

The 6th International Exhaust Emissions Symposium – Trends in automotive emissions legislation: impact on LD engine development, fuels, lubricants and test methods – a global view, with a focus on WLTP and RDE regulations

**14-15 June 2018
Bielsko-Biala, Poland**



A brief summary and overview from the perspective of the International Organising Committee

Dr. Piotr Bielaczyc*, Joseph Woodburn
[*piotr.bielaczyc@bosmal.com.pl](mailto:piotr.bielaczyc@bosmal.com.pl)

The 6th International Exhaust Emissions Symposium, organised by BOSMAL Automotive Research and Development Institute Ltd (hereafter BOSMAL) and the Polish Scientific Society of Combustion Engines (hereafter PTNSS, from its Polish acronym) took place on the 14th and the 15th of June, 2018. The symposium was the latest in a series of scientific meetings organised at BOSMAL since 2010.

Introduction

Decades after the introduction of automotive exhaust emissions legislation and the introduction of exhaust gas aftertreatment hardware, concern over the environmental impact of vehicles remains high and has arguably only increased over time. Although the specifics have changed somewhat during the past 40-50 years, the fundamental problem of the overall negative impact of vehicles on air quality remains a daunting challenge. While distance-specific emissions have been reduced, growing vehicle fleets and heightened understanding of the negative impacts of emissions mean that the topic

remains very high on the political agenda. Broader energy usage/efficiency concerns have become very much part of the automotive development landscape; the majority of new vehicles sold globally subject to energy efficiency regulations of varying levels of rigour. Concern over exhaust gas pollutants – NO_x, particulate matter and others – has become a concern for all major global markets, not just the United States and European Union. While both fuel consumption and regulated emissions need to be as low as possible, these goals tend to conflict with each other (to an extent) and R&D, optimisation and

certification requirements are all significantly more demanding than they were even a few years ago.

With a proven track record of organising scientific meetings [1-17], BOSMAL was proud to host its 6th International Exhaust Emissions Symposium (IEES), with the title 'Trends in automotive emissions legislation: impact on LD engine development, fuels, lubricants and

test methods – a global view, with a focus on WLTP and RDE regulations'. The event built upon the successes of the past, in particular the 4th IEES (2014) and the 5th IEES (2016) and included the very latest developments in the various branches of the field. Implications for the various branches of the automotive industry and beyond were discussed. Further details on the event appears in later sections of this paper and also elsewhere.

The 6th International Exhaust Emissions Symposium: background, aims and structure

This sixth symposium was hosted as a direct result of the resounding successes of the previous emissions-related events hosted at BOSMAL [1-17].

The aim of the symposium was to repeat the successes of the past, by bringing together experts and specialists in a professional yet informal atmosphere, so that they might exchange information learn from one another and make new contacts. Given the importance of human contact in scientific collaboration and business relationships, a social programme was integrated into the two-day event, providing ample networking opportunities.

With the assistance of PTNSS and the various patrons and sponsors of the event, steps were taken to begin to arrange the event and invite both speakers and attendees. Following preliminary negotiations from summer 2015 onwards, the organising committee received an excellent response from invited speakers, including high-level representatives of international organisations (see the programme for details of all speakers).

Submissions to the conference were divided into three categories: oral presentations

(delivered to the plenary audience in timeslots from 15-40 minutes) and written only entries (a poster with abstract). All entries were accompanied by short written abstracts, which both aid the organisation of the event and add to the archival value of the proceedings. The posters were prominently displayed in the area where delegates spent the coffee breaks. Together, the keynotes, presentations and posters make up the proceedings of the event. The media partners of the event were *Combustion Engines* – a scientific journal published by PTNSS; the *DieselNet.com* website of Canada; the polish technical magazine *Przegląd Techniczny* and the Polish web portal for gaseous fuels *Gazeo*.

The event was held over two days, divided into five thematically themed sessions, entitled 'General automotive exhaust emissions', 'CO , GHG & air quality (including particulate matter)', 'Emissions reduction technologies & aftertreatment', 'Test methods: laboratory-based & RDE-PEMS' and Fuel & alternative powertrains. Each session featured multiple presentations, giving a total of 5 sessions and 25 presentations. (See the symposium programme for full details.)

The symposium itself

The event commenced on the morning of the 14th of June at BOSMAL (following registration of delegates). A number of delegates had participated in BOSMAL's scientific meetings before, but there were a number of new

participants, including those who were visiting Poland for the first time. Around 120 delegates attended, representing 67 firms from 17 countries (both in Europe and North America). Organisations participating in the event

included firms from the automotive and fuel industries, governmental agencies and research bodies, consultancies and engineering service providers, equipment manufacturers, technical universities and the European Commission. The symposium commenced with a presentation by its organiser Dr. Piotr Bielaczyc, which served as a remind of some of the main topics and their importance. The following presentations expanded upon those themes.

The sessions of the first day were punctuated with coffee breaks (which also served as the

poster presentation sessions and networking time) and lunch. (The breaks also allowed attendees to inspect BOSMAL's recently-upgraded exhaust emissions laboratories and to inspect some industry display booths.) At the end of the first day (Thursday 14th June) delegates attended the Symposium Dinner & Musical Soirée, hosted at a hotel in Bielsko-Biala. As before, this evening event formed an important part of the symposium and proved a great success for familiar faces and also for those attending the symposium for the first time.

The final programme, which lists all keynotes, presentations and posters, together with listings of authors and their affiliations, can be found in the proceedings. A full list of firms and organisations in attendance at the symposium is also presented.

BOSMAL Bielsko-Biala, Poland

6th International Exhaust Emissions Symposium 14-15 June 2018

Final Programme

Trends in automotive emissions legislation: impact on LD engine development, fuels, lubricants, and test methods – a global view, with a focus on WLTP and RDE regulations

Media patronage:
Combustion Engines Journal published by PTNSS, DieselNet (Canada), gazeo.pl and Przegląd Techniczny

PTNSS DieselNet gazeo.pl PRZEGŁĄD TECHNICZNY

Organiser:
BOSMAL Automotive Research and Development Institute Ltd
93 Sami Stok
43-300 Bielsko-Biala
Poland

Polish Scientific Society of Combustion Engines (PTNSS)
93 Sami Stok
43-300 Bielsko-Biala
Poland

The second day continued where the first day had left off, with sessions on Following that, Dr. Piotr Bielaczyc offered some closing remarks to close the event. Finally, guided tours of BOSMAL's test facilities were

conducted, so that delegates might see all of BOSMAL's test facilities and departments (which extend well beyond engine/emissions research).

Symposium content and the technical message of the symposium

As previously mentioned, the symposium consisted of five sessions, with the titles 'General automotive exhaust emissions', 'CO₂, GHG & air quality (including particulate matter)', 'Emissions reduction technologies & aftertreatment', 'Test methods: laboratory-based & RDE-PEMS' and 'Fuel & alternative powertrains'. These session titles reflect the broad range of topics, fields and experts involved in the wider topic of exhaust emissions, their origin characteristics and impacts, their legal control, measurement and technical measures taken to reduce them. This global, holistic consideration of the full topic is arguably a strength of the symposium and certainly contributed to the rich technical programme.

The first session, 'General automotive exhaust emissions' set the scene by examining the problems caused by and related to exhaust emissions (particularly – but not exclusively – from LD vehicles). The session featured three presentations; Dr. Piotr Bielaczyc of BOSMAL) set the scene, followed by an important address by Dr. Vicente Franco (European Commission, Belgium), who confirmed that legal efforts to reduce exhaust emissions are ongoing and that recent changes are by no means end of the story. The final presentation was delivered by Les Hill (Horiba Europe, UK), who examined international exhaust emission legislation, test procedures and some of the practicalities and idiosyncrasies of meeting emissions requirements in various markets.

The second session, 'CO₂, GHG & air quality (including particulate matter)' featured four presentations, two of which covered CO₂ and fuel consumption for the automotive sector – notably WLTP test procedure and the so-called laboratory-road gap. The other two presentations focused on particulate matter: legislative steps to limit and measure emissions (Dr. Barouch Giechaskiel, JRC) and the properties of the particles themselves (Amanda Lea-Langton, University of Manchester).

The third session, 'Emissions reduction technologies & aftertreatment' arguably covered the core of the topic and thus it was fitting that this session featured the highest number of presentations. A total of twelve speakers addressed the symposium, speaking on a range of topics. The initial presentation was given by Dr. Ameya Joshi of Corning USA, who offered a broad yet highly detailed view of the latest aftertreatment technologies and strategies. Other presentations in the session focused on SCR systems, real world emissions control, RDE development and associated calibration challenges, diagnostic techniques and measurement challenges.

The fourth session, 'Test methods: laboratory-based & RDE-PEMS' featured five presentations examining how demanding requirements for accurate measurements both in the laboratory and on the road can be realised. Sample RDE results were presented and interpretations offered. Here it was clear that type approval tests are merely the tip of the iceberg – the preparatory development process changes as a result of RDE requirements and the effort involved is perhaps an order of magnitude higher than in the past.

The final session, 'Fuel & alternative powertrains' featured two related yet distinct presentations which examined usage of electricity as a 'fuel' for light duty vehicles. This idea, while far from new, is an important direction both politically and technically and it should not be neglected.

The paragraphs that follow offer some summaries and tentative conclusions on various main points from the symposium which were mentioned in multiple presentations and which featured prominently in discussions.

- The WLTP is now the standard test cycle for the EU market and is undergoing implementation in large and important markets such as India,

China and Japan. While implemented to make up for shortcomings in the determination of official CO₂/FC figures, the new test procedure also has an influence on regulated emissions. However, the stringency of RDE requirements mean that in terms of regulated emissions the WLTP is not the main challenge. That laboratory cycle will be the focus of CO₂/FC optimization, but regulated emissions will be largely examined by the RDE test. The development of a type VI test (cold start at -7°C) using the WLTP may alter this situation somewhat, but this test requirement has not yet been finalised or implemented. However, notwithstanding the new test procedure, the current limits have been in force since 2014 (and were decided and published back in 2007). The term 'Euro 7' is starting to be used and informed sources confirm that Euro 6d will not be the end of the story in the EU. In addition to potentially reducing numerical emissions limits, a greater size range of particulates will be measured for comparison to the PN limit (from 10 nm, as opposed to 23 nm). A further possible development is the introduction of limits for NO₂, and even N₂O, NH₃ and aldehydes. Such changes may increase the difficulty of meeting laboratory test requirements in comparison to RDE requirements, as new emissions limits are likely to be introduced in the laboratory first (and perhaps later copied in RDE legislation).

- There has been considerable convergence in the design and emissions control requirements of spark- and compression-ignition engines, to the point where traditional categories are blurring. The prospect of gasoline compression ignition could alter this situation further still in the future. Current production DISI

engines have a parallel in with Diesel engines in terms of particulate emissions and their control. Legislative limits for PN are now identical for DISI and CI engines, reflecting the slow but ongoing trend towards numerically identical emissions limits for all engine types.

- After decades of catalytically facilitated emissions control, progress continues to be made in altering the chemical composition of exhaust gas to reduce its harmful effects. Even a seemingly "simple" device such as a three-way catalyst for stoichiometric applications is a complex system which requires considerable optimization to meet all the requirements demanded of it. Now that GPFs are essential for approximately half of all gasoline-fuelled engines sold in the EU, the question of integration of the GPF and TWC into a four-way catalyst has become an urgent practical question. For Diesels, the success of DPFs over the past decade is an inspiration to achieve the same successes with DeNO_x systems. Here, despite the complexity of the overall challenge in the era of RDE, the fundamental fact remains that ammonia is the chemical antidote to NO_x, capable of completely eliminating NO_x from the tailpipe gas stream – it is a matter of creating the right thermochemical conditions which favour the appropriate reactions, while keeping side reactions to a minimum and avoiding excessively high urea consumption. Despite the bad press that NO_x storage catalysts have received recently, they can play a part in combination with SCR systems, as they have advantages, especially at cold start and for urban operation. Alternatively (or even additionally), gaseous (non-urea) ammonia delivery systems allow for dosing at lower temperatures to take care of NO_x

emissions as soon as possible after cold start, thereby avoiding the fuel consumption penalties associated with catalyst heating modes.

- The introduction of electrical and electromechanical powertrains is hardly a new topic, but the issue is of paramount importance in the current political and technical climate. Hybrid powertrains are not simply a combustion engine with an electrical motor/generator/battery system added “on top”; the altered working regimes and added degree of freedom radically change the way the engine is used during a test cycle or during normal driving. Of particular concern regarding emissions control is the reduced availability of waste heat during episodes of engine shutoff, which has the potential to create perpetual cold start conditions. Here, the number of parameters which have to be optimised is very high in comparison to more traditional powertrain concepts and the calibration effort therefore increases massively. However, a manifold
- Fuel and lubricant are of vital importance to all the aforementioned efforts to combat harmful emissions and minimise CO₂/FC. As is

increasingly often pointed out, they should be considered powertrain components – and are as important as research on engine hardware, etc. Longstanding technical conventions are beginning to break down somewhat – some of the differences between “gasoline engines” and “Diesel engines” are slowly disappearing; some SI engines will soon be able to run at the high efficiency levels which were once only thought to be achievable for CI engines running on Diesel. A limiting factor – a glass ceiling – for gasoline efficiency is the octane number of the fuel. Pressure is building to alter specifications to boost the fuel’s octane rating and thereby increase the realizable thermodynamic efficiency. On the subject of lubricants, it might be thought that little scope for further improvement remains – however, that is not the case, as improved formulations can have measurable impacts on a range of parameters, from fuel consumption to engine wear to particulate emissions and their toxicity. As improvements are made to fuels and fuel delivery systems to reduce the quantity of fuel-derived particulate, oil-derived particulate will necessarily increase in importance and relevance as a result.

Overall technical message of the Symposium

The automotive industry has never been in the spotlight as much as it is currently. Recent revelations, publications and news stories have severely tarnished the image of the automotive industry and this has provided an incentive for the EU to implement very strict rules relating to exhaust emissions. Other jurisdictions are also undergoing similar processes. RDE-type tests are now the key challenge for most large automotive markets; whether the USA introduces a formal RDE-type

requirement for passenger cars remains to be seen. However, as discussed during the 6th IEES and elsewhere, technology exists to create powertrains with real-world environmental performance which meets even the toughest legal requirements. For this reason and based on the ongoing superiority of liquid fuels as energy carriers, at present it appears that for the foreseeable future internal combustion engines will be the main source of power for road transport. Hybridisation is an

important trend, but one must not neglect the importance of the combustion part of such a system. Fully electric powertrains do have certain advantages, but are likely to remain a niche propulsion system. Nevertheless, there are serious existential challenges faced by internal combustion engines which cannot be ignored – chiefly the implementation of advanced powertrain technology in a manner which is practical, affordable, reliable and which creates vehicles which consumers want to buy, thereby facilitating fleet turnover and making the fleet as a whole significantly cleaner.

Scenes from the 6th IEES



BOSMAL director Dr. Arkadiusz Stojek and Dr. Piotr Bielaczyc during the event



Wolfgang Thiel (TRT Engineering, Germany) and Dr. Vicente Franco (European Commission, Belgium)



Les Hill (Horiba, UK)



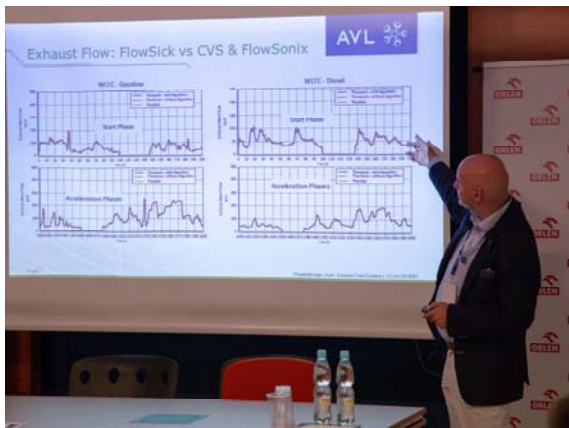
BOSMAL's exhaust emissions laboratory being presented to attendees



BorgWarner's booth in the display area



Dr. Barouch Giechaskiel – (EC JRC-Ispira, Italy)



Kurt Engeljehring (AVL, Austria)



Dr. Marcos Alonso Baez (Nissan Technical Centre Europe, Spain)



Dr. Katarzyna Matusik (Argonne National Laboratory, USA)



Alexander Terres (BMW & PTB, Germany)



Dr. Sophie Kinnear (Jaguar Land Rover, UK)



Prof. Gordon Andrews (University of Leeds, UK)

Closing comments; archival of the event as official Symposium Proceedings

From the perspective of both the organisers and the participants, the 6th International Exhaust Emissions Symposium was a resounding success, with overwhelmingly positive feedback. The International Organising Committee expresses its sincerest thanks to all those who were involved, from organisers and sponsors to speakers, attendees and those working behind the scenes with logistics, as well as all media partners involved. The journal *Przegląd Techniczny* has published a short summary in Polish [18]. The well-known technical reference website DieselNet (Canada) has published a technical summary of the event, which is generously available as an open access article, hosted at

<https://dieselnet.com/news/2018/06bosmal.php>. All presentations delivered during the symposium, together with their abstracts, have been archived in the following publication: 'Symposium Proceedings – Trends in automotive emissions legislation: impact on LD engine development, fuels, lubricants, and test methods – a global view, with a focus on WLTP and RDE regulations, ISBN: 978-83-946334-1-7, published by BOSMAL. A Book of Abstracts is also available, ISBN: 978-83-946334-2-4. Film reportage is also presented on a DVD. Both of these discs will be included as attachments to PTNSS' scientific journal Combustion Engines [20], to be accompanied by a range of written papers which also form part of the event's proceedings.

Further information

DieselNet's summaries of this symposium and the previous two events are available online [14], [17], [19]. For further information on the 6th IEES and all previous events of this type hosted at BOSMAL, visit # <https://www.bosmal.eu/605-organised-events>. For further information on any of the topics addressed in symposium

presentations or posters, please contact the relevant author/s. Please note that the views and opinions expressed in contributions to the symposium are not necessarily those of BOSMAL, PTNSS or any of the individuals involved in the organisation of the event.

References

- [1] Bielaczyc, P., Woodburn, J. Global trends in emissions regulation and reduction. *Combustion Engines*, 3/2010 (142), 3-27, 2010.
- [2] Bielaczyc, P. (editor) and 13 co-authors. Global trends in emissions regulation and reduction from the perspective of powertrain and fuel development. *Proceedings of the 1st International Exhaust Emissions Symposium*, ISBN 978-83-931383-0-2, 2010.
- [3] Bielaczyc, P., Woodburn, J. Analysis of current and future trends in automotive emissions, fuels, lubricants and test methods. *Combustion Engines*, 4/2011 (147), 104-118, 2011.
- [4] Bielaczyc, P. (editor) and 17 co-authors. Global trends in emissions regulation and reduction from the perspective of powertrain and fuel development. *Proceedings of the 2nd International Exhaust Emissions Symposium*, ISBN 978-83-931383-1-9, 2011.
- [5] Bielaczyc, P., Woodburn, J. Current and future trends in automotive emissions, fuels, lubricants and test methods – the view from the year 2012. *Combustion Engines*, 2/2012 (149), 94-116, 2012.
- [6] Bielaczyc, P. (editor) and 21 co-authors. Current and future trends in automotive emissions, fuels, lubricants and test methods – 2012. *Proceedings of the 3rd International Exhaust Emissions Symposium*, ISBN 978-83-931383-2-6, 2012.
- [7] Bielaczyc, P., Czerwinski, J., Woodburn, J. Current trends in measurement and control of particle emissions from engines. *Combustion Engines*, 3/2012 (150), 89-96, 2012.
- [8] Bielaczyc, P. (editor) and 18 co-authors. Particulate matter emissions from engine and automobile sources. *Proceedings of the 1st Workshop on Particulate Matter Emissions from Engine and Automobile Sources*, ISBN 978-83-931-383-3-3, 2012.
- [9] Bielaczyc, P., Sutkowski, M. (editors) and 5 co-authors. Gaseous fuels in power generation and the automotive sector. *Proceedings of the technical seminar on gaseous fuels in power generation and the automotive sector*, ISBN 978-83-931383-4-0, 2012.
- [10] Bielaczyc, P., Woodburn, J. Powertrain development for low-to-zero emissions and efficient energy usage – the industry session held during the 5th PTNSS congress on combustion engines. *Combustion Engines*, 4/2013 (155), 75-79, 2013.
- [11] Bielaczyc, P. (editor) and 19 co-authors. Powertrain development for low-to-zero emissions and efficient energy usage. *Proceedings of the Industry Session held during the 2013 PTNSS Congress on Combustion Engines*, ISBN 978-83-931-383-5-7, 2013.
- [12] Bielaczyc, P. (editor), “Trends in automotive emissions , fuels, lubricants, legislation and test methods present and future – 2014” *Symposium Proceedings of 4th International Exhaust Emissions Symposium* , 22-23 May 2014, Bielsko-Biala, Poland, ISBN 978-83-931383-7-1. Published also at *Combustion Engines* 3/2014 (158) PL ISSN 0138-0346.
- [13] Bielaczyc, P., Woodburn, J., Trends in Automotive emissions, fuels , lubricants, legislation and test methods – present and future. A brief overview from the perspective of the International Organising Committee of the 4th International Emissions Symposium. *Combustion Engines* 3/2014 (158), PL ISSN 0138-0346, pp 93-100.
- [14] <https://www.dieselnet.com/news/2014/05bosmal.php>
- [15] Bielaczyc, P., Woodburn, J., Gandyk, M. Trends in automotive emissions, fuels, lubricants, legislation and test methods – a global view, with a focus on the EU & US.... *Combustion Engines*. 2016, 166(3), 76-82. DOI:10.19206/CE-2016-342.
- [16] Bielaczyc, P. (editor), *Symposium Proceedings – “Trends in automotive emissions, fuels, lubricants and test methods – a global view with focus on the EU & US”, Proceedings of the 5th International Exhaust Emissions Symposium*, 19-20 May 2016, Bielsko-Biala, Poland, ISBN 978–83–931383-9-5.
- [17] <https://www.dieselnet.com/news/2016/05bosmal.php>
- [18] Bielaczyc, P., Światowe trendy w ograniczaniu emisji samochodowej i ich wpływ na rozwój napędów pojazdów, paliw, olejów silnikowych i metod badawczych – znaczenie globalne nowych regulacji ograniczania emisji WLTP i RDE, *Przegląd Techniczny*, 21-22, 14.10.2018
- [19] <https://www.dieselnet.com/news/2018/06bosmal.php>
- [20] <http://www.combustion-engines.eu/en>

#