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Technology Watch Report

AACHEN COLLOQUIUM
SUSTAINABLE MOBILITY

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Contents

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DESCRIPTION

- **Objet :** Report on the visit of the 30th Aachen Colloquium
- **Location:** Aachen - Germany
- **Date:** 05 to 06 October 2021
- **Web site:** https://aachener-kolloquium.de/en/
- **Participant:** Anthony Auert, Cluster Manager – AutoMobility, Luxinnovation
- **Report version:** version #1

OBJECTIVES

- Improve market intelligence in engine technologies and sustainable mobility.
- Participation in technical conferences related to above-mentioned topics.
- Visit technical exhibition; detect new technologies that could contribute to the development of the Luxembourg and Greater Region automotive eco-system.

SUMMARY

The Aachen Colloquium Sustainable Mobility continues the long tradition of the Aachen Colloquium Automotive and Engine Technology, while setting a clear focus on sustainable mobility solutions. For the 30th time, international experts from the automotive industry and research met in Aachen to exchange ideas on the mobility of the future.

After last year's digital event, the 2021 edition took place again at the Eurogress Aachen. Participants were able to access a diverse lecture program with selected presentations and keynote speeches. Outside of the lecture halls, a large exhibition hosted numerous well-known companies presenting their innovations and answering visitor's questions.
The readers of this report can access the technical papers of interest by contacting anthony.auert@luxinnovation.lu

ABOUT THE AACHEN COLLOQUIUM

The Aachen Colloquium has developed to the largest and most important congress in the area Automobile and Engine Technology in Europe. The growing number of participants demonstrate the automotive and supplier industries great interest to meet in Aachen once a year at the beginning of October.
Under direction of Professor Lutz Eckstein, Institute for Automotive Engineering (ika), and Professor Stefan Pischinger, Institute for Combustion Engines (VKA) of RWTH Aachen University, this event is considered one of the leading technical conferences in the automotive area worldwide.

ATTENDED CONFERENCES

1. ULTRA-FAST CHARGING URBAN DELIVERY VEHICLES

- **Speakers:**
  M. Bassett, J. Hall – MAHLE Powertrain Ltd.
  P. Wilson – Allotrope Energy Ltd.
- **Summary:**
  The rise of the on-demand economy has led to a rapid increase in the delivery of meals from restaurants and fast-food outlets by delivery drivers using bicycles, mopeds, cars and light-vans. Urban delivery is dominated by internal combustion engine powered vehicles, from take-away delivery mopeds to diesel powered delivery vans, which contribute to urban air quality issues. Grocery and parcel deliveries are handled as efficient multi-drop deliveries with vans covering typically 20-60 km per day, depending on the level of urbanization. Take-away delivery and postal courier activities are fulfilled as a hub-centred series of short (<4 km) journeys, but with insufficient time to recharge. To decarbonise these industries, so far, the only way to do this is to use electric vehicles with an excessive range compared to their requirements, which leads to heavier than necessary vehicles, with reduced payload capacity and increased energy consumption.
  Higher purchase costs due to large battery packs also slows adoption of electric vehicles, reducing the potential rate of decarbonisation. If the recharging time for a vehicle can be reduced to only 2-5 minutes for a full charge, then this enables the re-optimisation of the battery pack to a very small size. Two main challenges associated with ultra-fast recharging times are the ability of cells to accept very high charging rates over the full capacity and the charging infrastructure required to supply this power at the voltage required.
  Allotrope Energy's novel Lithium Carbon battery cell technology combines the benefits of super capacitors with the energy storage capacity of lithium-ion cells. MAHLE Powertrain have used Allotrope's technology to design an ultra-fast charging, aggressively downsized battery pack for an urban delivery eMoped application.
  MAHLE Powertrain have also devised the recharging hardware necessary to enable a fleet of eMoped to be charged rapidly from a domestic power supply. The target charging rate will allow vehicles to recharge fully in just a few minutes, enabling an opportunistic charging strategy with frequent top-ups, thus eliminating the need for a large battery pack.

2. FUTURE BATTERY SYSTEMS – AFFORDABLE, SAFE AND HIGHLY INTEGRATED

- **Speakers:**
  M. Teuber, M. Stapelbroek, R. Beykirch – FEV Europe GmbH
  C. Kürten, O. Lück, H. Wenzel – FEV Vehicle GmbH
- **Summary:**
  This presentation focused on current and future development targets of battery cells and packs for automotive use. Lithium-ion batteries are currently the cutting-edge technology employed for the electrification of road transport. Herein, the battery cell itself and its chemistry are under constant development.
  The presentation gave some insights into cell chemistries, advantages, challenges, as well as alternative technologies. The strive for ever higher energy contents comes with the risk of reduced thermal stability. Therefore, the second part provided insights into current generation thermal propagation tests and development methods which guarantee a safe design with the

least possible effort. Lastly, concepts for engineering optimization of the battery pack and its integration into the chassis were discussed.

3. NEXT GENERATION BATTERIES FOR MOBILITY IN KOREA: TECHNICAL TRENDS, PATENT FILINGS AND LEGAL ISSUES

- **Speakers:**
  S.-E. Kim, I.A. Kwon – Kim & Chang
- **Summary:**
  While the market for lithium ion batteries (LIBs) for electric vehicles (EVs) has expanded at a remarkable rate, we expect LIBs will not be the final solution for powering EVs in view of their limited mileage, potential for fire hazards, and other limitations.
  The most promising candidate for the next generation of batteries for EVs is the solid state battery (SSB). However, there are many hurdles still to be overcome in order to successfully commercialize SSBs. Patent analysis can provide useful information regarding the technology plans of the major players in the battery field, including candidates for future generations of batteries besides SSBs.

4. TOYOTA'S STRATEGY FOR FUEL CELL TECHNOLOGY AND THE PROGRESS IN THE SECOND GENERATION MIRAI

- **Speakers:**
  T. Paquet, T. Hayashi – Toyota Motor Europe
  K. Yoshida, T. Imanishi, T. Takahashi, N. Kobayashi – Toyota Motor Corp.
- **Summary:**
  Hydrogen and Fuel Cell technologies are expected to further spread to realize a sustainable society for the future. In this presentation, the latest FC technologies utilized in 2nd generation MIRAI and Toyota's approach to expand the hydrogen society were introduced focusing on the updated FC technologies, Toyota's FC module concept and the activities with partners.

5. HYDROGEN POWERTRAIN DESIGNS FOR EUROPEAN LONG-HAUL TRUCKS

- **Speakers:**
  K. Godard, L. Chauvin, C. Vacquier, T. Justin – Symbio
  G. Queney – Faurecia
- **Summary:**
  The presentation focused on European tractor-trailer trucks and especially on the HDV group number 5. It provided general insights on hydrogen trucks powertrains, mainly focused on PEM fuel cell based solutions.

6. FUEL CELL FREEZE START – FROM SIMULATION AND BENCHMARKING TO SYSTEM OPTIMIZATION

- **Speakers:**
  M. Zubel, M. Walters – FEV Europe GmbH
  M. Schmitz – VKA, RWTH Aachen University
- **Summary:**
  Fuel cells for vehicle propulsion are promising for future zero emission and zero CO2 mobility. Although there are already vehicles powered by fuel cells from several manufacturers, there is still a great need for development.

In addition to cost reduction and aging effects, freeze start is also challenging. The cell produces water that can freeze at temperatures below zero, not only preventing a successful start-up process but also permanently damaging the cells. The Hyundai Nexo freeze start was analyzed in detail within the FEV Benchmarking program. The vehicle utilizes a variety of strategies to support the freeze start. These include various heating elements as well as the operating strategy.
To better understand the effects of freeze start at the cell level, detailed multi-dimensional CFD studies were conducted using the results from the benchmarking activities.

7. THE EKPO NM 12 STACK MODULE – A MODULAR STACK PLATFORM FOR HD-APPLICATIONS

- **Speakers:**
  J. Kraft – EKPO Fuel Cell Technologies
- **Summary:**

The NM12 stack platform was developed for heavy duty applications with a rated power in the range from <100 kW - 200 kW, but is also suitable for a number of other applications. Core characteristics are besides its high power density and compact design the implementation of a number of system functionalities, standardized interfaces as well as a water and dust proof housing.
Besides intense testing of the stack under a variety of operating conditions an operational model of the stack was developed to predict its behaviour under a wide range of different operating conditions.
A core requirement for most mobile applications is the freeze-start capability of the stack, which was one focus when designing the NM12 stack, resulting in a stack with low thermal mass and excellent insulation between cell block and end plates. This proved to be a very successful approach as freeze-start capability from temperatures down to -30 °C was proven without external heating and with very simple shutdown and startup procedures.

8. BORGWARNER'S INJECTION SYSTEM SOLUTIONS FOR NATURAL GAS AND HYDROGEN

- **Speakers:**
  G. Hoffmann, G. Dober, L. Doradoux, G. Meissonnier, W. Piock – BorgWarner Inc.
  C. Cardon, T. Williams – BorgWarner Inc.
- **Summary:**

The decarbonization of the transportation sector is particularly challenging for high power, long distance applications where total cost of ownership is critical. An attractive option to meet these challenges is with renewably sourced methane or hydrogen utilized within internal combustion engines. A key component to enable efficient combustion and high power is the fuel injection system.
The spectrum of BorgWarner's fuel injection system solutions for both hydrogen and natural gas injection were presented.
Investigations around a medium pressure gas injection concept show that internal combustion engines with gas injection could be an attractive technology for the fast implementation of low and even net zero CO2 emission solutions in the market.

9. EFFECTS OF DIFFERENT LOW CARBON FUELS ON PERFORMANCE AND EMISSIONS OF COMPRESSION IGNITION ENGINES

- **Speakers:**
  F. C. Pesce; A. Vassallo – PUNCH Torino S.p.A.
  R. P. Durret, M. A. Potter – GM R&D
  P. Gaillard, V. Gordillo – Aramco Overseas

- **Summary:**
  Low carbon fuels can be produced with renewable feedstock and energy sources, thus facilitating the transition to cleaner fuels for the transportation sector without the need for a complete overhaul of the infrastructure. In addition, as drop-in fuels, they support the decarbonization of the existing fleet while the transition to newer vehicles is underway and can lower criteria pollutants in older engines thanks to their physical and chemical properties.
  In this sense, they constitute a valuable topic in the sustainability of internal combustion engines. The presentation evaluated different low carbon fuels that consist of blends of synthetic and biofuels tested under 5 different operating conditions and evaluated in terms of performance and emissions on a modern 1.6-liter Diesel engine which are then compared to conventional Diesel combustion.
  The fuels are first assessed as drop-in fuels using the standard engine calibration for B7 Diesel fuel and then an optimized calibration is obtained by performing a design of experiments dedicated to find the best operation settings for each condition and fuel.
  Five optimization criteria are pursued to find the most balanced operation point inside the optimized space, i.e. lowest NOx, lowest PM, lowest CO2 emissions, lowest BSFC and highest efficiency point, for an overall balanced optimum. Fuel consumption is then estimated by weighting factors obtained from a simplified version of the WLTP driving cycle. Results showed that the low production of particle matter allows considerable increases of EGR rates at acceptable soot levels, thus reaching very low engine-out NOx, while fuel consumption and engine efficiency are not penalized or even improve. Improvements in HC and CO have been also observed.

10. WEIGHT REDUCTION AND FUNCTIONAL IMPROVEMENT OF FUTURE ICES WITH ADDITIVE MANUFACTURING AND COMPOSITE MATERIALS

- **Speakers:**
  R. Bey, D. van der Put, R. Jans – FEV Europe GmbH, C. Kayacan, N. Büchau – VKA, RWTH Aachen University
- **Summary:**
  Using additive manufacturing (AM) for passenger car engines allows significant weight reduction potential. In the LeiMot project a cylinder head and a crankcase have been developed for the LPBF-Process (Laser Powder Bed Fusion). AM design was used not only to reduce weight but also to improve the function of the engine.
  New manufacturing methods like LPBF allow realization of further lightweight potentials. In the LeiMot project, the weight of the cylinder head and the crankcase was so far reduced by approx. 21 %, compared to the latest Volkswagen 2.0 l EA288 evo Diesel engine. Furthermore, for the cylinder head a weight reduction potential of up to 30 % has been achieved with the use of automated structural optimization methods.
  In addition to weight reduction, the LeiMot project offers the following potentials for efficiency increase:
  - Reduction of the coolant pump power
  - Reduction of the oil pump power
  - Friction reduction of the piston/liner group
  - Emission reduction at cold start with the isolation of the exhaust ports
  - Increase of the turbocharger turbine power with the isolation of the exhaust ports

11. DEVELOPMENT OF THE SECOND-GENERATION VC-TURBO, KR15DDT ENGINE

- **Speakers:**
  Y. Tsuchiya, K. Matsuoka, S. Kiga – Nissan Motor Co., Ltd.
  N. Hiraki, Y.Tanaka – Nissan Motor Co., Ltd.
- **Summary:**
  In 2018, commercial production started for the KR20DDET, the world's first engine fitted with a Variable Compression Ratio System, VC-TURBO.
  As the second-generation VC-TURBO, Nissan has recently developed the KR15DDT, a 1.5 L, three-cylinder direct injection turbo engine combined with the cooled-EGR system that balances power performance with reducing environmental impact by further improvement of thermal efficiency and other aspects for application to core models.
  Nissan challenged Noise and Vibration (NV) performance of high power and high torque three-cylinder engine by adopting the VC-Turbo's multi-link mechanism and an outer balancer. On that basis, the development of the second-generation VC-Turbo combined with cooled-EGR system was presented, focusing on its response and NV performance.

12. ADDITIVE MANUFACTURING OF HIGHPERFORMANCE POWERTRAIN COMPONENTS

- **Speakers:**
  F. Ickinger, M. Klampfl – Dr. Ing. h. c. F. Porsche AG
  V. Schall, D. Abele – Mahle International GmbH
- **Summary:**
  The advanced development departments of Porsche, Mahle, and Trumpf carried out a collaborative project: high-performance powertrain components utilizing the potentials of additive manufacturing (AM), demonstrated by developing, producing and testing a piston for a 911 GT2 RS.
  According to the loads on the piston, a computer-aided topology optimization assists in shaping the structure while an added cooling gallery helps reduce the thermal loads. In comparison to the forged series part, the result shows a reduction of 20 K in the critical area as well as a mass reduction by 10 percent.
  To validate the use of additive manufacturing for high-performance powertrain components, these innovative parts were tested on one of the most straining Porsche endurance test bench. All pistons passed the test successfully. Furthermore, it is possible to shorten the procurement time for prototype pistons by about 30 percent by eliminating the tools required for cast pistons.

13. PUNCH H2-ICE & FLYBRID KERS FOR DECARBONIZING OFF-HIGHWAY APPLICATIONS

- **Speakers:**
  S. Scalabrini – PUNCH Hydrocells
- **Summary:**
  The presentation shared the results of an innovative green power pack consisting of an hydrogen-powered Internal Combustion Engine (H2-ICE) combined with a Kinetic Energy Recovery System (KERS). The presenter analysed the case of off-highway machinery, i.e. gensets and construction equipment, where requirements for durability, efficiency, energy consumption and dependability are high.
  The results showed that the combination of KERS with H2-ICE represents a viable alternative in terms of performance, efficiency, and total cost of ownership towards sustainable off highway applications.

14. THE HYDROGEN COMBUSTION ENGINE AS ZERO IMPACT EMISSION POWERTRAIN CONCEPT

- **Speakers:**

  V. Huth, L. Virnich, A. Pfortje – FEV Europe GmbH
  S. Sterlepper, S. Pischinger – VKA, RWTH Aachen University
  T. Wolff, A. Moreno, E. Georgiadis – Dinex A/S

- **Summary:**

  Current and future CO2 targets pose major challenges for the automotive industry. In addition to battery-electric vehicles and fuel cell drives, carbon-free fuels also offer an opportunity to significantly reduce CO2 emissions.

  Current studies show that the hydrogen engine can find useful application in the commercial vehicle and off-road machinery sector, as it can achieve similar performance and efficiency compared to diesel engine. However special attention should be paid to the reduction of nitrogen oxide (NOX) emissions and the substances such as ammonia (NH3) and nitrous oxide (N2O) that may result from them.
  The design of the combustion process, the choice of exhaust gas after treatment are decisive for an efficient control of the emissions.

Steady-state and transient tests on a H_2 combustion engine with exhaust gas after treatment have shown the influence of the air/fuel ratio on NOX emissions and exhaust gas temperature, and by extension on tailpipe emissions. Optimized tuning of the engine's calibration will make it possible to turn the H_2 combustion engine into a propulsion system with nearly zero emissions.

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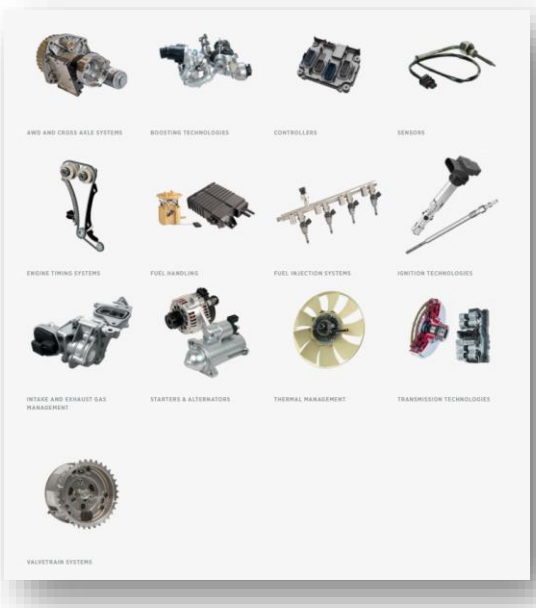
LUXEMBOURG PRESENCE

1. BORGWARNER (TECHNICAL PRESENTATION & EXHIBITION)

- **Offering:**
  Whether in a highly efficient combustion engine, an intelligent hybrid system or the very latest electric drive, BorgWarner is driving mobility for today and tomorrow. As the product leader with more than 130 years of experience in the field of powertrain systems, BorgWarner is supporting the automotive industry in realizing clean propulsion and efficient technology solutions for light-, medium- and heavy-duty vehicles as well as off-highway applications.
  https://www.borgwarner.com/home
- **Main products:**
  - Combustion technologies



- Hybrid technologies

- Electric technologies

- **Technical presentation:**
  - Injection system solutions for natural gas and hydrogen

IMPRESSIONS

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