FEATURE ARTICLE

Evaluation and Testing of the Partial Flow Sampling System for PM Measurement

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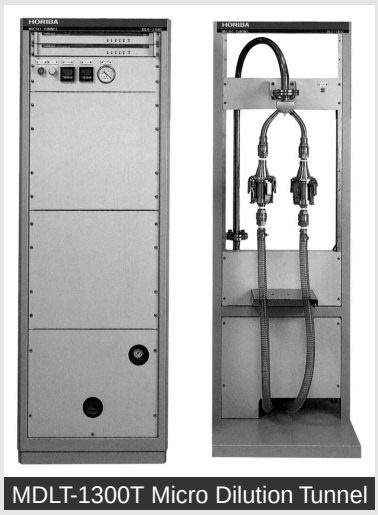
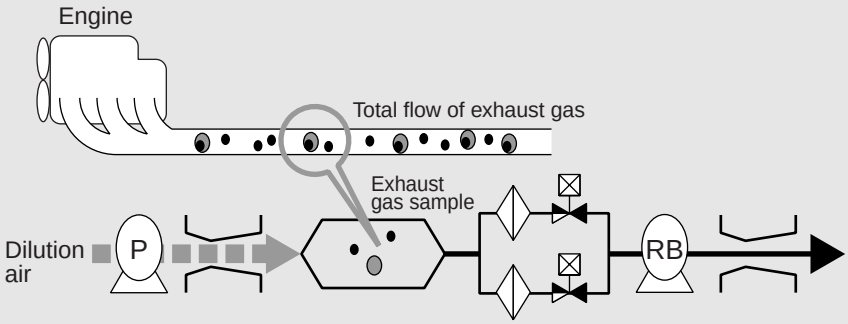
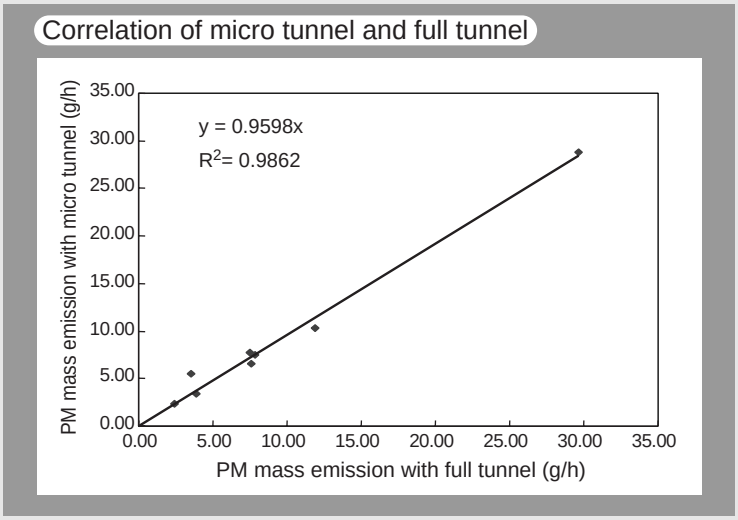


MDLT-1300T Micro Dilution Tunnel





Abstract

For the object to measure particulate matter (PM) from diesel exhaust, there is a growing interest in the feasibility of switching from full dilution method using CVS for steady-state test cycle, to partial flow sampling system for transient for tests. Bringing the partial flow sampling method into general use, it is important to clarify the correlation of PM sampling results with current full dilution method. This paper presents the results of our testing to establish the repeatability of the Partical Flow Sampling System MDLT series developed by Horiba and its correlation with the full dilution sampling.

1 Introduction

As technology advances for reducing particulate matter (PM) from diesel exhaust, a reevaluation of PM measurement methods is taking place. Current regulations prescribe that PM measurement be performed by means of a full dilution sampling method for steady-state test cycle using a filter weighing method; however, this method requires elaborate equipment and does not satisfactorily elucidate the exhaust state, which changes dynamically.

The International Organization for Standardization (ISO) is studying the introduction of PM sampling methods for transient test cycles[1)], and the same testing and research is being pursued in Japan.

Horiba is actively participating in these endeavors, and is pursuing the development and commercialization of the MDLT Series of transient PM sampling instruments, which employ a partial flow sampling system.

2 Basic Configuration of the Micro Tunnel

A dilution sampling system with a tunnel is used for PM collection, and the dilution methods may be classified as full dilution and partial sampling using large size tunnel and CVS, or partial dilution and full sampling using small size tunnel without CVS depending on the dilution and sampling methods. In the case of a full dillution sampling, all of the exhaust gas from the engine is taken into the tunnel and diluted. For this reason, the full dilution method is thought to have high accuracy because there is little probability of PM loss during introducing the gas from engine exhaust. However, massive equipment, including CVS is needed for this method, which means that the testing must be performed in a dedicated laboratory.

The partial flow sampling system collects 1/100 to 1/5000 or less of the total exhaust gas and dilutes it. The equipment is very compact, inexpensive, easy to move, and a CVS is not required. In addition, it can measure in transient mode, and thus many expect that it will become the main method used to measure PM in near future.

The partial flow sampling system shall collect a sample that is an accurate proportion of the entire quantity of exhaust gas. For this reason, high-precision control and measurement of gas flow are key technologies. Horiba's MDLT series achieves proportional sampling through the combination of a piezo valve and a venturi flow meter.

Fig.1 shows the basic configuration of the MDLT series. For details on the hardware such as the principle of operation and flow control, please refer to our article published in Readout No.19[1)].

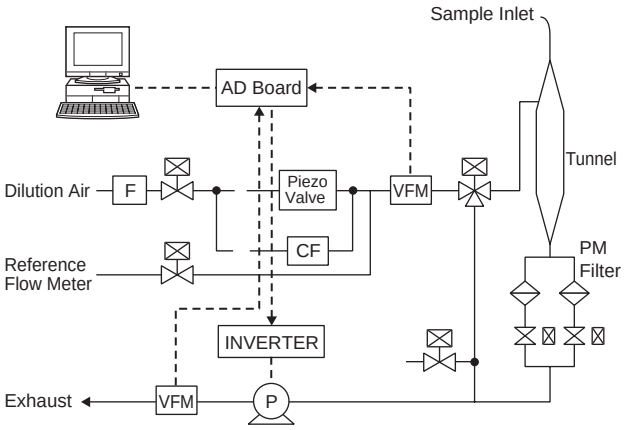


Fig.1 Flow of MDLT-1302T Measurement

3 MDLT Series Reproducibility Testing

To perform accurate PM measurement, testing conditions must be carefully adjusted to avoid the effects of complex dynamics such as absorption and desorption of hydrocarbons and particles in the PM. When the same engine is sufficiently warmed and measurements repeatedly performed, the full tunnel method normally provides a repeatability of approximately ±5%. We therefore tested the repeatability of the MDLT based on the equal test conditions.

3.1 Testing in Steady-State Mode

Running an automotive diesel engine of approximately 2.5 litter volume with a turbocharger and intercooler in J13 mode, we tested the repeatability of the MDLT-1302T Partial Flow Sampling System, which supports steady-state mode, using single filter sampling. The results are shown in Fig.2. A repeatability with error of approximately ±5% or less was obtained, confirming that performance is the same as the full dilution method. Repeatability tests were also performed four times in a couple of days, and the deviation from the average was expressed as a percent.

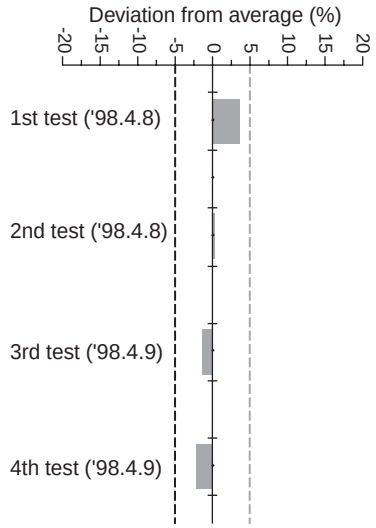


Fig.2 Results of Repeatability Tests of MDLT-1302

3.2 Transient Mode Testing

As stated earlier, the use of transient mode testing for PM measurement is being studied. A new MDLT-1302 Partial Flow Sampling System, which can support transient mode has been developed and tested for repeatability.

The results of our testing enabled us to confirm a repeatability of ±2% as shown in Fig.3. Transient mode testing was performed in U.S. FTP test cycle using a diesel engine rated at approximately 140 hp and of approximately 7 litter volume. We also ran the engine in J13 mode and tested steady-state mode, confirming a repeatability of approximately ±3%.

We discovered that in order to obtain high repeatability throughout the sequence of tests, it is very important to preheat the engine and tunnel parts before testing so as to eliminate the effects of the previous test.

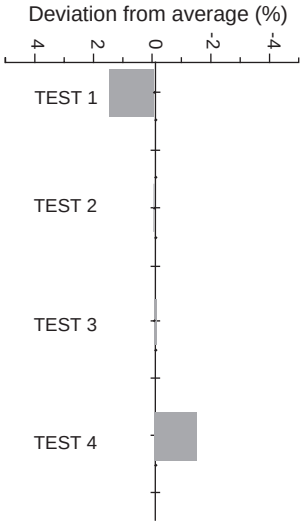


Fig.3 Reproducibility Test Results of MDLT-1302T (Transient Mode Type)

4 Correlation Testing

For the partial flow sampling system to be recognized as a standard method for PM measurement, it is essential that a correlation with the full dilution method using CVS be established. Centering on ISO/TC22/SC5/WG2, the correlation between the two methods has been under study and evaluation since 1999.

We ran a small diesel engine (approximately 1.5 litter volume, direct injection, without turbocharger) in ISO C1 mode and performed testing using both the full dilution sampling and partial flow sampling (MDLT-1302T) methods. The PM mass emission (Fig.4) from the partial flow sampling is slightly less than that with the full tunnel; however, a good correlation (Fig.5) between the two can be seen.

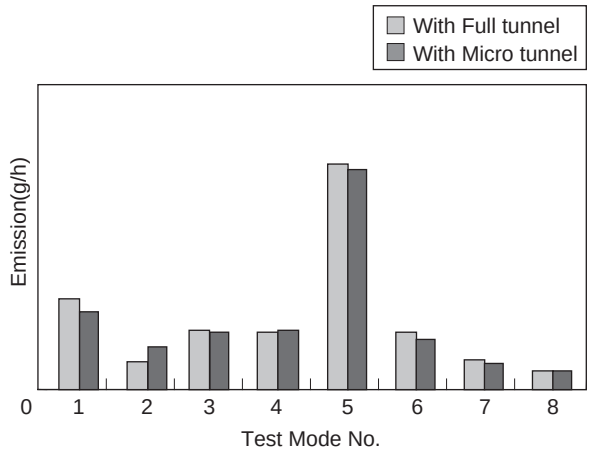


Fig.4 PM Mass Emission for Partial Flow Sampling System and Full-Dilution System When Running in ISO C1 Mode

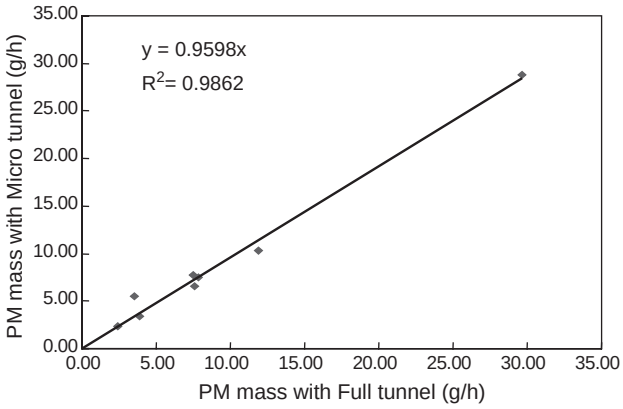


Fig.5 Correlation Between Partial Flow Sampling System and Full Dilution Sampling System

The Japan Automobile Research Institute has performed repeated tests in many more running modes, and reports that the two methods agree to within a range of 95 ± 5% (Table 1)[2].

Regulation	Test Mode	Rerative ratio(μ/full)
WHTC	Transient	0.945
regional Japan	↑	0.973
regional Europe	↑	0.930
regional USA	↑	0.921
MOT-JARI	↑	0.939
ETC	↑	0.880
FTP	↑	0.949
WHSC	steady	0.920
J13	↑	0.983
ESC	↑	0.914

Table 1 Ratio of Micro Tunnel to Full Tunnel Results When Running in Various Modes

5 Parameter Tests

Parameters that may affect the results of PM measurement using a micro tunnel include:

1) dilution ratio
2) dilution/exhaust flow rate
3) tunnel temperature (positive heating or insulation only)
4) transfer tube temperature
5) transfer tube length
6) inner diameter of transfer tube
7) sample probe shape and collection method.

We performed repeated tests varying these parameters and determined that the parameters mutually affect each other. The circumference of the transfer tube is particularly important. As an example, Fig.6 shows measurements demonstrating the effect that different transfer tube conditions have on the correlation when a general-purpose, direct injection diesel engine of approximately 6 litter volume is run in ISO C1 mode.

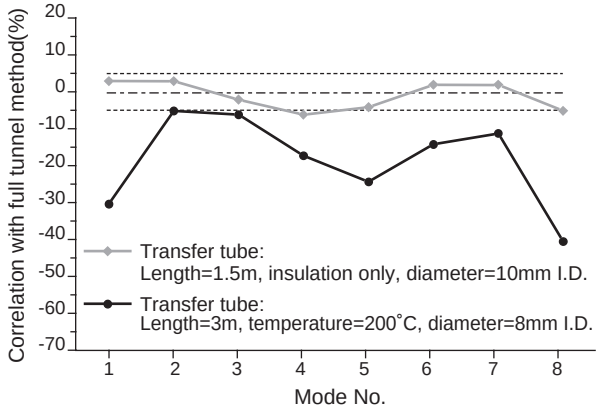


Fig.6 Effect of Transfer Tube

Shortening the probe and slowing the speed of filter surface passage enabled us to obtain good results (Fig.7)[2] for both steady-state (J13) and transient (FTP) modes.

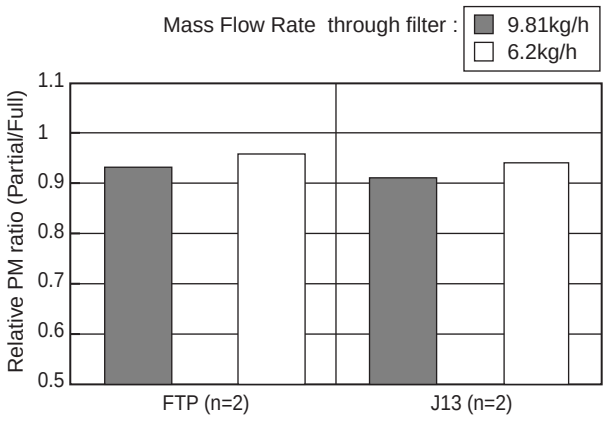


Fig.7 Effect of Diluted Exhaust Flow Rate

6 Conclusion

Various parameter tests and correlation evaluations have successively clarified the engineering issues involved with the micro tunnel method. Based on these achievements, it is highly likely that transient mode testing using a micro tunnel will become the primary method of PM measurement in the near future.

Horiba will continue to participate in testing research projects such as ISO/WG and develop new PM measurement technology. It is our desire to support those who are ceaselessly working to preserve the environment by providing the market with products of high quality and high reliability.

Lastly, we would like to express our deep gratitude to Assistant Director Shunichi Yamazaki and Chief Researcher Kenji Tsuchiya at the Department of Energy and Environment, Japan Automobile Research Institute, who provided us with much advice and cooperation during the evaluation and testing of the instrument.

References

1) Yamagishi, Y., (1999). The MDLT-1302T partial-flow dilution tunnel for transient test cycle PM sampling. Readout No.19, 45–49.
WWW: http://gaiapress.horiba.co.jp/readout
2) ISO/TC22/SC5/WG2 N178.

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