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Improving Diesel Car Smoke Measurement Probe Performance of Diesel Cars Using Hole Position

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홀 위치에 따른 디젤자동차 매연 측정프로브 성능 개선 연구

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ABSTRACT

Car inspection systems are regularly carried out by the state to ensure the safety and emission status of cars, thereby improving the safety and quality of life by reducing fine dust and greenhouse gases that are the main culprits of vehicle defects and air pollution. These automobile inspections are largely divided into either regular or comprehensive inspections. This study analyzed the smoke measuring probes used in the lug - down 3 mode. In the previously issued paper "Improvement of Soot Probe Efficiency for Automotive Emission Measurement," an improved smoke measurement probe(B) improved on the problems that arise from the current smoke measurement probe (A). In this study, a technique that can improve the probe's inhalation efficiency over the improved (B) probes was applied to probes (C). Probe (C) involves a structure designed close to the center of the circumference of the exhaust pipe, and the suction efficiency was improved by adding a variable center unit.

Key Words : Exhaust Efficiency(배기효율), Lug-Down3 Mode(러그다운3 모드), Reduction of Greenhouse Gases(온실가스 감축), Center Position Unit(중앙 위치 장치), Fine Dust(미세 먼지)

1. Introduction

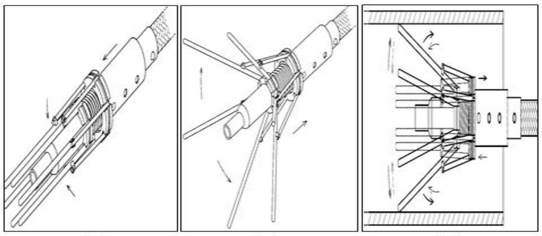
The vehicle inspection system plays the role of improving the safety and quality of life of people by regularly checking the safety and emissions of vehicles by the government to reduce particulate matter and greenhouse gases, which are the main culprits of vehicle defects and air pollution[1-7]. The vehicle inspections are divided into general and regular inspections, which also include emission and safety inspections[8-11].

Currently, the soot measurement of vehicles using diesel or a mixture of diesel and gas is performed by applying the KD 147 mode, lug-down 3-modes, and no-load rapid acceleration inspection technology[12-13]. In particular, lug-down 3-mode inspection technology is applied to the large diesel vehicle load test[14-16].

This study investigates the soot-measuring probe used for these inspections as well as the lug-down 3-mode inspection. In the previously published “Improvement of Soot Probe Efficiency for Automotive Emission Measurement,” we improved the soot-measuring probe (B) to solve the problem of the low soot-measuring efficiency of the existing soot-measuring probe (A) at the angles of the exhaust pipe shape of 75° and 90° and in irregular conditions. The present study additionally improved the suction efficiency of the probe (B) that had been improved in the previous study to probe (C). The soot suction efficiency was improved further when the exhaust pipe was positioned closer to the center of the exhaust gas pipe’s cylindrical surface. The probe (C) designed to be positioned close to the cylindrical surface of the exhaust pipe and the excellence of its performance were verified. The three different types of soot probe are indicated as (A), (B), and (C).

2. Soot-Measuring Probe Theory

Probe (A) used in vehicle inspection has several ribs beside the inlet, which have the problems of becoming bent or damaged as the ribs contact the wall of the exhaust pipe and an inability to withstand shock or high exhaust heat. As a result, the inlet cannot maintain an appropriate distance from the wall of the exhaust pipe. Furthermore, probe (B) has the same tendency of the probe inlet becoming inclined to the wall of the exhaust pipe as that of probe (A), and when the exhaust pipe is bent severely, the suction temperature drops, although the soot-measuring amount is not different. To solve this problem, probe (C) was designed in this study. It has omitted the ribs of the probe, and the center hole of the probe is a variable type and can be positioned at the center of the circumference of the exhaust pipe. Since the probe has a center position unit that supports the center hole of the



(a) (b) (c)

Fig. 1 Development probe drawings

soot probe, the soot-measuring probe can always be maintained close to the center despite the various curvatures and diameters of the exhaust pipe. This probe can improve the soot suction efficiency and solve the problem of the existing product because there are no ribs.

Fig. 1 shows drawings of the improved probe (C). Fig. 1 (a) and (b) show the working schematic of probe (C), and Fig. 1 (c) illustrates the probe inserted in the exhaust pipe.

3. Vehicle Soot Measurement Technology

3.1 Engine RPM control load inspection technology

For the engine RPM control mode (lug-down 3-mode), the measurement of the engine-rated maximum PS must be within ±5% of the engine-rated RPM in load inspection mode 1, and the engine-rated maximum PS measurement must be at least 50% of the engine-rated PS. The mode configuration is as follows. First, when the measured vehicle condition is confirmed to be normal, the vehicle is preheated while driving for 40 sec at the vehicle speed of 50±6.2km/h under the 40% load of the engine-rated PS in the chassis dynamometer. Second, immediately after the preheating is finished, the gear shift that makes the vehicle speed close to 70 km/s but does not exceed 100 km/h is selected while the accelerator pedal is pressed the maximum amount in the chassis dynamometer (overdrive must not be used for automatic transmission). Then, the inspection mode is started according to the load inspection method. However, for trucks with a maximum speed-limiting device, the inspection mode is started by selecting a gear shift that does not make the vehicle speed exceed 85 km/h at the engine-rated RPM. Third, for the inspection mode, mode 1 is the engine-rated RPM of the maximum PS with the accelerator pedal pressed the maximum amount, mode 2 is 90% of the engine-rated RPM, and mode 3 is 80% of the engine-rated RPM. In each inspection mode, once the mode is stabilized after 5 sec, the measurement of engine RPM, maximum PS, and soot is started, and the final measurement value is the arithmetic mean of the measurements for 10 sec. For the soot concentration, if the soot concentration measured in each mode is within the acceptance criterion for the driving vehicle, it is judged as passing; if the acceptance criterion is exceeded in any one mode, it is judged as failing. The maximum PS and engine RPM are rounded to one decimal place and written in 10-rpm and 1-ps units, respectively. The final soot concentration measurement is written in 1% units and the decimals are discarded. For the engine-rated RPM, if the engine RPM measured in mode 1 is within ±5% of the engine-rated RPM, it is judged to have passed; otherwise, it is judged to have failed[17].

4. Configuration of Experimental Apparatus

Fig. 2 shows the configuration of the vehicle inspection system, and Fig. 3 shows the components of the diesel vehicle load test equipment in the general vehicle inspection center. The photographs on the left show the chassis dynamometer; light transmission soot-measuring system; soot-measuring probes (A), (B), and (C); and hose. The operating

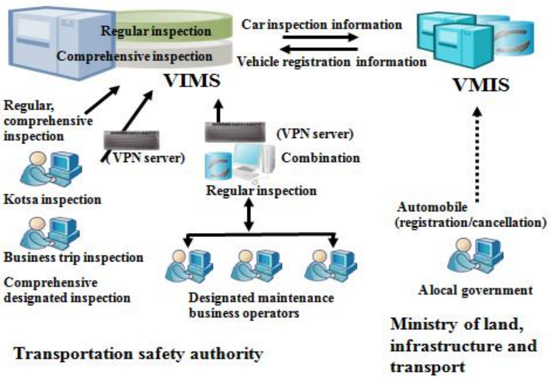


Fig. 2 Car Inspection System Configuration Diagram

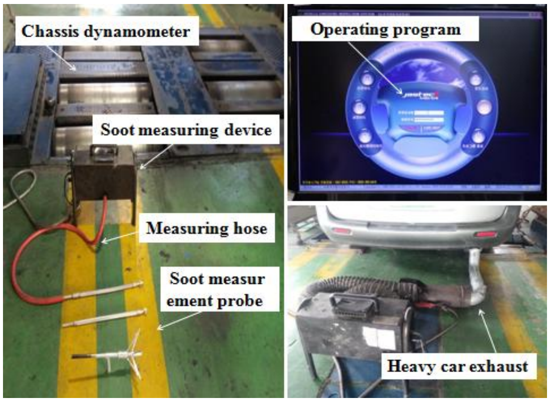


Fig. 3 Configuration of equipment

program is shown in the top right, and below it is an installation example of the curved exhaust pipe of a real medium diesel car in the experimental vehicle[17].

5. Experimental Method and Discussion

5.1 Experimental method

For this study, at the exhaust pipe angles of 70° and 90°, probes (A), (B), and (C) were inserted into the exhaust pipe. With the lug-down 3-mode inspection technology, the suction efficiency was determined with graphs of the soot suction rate and temperature. The same experimental vehicle and conditions as those in the previous study were used. The residual soot and actual experiments were also carried out by performing the lug-down 3-mode five times, which was the same method as that in the previous study, and a constant setting time was maintained for each mode. Fig. 4 shows photographs of probes (A), (B), and (C). Fig. 4 (c) and (d) are photographs showing the operation of probe (C). The left side shows the operation in the case of inserting an exhaust pipe with a large circumference, and the right side shows the operation in the case of an exhaust pipe with a small circumference. Fig. 5 shows the shape of an actual curved exhaust pipe of a large vehicle[17].

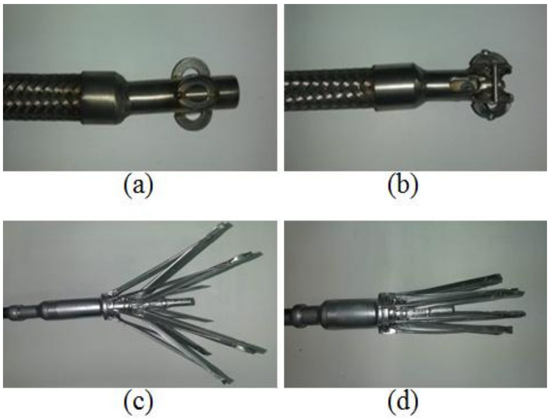


Fig. 4 (A), (B), (C), (D) Existing soot measurement probe

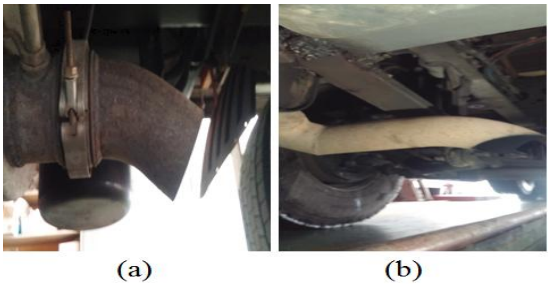


Fig. 5 Heavy car exhaust

5.2 Results

Figs. 6 to 9 show the soot and temperature measurement results of probes (A), (B), and (C) measured using the lug-down 3-mode inspection technology after being inserted into the exhaust pipes at 75° and 90°. Fig. 10 shows a photograph of the position of the probe hole with probe (C) inserted in the exhaust pipe and rotated 360°. It can be seen that the probe hole was positioned close to the center in all conditions. At the 70° condition in Fig. 6, the differences in the concentrations of all probes were insignificant. At the 90° condition in Fig. 7, probe (C) showed improvements in the soot concentration of approximately 89% and 25% relative to the mean soot concentration for the three modes of probe (A) and probe (B), respectively.

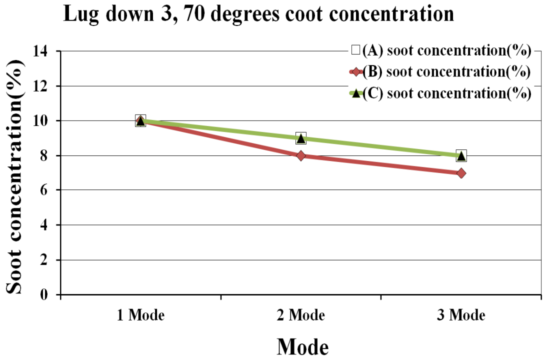


Fig. 6 Soot change due to 70 angle change

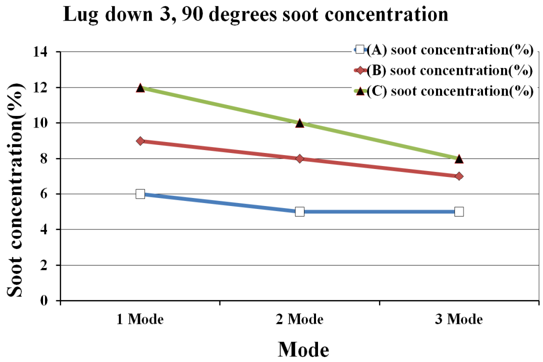


Fig. 7 Soot change due to 90 angle change

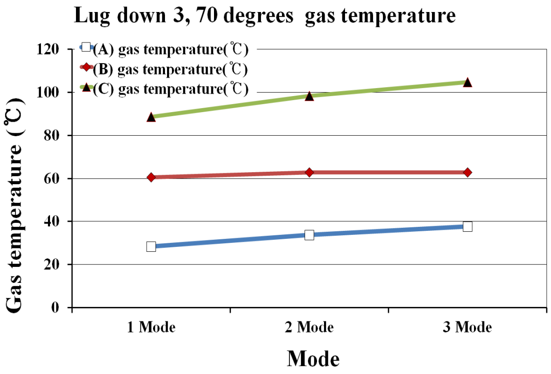


Fig. 8 Temperature change due to 70 angle change

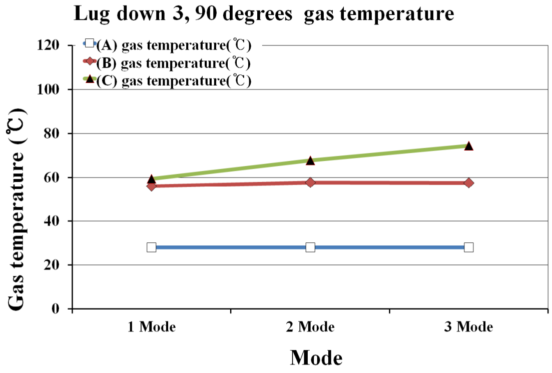


Fig. 9 Temperature change due to 90 angle change

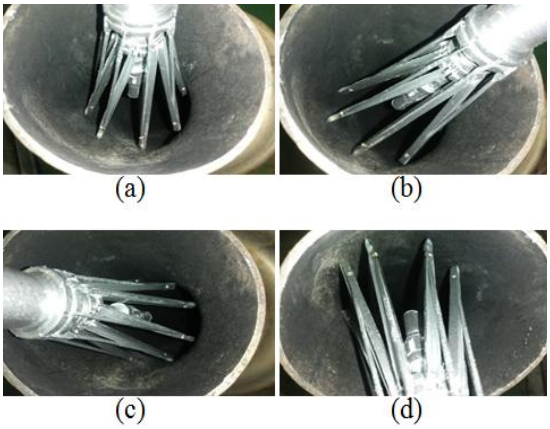


Fig. 10 (C) Example of probe exhaust pipe insertion

Figs. 8 and 9 show the temperature changes. The temperature of probe (C) showed improvements of approximately 193% and 56% relative to the mean temperature of the three modes of probe (A) and (B), respectively, in the 70° condition and improvements of approximately 140% and 18%, respectively, in the 90° condition. As shown in the graph data, probe (C) showed better performances than probes (A) and (B) in all conditions. Particularly in the condition of a large angle change, the suction efficiency of probe (C) improved compared with the other probes because the inlet was sufficiently secured.

6. Conclusions

The performance improvement of the soot-measuring probe for diesel vehicles was investigated according to the hole location, and the following conclusions were reached.

1. The soot measurements changed depending on the insertion position and shape of the vehicle soot-measuring probe.
2. The larger the exhaust pipe shape and angle, the more inclined to the wall the center hole of the soot-measuring probe became, which decreased the suction efficiency.
3. When the soot-measuring probe hole was closer to the center of the exhaust pipe, the soot measurements showed fewer variations and higher accuracy even if the exhaust pipe angle was changed.
4. Even when the inlet was not secured, the probe hole of the improved probe (C) was located near the center of the exhaust pipe. Consequently, probe (C) showed improvements in the soot concentration of approximately 89% and 25% relative to the mean soot concentration for the three modes of probe (A) and probe (B), respectively. The temperature of probe (C) showed improvements of approximately 193% and 56% relative to the mean temperature of the three modes of probe (A) and (B), respectively,

in the 70° condition and improvements of approximately 140% and 18%, respectively, in the 90° condition.

5. The results of this study verified the possibility of improving the inspection efficiency and lowering CO2 emissions in the transportation area when the improved probe (C) is applied to regular and general inspections.

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References

1. Jo, H. S., Sim, J. I., Kim, J. R., “Quantitative Effectiveness Analysis of Vehicle Inspection,” Journal of Korean Society of Transportation, Vol. 25, No. 3, pp. 65-74, 2007.
2. Jin, K. S., Lee, C. H., “A Study on the Characteristics of Smoke Emissions from Heavy Duty Diesel Vehicles Using a Chassis Dynamometer,” Journal of the Korean Society of Safety, Vol. 24, No. 4, pp. 1-10, 2009.
3. Yi, C. S., Lee, T. E., Lee, C. W., “Numerical Analysis of the Internal Flow of 8kW Grade Diesel Generator Muffler,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 17, No. 3, pp. 45-50, 2018.
4. Kim, T. H., Lee, C. W., “A Comparative Study on Engine Performance and Exhaust Emission Characteristics of Response Power 150HP & 240HP Turbocharged Marine Diesel Engine,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 12, No. 1, pp. 43-51, 2013.
5. Sim, H. S., Jun, J. H., “A Design for Water Cooling of a Marine Diesel Engine with Verification of Improvement,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 15, No. 6, pp. 58-63, 2016.
6. Yang, Y. J., “Study on Simulation of Fuel Injection Nozzle for Marine Medium Speed Diesel Engine,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 12, No. 3, pp. 41-47, 2013.
7. Sim, H. S., Lee, M. K., Lee, K. Y., “A Development Study on an Engine Control Module of an Electronic Marine Diesel Engine,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 14, No. 5, pp. 134-140, 2015.
8. Yi, C. S., Jeong, I. G., Suh, J. S., Park, C. D., Jeong, K. Y., “A Numerical Analysis on Flow Uniformity of SCR Reactor for 5,000PS Grade Marine Engine,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 11, No. 6, pp. 28-35, 2012.
9. Yi, C. S., Lee, C. W., “A Study on the Exhaust Gas After Treatment for Small Ship,” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 16, No. 3, pp. 76-81, 2017.
10. Kim, T. J., Hong, S. I., “Study of the Effect of Cleaning the Intake Manifold on Common Rail Diesel Engine and Exhaust Gases,” Journal of the Korea Academia-Industrial cooperation Society, Vol. 15, No. 10, pp. 5912-5918, 2014.
11. Kang, H. J., Kim, T. J., “Study on the Characteristics of Exhaust Emissions in accordance with the Intake Manifold and Fuel Injector Maintenance of the Electronic Control Diesel Engine,” Journal of the Korea Academia-Industrial cooperation Society, Vol. 17, No. 9, pp. 196-205, 2016.
12. Kim, Y. J., Park, K. S., “A Study of the Opacity Correlation Factor between the Filtration Type and Light Extinction Type Diesel Smoke Meters,” Transactions of the Korean Society of

Automotive Engineers, Vol. 15, No. 5, pp. 146-152, 2007.
13. Jung, Y. D., Yeo, U. S., Yun, Y. G., Hong, M. S., “A Study on Emission Inspection Method Improvement of Heavy-Duty Diesel,” Vehicles Transactions of the Korean Society of Automotive Engineers, Vol. 22, No. 1, pp. 165-173, 2014.
14. Jung, Y. D., Yeo, U. S., Lim, Y. J., Ryu1, I. H., “Research on the Improvement of the Emission Inspection Program for Diesel Vehicle,” Vehicles Transactions of the Korean Society of Automotive Engineers, Apr. 29, pp. 394-399, 2009.
15. Jo, J. G., Lee, D. W., “Research on the Relation of the Exhaust Gas Concentration between Lug-Down3 Test Mode and D147 Test Mode on the Driving Car Using Diesel Fuel,” Korean Society for Atmospheric Environment, Oct. 13, pp. 62-65, 2008.
16. Kim, J. C., Eom, M. D., Park, Y. H., Kwon, S. I., Lee, J. B., Kim, J. W., Yeo, U. S., “Research on the Introduction and Application of the Road-Load Inspection Program for Heavy Duty Diesel Vehicle” Korean Society of Automotive Engineers, Vol. 1, pp. 306-311. 2005.
17. Chae, I. S., Kim, S. Y., Kim, J. Y., “Improvement of Soot Probe Efficiency for Automotive Emission Measurement.” Journal of the Korean Society of Manufacturing Process Engineers, Vol. 18, No. 8, pp. 74～81 2019.