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CleanER-D puts diesel propulsion on the right track

The European railway network is the densest in the world and features the highest percentage of electrification – nearly 50%. Approximately 80% of total transport volume is hauled on the electrified part of the network. Nevertheless, diesel traction plays an important role in providing rail services and serves as the backbone of railway operation in countries with little electrification, such as the UK, the Baltic states of Estonia, Latvia and Lithuania, as well as Ireland and Greece. Diesel locomotives have key importance for freight transportation and the liberalisation of the freight market.

The environmental benefit that rail carries over other modes of transport is a vital precondition in ensuring social and political support for this mode of transport. Although air pollutant emissions from the railways only contribute a small proportion of total emissions from the transport sector, rail diesel exhaust emissions are increasingly attracting the attention of the public and authorities alike.

The total emissions from rail diesel traction are very low today compared to the whole transport sector (less than 2.5%[1]). The emissions of Nitrogen Oxides and particulates have already decreased by ~ 35% from 1990 to 2008 and it is expected that emissions will further decrease due to:

- The introduction of cleaner technologies
- Smaller diesel traction fleets and lower total mileage
- Electrification.

A collaborative project to face the challenges

With the newly established emission level limits set by the European Directive 2004/26/EC soon coming into force, the CleanER-D project was launched to find technical solutions to the challenges faced in complying with this new regulation framework. The project also anticipates that further regulation is likely and seeks to provide the sector with dynamic and innovative solutions for future applications. Keeping this in mind, the project will analyse hybrid technologies and their contribution to the reduction of energy consumption and CO_2 emissions. In order to reach the goal of 'greening' diesel vehicles, the consortium's 26 partners from across Europe are putting forth a strong, collaborative effort.

The project's main goal is to demonstrate the feasibility and reliability in service of railway rolling stock powered with diesel engines which are compliant with the requirements of stage IIIB of the NRMM Directive. To ensure the success of the project target, three operational subprojects have been established, two of which focus on re-powering existing diesel vehicles – a railcar and a locomotive – through a low-emission engine. The third operational subproject deals with the installation of a stage IIIB engine in a newly designed locomotive.

The CleanER-D 'Railcar Demonstration'

This demonstration project aims at designing, integrating and testing a railcar equipped with a diesel power pack, including a TD242 RH TA2 engine sized below 300kW. The main challenge of this refurbishment exercise is the space constraint due to the under-floor installation. To comply with the Stage IIIB requirement, the operator has chosen a two fluid solution, a so-called SCR system. The necessary SCR after-treatment equipment, as well as the Adblue tank, have to be fitted into the restricted space. The objective of this exercise is also to deliver valuable information to engine manufacturers, integrators and operators concerned with local emissions reduction for diesel railcars. In this regard, and due to its narrower rail gauge, a special examination is carried out to study the applicability of the design solutions to UK DMUs.

A Class 842 railcar from the fleet of Czech Railways has been selected for the refurbishment. The target of this re-powering exercise is to replace an almost 20-year-old engine with a stage IIIB engine. In parallel, the same Class 842 diesel railcars are equipped with IIIA engines which would provide a valuable comparison on the emissions, as well as technical performance, of IIIA and IIIB compliant engines.

Currently, the feasibility analysis, the vehicle requirement specifications, and the engine specification are finalised. The study concluded

that the railcar weight would not increase significantly. The test bed and in-service trials are scheduled for 2011. The results will provide valuable information on the engine package system durability, reliability, and endurance.

The CleanER-D 'Heavy Haul Demonstration'

This demonstration project provides an opportunity to an engine manufacturer to test its engine solution for stage IIIB in a running mainline locomotive. This project will also lead to real data about the efficiency of IIIB implementation in a newly built locomotive which is already IIIA compliant.

The prototype locomotive will be operated, performing revenue service under a special monitoring programme, after fulfilling the following pre-conditions:

- The installation of a new-generation 2.800kW series manufactured engine
- The 16 cylinder C175 rail engine is designed to comply with the stringent stage IIIB emissions limits and will be integrated in the newly designed diesel-electric locomotive
- Once the installation is completed, extensive testing like exhaust gas emissions measurements will be carried out on the locomotive.

This demonstration subproject faces a weight challenge – mounting a high-powered stage IIIB diesel engine in a typical European four axle locomotive configuration while not exceeding the maximum axle load restrictions. The emission reduction technology for Stage IIIB exhaust emissions will add additional engine weight, and therefore weight reduction in other areas of the locomotive will be required. This subproject will also extract useful and validated technical information on the new low-emission technologies from tests.

Directly following the project's kick-off, general specifications for the new Stage IIIB compliant engine package were defined. These were complemented with the specific locomotive specification and its maintenance interval requirements.

The next step was the selection of emission technology to be used for this diesel engine. As single fluid was preferred, the EGR technology plus particulate after-treatment DPF was selected. The EGR technology will reduce the Nitrogen Oxides. The DPF which will be replacing the locomotive silencer will reduce the particulates (soot and ash). In order to remove the soot accumulated in the DPF at lower exhaust temperatures, a pre-oxidation catalyst is installed. This avoids the use of burners for active regeneration and reduces maintenance.

The main targets for the design modifications are to maintain the same high-power output of 2.800 kW, while at the same time keeping the low axle load, despite the components added to the original vehicle. The design also seeks to minimise maintenance and operational costs related to the new after-treatment components.

During 2011, the engine package will be mounted in the locomotive and undergo the defined installation and commission audits before being placed in service, in order to validate and optimise under real conditions the correct performance of the new low-emission components.

The CleanER-D 'Light-weight Demonstration'

This demonstration project is facing a challenge to re-power a 40-year-old mainline locomotive with a diesel engine which meets the future emission regulation stage IIIB. In order to comply with the new emissions limits the re-powering will require the installation of new technologies, such as diesel particulate filter and exhaust gas recirculation.

The project team will equip the locomotive with a prototype 12V4000R84 engine with exhaust after-treatment technology for a 14-month period of field trials under realistic working conditions. The engine produces 1.800 kW and the exhaust after-treatment system incorporates a passive regeneration DPF dimensioned and designed by the partners' engineers.

In order to achieve high-quality field trials, the engine and its DPF system are currently being fine-tuned on the test stand by specialists, with the aim of ensuring that it meets all the demands placed on it in terms of emissions and vehicle requirements.

At the same time, preparations are being made to integrate the system in the Type BR225 freight locomotive. At present, the locomotive is powered by a 12V956TB10 engine dating back to 1971, and modifications to the engine bed, gearbox, cooling system and other assemblies will be needed in order to adapt it for the new engine which is designed for future needs. Intensive cooperation between all of the participants has facilitated the development of an extremely promising concept.

In the first quarter of 2011, the new engine and the DPF will be installed in the prototype locomotive, which will be operated in regular service after the re-powering takes place. The engine and exhaust after-treatment system will undergo a comprehensive program of inspections and emission measurements during the field test in order to gain information on the performance of the re-powered system.

This subproject also aims at providing reliable technical data on the use of a DPF system in a shunting locomotive equipped with a stage IIIA engine.

Sustainability and Integration

The CleanER-D project has been strongly focusing on the socio-economic and green aspects of rail diesel applications. Rail is proven to be the most environmentally friendly mode of transport. Special attention must be devoted to improve the emission performance of diesel-powered vehicles which still constitute about 20% of European operations. In addition, the European railway sector is prepared to meet the challenges of increasing energy prices and stricter environmental frameworks set by the European Union. The calculation of life cycle costs and development of a methodology for cost/benefit analysis are core elements of this specific work. Finally, optimisation of technical solutions and possible trade-offs will be studied and identified.

The so called 'Sustainability Study' tackles the major factors that can influence the European rail diesel vehicle fleet and related future diesel exhaust emissions. Push and pull factors, such as legislation, market development, the development and operation of emissions reduction technologies of competing modes of transportation will be focused on in particular. Together with an assessment of future emission reduction technologies, the findings of the Sustainability Study will result in an Impact Assessment. Finally, CleanER-D will provide recommendations on future emission reduction approaches and strategies of rail diesel traction in Europe.

Emerging technologies

An investigation of existing and potential emission reduction technologies for integration into locomotives, DMU, railcars, diesel plants and power packs leading to recommendations concerning these technologies has been undertaken by the partners. The objectives of this group are as follows:

- Identifying the state-of-the-art on low-emission technologies suitable for railway application
- Benchmarking low-emission technologies applied to other transport sectors
- Assessing the impact and feasibility of using innovative low-emission technologies on engine and rail vehicle performance and integration
- Providing recommendations on existing and alternative solutions for emission reduction of diesel railway vehicles based on potential scenarios beyond stage IIIB.

So far, the state-of-the-art of after-treatment technologies, for rail and automotive applications in particular, have been identified and will be used at a later stage to assess the most promising solutions.

Currently, a strong focus is given to the influence of fuel type and quality on emissions, evaluating diesel DPF strategies, and assessing emerging after-treatment technologies using stage IIIB emissions levels as a baseline, but also researching the suitability of these solutions beyond IIIB. Numerical simulation tools, including computing fluid dynamics are being developed to complete these tasks.

In addition, an investigation of vehicle-related topics associated with the integrations of using such technologies will be carried out. These vehicle-related topics include optimum management and utilisation of dissipated heat from engine, packing, control, durability and maintenance. This activity will complete the assessment of technology innovations for future measures beyond IIIB on diesel railway applications.

Hybridisation

It is sector-wide agreed that energy efficiency is best reached by reducing fuel consumption and by minimising both CO_2 and pollutant emissions of certain diesel-driven rail applications through hybrid solutions. The partners evaluate the energy saving potential of onboard energy storage system concepts. A conventional diesel-driven train mainly dissipates the braking energy into heat by the braking resistor.

This subproject is investigating technologies of hybrid drive systems for rail applications and their influence on reduction of fuel consumption and emissions through the following objectives:

- Identification of the state-of-the-art hybrid technologies
- Definition of 'standard duty cycles' for different rail vehicle types
- Investigation of influences on energy use and emission of the drive systems and management of the auxiliary systems
- Comparison of innovative energy storage technologies
- Assessment of impacts due to hybrid technologies
- Recommendations for further reduction of fuel consumption and emissions using innovative hybrid technologies.

There has been a special emphasis on identifying state-of-the-art hybrid technologies for onboard storage systems such as flywheel, hydrostatic accumulator, double layer capacitors, and batteries. It has described recent innovative developments made for different types of railway applications, particularly in urban rail vehicles, trams and metros, but also for mainline rail vehicles and especially in the field of diesel-driven vehicles as well as potential technology transfer from developments made in road transport and stationary applications.

Duty cycles for different diesel powered rail vehicles – suburban, regional, high speed DMU, intercity locomotive, freight mainline locomotive and shunter – were defined to determine the energy performance and the emissions. Furthermore, this requires the preparation of comparable data for rolling stock to define standardised duty cycles which make emission and fuel consumption comparable. The objectives are:

- Defining duty cycles and parameters to run an emissions simulation based on an evaluation of existing driving cycles and the results of the Railenergy project
- Proposing these standard duty cycles to CEN for a possible EN standard
- Identifying the effect of the required pollution values.

Different energy storage technologies for diesel hybrid rail vehicles were evaluated. The defined duty cycles for the different train types were analysed to identify the train behaviour as well as to elaborate the power at the wheel. The repartition between the several energy storage systems and the diesel engines were fixed with integration of auxiliary supplies taking into consideration the engine stop periods and the equalization of the energy content for the whole duty cycle.

Outlook

Figures from the European Environment Agency have shown that at a global level, the total atmospheric pollutant emissions from the existing diesel railway fleet in Europe are low, especially when compared to other transport modes and industrial sectors. In addition, the specific CO_2 emissions of the rail sector (electric and diesel) have decreased since 1990 (minus 11% for passenger, minus 35% for freight).

Preliminary results of the demonstration subprojects show that the rail industry is able to meet the requirements and will further contribute to the reduction of the overall emissions. Nevertheless to reach these goals, there are major technical and financial challenges to be solved.

After all, because we do not know the impact of all existing uncertainties, it can be roughly estimated that the total emissions of Nitrogen Oxides and particulates from rail diesel traction may further decrease by approximately 20% by 2020.

Certainly, diesel will remain one mode of propulsion for the European railways sector. The CleanER-D project will demonstrate the possibilities against the background of the actual challenges and restrictions. Finally, the project and its partners will prove the viability of this traction mode and offer various technical solutions and research which can be used in discussions about the use of diesel on European tracks.

Reference

1. 'European Union emission inventory report 1990-2008 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)' issued by the European Environmental Agency EEA, in July 2010.

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