Emissions of volatile and nonvolatile nanoparticles from HDDE running on different gas-diesel mixture fuels

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Background

Diesel engine exhaust contains hazardous gas pollutants and nanoparticles (<100 nm) that have been linked to adverse health effects and environmental impact. Amongst, **diesel engine particles (DEPs)** are a complex mixture of nonvolatile (or solid) and semivolatile components. The emission characteristics of the DEP depend on engine type, speed, load, fuel type, aftertreatment and sampling conditions.

Recently, the need and trend of energy conservation and pollution abatement have given rise to the use of gas fuels (e.g., hydrogen, methane, natural gas) **gas-diesel mixture fuels** in diesel engines. The pollutant characteristics of such dual-fuel system are not well studied, especially for number-based nanoparticles.

With that in mind, this study aims to evaluate the effects of gas-diesel mixture fuels and **diesel particulate filter (DPF)** on the emission characteristics (number/size distribution) of **volatile and nonvolatile nanoparticles** in **heavy-duty diesel engine (HDDE)** exhaust.

Experimental

- The experiments were conducted on a 6-cylinder, 6 L, naturally aspirated, water-cooled, equipped with DPF, direct-injection HDDE of model year 1992 (Hino W06E). The HDDE was tested under two loads, 25% and 75%, under steady cycle on a dynamometer.
- The test fuels included neat diesel (reference fuel), hydrogen-, methane- and natural-gas mixed with diesel.

Items	Contents	Notations
Commercial diesel	Neat diesel	**Pure Diesel**
Hydrogen	H_2:100%	**H100**
Methane	CH_4:100%	**M100**
Biogas A	CH_4:90% + CO_2:10%*	**M90C10**
Biogas B	CH_4:70% + CO_2:30%*	**M70C30**

- Aerosol sampling, dilution and thermal conditioning include:
  - a rotating disc thermo-dilutor (Matter Engineering Model MD19-2E)
  - a thermal conditioner (ThC, Matter Engineering Model ThC-1).
    - The diluted exhaust samples were then measured at ~25 and 300ºC, with which the former is referred to as **"volatile"** and the latter as **"nonvolatile"** particles.
  - a scanning mobility particle sizer and condensation particle counter (SMPS/CPC) system (GRIMM Model 5.500).

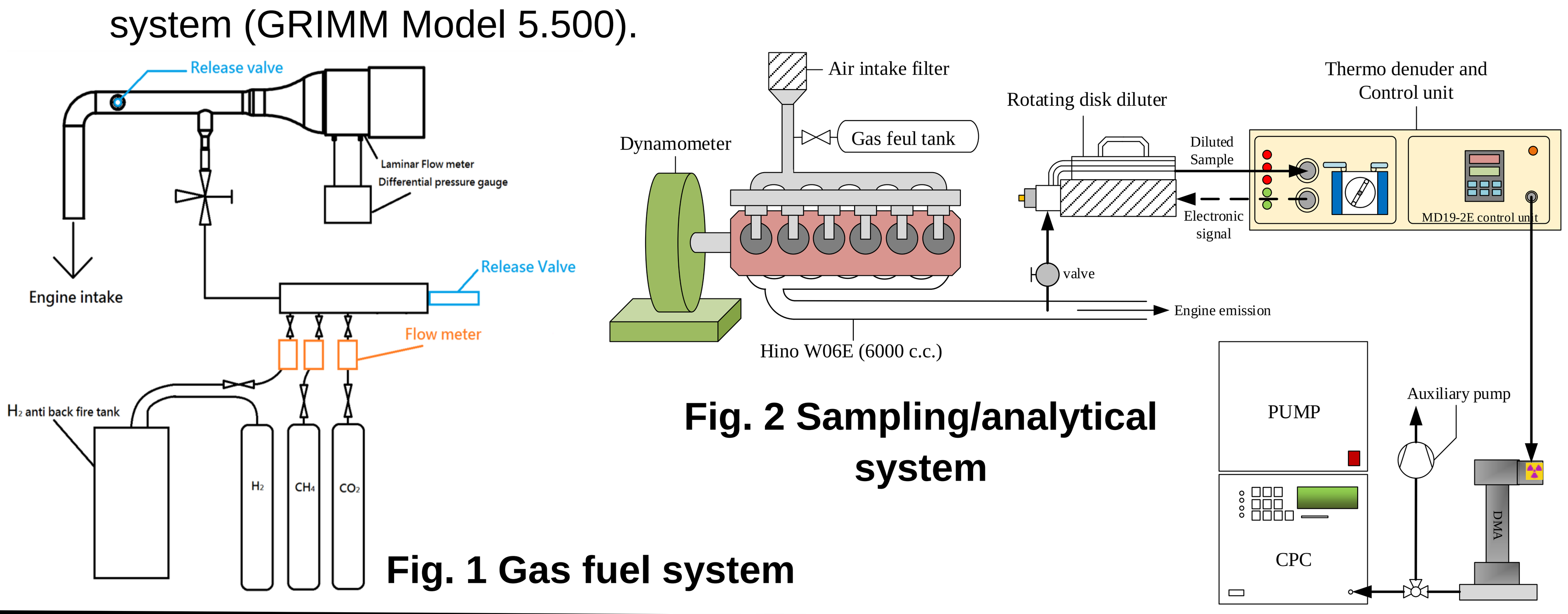

Fig. 2 Sampling/analytical system

Fig. 1 Gas fuel system

Results and Discussion

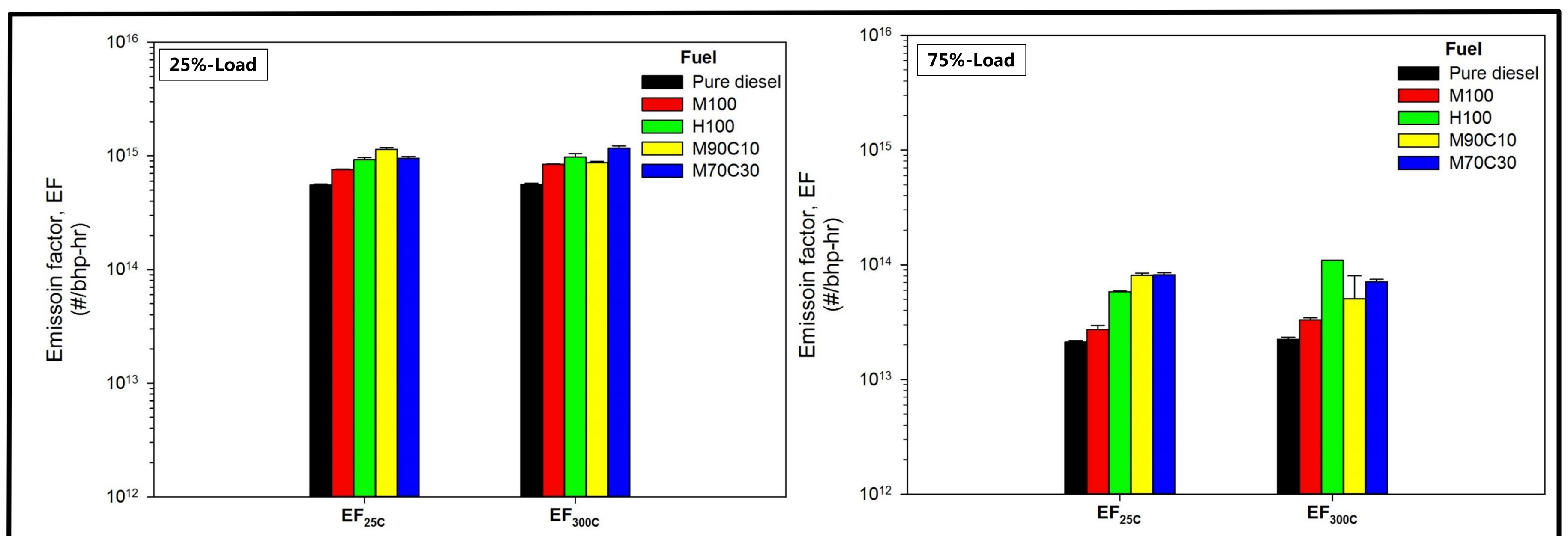

Fig. 3 Emission factors of volatile (EF_{25C}) and nonvolatile (EF_{300C}) particle number for HDDE running on different gas-diesel mixture fuels under 25% and 75% load.

- The use of gas-diesel mixture fuels resulted in increases of both volatile and non-volatile particles number emissions, compared to that from pure diesel fuel. In general, hydrogen and biogases resulted in the highest EF.
- The increase of engine load (mostly in rpm) resulted in decreases of both EF_{25C} and EF_{300C}, but slight increases of particle mode diameters.
- The particle number remained relatively stable before and after heating to 300ºC, indicating little volatile materials on the nanoparticles, except H_2.

Results and Discussion

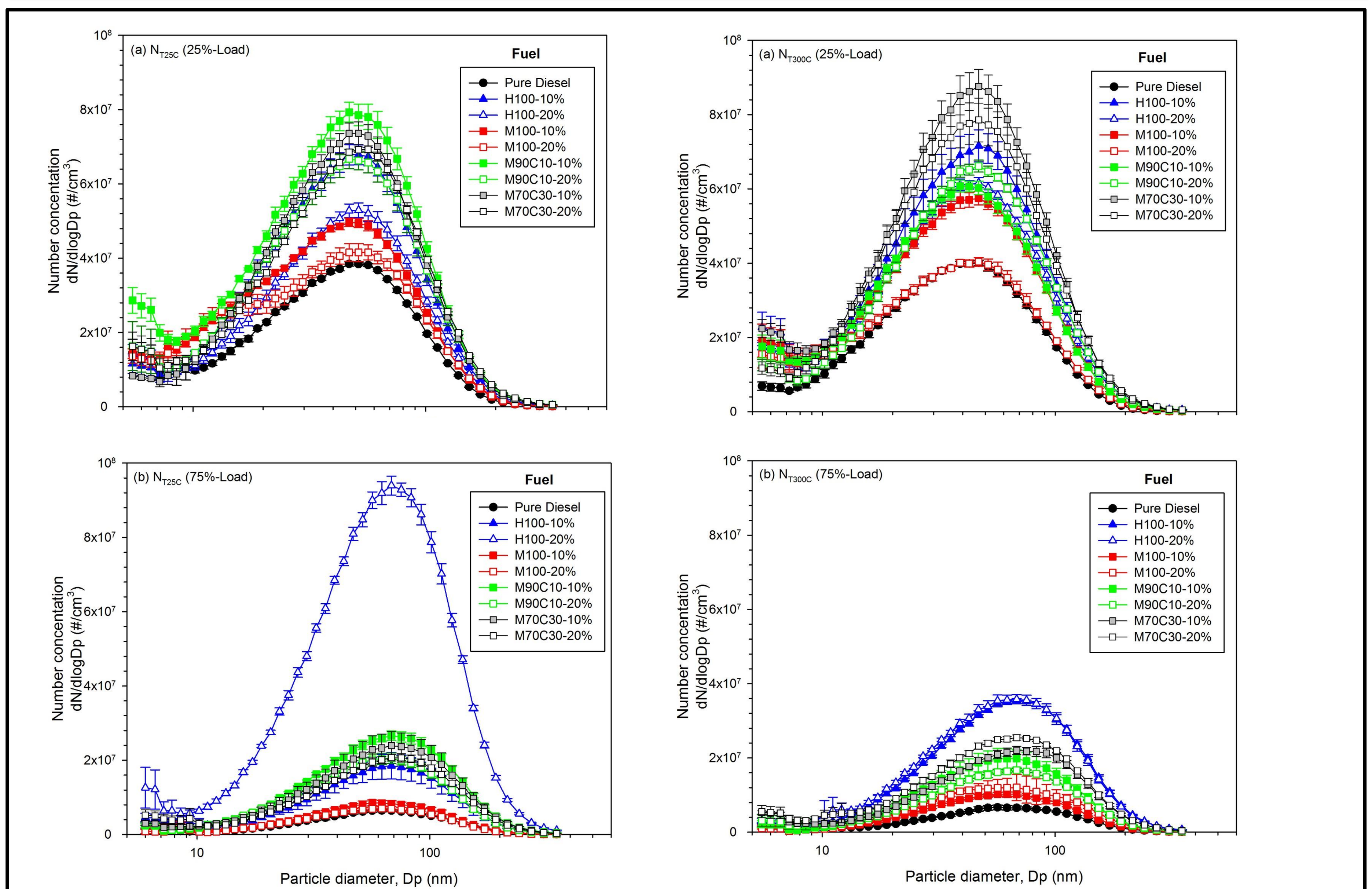

Fig. 4 Size distributions of volatile (N_{25C}) and nonvolatile (N_{300C}) particle number for HDDE running on different gas-diesel mixture fuels under 25% and 75% load.

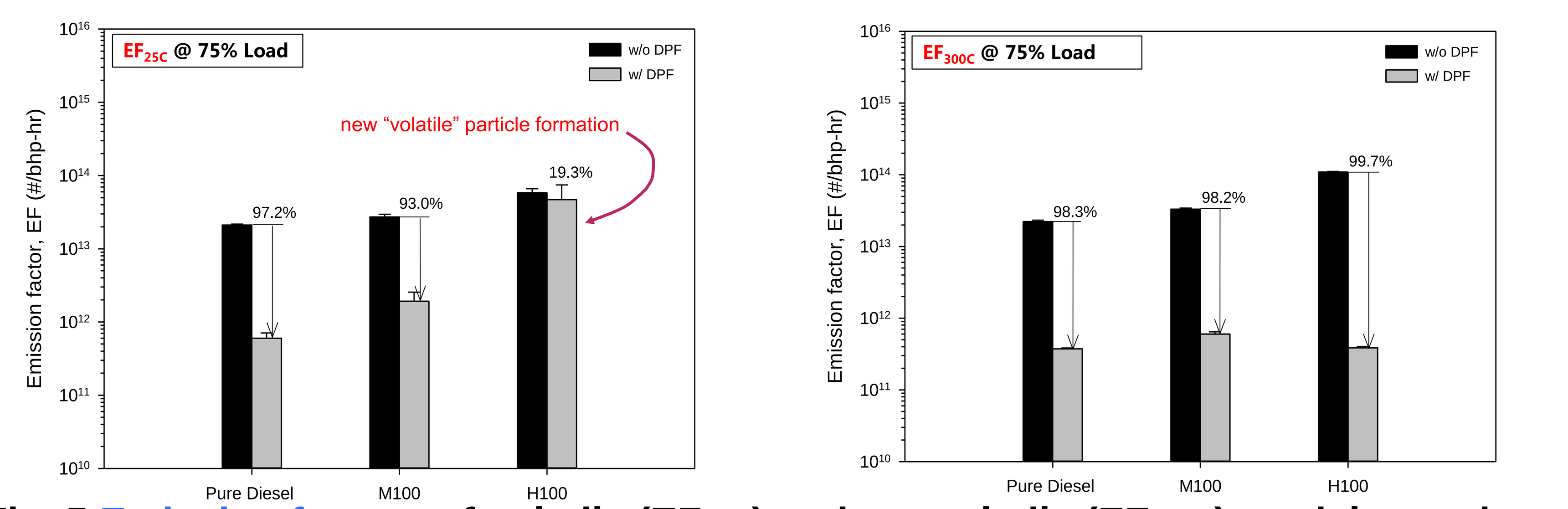

Fig. 5 Emission factors of volatile (EF_{25C}) and nonvolatile (EF_{300C}) particle number with and without DPF under 25% and 75% load.

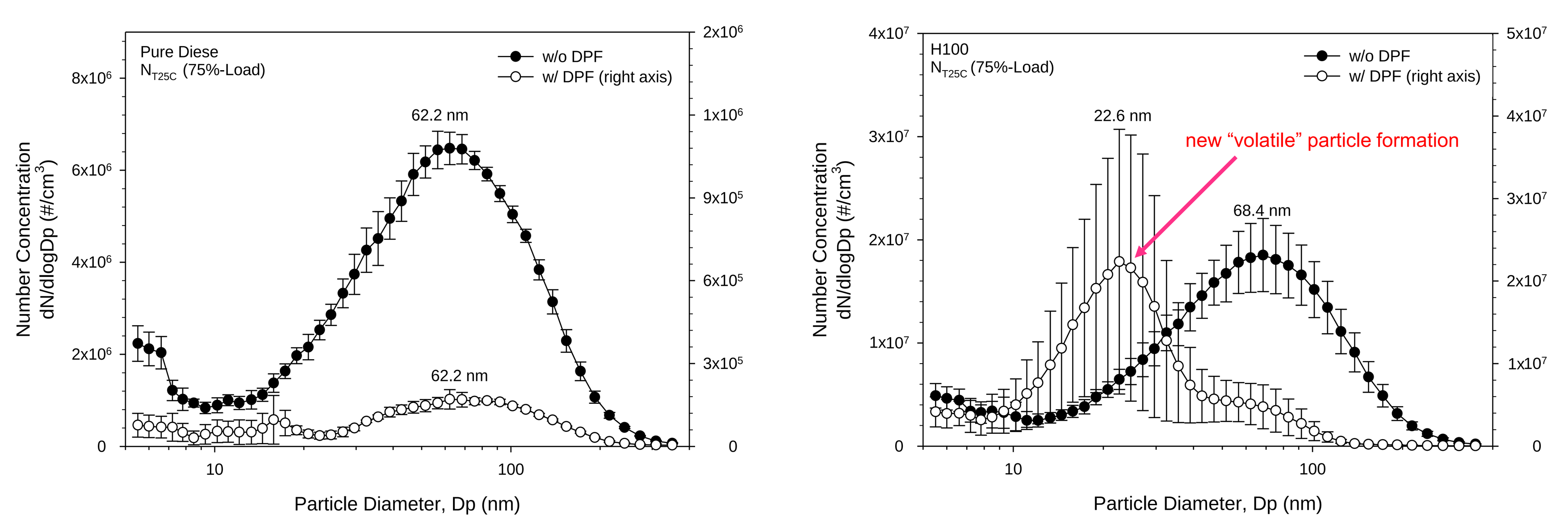

Fig. 6 Size distributions of volatile (N_{25C}) particle number with and without DPF under 75% load.

Conclusions

- The use of gas-diesel mixture fuels resulted in increases of both volatile and non-volatile particles number emissions, compared to that from pure diesel fuel, but have negligible effects on the size distribution. Such observations may be related to the replacement of O_2 by the fuel gas, decrease of A/F ratio, and hence more incomplete combustion or unburned fuel, indicated by the increase of HC emissions.
- The DPF is highly effective for the removal of nonvolatile nanoparticles, regardless of the engine load and gas-diesel fuel type, but not necessarily for volatile nanoparticles.
- The increase of HC emissions from the use of gas fuels (H_2 and CH_4) may also increase the likeliness of new "volatile" particle formation downstream of the PDF.
- The increase of engine load (mostly in rpm) resulted in decreases of both volatile and non-volatile particles number emissions, but slight increases of particle mode diameters. This may be attributable to the high particle number and thus stronger coagulation growth under high load.
- The nanoparticles emitted under the tested conditions contained little volatile materials on the nanoparticles, except H_2.
- The above results highlight that the benefits of gas-diesel mixture fuels for aerosol mass reductions are possibly accompanied by the increase of aerosol number emissions.

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