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Volkswagen Group Research
Future Mobility Day 2017

Module 1:

Smart Performance –
The integrated drive strategy of the Volkswagen Group

GasOn – Lean CNG Combustion

Compressed Natural Gas (CNG) offers substantial advantages as a fuel in relation to CO_2 and emissions of harmful pollutants. This is associated with the chemical composition of methane and the efficient combustion process. The optimum situation is if the engine has been designed for monovalent operation with CNG alone. However, to date no monovalent gas-powered vehicles have been offered in the automobile market. Volkswagen Group Research has now joined forces with partners to develop a highly innovative engine powered by natural gas in the GasOn EU Research Project. The power unit is based on a two-litre diesel engine and permits very high compression. Extremely lean combustion ($\lambda \sim 2$) leads to low consumption and initially to very low NOx engine-out emissions. Nevertheless, exhaust gas treatment continues to be a technological challenge with lean combustion processes ($\lambda > 1$) by comparison with the homogeneous concepts ($\lambda = 1$) found in the marketplace. The cold-start procedure with all-gas operation is another focus of research related to monovalent CNG power units.

Vario.Drive

Alongside an all-electric drive, the plug-in hybrid drive with the option of charging the vehicle from an electric socket will continue to retain an important place in the drive strategy of the Volkswagen Group in the future. Ultimately, it links up local zero-emission driving – for example in city settings – with the high overland range of an efficient SI engine. This is particularly the case if the power values become enhanced even further by comparison with the status quo. Volkswagen Research is adopting new approaches with the Vario.Drive and integration of the e-motor, the transmission setup with planetary gear set and claw clutches, but without hydraulics. The reward is significantly higher power yet with a more compact design and improved efficiency. Electric all-wheel drive is also possible with an additional e-motor on the rear axle.

Fuel Cells – Business Environment and Market Introduction

While technical development of the fuel cell has made significant progress towards series application, the scenarios of a successful market launch have not yet been clarified. Public perception is currently focused on battery-powered electric cars. Furthermore, hydrogen infrastructure is currently in an initial phase and it has posed a variety of issues. Group Research has highlighted the potential scenarios for market development in a comprehensive study and the subsequent simulation.

Fuel Cell Activities

The hydrogen engine is the supplement to the all-electric battery-powered drive and is a fixed element of the drive strategy on the route to zero emissions. A fuel cell is an energy converter like an SI engine and not a storage device like a battery. This results in comparatively short fuelling stops like those familiar from conventional vehicles. It also offers particularly significant potential if a lot of energy has to be accommodated in the vehicle. The application of fuel-cell technology is therefore advisable especially in large vehicles, utility vehicles and vehicles that have to travel long distances.

Group Research Fuel Cell carries out fundamental research into fuel-cell technology, and the development and testing of fuel-cell systems as a platform for series development in the Group.

The focus is on reduction of the overall system costs and increase in efficiency and service life. Consequently, the expansion of simulation operations has considerably enhanced development speed and concepts have been developed for reducing costs, e.g. through reduction of the platinum content.

Module 2:

Smart Performance –
The integrated drive strategy of the Volkswagen Group

HyMotion Driving Experience

The fuel cell is a fixed element in the future strategy at Volkswagen as a supplier of electrical energy designed to power automobiles. The Group is carrying out intensive research and developing this technology with the HyMotion Project. Two concept vehicles provide evidence of the high standard already achieved:

The **Audi A7 Sportback h-tron quattro** is a test platform powered by the first fuel-cell system developed in entirety by the Group. This Audi A7 is also the first electric all-wheel vehicle and the first plug-in hybrid based on a fuel cell in the Group. And the driving style is extremely dynamic. The maximum output of the two e-machines on the front and rear axles is an impressive 170 kilowatts. And the continuous output of the fuel cell permits a top speed of 180 km/h.

The **Passat HyMotion Fuel Cells** based on the US version of the Passat is a comfortable touring saloon designed as a hybrid based on fuel cells. The fuel-cell system and the hybrid battery together supply the innovative drive system with energy through the most efficient direct-current converter in this power class. The e-machine can therefore generate a maximum output of 100 kilowatts. The continuous output of the fuel cell allows a top speed of 160 km/h here. The fuel cell is supplied from a total of four H_2 pressurised storage cylinders with a maximum pressure of 700 bar.

CO_2 Lighthouse Diesel Engine

Over the past four years, engine researchers looking at diesel engines have also been working out the potential for further reducing consumption in a “Lighthouse Project”. At the same time, it was also important to sustainably reduce NOx emissions in operation relevant to customers. The platform for this is the three-cylinder engine with a capacity of 1.5 litres. It has been engineered with an advanced combustion chamber, new pistons and fully variable valve train on the inlet and outlet side, comprehensive packages for friction reduction, heat storage and variable cooling circuit. The injection pressure here is at a scarcely conceivable 3,000 bar. An electric booster powered by 48 volts and a 48V hybrid system provide additional advantages. There is also impressive potential here as well. A modern Golf fitted with this engine would generate 25-30 percent less CO_2 emissions on the standard test route.

The demonstrated technologies can be easily transferred to other diesel passenger cars without any restrictions. This clearly demonstrates that the diesel engine remains an important player in the competition to achieve CO_2 targets.

CO_2 Lighthouse SI Engine

In future, the SI engine will continue to be an important constituent element of mobility throughout the world. It therefore needs to be developed further and optimised. Over the past four years, Volkswagen Group Research has used its "CO_2 Lighthouse SI Engine" to assess the potential still available in the engine if all currently conceivable efficiency technologies are integrated – initially without taking costs into account. Engineering freaks are likely to be getting very excited. The research engine developed here was a highly compressed SI engine with a variable compression ratio, centrally positioned injection valves, fully variable valve timing on the inlet and outlet side, cooled exhaust gas recirculation (EGR) and a petrol particulate filter. The associated 48 volt hybrid system operates with a 10 kilowatt electric motor. There is impressive potential. This drivetrain can reduce CO_2 emissions by more than 20 percent compared with a comparably powered vehicle. This demonstrates that it is worth pursuing further development of the technology packages presented.

Module 3:

Automated Driving –
The safe route to autonomous driving

Level 5 Urban CoCar Mobility System

In future, the world of the autonomous automobile will be as varied and diverse as the range of conventional cars. Right from the start, autonomous minibuses will play an important role – as an integral element of mobility systems and as a complement to public transport. These minibuses are initially likely to drive in a large number of small towns in specially allocated lanes and routes. They will be quiet, zero emission and safe. Autonomous driving will start here and this will be in just a few years' time. Group Research has developed the technical concept for this kind of vehicle within the project. Several versions have been designed for the interior and scenarios have been simulated for optimum deployment of an autonomous fleet of minibuses.

Self-Learning Chassis – AI-in Vehicle Dynamics

Vehicle dynamics are a key module for automated driving so as to take our customers to their destination as efficiently, safely and comfortably as possible. The vision of Group Research is a self-learning chassis which adapts dynamically to the vehicle and the circumstances at any point in time. Ultimately, these dynamic driving systems achieve the best vehicle control in all situations. The latest approaches to machine learning and artificial intelligence build on components for planning the route trajectory and for controlling and regulating the vehicle. The journey is continuously analysed, the driving behaviour is learnt and adjusted in order to ensure that the next journey runs more smoothly.

Fellow Trucks – Automated Driving of Heavy Duty Vehicles

Trucks driving autonomously are intended to create greater safety on the roads and contribute to more efficient driving. This is true for motorway traffic and for truck transport in mines. However, the mission for development engineers designing self-driving systems in the latter context is significantly more difficult. If there are no roads and no road markings, but at best dirt tracks where potholes or deep excavations impose limits on the route, sensor systems have to be able to selectively identify these elements in the surrounding environment. Group Research has been working on these systems together with MAN and Scania.

Simulation of Chinese Traffic for Developing Piloted Driving

The behaviour of people in traffic differs from country to country. In China, for example, completely different situations are experienced on the roads as compared with German roads. However, the systems of a mobility system operating on the global stage need to operate everywhere. This requires a huge amount of test and harmonisation work, particularly for the development of self-drive automobiles. In future, a growing proportion of this work is likely to take place in virtual reality – with simulation of the particularly complex traffic situations in Chinese megacities.

Mobile Charging Robots

In future, rapid charging of the electric vehicle will be extremely convenient. Mobile robots will connect up the automobile for recharging. Group Research is therefore working on charging robot concepts for underground garages and multi-story car parks. The Gen.E research vehicle is charged by the robot. This provides an insight into the next generation of automobiles for efficient long-distance mobility with a range of more than 400 kilometres. The lightweight architecture has been designed for maximum crash safety including the battery. The battery is based on advanced lithium-ion cells and the efficiency of the electric motor has been optimised.

Robust Lane Fusion Using Camera and Radar

An automobile driving autonomously always has to know precisely where it is located, how other road users are responding in the surrounding area and which route it can use. And this precision has to be measured to within just a few centimetres. A sensor system on its own is not adequate for this degree of accuracy. The camera can only measure the depth and distance of objects to a certain extent, while radar systems can perceive contours only to a limited degree. However, if these two systems are combined, they eliminate the individual disadvantages to create a comprehensive and precise picture of the environment. In the course of this complex project, Group Research is developing a system which reliably fuses and evaluates the data from the sensors.

Module 4:

Virtual Technologies –
The digital route to new mobile worlds

Air Humidification

The quality of the ambient air is extremely important for the well-being of the people on board an automobile. Ideally, the relative humidity should be between 40 and 60 percent. When conditions in the summer are exceptionally dry or in countries with a very dry climate, the air in the vehicle needs to be adjusted to these values by humidification. Volkswagen Research is working on providing the customer with a tangible function for improved air humidity.

Digitalisation Powertrain

Big data, artificial intelligence and connectivity will also play a major role in the conceptual design and development of future drive systems. Where conventional calculation systems encounter boundaries, self-learning algorithms and high-performance analytical methods identify completely new solutions. A typical area of application is the development of individual customer drive functions which adapt to current driving behaviour. Group Research demonstrates these options in a project using the example of adaptive start-stop systems.

Vehicle Data Driven Business

Even the automobile of today – to say nothing of future cars – generates an enormous amount of data about its behaviour and its environment with every kilometre travelled. At the moment, vehicle data are mainly used to improve vehicle services. In future, the focus is likely to shift more emphatically to the use of vehicle data for other industrial sectors. For example, data on sun intensity from the series sensor systems of vehicles can be used by transmission grid operators in order to improve forecasts of regenerative energy sources such as solar energy. This will significantly reduce their costs for consumers. Vehicle data will be able to make an important contribution to the electricity grid of the future.

High Resolution LCoS Headlight

LED headlights are by no means fitted as standard everywhere, laser light is only in the initial stages. But researchers in Wolfsburg have been working on the next generation of light technology for a long time: Liquid Crystal on Silicone (LCoS). This lighting system facilitates an innovative, high resolution light distribution and replaces the conventional functions of dipped and main beam. There is even more to it than that. As well as enabling sensor-controlled, completely free light distribution, LCoS can also project symbols on the road in order to assist in enhancing safety in road traffic.

HMI for External Communication

Today, communication between vehicles emulates communication between people. Two drivers use eye contact or gestures to regulate the sequence when turning corners or they allow pedestrians to cross the road. In future, this will no longer be possible with autonomous self-drive automobiles. They need a new level of communication. Group Research has developed new pathways enabling the vehicle to communicate with the surrounding environment in order to take account of this key safety aspect in the context of autonomous driving. The research is testing different visual and acoustic transmission channels for conveying the necessary signals.

Barcelona Smart Shuttle

How can shared mobility operate optimally, how can an innovative shuttle system function in a major European city? Barcelona provides the concrete example in this project. The investigation focuses on the parameters for an optimum new mobility service as a supplement to existing public transport options. How many vehicles are necessary to fulfil which mobility needs? But another factor relates to the issue of what are the necessary cost structures? After the virtual analysis has been carried out, a pilot fleet comprised of twelve vehicles is to be used in the real world of the Spanish metropolis.

Module 5:

Sustainable Mobility – Sustainability and Environment

Mobility and Energy System: Interactions in a Decarbonised World

Wide-ranging measures are needed throughout the energy sector in order to achieve common climate-protection targets. However, how will costs develop in the energy sector if greenhouse gases are reduced by 80 or even 95 percent by the year 2050? And what effects will that have on the transport sector? A comprehensive study carried out by Volkswagen Group Research is examining different scenarios which can develop on this roadmap. The initial results demonstrate that the climate targets can be achieved in technical terms and that they even make economic sense. At any rate, the transport sector needs to electrify significant proportions of the vehicles used. Fuels generated from renewable energies such as green gas will gain importance in future and will play an important role in a networked energy system.

Eco-Factors World – Evaluation of a Resource Efficient Factory

The Volkswagen Group is using environmental factors to review its production factories and it is working consistently towards the goal of production without negative impacts on the environment. To date, environmental factors have been defined for production sites in Germany and Europe, and in application. The project is now being extended to the USA, Russia, India, South Africa, Mexico, China, Brazil and Argentina. This means that evaluation criteria for environmental aspects – such as CO_2 or energy and water consumption – will be adjusted to the regional circumstances, as a result of which country-specific measures will reduce environmental impacts more efficiently.

Resource Efficient Vehicle – Ecological Optimisation over Lifecycle

What measures can be used to reduce the CO_2 emissions of a vehicle over the entire lifecycle in the most cost-efficient way? How can the use of critical raw materials be reduced? This research project is not about individual technical topics. The entire system around the automobile is being investigated in all phases of its lifecycle – from manufacture, through use, to recycling. Drive systems and renewable energies naturally exert the strongest impact. However, as far as the customer is concerned, the issue of costs cannot be neglected.

Logistic Study of Battery Recycling

The batteries of current and future electric automobiles have been designed for a very long service life. However, in the medium or longer-term future so many electric vehicles and their batteries will reach the end of their lifecycle that recycling will become a task on an industrial scale. Ultimately, a lithium-ion battery will never be pure waste but the source of valuable raw materials. For example, clear regulations govern this area in China. The vehicle manufacturer is responsible for taking back and reprocessing. A joint project being carried out by Group Research (China), overall vehicle development and the sales department of Volkswagen is developing the first concept of recycling logistics for batteries in China. Tsinghua University is the external project partner.

Mobility Services – Traffic Modelling and Environmental Impacts

Autonomous mobility systems planned in the future are often regarded almost as saviours for the traffic situation in the world's overloaded metropolises. However, is it possible for mobility-on-demand packages, such as self-driving taxis or autonomous minibuses to deliver this outcome? What impacts do these transport solutions have on our roads and for the environment? A project being run by Group Research is looking for the answer based on comprehensive analyses and simulations.

Module 6:

Innovation Starts from the Beginning – New Materials and Processes of the Future

High Energy Battery Cells

In future, the battery will be a key component in the vehicle. And this is not simply the case in purely battery-powered vehicles but also in fuel-cell drives and in PHEV or hybrids with SI engines. For many years, Volkswagen Research has therefore been working intensively with different battery technologies. The main focus has been on increasing the energy density in lithium-ion battery cells but also on building up know-how on cell production. Work is being carried out over the entire breadth of cell development, from basic electrode composition with innovative material approaches to fine-tuning of numerous production parameters. The acquired in-depth knowledge of battery development and production forms the cornerstone for electromobility and strengthens the Volkswagen Group in global competition.

Silicon Carbide Components

Silicon carbide (SiC) is far superior as a material for semi-conductors to conventional silicon in a number of areas. A significantly higher power density, lower losses and higher switching speed make silicon carbide an extremely interesting prospect for power electronics in electric vehicles. Group Research is currently building the first DC/DC converters and inverters as test devices. Simple components (diodes) have already been used in series for a number of years. However, large volumes of the more complex components being investigated here are only expected in some years.

Fatigue of Electrical Sheets

Electric vehicles are a completely new topic area for most people. These cars first have to earn the confidence of customers in their robustness and long service life. However, manufacturers are continuously working on new and improved know-how for the durability of components in the e-drive. A project by Volkswagen Group Research is currently working on fatigue of electrical sheets.

Smart Block for Hybrid Engines

Engineers in Group Research working on development of new lightweight materials and production technologies in this project have sought out the most difficult component of all: the engine block. This is subject to extremely high requirements for stiffness and temperature resistance. The selected component should be understood as a technology platform and not necessarily as a target component. A concept has been developed for an engine block made of fibre-reinforced plastic, with liners and a base plate made of aluminium. A reduction of more than 15 percent in weight appears to be possible, although various issues remain to be solved in respect of vibration, fatigue and cooling, manufacturing feasibility and costs.

PP-Rod Reinforcement of Injection Moulding Parts

Lightweight construction is a continuously recurring challenge for automobile design engineers, as is stability and safety. An innovative production technology from Group Research combines both sides. So-called PP-Rods, cables made of endless glass fibres, are used here in conjunction with a polypropylene matrix to provide local strengthening for injection moulding plastic parts. The solutions are lightweight and stable. Applications have been submitted in respect of patents for this technology.

Hybrid-Glass Polymer Display Carrier

The all-digital cockpits of future automobiles need an innovative design. A pioneering technology developed in a project by Group Research will enable glass surfaces to be combined with plastic so that displays will appear to be an integral part of these surfaces. This will enable an extremely high-quality, clean and modern design of the interior and control elements.

Volkswagen Group Communication
Andreas Brozat
Issue Management, Innovation and Digitalisation
Phone: ++49 (0) 5361 9 43318
Email: Andreas.brozat@volkswagen.de
www.volkswagen-media-services.com
www.volkswagen.com