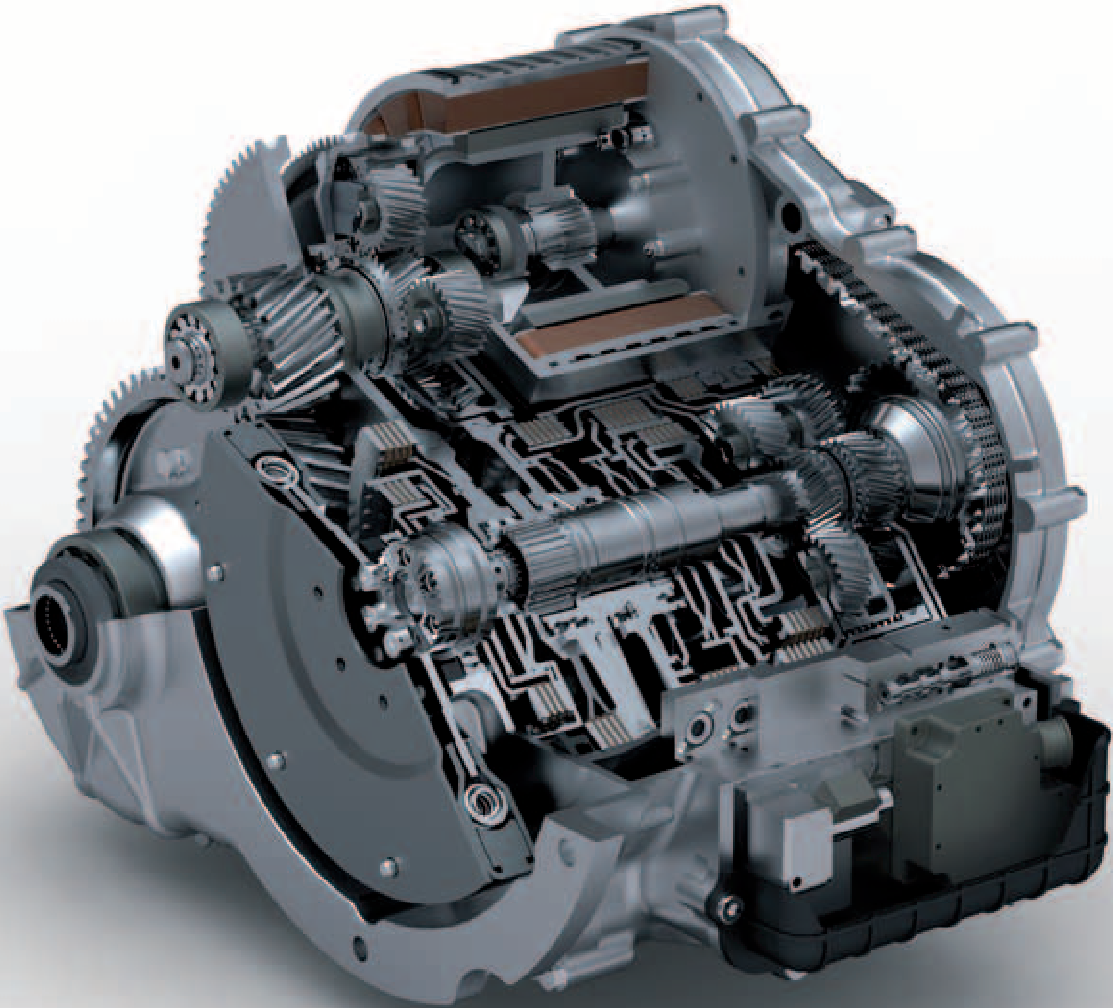
THANKS

Today, the development of the components of an automobile is teamwork everywhere. The authors like to thank Dipl.-Ing. (FH) Henrik Kalczynski, Team Leader Hydraulic Control Units Automatic Transmissions, at Daimler AG in Stuttgart (Germany), for his contribution to this article.



SYNTHESIS OF AN EIGHT-SPEED AUTOMATIC TRANSMISSION FOR HYBRID DRIVES

IAV develops future transmission generations by using computer-aided synthesis programs. The new eight-speed planetary automatic transmission for transverse applications results from a total solution amount of 1.6 billion transmission variants. The derivable modular transmission system comprises a conventional transmission as well as a mild and a full hybrid version. It offers numerous advantages in comparison with current systems regarding speed number, hybrid functions, efficiency, size and costs.

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MORE RATIO RANGE

The vehicle transmission harbors major potential for meeting the challenges exhaust gas and fuel consumption. Wide ratio ranges with a high number of well-stepped speeds ensure efficient coverage of the combustion-engine map and deliver plenty of traction.

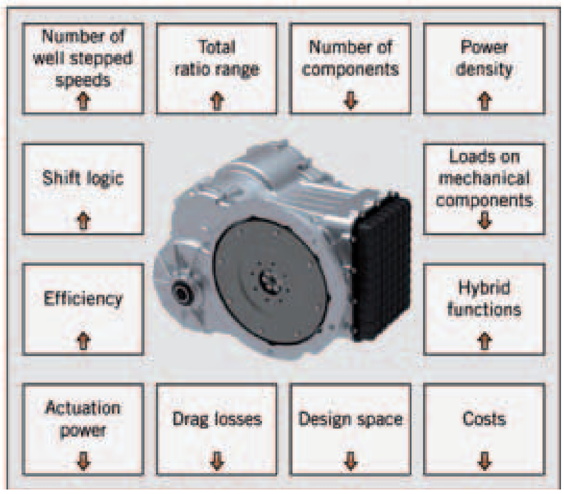
Manual transmissions currently providing a maximum of six speeds and ratio ranges up to $\varphi_{total} \approx 6$ will in future hardly be in a position to satisfy these goals. Further ratio steps reduce the driving comfort as a result of the greater amount of gear-shifting effort they involve and the risk of overburdening the driver becomes greater which is why theoretical fuel savings are not necessarily achieved in real operation.

Fully automatic transmissions are better suited to providing driving comfort from a large number of ratio steps. Present-day dual-clutch transmissions offer as many as seven speeds and ratio ranges of $\varphi_{total} \approx 6.5$. Even higher numbers of $\varphi_{total} \approx 7$ are possible with planetary automatic transmissions with up to eight ratios. As a result of the more exacting design-space restrictions in vehicles with front-transverse engines, map converters of this type are only mass-produced with a maximum of six speeds and a ratio range of up to $\varphi_{total} \approx 6$.

At present, round 80 % of all passenger cars worldwide are powered by front, transversally installed combustion engines. It is expected that with production figures rising, this percentage will increase over the next few years. This means that from the aspect of reducing fleet consumption, the significance of fully automatic, front-transverse transmissions with a greater number of speeds is set to grow. Dual-clutch transmissions, particularly those operated electromechanically, permit marginally better consumption over planetary automatic transmissions which, in turn, are more compact in design, more cost-effective to make and also provide better driveaway dynamics and shift strategies with greater flexibility [1]. It is for this reason that the following analyses focus on planetary automatic transmissions for front-transverse applications.

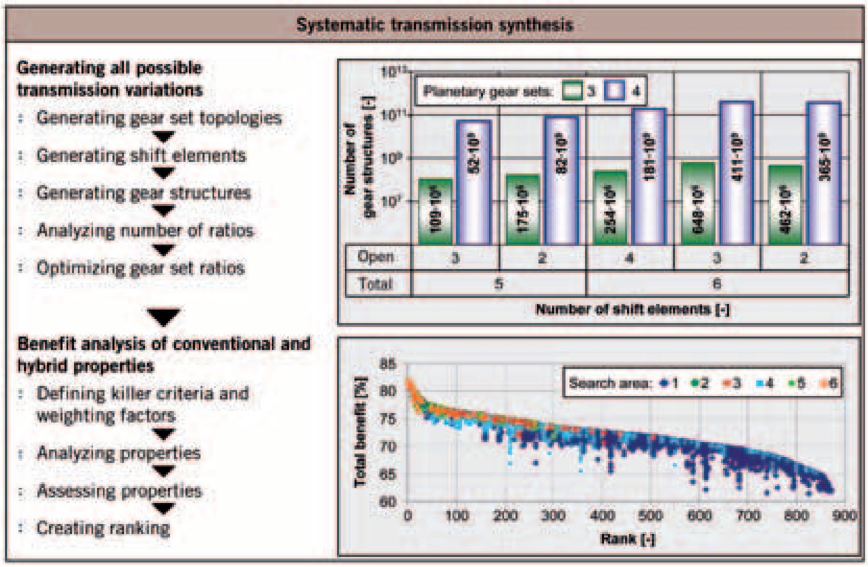
With planetary automatic transmissions, the traditional approach to providing additionally required ratio steps is to use further mechanical transmission components, such as gear sets or shift elements. Although this has an adverse effect on costs, weight and size, the trade-off can be resolved by means of innovative gear structures that employ the limited number of transmission components for more speeds. ❶ shows the key aspects developers are aiming to optimize, such as achieving high levels of efficiency, low drag losses and less loads on mechanical components. Hybridizing the conventional powertrain produces the means for realizing many demands as a result of the additional degree of freedom it offers on the energy-management side. Intelligent modular systems made up of conventional and hybrid transmission variants reduce development and production costs.

The conventional and predominantly intuitive search for new gear structures is less suitable for taking account of these complex challenges. The abundance of



❶ Key aspects and demands on a vehicle transmissions with each optimization aim potential solutions also harbors a high risk of overlooking significantly better transmissions. Instead, increasing use is being made of systematic syntheses that examine all realizable combinations of transmission topologies on a computerized basis [2].

IAV presents here the methodology behind such synthesis programs for creating new transmission generations with favorable properties for conventional and hybrid drives. By way of example, the potential of this approach is demonstrated on the basis of a new hybrid eight-speed planetary automatic transmission for front-transverse applications.



❷ Sequence and solution variety of the systematic transmission synthesis

PRINCIPLE OF SYSTEMATICALLY TRANSMISSIONS SYNTHESIS

Before synthesis can commence, it is necessary to define the demands that are placed on the new transmission for any type of powertrain, for example in passenger cars, commercial vehicles or railway applications. The following properties provide the input data for the synthesis program:

- demanded series of ratios
- necessary power shifts
- maximum number of components for the available package
- position of input and output
- maximum loads
- hybrid functionalities.

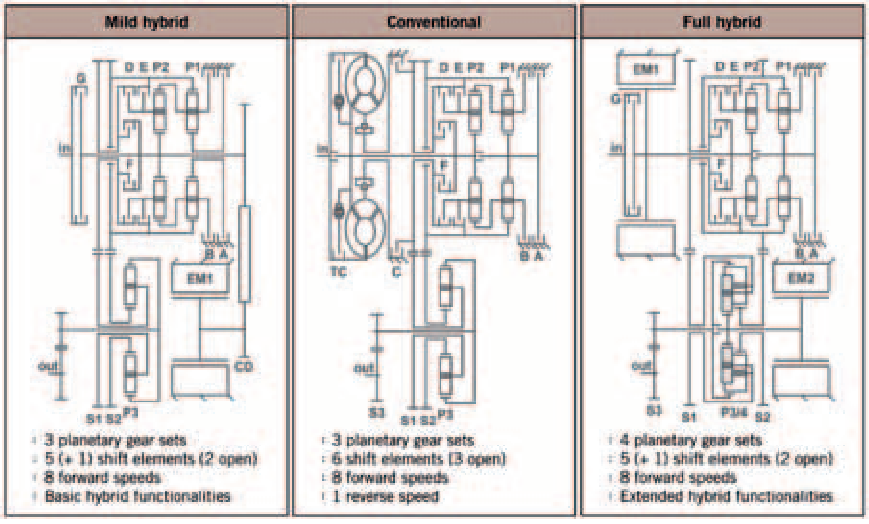
Using the example of planetary automatic transmissions ❷ on the left illustrates the principle followed by IAV-made synthesis software, this being divided into two program parts. The first program part initially generates all possible combinations of conventional transmission variants on the basis of the input data. The computer calculates all of the mathematically coded planetary gear set topologies as well as shift-element configurations, combining these to create gear structures that are then tested with graph-theoretical algorithms in relation to actually being able to implement the design. Only appropriate options are then examined for their maximum number of speeds. Once this has been done, the gear-set ratios for the gear structures offering a sufficiently high number of speeds are optimized in such a way that the demanded series of ratios is achieved in the best possible way while taking into account the necessary power shifts. By way of option, the algorithm also allows for additional secondary conditions, such as the achievement of high levels of tooth efficiency or low loads on the components. ② illustrates at the top right the tremendous solution diversity this synthesis step offers. Even as few as three planetary gear sets with five and six shift elements result in the program investigating some 1.6 billion gear structures. With four planetary gear sets, the number of solutions found rises to 1091 billion codings.

The second program part of the program performs a benefit analysis to examine and evaluate all of the generated gear structures in relation to their conventional properties, such as number of parts, series of ratios, shift logic, torque and speed loads on components, levels of efficiency and drag losses. The software also investigates the feasibility of implementing the demanded hybrid functionalities, such as starting the combustion engine, all-electric driving, boosting and recuperation capability as well as infinitely variable electrical power-split driving ranges. For this purpose, the synthesis program takes into account all of the options for integrating one or more electric motors in the transmission. The weightings and limit values for the various criteria can be matched extremely accurately to the specific application, leaving only transmissions with the best conventional and hybrid properties in the final set of solutions. This is then presented in a ranking list. ② shows at the bottom right the typical procedure for preparing the results in this way, with each point representing a newly synthesized transmission. Individual search areas are characterized by different component configurations. These transmissions that best meet the overall requirements are of major significance to the subsequent development process.

MODULAR SYSTEM OF THE NEW PLANETARY AUTOMATIC TRANSMISSION

The potential offered by systematically synthesizing transmissions in the way presented is now illustrated on the basis of a generated transmission system. The aim of developing the new eight-speed planetary automatic transmission for front-transverse applications is to arrive at significant advantages over the state of the art. Providing two additional forward speeds without further gear sets and shift elements, improving overall efficiency as well as permitting parallel hybrid modes that also offer the best possible level of efficiency are the main boundary conditions. Electric propulsion obviates the need for any mechanical reverse speed. In addition to this, the gear-set topology is to form the basis for a variable modular system.

The results of synthesis is the gear-set structure of a mild hybrid planetary automatic transmission presented in ❸ on the left with the associated shift logic shown in tabular form in ❹. Using just three simple minus planetary gear sets, two brakes and three clutches, it is possible to produce



❸ Construction set system of the eight-speed automatic transmission

		1st Variation	2nd Variation
Stationary ratios	P1	–3.16	–3.16
	P2	–3.32	–3.32
	P3	–2.02	–2.02
Additional ratios	S1	–0.99	–0.995
	S2	–1.10	–1.00
	CD	1.67…2.22	1.67…2.22

■ Shift element engaged

▨ Shift element engaged for operation with combustion engine

Structure	Speed	Brake A	Brake B	Brake C	Clutch D	Clutch E	Clutch F	Clutch G	Ratio (1st Variation)	Step (1st Variation)	Ratio (2nd Variation)	Step (2nd Variation)
Conventional + Mild hybrid + Full hybrid	1		■		■	■		▨	4.63	1.59	5.09	1.75
	2	■	■		■			▨	2.92	1.52	2.90	1.60
	3	■			■	■		▨	1.92	1.47	1.81	1.51
	4	■			■		■	▨	1.31	1.23	1.20	1.19
	5				■	■	■	▨	1.07	1.26	1.01	1.22
	6	■				■	■	▨	0.85	1.15	0.82	1.13
	7					■	■	▨	0.74	1.10	0.73	1.08
	8	■	■				■	▨	0.68		0.67	
										φ_{total} **6.9**		φ_{total} **7.6**
Conventional	R	■		■		■		▨	–3.3		–3.63	
Mild hybrid	Start ICE							▨	1.67…2.22		1.67…2.22	
	1 E		■		■	■			7.72…10.28	1.59	8.48…11.31	1.75
	2 E	■	■		■				4.87…6.48		4.83…6.44	
Full hybrid	Start GN		■		■			▨	∞…2.92		∞…2.90	

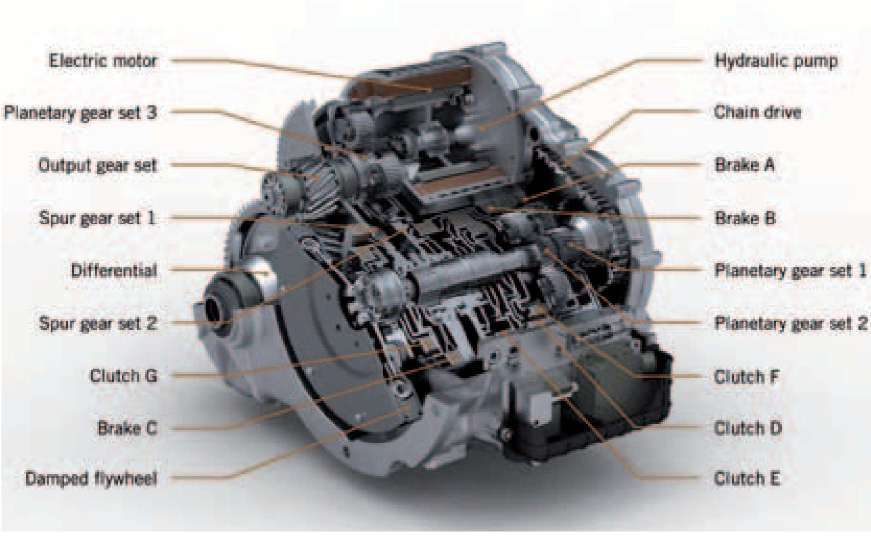
❹ Shift logic of the eight-speed automatic transmission

eight well-stepped forward speeds with a high ratio range of, for example, φ_{total} = 7.6 by selectively engaging three shift elements. Both configurations illustrate how easy it is to adapt the series of ratios to different requirements. The high driveaway ratio provides the capability of driving off in first gear with one internal shift element. Combustion-engine power is transferred extremely economically as a result of high levels of tooth efficiency and low engine speeds, keeping drag losses low in only ever two open shift elements and in the bearings. The large number of possible power shifts forms the basis for flexible driving strategies. The electric motor is integrated by means of an additional ratio stage to the input shaft. The resultant torque multiplication permits comfortable combustion-engine starting and dynamic electric operation in both directions of travel with an electric motor smaller than a crankshaft starter generator. The higher engine speed also makes it possible to exploit maximum electrical power output during boost and recuperation cycles, even when driving in an economical style at low combustion-engine speeds. The clutch on the input side decouples the combustion engine during electric propulsion and starts the primary engine without repercussions while the vehicle is in motion.

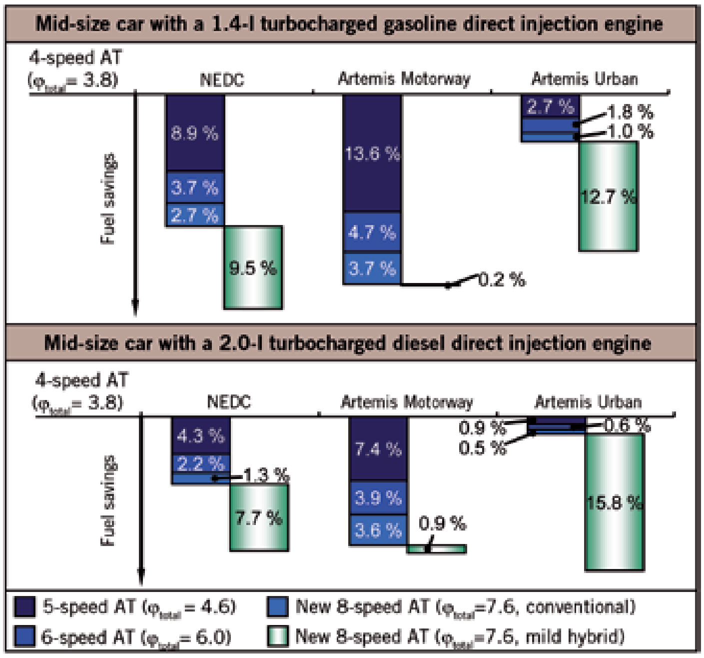
Further transmission variants can be derived from this gear-set topology with only minor component modifications. For a conventional planetary automatic transmission (③, center), a mechanical reverse speed is supplemented by a third brake. The use of a hydrodynamic converter as a drive-off element is a conceivable option. The full-hybrid derivative (③, right) with a further sun gear shaft on the output planetary gear set provides comfortable, infinitely variable, electrical power-split driving ranges with low levels of electric actuation power at the two electric motors. Continuously variable start-off from neutral can be used for both directions of travel and replaces a conventional drive-off element. Modular systems of this type can be used in future to help reduce manufacturing costs as they permit a high level of component sharing.

DESIGN OF A MILD-HYBRID PLANETARY AUTOMATIC TRANSMISSION

Selected design details of the eight-speed planetary automatic transmission for a mild hybrid are described in the following as a way of permitting better assessment of the synthesized gear set structure (③, left). The gear structure is extended by an additional reverse-speed brake to ensure a representative comparison with today's conventional transmission generations. A typical front-mounted transverse combustion engine with a maximum torque of 350 Nm and maximum speed of 6000 rpm provides the platform. With the hybrid transmission, it is necessary to consider the additional typical load profiles for the electric



❺ Components of the mild hybrid eight-speed automatic transmission



❻ Fuel saving potentials with increasing number of speeds

motor which has a maximum torque of 75 Nm and a maximum power of 12.5 kW.

All of the clutches and brakes as well as two of the planetary gear sets are positioned on the main drive shaft, ❺. To realize all power shifts, the shift elements are of disk-type design. To reduce axial length, the third planetary gear set is positioned on the intermediate shaft and connected by means of two spur-gear sets. The output gear set to the differential has a ratio of 3.56. In combination with the second option for configuring the gear-set ratio shown in ④, plenty of drive-off traction can be provided with internal shift elements which is why there is no need for any hydrodynamic converter, also saving space.

All planetary gear sets are extremely compact on account of the favorable stationary gear ratios. As a result of higher levels of torque, it is necessary to make the third planetary gear set just slightly more solid by using an additional fifth planetary gear. The permanent-magnet excited synchronous motor is positioned close to the intermediate shaft. Use of the chain drive allows easy adjustment of ratio to the input shaft and provides high degrees of freedom in radially positioning and defining the size of the electric motor. Its water-cooled stator allows high overcurrent for a short period of time for effective hybrid functionalities. Simple gear set structure as well as well-balanced component loading help to keep the mild hybrid transmission compact, thereby making it possible to reduce its axial length over present-day transmissions to below 350 mm.

POTENTIAL FOR SAVING FUEL

The design of transmission permits an accurate estimation of fuel consumption and carbon dioxide emission by simulating longitudinal dynamics. ❻ summarizes the results for a mid-size car with modern combustion engines for different driving cycles.

Consumption tends to fall as the number of speeds and ratio range of the automatic transmission (AT) increase. The new eight-speed planetary automatic transmission is realistically capable of achieving savings of up to 4 % compared with the six-speed generation. The hybrid functionalities permit a further maximum reduction of 16 %, mainly while driving about town.

SUMMARY

The demands on future vehicle transmissions are highly challenging, particular in relation to front-transverse powertrains. To achieve a high level of development certainty as done at IAV, new transmission generations are being created on an increasing scale by means of computer-based synthesis programs that take into account all possible combinations of gear set topologies while optimizing them in relation to various conventional and hybrid properties.

The modular system of the new eight-speed planetary automatic transmission clearly illustrates the potential of such methods. The main advantages over present-day transmissions include the large variety of efficient functionalities, small design space, flexibility of use for different applications, significantly improved consumption and minimized costs.

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WOB P 7492

THE NEW VW PASSAT

In six generations, the Passat has become the benchmark in its class. This success is due to the sum of its product properties as well as its quality and precision. The current seventh series of model year 2011, the B7, features fuel-efficient and environmentally friendly powertrains – one diesel engine even already complies with the Euro 6 Category N emissions standard –, as well as a high level of functional comfort and numerous driver assistance systems. For the first time, Dynamic Light Assist for glare-free driving is being introduced in this vehicle segment.

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DESIGN

The design of the new Passat of model year 2011 (internal designation B7) follows the Volkswagen design DNA established by Walter de Silva and visualises the high standards with regard to generosity, precision and value of the materials, ❶. Taut, powerful lines, subtle surfaces and balanced proportions characterise the design of the seventh generation of the Passat since 1973. At first glance, the new Volkswagen face with its dominant emphasis on the horizontal plane impresses the observer. The radiator grille and the headlights make up a formal unit, while the slightly angled headlights give the front a dynamic character.

Both inside and outside, the design of the new Passat marks a major step forward in actually available and emotionally perceivable value. Once again, the Passat and its design are redefining the demands of its class.

ENVIRONMENT

All vehicles and components of the Volkswagen brand are planned and developed in accordance with the "Environmental Objectives of the Technical Development Division". This involves not only fulfilling the legal requirements with regard to emissions and materials but also pursuing a holistic approach that includes the entire value chain. The Life Cycle Assessment includes not only the car's service life but also the phases before and after – from its product ion and its use phase rig ht through to its recycling. The information in the Environmental Commendation has been verified and certified by the independent technical inspection organisation Tüv Nord.

POWERTRAINS

The technologies pooled under the umbrella brand BlueMotion Technologies, in particular recuperation (recovery of deceleration energy) and the start-stop function, are fitted as standard in the Passat with the 1.4 I 90 kW Blue Motion Technology engine and in all TDI diesel engines. Furthermore, the Freewheel function familiar from the Passat B6 is available as an option for the 1.4 I 90 kW TSI DSG and as a new option for the 2.0 I 103 kW TDI DSG.

The development objective for all engine and transmission combinations was to reduce fuel consumption and emissions while maximising driving enjoyment and performance.

All engines comply with the EU5 standard. The Passat Blue TDI even exceeds this and fulfils the Euro 6 Category N emissions standard.

❶ Design sketch of the Passat, designed by Walter de Silva

1.6 L 77 KW TDI	
Engine design	In-line four-cylinder diesel engine with VTG exhaust turbocharger, direct injection
Mixture formation	Common rail
Cubic capacity	1598 cm³
Bore/stroke	79.5 / 80.5
Compression	16.5:1
Valves per cylinder / valve control	Four / roller rocker fingers with hydraulic valve compensation
Engine management / mixture preparation	Common rail injection system Siemens PCR2 with 1600 bar, seven-hole direct injection nozzle, VTG exhaust-gas turbocharger with charge air cooling, swirl optimised and tangential inlet channels
Max. power	77 kW at 4000 rpm
Max. torque	250 Nm from 1500 to 2500 rpm
Fuel	Diesel fuel according to EN 590
Emissions class	Euro 5
CO_2 emission	114 g/km
Transmission	MQ250-6F, manual shifting, six speeds, 250 Nm
Exhaust-gas purification system	Oxidation catalytic converter, water-cooled exhaust-gas recirculation with by-pass flap, coated maintenance-free diesel particulate filter

❷ Technical data for 1.6 l TDI diesel engine

SPARK-IGNITION ENGINES

The entry-level spark-ignition engine in the Passat B7 is the modern 1.4 I 90 kW TSI, which is also available with the DSG dual-clutch transmission as well as with a start-stop function and recuperation. The EcoFuel 1.4 TSI Twincharger has established itself worldwide as an engine that is superior to the competition. The application of twin supercharging with a mechanical compressor and an exhaust gas turbocharger combined with direct injection has made it possible to almost halve the displacement compared to a comparable naturally aspirated engine. Reduced friction and high boost values even at low engine speeds provide high torque with low fuel consumption.

The CO_2 emission for the CNG-powered saloon has been further reduced to 117 g/km (that is equivalent to 6.6 m³ CNG per 100 km in pure CNG operation and with the MQ manual transmission). The maximum driving range for the bivalent system is approximately 940 km (petrol approximately 460 km; CNG approximately 480 km) according to ECE R 101.

The MultiFuel 1.4 I TSI 118 kW E85 is a further innovative engine, which allows the use of renewable raw materials as an alternative to fossil fuels. This Twincharger can be operated with an ethanol content of up to 85 %. Due to the use of a precise ethanol sensor, the mixing ratio of conventional fuel to ethanol is precisely determined. As a result, optimum results are achieved with regard to emissions and fuel efficiency. This engine is used in Sweden and Finland.

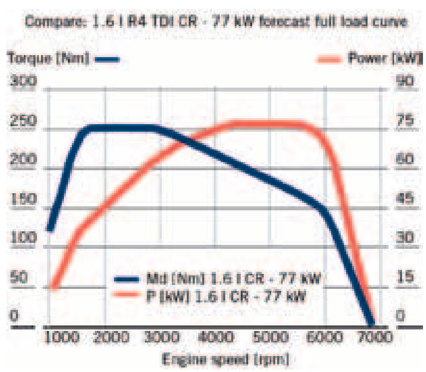
The Passat is also offered with the familiar 1.8 I 118 kW TSI and the 2.0 I TSI with power output increased from 147 to 155 kW. Compared to the 2.0 I TSI in the Passat B6, the combined CO_2 emission has been reduced from 183 to 169 g/km, in spite of the increase in power output, due to significantly reduced friction, an improved response of .the new exhaust gas turbocharger, the optimised transmission ratio and recuperation (saloon with MQ transmission).

The 3.6 I 220 kW six-cylinder engine with 4-Motion four-wheel drive familiar from the Passat R36 has been extensively revised. The application of numerous measures allowed the CO_2 emission in the NEDC to be significantly reduced by approximately 5 %. For the basic engine, the honing process for the cylinder crankcase made of GJL250 was converted to fluid -jet honing. Combined with a piston ring package with reduced tangential forces and a weight-optimised forged piston, this allowed a significant reduction in the friction losses of the piston/piston ring group to be achieved.

DIESEL ENGINES

In the new Passat, Volkswagen is presenting the second generation of its common rail diesel engine series in the power levels 77 kW (1.6 I displacement), 103 kW (2.0 I) and 125 kW (2.0 I). The diesel engines comply with the Euro 5 emissions standard. The BlueTDI version with this engine already achieves Euro 6 Category N due to the use of the SCR system familiar from the B6.

The version with the proven four-valve engine, the 1.6 I 4V CR 77 kW TDI, is equipped as standard with a start-stop sys-



❸ Output and torque of the 1.6 l TDI diesel engine

❹ Opening (2) the boot lid by detection of foot motion (1)

tem and recuperation and offers improved performance and low fuel economy due to the use of a six-speed transmission, ❷. The torque of 250 Nm is already available between 1500 and 2500 rpm, ❸. The power output of 77 kW at a rated speed of 4400 rpm is a guarantee for driving enjoyment. The CO_2 emission of 109 g/km (combined consumption 4.2 l/100 km) in the Passat BlueMotion Saloon is an outstanding value.

The further developed 2.0 I 4V 103 kW TDI engine from the B6 offers a balanced ratio between good performance, high fuel efficiency and exemplary environmental qualities. The engine already develops generous torque of 320 Nm between 1750 und 2500 rpm. Like the 1.6 I 77 kW TDI, the 2.0 I 103 kW TDI is also equipped with the new start-stop system and recuperation. The CO_2 emission and the fuel consumption of the saloon have been reduced.

The top-of-the-range diesel engine, the 2.0 I 125 kW TDI, is also offered as a 4-Motion version and, with the qualities typical of the TDI, is a particularly comfortable engine for the new Passat. In this engine, the CO_2 emission and the fuel consumption have been further reduced by approximately 18 % (saloon with MQ transmission).

COMFORT

The Passat has now been endowed with a higher level of technology, comfort and functionality. In addition to classic comfort measures such as reducing drive train, wind and chassis noise, a key role was also played by the application of comfort-oriented assistance systems to relieve the burden on the driver. These assistive, active comfort systems are summarised by the term ”Active Comfort“.

In the diesel engines, low-frequency noise components when pulling away from a standstill have been significantly reduced. At the same time, weight savings of up to 4.4 kg have been achieved in the exhaust system. In the dashboard area and also in the rear of the car, additional, very lightweight but highly effective absorption components have been installed.

The vehicle occupants are shielded against wind noise and external noise in all speed ranges by an acoustic PVB windscreen and thicker side windows. With the optional acoustic PVB front side windows, even a luxury class noise level is achieved.

The chassis of the new Passat is based on the axle components of its predecessor. By the optimisation of details, the components have been further developed compared to the predecessor and comfort has been significantly improved as a result.

BODY AND INTERIOR

A further upgrading of the Passat Variant is the panoramic sunroof. Its large visible surface ensures undisturbed entry of light to provide a more spacious, airy atmosphere for the occupants. A new sliding shade keeps out the sun if necessary in order to keep the interior cool. The new Easy Open system enables the boot lid to be opened without the need to put shopping bags down or to use the remote control key. In combination with the Keyless Entry Start System (Kessy), a “virtual pedal” opens the lid without contact. A sensor underneath the car detects the motion of a foot, ❹, and recognises that someone wants to open the boot lid. A so-called kick motion of the foot is sufficient to open the boot – provided, of course, that the right radio frequency identification key to the car is in the vicinity of the boot. Other motions are ignored by the sensor. People walking past the car or even animals that have crawled under the car close to the sensor will not cause the boot lid to open.

❺ Remote rear seat backrest unlatching from the luggage compartment

The new rear seat unlocking feature, ❺, which is fitted as standard equipment, allows the rear seat system to be unlatched from the luggage compartment. The backrest automatically releases. The customer can now directly load bulky goods right through to the front seat backrests from the luggage compartment.

A convenient, swivelling towbar with an electric release function can be conveniently clicked manually into the towing or rest position.

Particular emphasis has been placed on using high value materials for dashboard, centre console and door trims, ❻. The newly developed graining provides a soft surface texture. In addition, the doors have high-quality decorative trim with chrome applications. The customer can choose from different materials. The attractively contoured design of the dashboard trim now integrates a high-quality analogue clock.

Chrome applications now also surround all the air vents, and the adjuster wheels have new control symbols and lights, thus ensuring that the night design also corresponds to the high quality demands. Those who want to set a further highlight can order backlighting for the chrome trim strips in the doors. The light is emitted below the trim to generate a cosy atmosphere.

The high-value optics of the instrument panel is continued in the centre console. In addition to the many familiar functions that are expected and taken for granted in a Volkswagen (for example, cupholders, a 12-V socket, a variable storage compartment under the ergonomic centre armrest and connection for an iPod), the area around the gear lever has been redesigned. All switches are harmoniously integrated and include the new ignition switch for vehicles equipped with Kessy. The electronic parking brake has also been moved into the usual place in the centre console.

SEAT SYSTEM

The seats of the new Passat represent a consistent further development with regard to seat comfort and a climate of well -being. That is true both for driving on winding roads and on long journeys. In addition to the Trendline, Comfortline and Highline seats, a sports seat version with optimum lateral support for dynamic driving is also available.

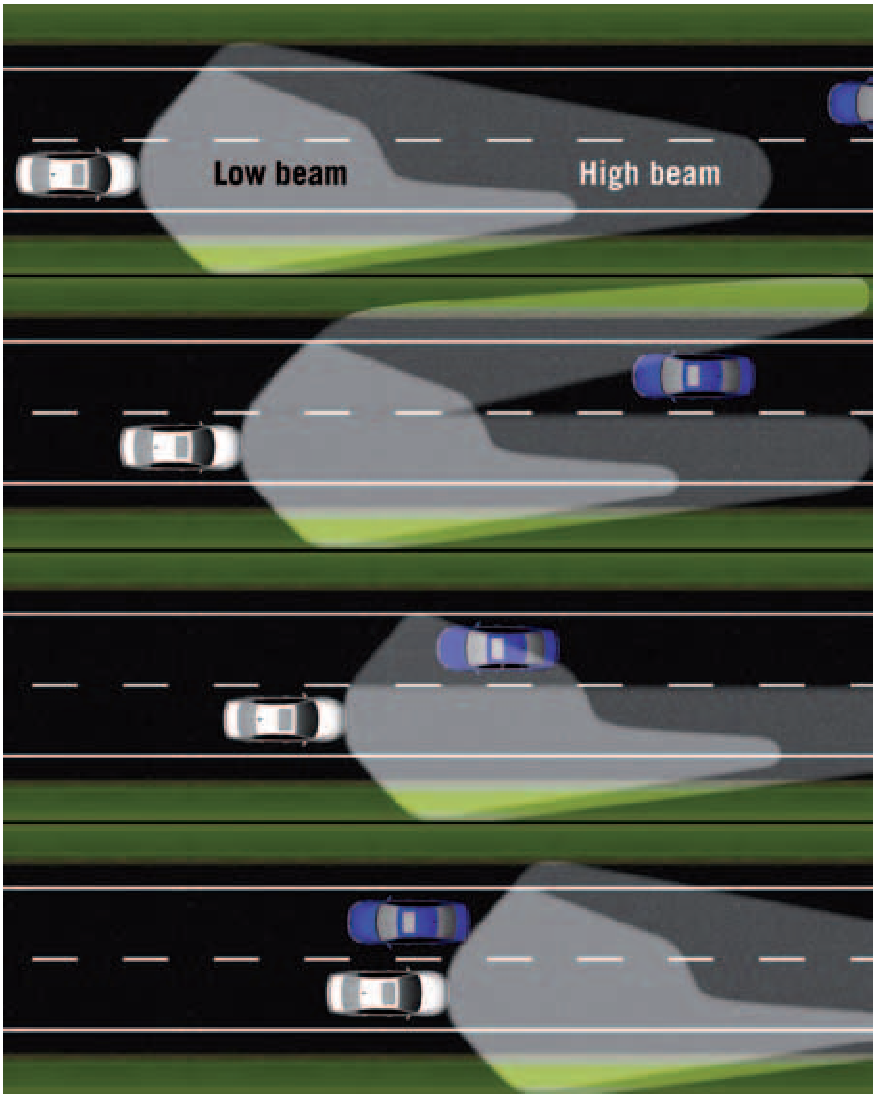
Active ventilation, ❼, of the front seats is also offered as an option in the Comfortline and Highline versions. The seat and backrest surfaces as well as the side supports are ventilated with air from high-performance radial fans. The ventilation effect is based on reducing the humidity between the body and the seat, thus enhancing climate comfort.

Optimum climate comfort is also achieved by air ducts in the foam upholstery that are specially matched to the seat geometry as well as by specially cho-

❻ High-quality materials and chrome applications in the interior

❼ Active front seat ventilation with radial fans and air ducts in the foam upholstery

❽ Bi-xenon headlights with cornering light



❾ Drive-by sequence without dazzling oncoming traffic with the Dynamic Light Assist

sen upholstery materials and leather perforations. The system is operated by a switch at the base of the seat next to the seat adjustment elements. Three ventilation stages can be individually selected. Parallel to the seat ventilation, the seat can also be heated if required in order to achieve a comfortable temperature.

VEHICLE SAFETY

The new Passat builds on the excellent level of its predecessor in vehicle safety that achieved the highest rating of five stars in the EuroNCAP test in Europe. Interaction of measures to avoid accidents and to reduce the consequences of accidents, called "Integral Safety" at Volkswagen, also played a key role in the development of this vehicle version.

The new Passat features a new tyre pressure monitoring system. The system uses sensors in the tyres that monitor the tyre pressure and send a signal to a control unit in the car. The Autolocation extension enables the system to identify and display a tyre that has lost pressure. Furthermore, it offers the possibility to display the pressures of all tyres on the instrument cluster.

LIGHT ASSIST

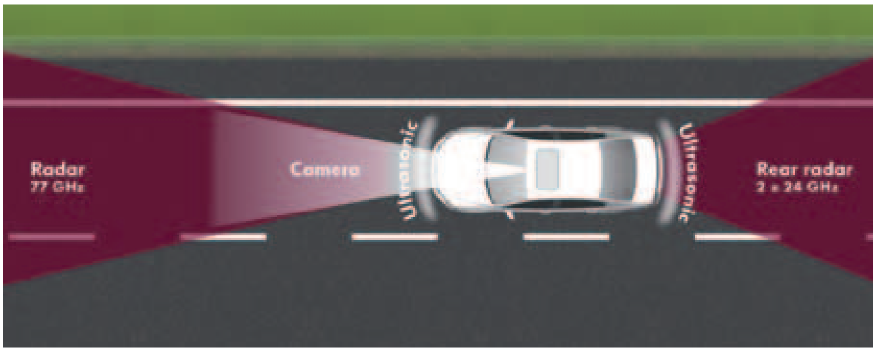
Light Assist is offered in the Passat for halogen headlights. The front camera integrated into the interior rear-view mirror detects vehicles in front or oncoming traffic and transmits a signal to the Body Controller module of the Passat to switch the main beam on or off.

Optional bi-xenon headlights with mercury-free D3S lamps are equipped with dynamic cornering light for highways and motorway driving, ❽. In addition, daytime running lights consisting of 15 individual Advanced Power Top-LEDs are arranged around the bi-xenon module. The power consumption for these lights is reduced to around 30 W compared to the approximately 140 to 180 W required for driving with dipped-beam headlights.

As the top version, Dynamic Light Assist is being offered by Volkswagen for the first time in the midsize segment, ❾. This innovative headlight system integrates familiar systems such as cornering light, dynamic headlight levelling, dynamic main beam control and main beam assistant, and their functionality has now been expanded by the use of variable light distribution to form a new lighting system.

This lighting system enables the driver to benefit from maximum use of the main beam headlight and a correspondingly long range of visibility without dazzling other road users. When the assistant is activated and at speeds above 65 km/h in extra-urban areas, the main bean is switched on automatically. Other road users are protected from the glare of the main beam and are not dazzled, whereas the remaining area of the light distribution is still illuminated by the full main beam performance.

This is made possible by the perfectly coordinated interaction between various vehicle components, such as a new front camera system behind the windscreen, the cornering light control unit, the headlight electronics and the new actuator in the headlight for the variable adjustment of the light distribution. The "intelligent" control of the module units, which swivel both horizontally and vertically, and the fact that each headlight is controlled inde-



⑩ Identification area for front radar, camera, ultrasonic sensors, and rear radar

pendently ensures the optimum illumination of the road at all times.

ADAPTIVE CRUISE CONTROL

The Adaptive Cruise Control (ACC) [1] ensures more comfortable driving by using a front radar sensor, ⑩, to automatically implement controlled acceleration and deceleration in traffic in accordance with the type of driving specified by the driver. ACC additionally includes Front Assist with the automatic City emergency braking system.

The driver selects the required driving speed and distance from the vehicle in front – while complying, of course, with the minimum legal distance. ACC works like an intelligent cruise control system by automatically maintaining the required distance from the vehicle in front depending on the preset speed. If there is no vehicle in front, ACC works like a conventional cruise control system.

A new feature is the overtaking function: when the driver is about to perform an overtaking manoeuvre and activates the indicator, the system ensures that the car can already be sufficiently accelerated in order to facilitate joining the other lane safely. The system dynamics can be adapted by selecting one of three driving modes (Comfort, Normal or Sport).

In combination with an automatic transmission, ACC can brake the car even to a standstill and keep it there if a vehicle is in front. As soon as the car in front has moved out of the way, the driver in the new Passat can immediately resume ACC control by touching the accelerator pedal. In all situations of active ACC driving, the driver remains fully in control and responsible for driving the car and is able to override the system at any time by deactivating it, braking or accelerating.

EMERGENCY BRAKE FUNCTIONS

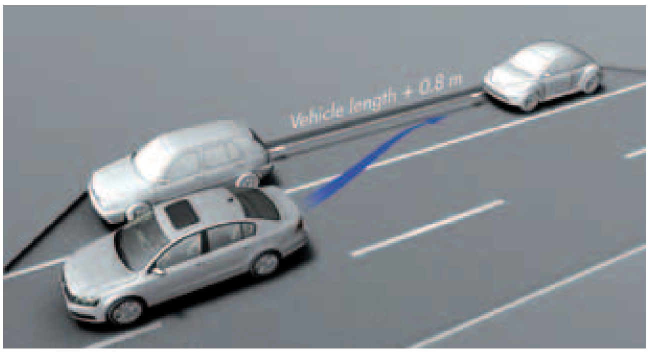
The assistant system Front Assist acts as an "alert passenger" to avoid nose-to-tail collisions – even when ACC is deactivated. The front radar sensor permanently monitors the traffic situation and warns the driver of critical situations. The driver is supported even before a critical rear-end collision situation involving the vehicle ahead is allowed to become serious. The braking system preconditions itself by applying the brake pads gently to the brake discs and the brake assist system is made more sensitive.

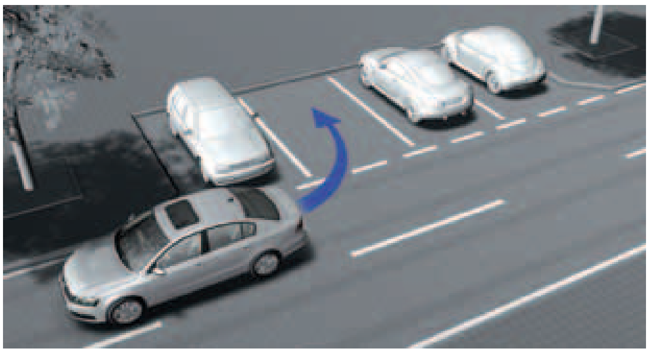
If the risk of a nose-to-tail collision increases, visual and acoustic warnings are initiated and a jerking movement of the brake pedal instructs the driver to operate the brakes. If the driver reacts by applying insufficient pressure to the brake pedal, the vehicle automatically applies enough braking pressure to avoid a collision. If the driver fails to react to the warning signals, Front Assist will brake the vehicle and reduce the speed of a collision under optimum conditions.

For speeds below 30 km/h, the city emergency braking system is a technical highlight. This active function reacts to stationary vehicles. When necessary, the city emergency braking function initiates automatic braking and in the event of an imminent nose-to-tail collision will reduce accident damage or, in an ideal case, help to avoid it altogether.

LANE KEEPING ASSISTANT

The further developed Lane Assist system helps in many driving situations to keep





⑪ Easier parallel parking (left) and diagonal parking (right) with the Park Assist the vehicle in lane by means of corrective steering intervention. Of course, this does not relieve the driver of his or her responsibility to drive the vehicle with full concentration. Lane Assist is activated via the multifunction display and operates at speeds above 65 km/h. A camera detects the road markings.

A new feature is that the assistance system is now able to support the driver even if there is only one lane marking on the right or left of the vehicle. If the system recognises that the vehicle is about to leave its lane, it steers in the opposite direction. This countersteering takes place very continuously and gently and can be overridden by the driver at any time with little effort.

LANE CHANGING ASSISTANT

In addition to Lane Assist there is now also Side Assist, which supports the driver on both sides when changing lanes. Visual warning signals integrated into the exterior mirrors warn drivers of vehicles that are in blind spots or which are approaching quickly from the rear. Vehicles are detected by two 24 GHz radar sensors. The system status is indicated by a multicolour illuminated symbol. The system is always active at speeds above 30 km/h and can therefore also be used in urban areas.

The display philosophy within an information stage and a warning stage has proven itself in practice. In the information stage, the displays are continuously shown in the mirrors with a low level of illumination. If the indicator is actuated in the information stage, an intended lane change is displayed. If a potentially dangerous situation is detected, the driver is alerted by brightly flashing LEDs. The driver‘s attention is therefore drawn to the corresponding rear view mirror, allowing the driver to assess the situation accordingly and cancel the lane-changing manoeuvre if necessary.

PARKING ASSISTANT

The new Park Assist in the Passat is a significant further development of the familiar first-generation Park Assist. New features include diagonal parking, leaving tight parking spaces and a brake warning systems, as well as extensions to the parallel parking function, ⓫.

TRAFFIC SIGN RECOGNITION

When the traffic sign recognition function is activated, a multifunctional camera detects the traffic signs in front of the vehicle and, when the data from the camera, the navigation system and the current vehicle data have been evaluated, up to three traffic signs currently in force (speed limits or no overtaking signs) with the corresponding additional signs are continuously displayed on the instrument cluster and on the map display of the navigation system.

The traffic sign that is currently in force is shown in first place. A traffic signs that is only conditionally applicable (for example 90 km/h with the additional sign ”In wet conditions“) is displayed in second place. If the car‘s rain sensor detects that: rain is starting as the car is being driven, the traffic sign with the additional sign ”In wet conditions“ is moved to first place, as it has now come into force.

FATIGUE DETECTION

In the Passat, Volkswagen is introducing a fatigue detection function for the first time. This function supports the driver on long journeys by detecting reduced driver concentration and displays visual message in the instrument cluster recommending that the driver should take a break from driving. It also gives an acoustic signal to support the display. An algorithm evaluates signals in the vehicle in order to draw conclusions about the driver‘s drowsiness from his or her driving behaviour.

The most important signal is the steering angle, although many other signals such as the use of the accelerator pedal, lateral acceleration and the use of the controls are also included in the assessment of the driver‘s ability to concentrate. At the beginning of the journey, the driver‘s characteristic behaviour is analysed in order to evaluate his or her drowsiness when driving. If the driver does not take a break, t he recommendation is displayed again.

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THANKS

Cooperation is essential in the development of a high-quality and innovative car. The author would like to thank the following persons from Volkswagen AG for their support in the writing of this article:
Ralf Fruet:
Technical Project Management
Philipp Dohmann:
Technical Manager Complete Vehicle
Klaus-Dieter Schrader:
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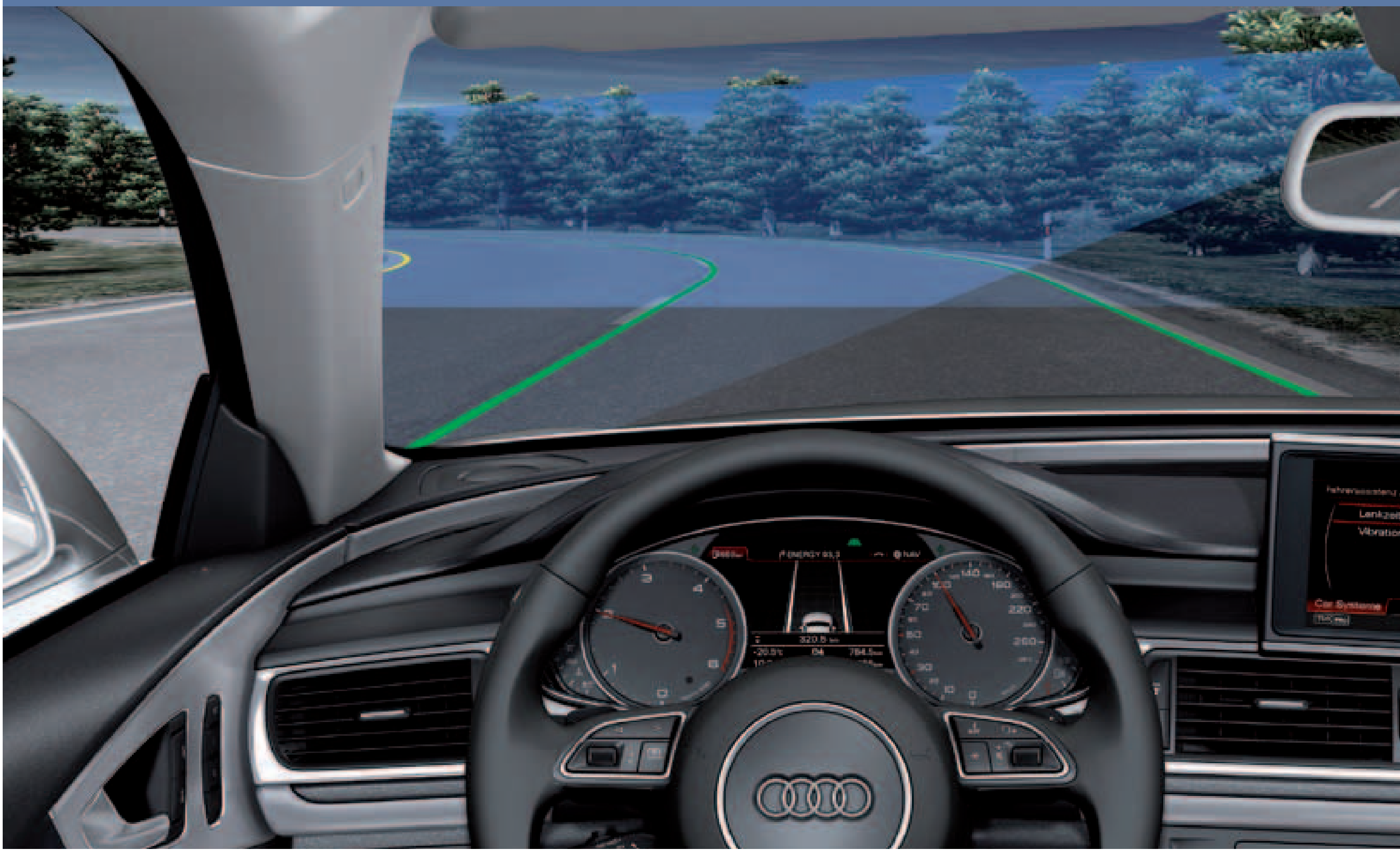
A LITTLE BIT MORE ATTENTIVE
AUDI ACTIVE LANE ASSIST

"Audi active lane assist", which was presented for the first time in the Audi A7, represents a new generation of lane assist systems. The driver assistance system is capable of warning the drivers when they are about to leave their lane unintentionally but also provides continuous assistance in keeping the vehicle in the middle of the lane during normal driving. The basis is provided by the networking of electronic control units over the Flexray bus.



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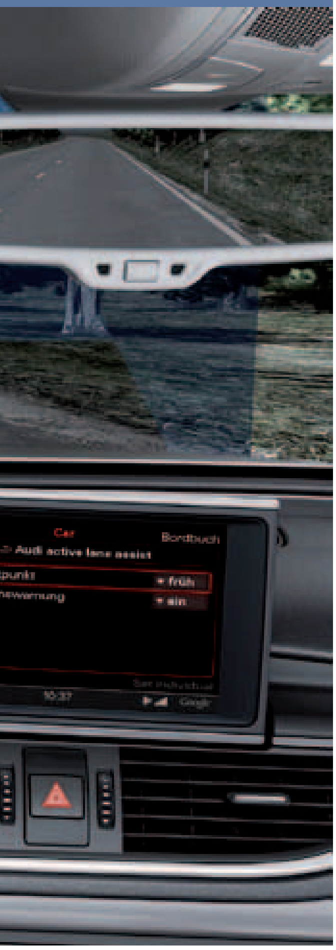


BACKGROUND

Driving a car is a highly complex activity. Alongside selecting an appropriate speed, one of the key factors is steering, and specifically keeping the vehicle in lane. This requires the driver to maintain a constant eye on the road and to continuously monitor the vehicle‘s movement. Even a short lapse of concentration may cause the vehicle to move unintentionally out of lane and collide with other road users or crash in some other way. A look at the accident statistics clearly underlines this problem: 32.9 % of road traffic accident fatalities in Germany in 2008 resulted from vehicles leaving their lane [1].

In view of this, it is advantageous to the automotive industry to assist the driver in maintaining lateral control of the vehicle by means of assistance systems.

Many European car makers offer lane departure warning systems aimed at preventing a vehicle from unintentionally moving out of its lane. These systems use visual recognition of the lane markings ahead of the vehicle to detect when it deviates from them and warn the driver by a variety of methods according to the specific manufacturer: by vibration of the steering wheel or the driver‘s seat, or by means of an acoustic signal [2]. The driver can decide, based on the warning, whether he or she needs to react in the given situation by rapidly steering or braking as appropriate to avoid an accident.

However, in view of the often very short reaction time remaining in the case of a suspected lane departure, an even better method is not only to warn the driver but also to provide active assistance in avoiding an accident. Active assistance instantly indicates to the driver the correct action to take, thus shortening the time needed to recognise the situation and decide on an appropriate response. A variety of research projects indicate that automatically setting steering torques on the wheel to provide the driver with an intuitive feel for the right steering wheel motion needed are capable of improving lane keeping [3] and, as such, are superior to purely warning systems [4].

This method of assistance has another key advantage: whereas lane departure warning systems are only designed to warn in the event of a suspected critical departure from a lane – a situation which is very rare, and is experienced by few drivers in their actual driving practice – active assistance can help the driver in staying normally within the lane. A lane keeping assistance function of this kind can provide drivers with continuous help in keeping their vehicles in lane, making driving a more relaxed and comfortable activity generally – and not only on long-distance motorway journeys.

The “Audi active lane assist” feature, presented for the first time in the Audi A7, represents a new generation of lane keeping assistance by combining the aforementioned functions. Whereas many present-day lane keeping assistants issue a warning only shortly before the vehicle crosses a lane marking, Audi active lane assist applies steering torques to the steering wheel which help the driver to steer intuitively in a manner appropriate to the given situation. Drivers can choose whether to have the system only warn them shortly before the vehicle moves out of lane, or whether it provides continuous assistance in keeping the vehicle in the middle of the lane. In this way, the system is able to provide drivers with assistance which markedly enhances comfort while driving normally along motorways and highways.

NEW GENERATION OF LATERAL CONTROL ASSISTANCE

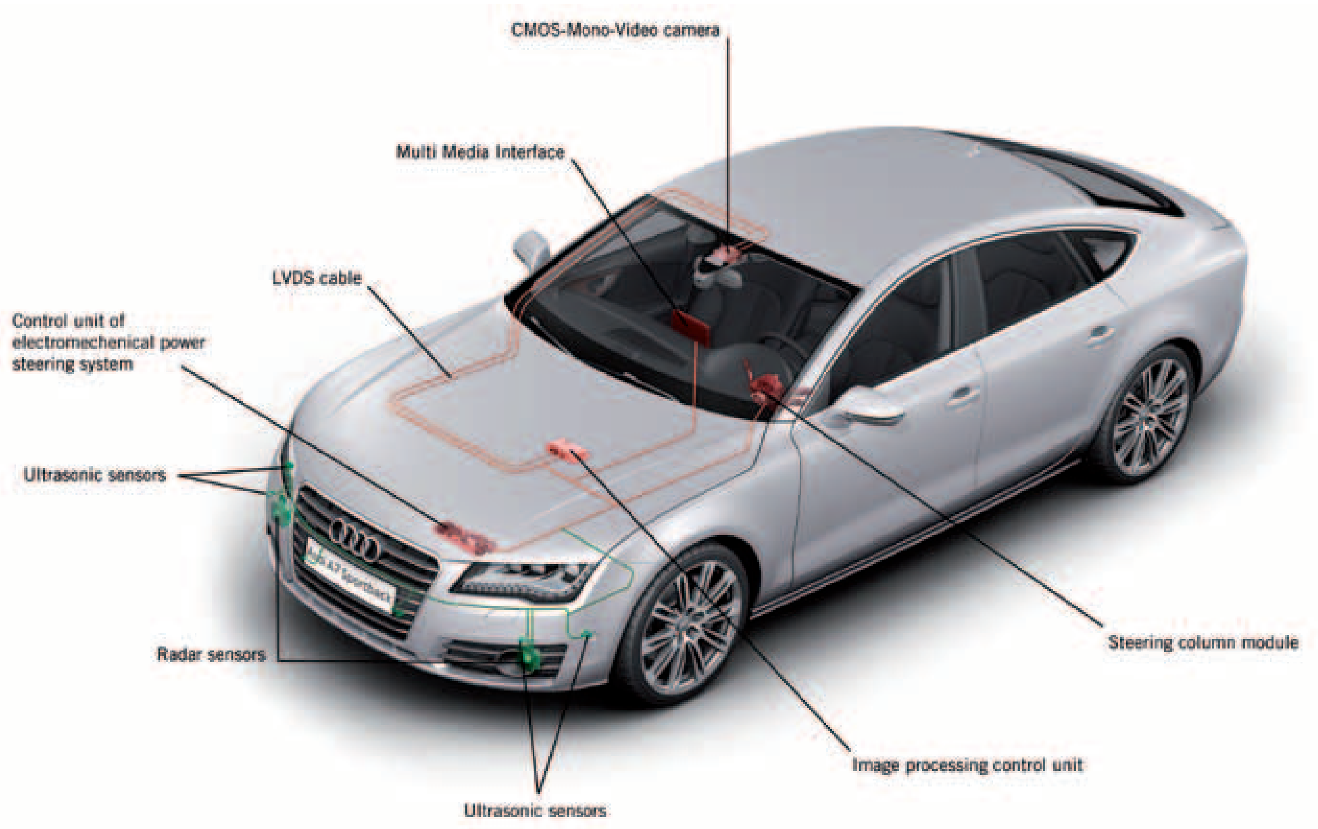
The basis for this assistance function is provided by the networking of electronic control units over the Flexray bus, which provides timed data transfer and safeguards error and failure tolerance. All the control units relevant to the function are shown in ❶.

The first module in the system is a CMOS-Mono-Video camera between the interior rear-view mirror and the roof module, which is capable of registering eight independent road markings. The system also differentiates between the various line types (broken or solid) and between line colours (yellow or white). Lane detection poses a particular challenge because not only is the quality of some lane markings poor, but also line and gap lengths and line widths vary widely across the world. There are also a number of country-specific special features, such as “Botts‘ Dots” in the USA. A key factor in terms of the robustness of such a system is that lines which are not useful to lateral control functionality are also detected and tracked. Stable recognition and classification of disturbing infrastructure features such as crash barriers or bitumen joints ensures that the feature does not activate a false response to them. The lines marking the lane in which the vehicle is driving which are relevant to lateral control are then plausibility checked and selected by a software module. The system is thus capable, based merely on one detected lane marking, of assisting in more varied scenarios, such as on country roads or even in complex situations such as when driving through road works.

The lane marking information is transmitted over an LVDS cable from the camera control unit to the image processing control unit, where the actual control algorithm of the Audi active lane assist feature is executed. This algorithm additionally requires data relating to the vehicle‘s status, such as its speed and the steering wheel angle, which are received over the Flexray bus. Those variables are then used to calculate the actual trajectory of the vehicle relative to the lane routing ahead and to plot a target trajectory to keep the vehicle in lane.

If all the basic conditions – such as a vehicle speed of more than 65 km/h – are met, assistance is made available and enabled by way of a classification of the given situation. The system then controls the vehicle according to the difference between the target and actual heading. It also takes into account the driver‘s own wishes and needs in terms of assistance, calculated, among other criteria, on the basis of the manual steering torque applied to the wheel by the driver.

The ultimate control variable is the system steering torque on the steering wheel, which in the event of a lane departure is transmitted over the Flexray bus to the control unit of the electromechanical power steering system. In contrast to



❶ Audi active lane assist control units (red elements are essential, green elements enable functional add-ons) hydraulic steering assistance systems, electromechanical power steering permits controlled adaptation of the steering moment characteristic and thus targeted activation of steering torque to provide lane keeping assistance. If the driver allows those steering torques to take over, the vehicle is gently guided back towards the centre of the lane and maintained on its predetermined heading. If the driver steers against the system setting, or operates the turn indicator, it is assumed that he/she is intending to change lane and the assistance is cancelled. In addition to actually activating the steering torques, the electromechanical power steering control unit also limits the steering torques and the associated gradients so that they remain controllable by the driver in every situation.

OPERATING AND DISPLAY CONCEPT

To ensure optimum interaction between the driver and the system, a good operating and display concept is essential. When the driver has activated Audi active lane assist by way of a button on the indicator lever (steering column module) and the vehicle has exceeded a speed of 65 km/h, the system is enabled if at least one road marking is detected. A status LED on the dash panel indicates the system status, and detected road markings are displayed graphically by way of a selective assistance screen, ❷. The detected road markings may also be depicted on an optionally head-up display.

The driver can choose between two assistance variants on the Car menu of the vehicle‘s Multi Media Interface (MMI). When “Steering input: late” is selected, the system intervenes in the steering shortly before a road marking is crossed, thus helping the driver to avoid unintentionally moving out of lane. If the driver keeps to the centre of the lane, no intervention takes place. The system can thus intervene in critical situations without impeding the driver‘s normal driving practice. This mode of assistance is illustrated in ❸.

In addition to lane departure warning assistance, Audi active lane assist also offers a further form of lateral vehicle control. On lengthy journeys especially, keeping in lane can place a strain on the driver, and this can be alleviated by a more active level of assistance. If the driver selects the “Steering input: early” setting, the assistance system generates controlled steering torques in the event of even minor deviations from the centre of the lane, keeping the vehicle permanently towards the centre position and thus helping the driver continuously throughout the journey. Even though Audi active lane assist only intervenes with gentle steering torque adjustments, it provides significantly improved lane keeping and markedly enhances driving comfort. A diagram illustrating the assistance provided with the “Steering input: early” setting is shown in ❹.

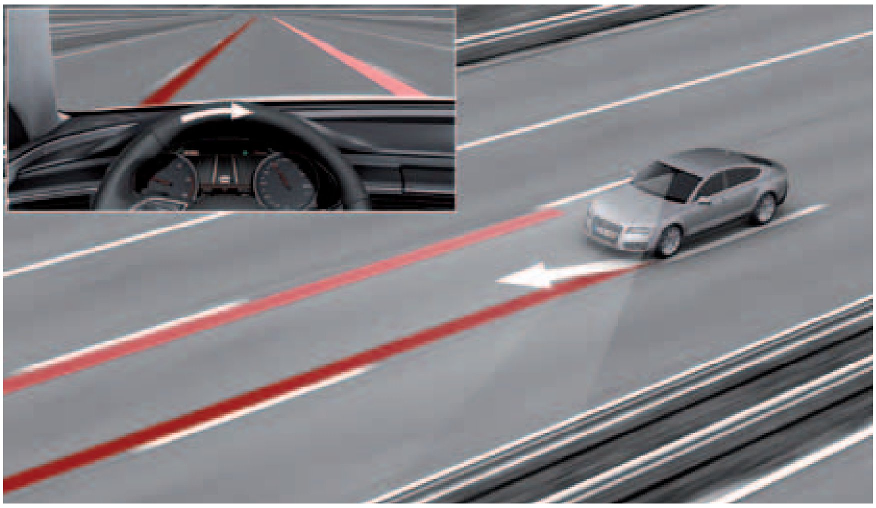
If the driver wants a warning in addition to the steering assistance, an option for the steering wheel to vibrate if a road marking is crossed can be selected on the MMI.

The basic principle is that responsibility for control of the vehicle remains with the driver in every situation. If Audi active lane assist detects that the driver has taken his or her hands off the steering wheel, the system is disabled. It serves only to assist the driver, and does not replace the driver‘s own lane keeping action.

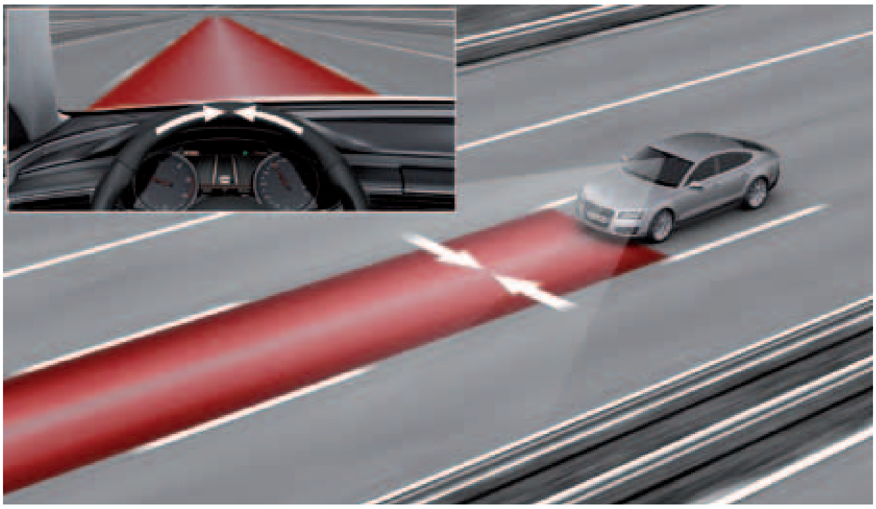
MORE FUNCTIONALITY THROUGH INTELLIGENT NETWORKING

To guide their vehicles safely through the traffic, drivers not only have to follow lane markings but also take into consideration other vehicles or objects in the lane in which they are driving or by the side of the road. The sensor data collected by an optionally fitted adaptive cruise control or Audi park assist feature (parking system

❷ System status (green LED) and detected road markings on central display: two road markings detected (top), one road marking on the right detected (bottom)



❸ Assistance with “Steering input: late” setting



❹ Assistance with “Steering input: early” setting

or park assistance system) enables Audi active lane assist to offer even more targeted assistance. If it unambiguously detects that the driver wishes to overtake, the system does not intervene when moving out of lane and back in, regardless of whether the indicators are activated or not. If the assistance system detects other vehicles or crash barriers close to the vehicle by way of its radar, video and ultrasonic sensor systems, assistance is provided earlier. The system thus intervenes in the vehicle‘s steering precisely when really needed, yet without impeding the driver‘s normal driving practice.

Audi active lane assist represents a further milestone in state-of-the-art driver assistance systems from Audi, making motoring considerably more comfortable. It enhances intelligent driver assistance not only in dangerous situations but also during normal driving.

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In 2008, the peer review process utilized by ATZ and MTZ was presented by the WKM (Wissenschaftliche Gesellschaft für Kraftfahrzeug- und Motorentechnik e. V./German Professional Association for Automotive and Motor Engineering) to the DFG (Deutsche Forschungsgemeinschaft/German Research Foundation) for official recognition.

THE SEAL OF APPROVAL FOR SCIENTIFIC ARTICLES IN ATZ.
ATZ PEER REVIEW
REVIEWED BY EXPERTS FROM RESEARCH AND INDUSTRY.

CURRENT AND FUTURE DEVELOPMENTS IN THE AREA OF PEDESTRIAN PROTECTION ON MOTOR VEHICLES

The requirements for pedestrian protection of passenger vehicles will be increasing within the next years. The component-based methods, which originate from the work of the EEVC WG 17, are widely used in pedestrian protection testing procedures. The development of the testing procedures described in the following pages by RWTH Aachen University aims at bringing real world scenarios as accurately as possible into the test lab.

THE SEAL OF APPROVAL FOR SCIENTIFIC ARTICLES IN ATZ.
ATZ PEER REVIEW
RECEIVED 2010-06-10
REVIEWED 2010-08-02
ACCEPTED 2010-09-24
REVIEWED BY EXPERTS FROM RESEARCH AND INDUSTRY.

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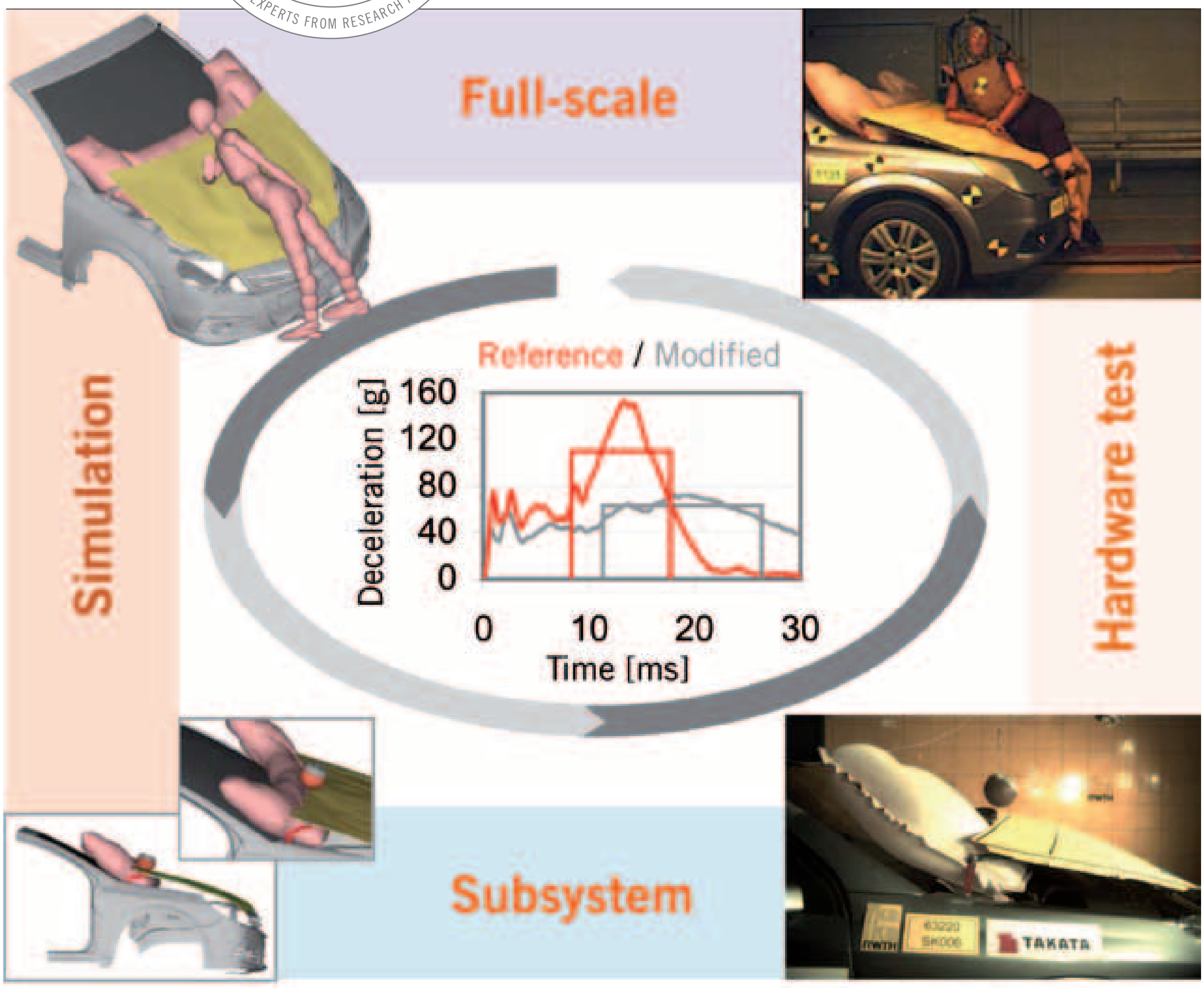
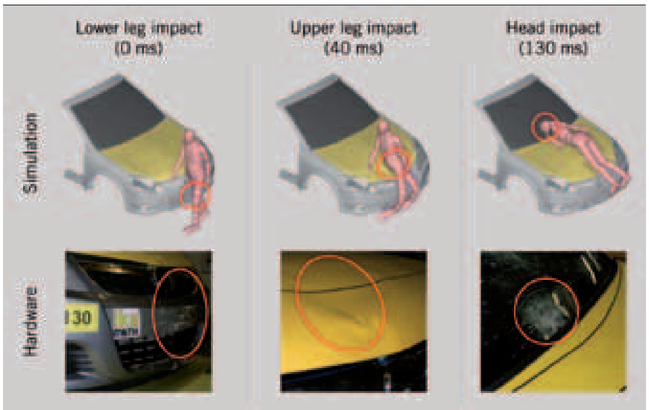


1 INTRODUCTION

In legislation, all relevant demands regarding the pedestrian protection performance of vehicles are stated in Regulation (EC) No. 78/2009 [1]. The global harmonization of standards has also been implemented within the framework of Global Technical Regulation (GTR) No. 9 [2]. The first phase legislations were already introduced in 2005 in Europe, while Japan was using similar requirements. The introduction time of the more demanding requirements, specified in the so-called phase two, has been determined depending on the vehicle classes and masses. Euro NCAP has also fulfilled a step to harmonize its testing procedures according to the legislative requirements by the end of 2009. A new rating system will put much more focus on pedestrian safety by introducing an “overall rating” with a so-called soft landing by 2012. The next step will be to introduce the new flexible legform FlexPLI, which has been developed in Japan.

The component-based methods, which originate from the work of the EEVC WG 17, are widely used in pedestrian protection testing procedures [3]. The development of the testing procedures described in the following pages aims at bringing real world scenarios as accurately as possible into the test lab. The accuracy of the hardware testing methods can be improved by using supplementary numerical simulations to analyse accident kinematics.

On the vehicle-side, active safety systems for the prevention of accidents are supplemented by the passive safety systems with the aim of mitigating the injuries in case of an unavoidable accident. In addition to the purely-passive solutions, the deployable protection systems, e.g. pop-up bonnets and external pedestrian airbag systems, are also investigated to fulfil the new requirements. Furthermore, an integrated head protection concept that merges the pop-up bonnet functionality with an advanced pedestrian airbag and a deployable impact plate is developed and presented in the following.

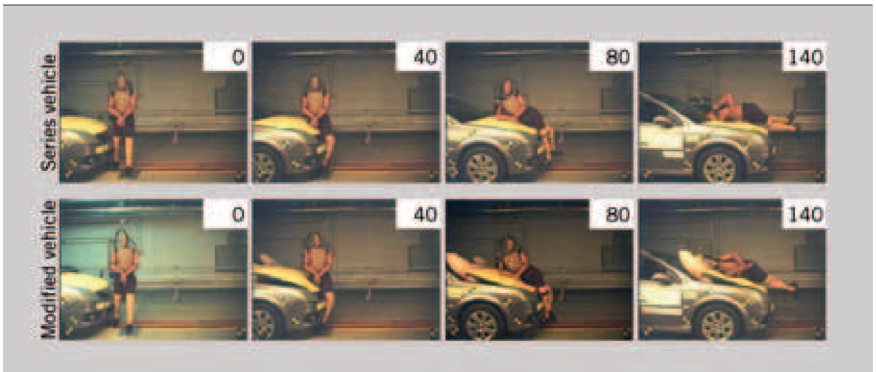


❶ Vehicle-pedestrian impact scenario

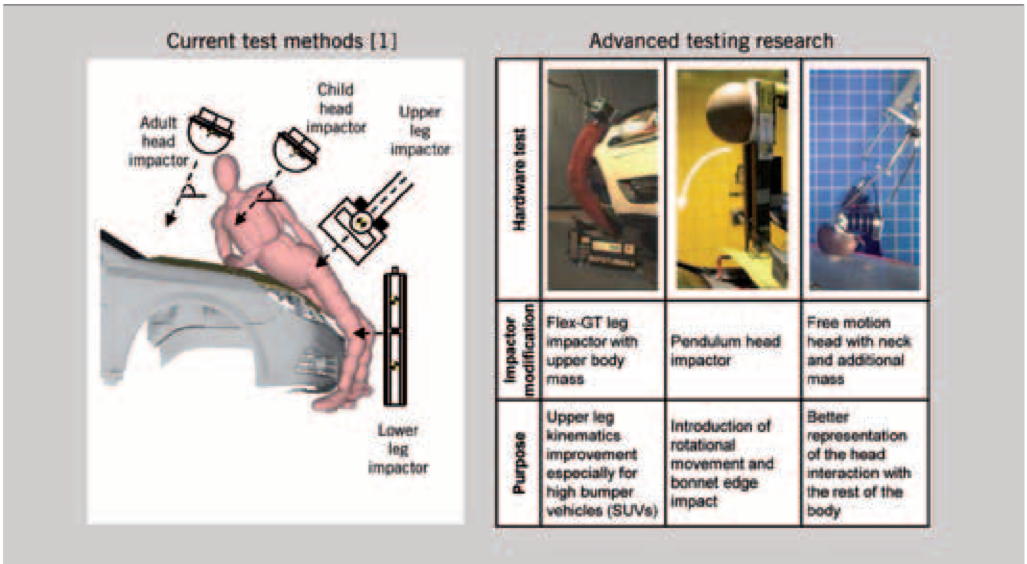
2 VIRTUAL AND HARDWARE METHODS FOR VEHICLE-PEDESTRIAN COLLISION ANALYSIS

In a vehicle versus vulnerable road user accident scenario, the primary impact consisting of the interaction of the human with the vehicle is followed by the secondary impact with the ground. There are three characteristic impact areas on the car front for the primary impact. In a typical collision, the pedestrian first hits the bumper with the legs, starts wrapping around the bonnet leading edge, and finally, the head impacts the bonnet or the windscreen area, ❶. The collision can be investigated using virtual analysis methods such as a coupled simulation setup that utilizes the interface between the multi-body solver (Madymo) and the finite element-solver (LS-Dyna). Thus, the validated human models can be used together with the realistic deformations of the vehicle parts.

The hardware testing with the Polar II dummy (Pedestrian dummy fOr LAboratory Research) [4] has the advantage of representing the whole body of a pedestrian, which means that the impact points of the body parts, such as the head, depend on the whole body kinematics of the pedestrian. High speed sequences of 40 km/h crash tests with a series vehicle and a vehicle modified by installing a pedestrian airbag system can be compared, ❷. In these tests, the injury values during the primary impact and the overall kinematics until the secondary impact can be analysed in detail.



❷ Polar II dummy tests with the series and the modified vehicle [4], time in [ms]



❸ Current test methods and advanced testing research

3 TEST PROCEDURES FOR EVALUATING PEDESTRIAN SAFETY

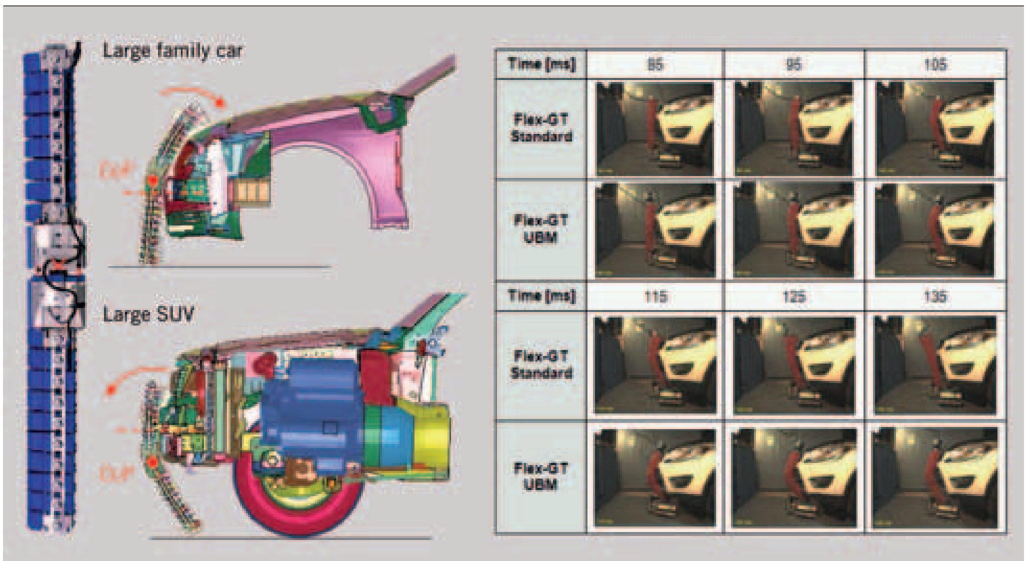
Pedestrian-side studies focus on the testing procedures to assure their accuracy, simplicity and reproducibility. Subsystems, i.e. linear head and leg impactors, are currently utilized due to factors such as cost and availability, although the whole body kinematics and the interactions between the human body parts cannot be studied, ❸ left.

Current procedures and subsystem tests are continuously studied and improved for a better representation of the reality, ③, right. For higher front end vehicles like SUVs, an effective mass representing the upper body is added to the flexible legform impactor FlexPLI to improve the bending and rotational behaviour of the upper leg [5]. For the head motion, a rotational trajectory or an eccentric neck mass are introduced to better reflect the dependency of the head on the body motion as well as the head-neck interaction [6].

3.1 LEG IMPACT WITH FLEX-GT AND UPPER BODY MASS

Numerical simulations of pedestrian lower and upper leg impacts as defined by Regulation (EC) No. 78/2009 are documented in [7] to assess the existing pedestrian lower extremity regulatory test procedures. These investigations have clearly highlighted that the biofidelity of the EEVC WG17 legform impactor is limited and the lack of an upper body mass prevents its use in the case of high bumper vehicles.

Possible improvements for the lower leg impactor procedure are investigated by the new impactor Flex-PLI, ❹ left. For this purpose, the Flex-GT status of the legform is used. A more up-to-date status, the Flex-GTR, is currently introduced to the legislation. Simulations with the leg impactor against a large family car and a large sport utility vehicle have been performed to cover the range with low and high bumpers [8]. The dependency of the tilting movement direction of the legform after the impact on the bump-



❹ Simulations and hardware tests with Flex-GT [7,8] er height of the vehicle can be clearly identified in, ④, middle, which shows the position of the centre of percussion relative to the bumper height. Furthermore, SUV validation tests with and without the upper body mass have been carried out to compare the results of the two Flex-GT versions, ④, right.

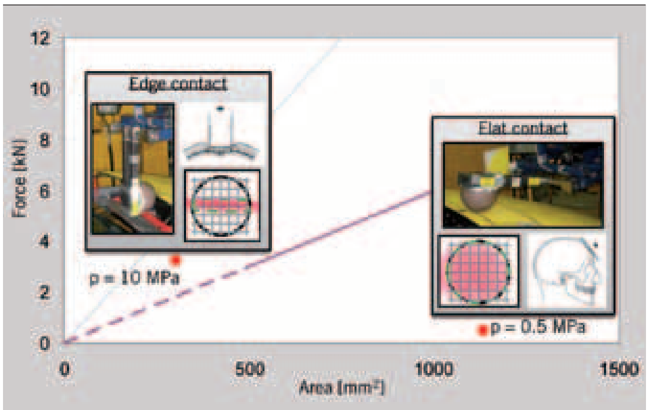
Test results indicate that the addition of an upper body mass of approximately 6 kg improves the kinematics of the femur especially for large sport utility vehicles and provides a better representation of the reality [5]. An advantage is that the current test facilities are sufficient to propel the impactor with the upper body mass.

3.2 HEAD IMPACT WITH PENDULAR AND ECCENTRIC MASS IMPACTORS

During the last years, pop-up bonnets received interest from the industry and will be more used in the future, which will influence the kinematics, especially for the head, in pedestrian-vehicle collisions. The contact location of the head can either be the sharp edge of the lifted bonnet-end or the gap between the bonnet and the windscreen, where new injury risks such as skull fracture may occur. The current EEVC linear impactor test, however, cannot meet the evaluation requirements of this new contact typology, because it neither estimates the contact pressure nor follows the head rotational trajectory.

In order to overcome this problem, an improved method making use of an impactor with the focus on the rotational movement of the head, and a pressure-based criterion has been developed [9]. The headform impactor prototype, which is a pendulum with a force sensor based on the EEVC adult head, has been used to verify the high-pressure level achieved in head to edge impact. Two different crash configurations are performed, i.e. edge and flat contact, ❺. The area through which impact force is transferred is marked in red together with the border of the force sensor (black). The result is obvious that the edge impact resulting in a 10 MPa maximum pressure represents a higher risk of injury than the flat impact with the pressure of 0.5 MPa [6].

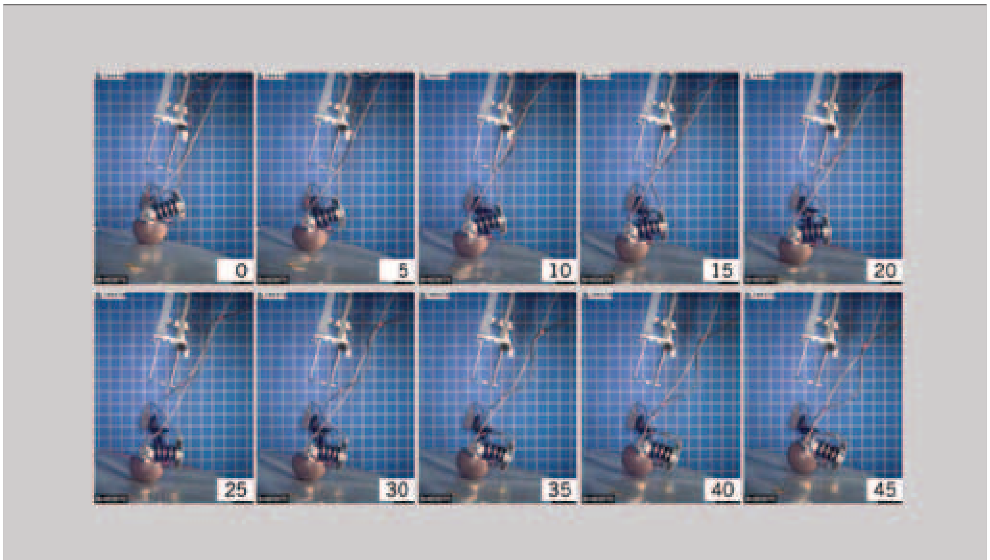
Another approach for a better representation of the head rotation for the flat contact is the usage of an additional mass connected to the headform by an element which stands for the neck. Studies regarding the dependency of the head and neck region on the rest of the body show that coupling of the head with the body cannot be neglected, because angular accelerations could be extensive and dangerous [6]. However, this situation is not reflected by the current head impactors. An improvement is achieved by connecting an additional mass to the original headform with a certain joint characteristics. From the hardware tests with the eccentric mass impactor, which makes use of the Hybrid III neck, it is concluded that the improved impactor is able to realize the angular accelerations predicted in the human model simulations, ❻.



❺ Tests and the corresponding injury risks

4 VEHICLE-SIDE MEASURES

Innovative active safety systems rely on pedestrian recognition methods in order to prevent accidents or reduce the impact velocity. Detection of pedestrians is a challenging task due to the difficulty of identifying the pedestrians and differentiating the ones posing a risk from the other road users and the surrounding. Us-



❻ Head impactor with neck and additional mass [6], time in [ms]

7 Hybrid protection system prototype

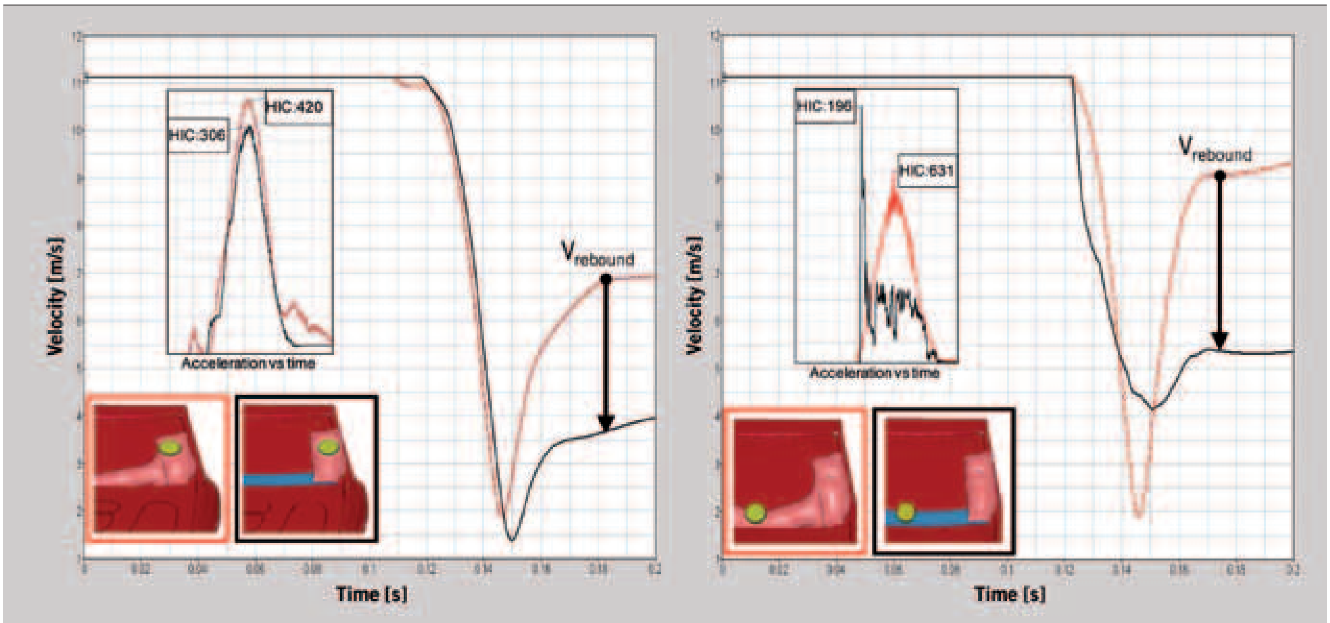
ing technologies such as sensor fusion, stereo cameras, radar, lidar and infrared sensors, pre-crash detection is possible. In addition to warnings and braking interference, the pre-detection can also be used for triggering the preparation phase of passive safety systems. Since passive safety systems are mostly irreversible, e.g. the pedestrian airbag, their activation has to be confirmed by the acceleration- and contact sensors, which have a higher reliability than the pre-crash sensors. The sensor testing methods or the sensing technologies are not discussed in detail within the context of this paper.

Purely passive solutions imply material or geometry optimizations, which are preferred in terms of simplicity and cost. Sharp edges of the body are eliminated and a more continuous front shape is adopted. During the design process, measures are taken to provide more room between the bonnet and the engine block in order to increase the available deformation space. Aluminium is an increasingly preferred bonnet material with a lower stiffness to utilize this space for a better protection performance. Deployable protection systems, alternatively, are gaining more and more importance due to the tightening demands of legislation and consumer testing. Some of the series production vehicles leading the development in this area are Citroën C6, Jaguar XK and Honda Legend (2005/2006, first implementation of deployable bonnets), Mercedes E-Class (2009, first reversible deployable bonnet) and BMW 5-Series (2010, fibre-optic sensors and fully deployable bonnet capable of front and back elevation).

4.1 PEDESTRIAN AIRBAG WITH DEPLOYABLE BONNET

Deployable bonnets, which offer an improvement for the torso and head impact area, increase the distance between the bonnet and the stiff engine parts. Another solution for reducing the head impact severity, also for the windscreen region, is using a U-shaped airbag system combined with a bonnet lifting function. Providing additional deformation space in the bonnet area, covering the hard structures, especially the A-pillars, and closing the gap between the bonnet rear end and the windscreen base are the main benefits. Dummy tests with a sedan, travelling at 40 km/h average and a 90 l airbag have indicated a 42 % HIC reduction, 60 % neck force decrease and 30 % neck moment reduction for the airbag-equipped vehicle in comparison to the series vehicle [4].

On the other hand, vent holes used in the occupant airbags for energy absorption cannot be employed, due to the high volume and the required sustaining time of the pedestrian airbag, during which the pressure has to be maintained. This leads to the lower energy absorption of the airbag resulting in an increased risk of head rebound.



8 Head impact simulation results

4.2 ADVANCED AIRBAG SYSTEM WITH VENT HOLES

For a further improvement of the protection in the bonnet rear region and the rebound behaviour of the airbag, a hybrid system is reasonable. A prototype of the system has been designed and built at ika for demonstrational purposes, while the simulation model has been created for assessing the effectiveness of this idea [10]. In such a system, the gap between the bonnet and the windscreen is completely closed by the so-called impulse plate in the middle region where there is enough deformation space, ❼ left-1, and by the airbag in the region close to the A-pillars where no deformation space is available, ⑦ left-2. Thus, the discontinuity in this region is minimized by the combined airbag-plate design, resulting in a favourable bending angle of the neck. Also, the head is protected from the sharp bonnet rear edge. Such an impulse plate, e.g. flat aluminium plate, and an airbag can be packed inside a module that is mounted on the lower surface of the bonnet rear, ⑦ right.

The reduced size of the pedestrian airbag makes the usage of pressure triggered vent holes on the airbag possible, so that the well-known behaviour of airbags used for occupant protection systems can be utilized to minimise the undesired rebound effect. Furthermore, for the central region, the energy absorption of the head can be optimized by the design of the impulse plate, which normally lies under the bonnet and deploys by sliding towards the windscreen. The HIC reduction due to the optimized energy absorption on the airbag and the impulse plate, and the improvement in the airbag rebound effect, are proven by simulations, ❽. However, these simulations have to be validated by head impactor tests on the prototype. Furthermore, there are design concerns regarding the robust deployment of the mechanism that have to be solved for the series application of such an early stage system.

5 CONCLUSION

Pedestrian protection constitutes a design challenge due to significant trade-offs with e.g. visibility and occupant protection. Considering the requirements, intelligent systems including accident prevention, structural measures, and deployable systems are currently studied. Furthermore, methods for evaluating the protection offered by these systems are designed concurrently.

The behaviour of the pedestrian body in an accident is studied with the help of full-scale methods. Virtual analysis and hardware testing are used to investigate the effects of the complex protection systems. Applications for both methods have been utilized and proven to be helpful in understanding the overall accident kinematics.

It has been shown that the existing component-based test procedures are not able to recreate the real world conditions. The upper body mass addition to the legform Flex-GT has improved the kinematics, especially for high front vehicles, e.g. SUVs. Moreover, the pendular head impactor has indicated the risks related to the head impacting the sharp bonnet rear edge, and the headform with the additional mass has successfully represented the head-neck interaction that exists in real world accidents.

The studies targeting a more accurate representation of the real world accidents will shape the future of testing protocols. Currently, the approach is combining the full-scale virtual analyses of the accident kinematics with the hardware component-based methods using the previously determined boundary conditions. The suggested protection systems based on these results, such as airbags and their combinations with the other systems (hybrids), have a considerable potential for the comprehensive pedestrian protection, and can be considered as the basis for the future development of pedestrian safety measures in vehicles.

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THANKS

The authors would like to thank Dipl.-Ing. Ingo Kalliske, Takata-Petri AG, and Dipl.-Ing. Oliver Zander, Bundesanstalt für Straßenwesen (BASt), for their important input.