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Validation Test on a Light Duty Vehicle Equipped with a GDI Engine to Meet China 6b RDE Regulation for PN

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Abstract

China 6 (CN6) emission legislation for light duty vehicles was published in 2016, which introduced real driving emissions (RDE) requirements for new type-approval content. Nitrogen oxides (NOx) and particle number (PN) of RDE test are required to be monitored and reported from July 2020 in CN6a phase, fulfilled from July 2023 in CN6b phase. To meet the PN limitation of CN6 RDE, the optimized engine combustion and advanced emission control system like gasoline particle filter (GPF) are encouraged. Compared to traditional vehicle platform emission compliance which could be done in lab, much more vehicle development and validation efforts are expected on the open road for RDE compliance. High cost and complexity are expected to conduct a complete validation test matrix covering all the RDE critical boundary conditions on the open road. To investigate a logical RDE validation process from lab to open road covering various critical boundary conditions like soaking temperature, altitude and driving dynamics, and evaluate the PN RDE compliance risk on a CN6a vehicle, a group of surrogate RDE cycle lab emission tests and RDE tests on the open road were conducted on a CN6a vehicle equipped with a 1.5L TGDI engine. A developed surrogate RDE lab cycle for saving efforts on road and a complete RDE validation process for RDE compliance from lab to open road was introduced in this study. Test results showed that considering extreme conditions, such as -7°C ambient temperature, 2300m altitude and aggressive driving as well, the PN emission of the tested vehicle could fulfill the CN6b RDE PN limitations with GPF.

Introduction

Many studies showed that the exposure to fine particulate pollution had adverse effects on cardiopulmonary health [1,2,3]. Gasoline engine emits considerable particle emission which could reach similar level as diesel engine if GDI (gasoline direct injection) technology is applied [4]. Recent vehicle emission legislations introduced more stringent tailpipe particle emission limitations, not only for particle mass, but also for particle number (PN). China 6a (CN6a) light-duty vehicle emission legislation introduced the PN limit in 2020 for WLTC, and China 6b (CN6b) will implement the requirements for both WLTC and RDE in 2023 [5].

As emission legislations become more stringent, more challenges are raised for engine emission aftertreatment systems, and a growing number of studies on emission aftertreatment system development, diagnostic applications, heat management of aftertreatment system, and their impacts on certification or RDE emissions are reported [6, 7, 8]. The PN emission from the real road driving is found usually higher than that from the lab testing with WLTC cycle under certain driving conditions, because the RDE test covers more engine operating conditions than the WLTC. Thus more efforts on emission calibration and combustion optimization work in development phase will be required. To achieve the PN reduction requirements, GPF is proved to be a promising method and widely adopted in Europe and China [9, 10, 11, 12]. While more efforts are required on after-treatment system development and engine control strategy including soot management in filters [13, 14, 15], considering the key influencing factors, such as driving dynamic, ambient temperature and altitude, validation matrix would be further enlarged. Yoshioka's study proved aggressive driving would generate higher engine out particle emission than normal driving [16]. Other investigations found that the lower soaking temperature resulted in the higher particle emission [17,18]. But for altitude impact, Wang, X. et al conducted more than 300 RDE tests, found no clear correlation between testing altitude and RDE emissions [19]. In addition, wider engine operating range emission optimization efforts and complex validation tasks must be arranged to confirm the RDE emission compliance [20, 21]. Therefore, the vehicle development and validation process for RDE emission regulation compliance will be more complex than that considering the lab cycle compliance only.

For the future legislation trend like Euro 7, potential changes include significant PN limit reduction and inclusion of 10~23nm particles. Even more challenges are expected for performance and potential risk are well revealed with such a validation matrix. The well-designed surrogate RDE tests in lab with climate and altitude control could also substitute part of the RDE validation tests on the open road, thus could save the overall validation effort.

Summary

To fulfill the CN6b RDE requirements and investigate key influencing factors for RDE emissions, a series lab surrogate RDE tests in lab and open road RDE tests were conducted on a turbocharged GDI vehicle. A logical validation process for PN emission compliance and key influencing factors were also discussed.

Firstly, the engine out PN emission exhibits a strong correlation with ambient temperature. Raw PN emission increases significantly when ambient temperature goes down. While RDE PN results under -7°C may not be worse than that under 0°C because of extension factor applied. High temperature above 30°C shows mild impact than low temperature below 0°C.

Secondly, the altitude impacts on particle emission are not obvious in both lab surrogate RDE and open road RDE. However, the extension factor could dilute the effect of deteriorative PN raw emission if the ambient altitude outside the normal region.

Thus, the relative worse case for this vehicle to meet the RDE PN compliance would be in the normal region without extension factor, such as low altitude and low temperature at 0°C. The PN evaluation results from both lab surrogate RDE tests and real road RDE tests, suggest that the testing vehicle can meet the CN6b RDE requirement for PN with a wall-flow GPF installed. It also has the potential to meet Euro 6d regulation with RDE package 4. Further optimization or adopting GPF with higher filtration efficiency will be needed to meet future regulation such as Euro 7.

The combined validation matrix with lab cycle and open road RDE tests in this study reveal the potential RDE compliance risk. Results from the lab surrogate RDE tests are well aligned with the RDE tests on open road, which suggest that well-designed surrogate RDE lab cycle is a great supplement to real road RDE test and could help to narrow-down the validation complexity of real road RDE testing at the early age.

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