Article

The Opportunity to Develop Cleaner Diesel Engines

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Abstract

The current scandal engulfing Volkswagen (VW) regarding the falsifying of data in order for diesel cars to pass American and European emissions tests brings to light decades of deception by the company and the collusion of the research and industry bodies who failed to question and hold VW and their claims to account. It is also well-known that VW is not the only car manufacturer which has to clean up their act. It is for this reason that this paper was commissioned by Centre for Factories of the Future in the UK and Bahcesehir University in Turkey. This paper complements their recent research in making ships burn less fuel and hence produce fewer pollutants (Ziarati and Akdemir, 2015).

This paper gives the background to the relevant work on making diesel engines cleaner and more efficient. It's main message is that diesel is still a good engine type and can be made cleaner, particularly when used in a hybrid vehicle or by burning Petroleum Natural or Liquefied Gas (PNLG). Diesel engines can also be tuned to produce no or very little harmful particulates.

This paper focuses on removing NOx from the diesel engine exhaust fumes by either burning it as a fuel in a separate chamber, or in the exhaust recirculation systems. In either option NOx is used as a fuel and the extra oxygen can be used to produce power or help to reduce exhaust emissions.

Background to the Current Research on NOx

Diesel engines were developed in the 1980's taking into account issues relating to harmful engine emissions well known to the industry. As such there was a concerted effort to design 'Clean Diesel' engines to reduce harmful emissions; this work was carried out by many groups including companies like Volkswagen, Universities and private research companies.

One such research group was working out of Bath University where PhD student (now Professor Dr) Reza Ziarati and his colleagues, under the auspices of Professor Frank Wallace; a well-known and respected engine researcher, set up a new Engine laboratory with funding from Holset Engineering (Huddersfield, UK) and developed the first commercially viable Variable Geometry Diesel Engine. This new engine design provided a means of adding air in the engine cylinder to improve either the torque back up or to decrease the Nitrogen-Oxide (NOx) and Carbon Dioxide (CO2) emission levels (http://www.c4ff.co.uk/history/papers/Early_Bath_University_reports.pdf) . It is worth noting that Professor Ziarati's software and engine designs were bought by many companies including Scania, Brown Boveri, Cummins of the USA and several others from Bath University without the knowledge of Professor Ziarati. When Professor Ziarati found out he expressed no objection as he believed humanity would benefit from these sales and Bath University would have the funds to continue its good work in Engine research. Professor Ziarati, as Chairman at Centre for Factories of the Future (C4FF), led the Way for C4FF to design and develop clean diesel and first hybrid engines in Europe

(http://www.c4ff.co.uk/history/papers/Green_Machine.jpg). Two Bath University publications, which was never published due to confidentiality, were produced discussing how to make variable geometry diesel engines viable are available as Professors Ziarati and Professor Wallace's paper on Incidence Losses (http://www.c4ff.co.uk/history/papers/Incidence_Loss_Model.pdf) and their integrated universal equation of flow (http://www.c4ff.co.uk/history/papers/One_dimensional_unified_flow_Program.pdf). The work reported in these papers has helped many engine and engine systems manufacturers to improve their engines and systems and the findings still have relevance today. Some of the later research by MIRA was based on Professor Ziarati's research work (see AutoTech 95 published paper on aspects relating the now well-known first variable geometry diesel engine (http://www.c4ff.co.uk/history/papers/AutoTech_95_paper.pdf).

After completing his PhD Prof. Dr Reza Ziarati was appointed to Lucas, and with his team managed to convince Lucas Bryce to let them research-discover the reason why excessive smoke and pollutants are emitted by diesel engines. Working with Ricardo in Brighton the team placed a camera on top of an Atlas single cylinder diesel engine and it became readily apparent that the cause of most of the excessive smoke was a secondary injection. This was where after the intended injection period, and due to the closure of the delivery valve, fuel returned to the pump, then as there was no way for this fuel to escape the pressure waves were generated and returned the residual fuel back to the injector forcing it to open and allow some low pressure fuel to enter the cylinder at the wrong time in the combustion cycle thus causing excessive emissions of smoke and pollutants from partially burnt diesel fuel. In response to this discovery the team, with support from Harwell laboratories, developed revolutionary new high-pressure Fuel injection Equipment (FIE) to reduce smoke and CO2 emissions. Some of these findings were published by professional bodies including the Institution of Mechanical Engineers - http://www.c4ff.co.uk/history/papers/High_pressure_fuel_injection_system.pdf.

Following this work and because of the technology developed to help reduce diesel smoke and harmful emissions Professor Ziarati and his team gained the support of Lloyd's Register for their work in 'Clean Diesel', Lloyd's further showed their support based on the confidence they had in Professor Ziarati and asked for his support to develop more efficient diesel engines (http://www.c4ff.co.uk/history/papers/Lloyds_support.pdf).

Alongside such collaborations Professor Ziarati and his team continued their own lines of research to reduce diesel engine smoke and pollutants. This work resulted in the development of the first hybrid engines for buses and cars in 1994 (http://www.c4ff.co.uk/history/papers/Green_Machine.jpg).

A further line of research being looked at in the mid 1990s advocated the use of water injection to reduce engine temperature which directly reduces the level of NOx emissions combined with specially designed filters to remove harmful particulates. Tests in this area were carried out by Oxford University with the support of Professor Ziarati. In one of the reports on this subject it was pointed out to senior members in the UK Government that NOx could be substantially reduced and that engines can be tuned to produce no or very little harmful particulates. NOx was first used in Germany during the 2nd World War to supply the extra oxygen needed for efficient combustion of their ME109 fighters to keep up with the UK Spitfires.

All of these research initiatives, and the technologies developed, reduced the smoke and harmful emissions from diesel engines, however all these reductions fell short of the claims that would be made

by VW. By 1996 VW had begun claiming to have developed an engine that could give a 22% saving on fuel economy, 25% reduction in NOX and 36% reduction in CO2 emissions. These claims were believed by politicians, academics and research councils around the world. In fact when individuals raised concerns about the claims and the technology behind them they were shot down. The world had chosen to believe VW's claims and not investigate further despite contradictory evidence and alternative technologies being readily available as described above.

Yet some individuals sought to questions the claims. In particular Professor Ziarati raised his concerns through publishing papers such as the 1996 Scottish National Lecture on Road Transportation (http://www.c4ff.co.uk/history/papers/Emerging_transportation_system.pdf). The lecture was the awarded the National Diploma for Best Paper (http://www.c4ff.co.uk/history/awards/National_Diploma-Hybrid_Vehicles.pdf) and the MacKenzie's Junner Award - http://www.c4ff.co.uk/history/awards/Design_and_Use_of_Hybrid_Vehicles_National_Prize.pdf. But without the support of the Research Councils and academics there was no way for individuals or small groups like Professor Ziarati's to secure the funding to investigate and determine if what VW (and other companies) were claiming was true.

Professor Ziarati, and those like him, have supported many companies to improve their diesel engines but when the 1996 the claims by companies such as VW were believed and never questioned this impeded Professor Ziarti's and other individuals and groups ability to secure crucial research funding to continue their work, for why would a funding body fund work that could prove, through evidence, a reduction of between 5 - 15% in harmful diesel engine emissions when some of the largest car manufacturers in the world are building millions of Diesel engines that they claim give a 22% saving on fuel economy, 25% reduction in NOX and 36% in CO2 emissions - and these claims are backed up by falsified emissions tests results which were not noticed or investigated by the experts in the Research bodies? Over decades companies like VW intentionally or unintentionally belittled research into alternate methods of reducing diesel emissions and held back real developments to reduce pollution whilst making large profits by duping customers around the world.

Result of recent experiments

The question which needs to be answered is: why has no serious work on NOx engines or burning NOx as fuel and a means of producing more Oxygen been carried out in recent years? As stated earlier the Germans used it in their fighter jets but soon they realised that NOx can also severely damage their engines if used for a prolonged period of time. For this reason they used NOx for short periods, in fact it was only when their fighter aircraft had to match the UK's Spitfire superiority in climbing to higher altitudes. The modern engines of today with greater heat resistant capacities are more than able to use NOx as fuel when additional power is required or to use it in a mix as a normal fuel as a general means of propulsion. What is significant is that NOx as harmful emissions would be substantially reduced by developing cleaner diesel engines along these lines. There are no reasons as to why NOx can't be used in Petrol engines for boosting torque and hence power output. C4FF and BAU have access to data on recent tests where the torque on a 2.5 litre car engine increased by some 30% and in another test the power was used to increase the speed by some 25% by using the discharged NOx in the engines as a fuel. Furthermore, combining NOx burning with in-cylinder water injection can help to reduce NOx as

result of normal engine combustion and also substantially reduce heat loss which is often responsible for some 20% of total heat generated as a result of normal combustion.

Concluding remarks

These individuals who have always questioned VW's claims and who have wanted to investigate and learn the truth for the past 19 years have been vindicated by the revelations of the past weeks and its hoped that the politicians and research bodies will finally do their duty to investigate and hold VW (and other car manufacturers) to account, and in so doing turn their attention and funding back to worthwhile evidence based research projects to improve engine efficiency and reduce emissions by means such as: water injection, use of gas fuels and novel fuels, and development of novel hybrid systems and perhaps to look again at whether inner cities should require engines which only run on safe pollution modes to reduce smog and pollution to safeguard public health.

But if we are never to repeat this scandal then further steps need to be taken. As well as refocusing funding and research into new ways to reduce emissions, a review needs to be carried out into how car engine tests are designed and carried out, and what influence car manufacturers have over this process. Car engine and emissions testing should be independent and rigorous. If a system can be deliberately manipulated for nearly 20 years, as is the case with the current testing systems of the EU and USA, then they are clearly unfit for purpose and need to be overhauled.

The engine technologies, for the foreseeable future, are unable to produce clean engines; this applies to both diesel and petrol cars. Let us not fool ourselves; petrol is as almost as bad as diesel and the fact that it is a less efficient engine, is in itself, a cause for concern. Petrol engines also pollute and some of pollutants are extremely harmful. Apart from burning NOx, methods such as water injection, to cool the engine have been misrepresented and means to induce more air into cylinders to provide more air for the combustion have in the past been used to extract more power and not cut emissions, this has to stop and Research councils should lead the way and now promote cleaner engines and seek to support hybrid solutions more vigorously.

The most important message to the UK Government and other countries who manufacture diesel engines is for them to realise there are ways of burning NOXs as part of normal engine combustion and so there is no reason for these harmful by products of diesel combustion to be burnt as part of the exhaust gas recirculation. Furthermore, the UK Government is aware that the harmful particulates of Diesel can be filtered or transformed by special catalysts. C4FF and BAU are of the view that diesel engines should modified to burn gas as is the case with some of gas engines developed by C4FF. In the marine world, Wartsila have already reconfigured two of their diesel engines into gas engines with a great deal of success.

C4FF has been in the forefront of clean engine development and their AutoTech 95 papers (http://www.c4ff.co.uk/history/papers/Impact_of_new_transport_system.pdf) and http://www.c4ff.co.uk/history/papers/AutoTech_95_paper.pdf as well as their award winning papers such as http://www.c4ff.co.uk/history/papers/Emerging_transportation_system.pdf contributed greatly to making engines more efficient and cleaner. Most of C4FF's work has been commercially confidential as they main area of engine development has been on behalf of leading engine and engine system producers. C4FF is willing to share its engine test results and help in commercially developing the next

generation of clean diesel and petrol engines with or without water injection. The future is hybrid with gas as the main source of engine fuel as demonstrated by the C4FF award winning paper presented in the IRTE National Lecture in 1996 (http://www.c4ff.co.uk/history/papers/Emerging_transportation_system.pdf).