Potential of nano-particle formation by atmospheric species and vehicle exhausts

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Abstract

A lot of laboratory studies and field researches have been reported on nano-particle from vehicles in terms of human health. However, information is still not enough to understand particle size distribution observed on the rode side.

In this study, detail analysis has been done on formation of nucleation-mode particle under various driving conditions by the differential mobility particle spectrometer (DMS) which allows the transient cycle measurement. PPFD-II is used for dilution of exhaust to have good repeatable result by stable humidity, temperature and flow control of dilution air. Gasoline passenger vehicles with multi- port injection system and spark ignition direct injection system, light duty diesel trucks and heavy duty diesel engines were investigated in terms of particle size and driving conditions. Adding to usual driving cycles, cold start cycle, high speed driving, exhaust braking system and blowby were investigated. Potential of nucleation-mode particle formation by background species and emitted particle were also investigated. As the background species, automotive related inorganic chemicals such as ammonia, nitrogen dioxide, sulfur dioxide were selected. Influence of plume mixing by different type of vehicles on formation of nucleation-mode particle was also investigated. This poster focuses on the result of the analysis of transient cycle of light duty diesel truck and plume mixing gasoline with commercial diesel vehicles.

Some nucleation particle starts to form at the every point of fuel cut i.e. shift change, braking. Rapid acceleration causes the increase of exhaust temperature , flow rate of exhaust and fuel enrichment, then forms the nucleation particles. High speed also causes the increase of the temperature of exhaust pipe then nucleation mode seems to form by evaporation of adsorbed hydrocarbons inside of the wall. Plume mixing of different type of vehicle, i.e. gasoline and diesel vehicle doses not cause significant change of size distributions.

Introduction

The study of nano-particle from vehicles is on going in the world. Detail behavior of nano-particles seems to be clear by advanced instrumentation. Results of our past study for diesel vehicles and engines shows that the condition of nano-particle formation are ; idling, high exhaust temperature with oxidation catalyst and high sulfur contents fuel, deceleration period when fuel is cut etc. Nucleation particle caused by sulfur in fuel for diesel vehicle with oxidation catalyst is not a serious issue now. This kind of particle very depends on the dilution ratio and relative humidity. If the sulfur content of fuel is 28 ppm and relative humidity is 80% at 20 ˚C, nucleation particle is not formed by dilution ration of over 80[1)]. Contents of sulfur in recent market fuel in Japan is below 10 wtppm. No particle formation is expected with real-world dilution ratio any more. Many laboratory test results were done by dilution of filtered controlled air. However, on the roadside, there are many species in the air as a background. In some case, gasoline vehicles emits ammonium which will be a source of aerosols in the atmosphere. Therefore we should consider these species also as a factor of nano-particle formation.

Exhaust particle and gases from vehicles could have potential to react with atmospheric species on the road when these exhaust shredded into the air in a short time. This paper shows the results of diatil analysis of bench test and plum mixing by gasoline vehicle and diesel vehicle.

Experimental setup

Research for nano-particle formation from vehicles and engines were conducted with DMS500, partial flow diluter (PPFDII) and engine dynamometer or chassis dynamometer. Experimental setup is shown in Fig.1. Typical vehicles and engines are selected as shown in table 1. Driving conditions are transient modes (JC08 for LDV and JE05 for HDE/V) and steady state. Dilution air is controlled at 25°C and 50%RH. Dilution ratio is fixed at 200. Plume mixing of diesel vehicle with gasoline vehicle are done with the tunnel of 1 m in diameter by

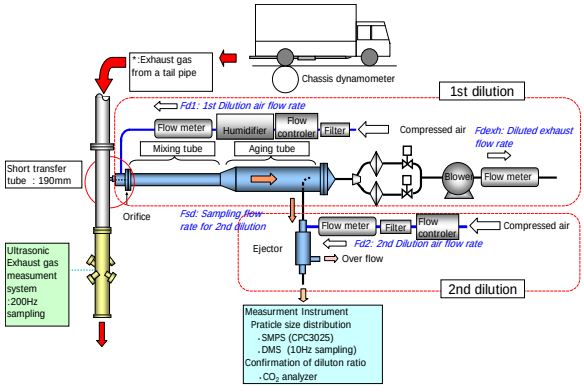


Fig. Experimental setup for C/D and E/D test

diluting with HEPA filtered ambient air in fig.2.

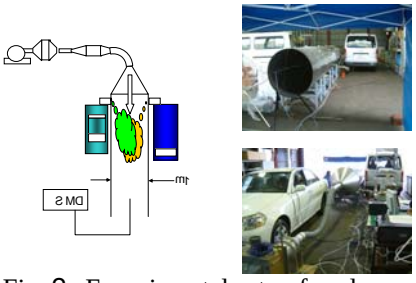


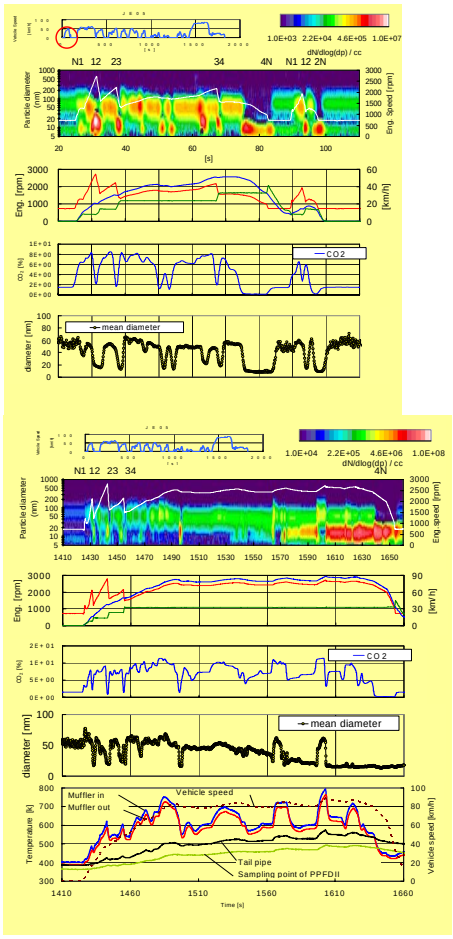
Fig. 2 Experimental setup for plum mixing

Table 1 Test vehicles and engine

Symbol	Vehicle or Engine	Exhaust gas regulation	Fuel S	Gross vehicle weight	Displacement	Fuel system	After treatment	note
			wtppm	kg	L			
G	Gasoline Passenger car	2000 regulation 25% reduction	10	1655	2.0	MPI	TWC	Plum mixing
D1	Diesel comercial vehicle	2003	6	3215	3.0	DI	none	Plum mixing
D2	Diesel comercial vehicle	1998	6	3165	2.5	DI-Common Rail	OxiCat	Plum mixing
D3	Diesel Passenger car	1998	28	2125	3.0	DI-Common Rail	OxiCat	
D4	Diesel Truck	1998	28	5675	5.2	DI	none	
E	Diesel Engine	1999	28	-	8.6	DI-Common Rail	none	

Results and discussion

Nucleation mode particle are formed under the conditions of - Idling. (D1,D2,D4,E) - High exhaust temperature driving with oxidation catalyst and high sulfur contents diesel fuels. (D2) .This type of nucleation strongly depends on dilution ratio ,relative humidity and sulfur contents in fuel but no more observed with commercial fuel (below 10 wtppm sulfur)- Deceleration with fuel cut (shift change, accelerator off, engine braking etc). (D4, E)(Fig. 3).These particle can be reduced by after- treatment devices [(1)]. Plum mixing of different type of vehicle exhaust is examined. Even though, ammonia exists in the plume of gasoline vehicle, no significant differences are observed between measured distribution and simply calculated distributions in Fig.4.



■: Shift change and fuel cut ■: Fuel cut ■: Rapid acceleration ■: High temperature period

Fig.3 Nano-particle formation during transient cycle

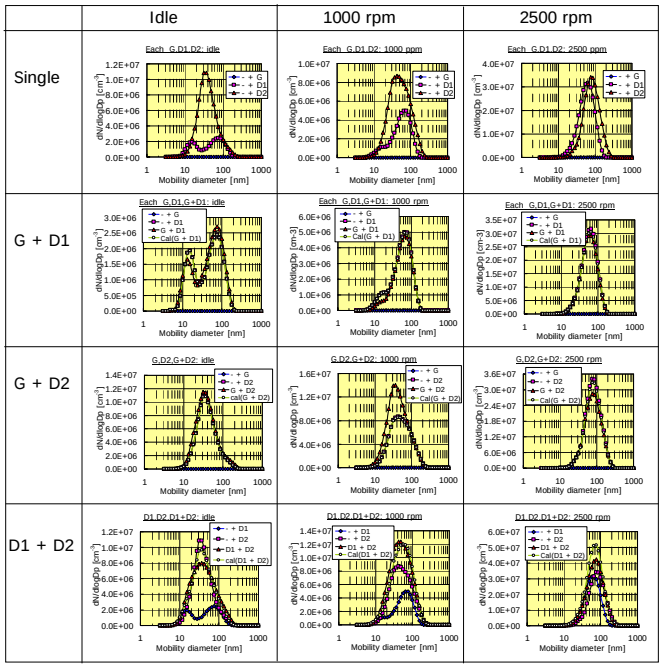


Fig. 4 Plume mixing of gasoline vehicle with diesel vehicle

Conclusion

1. Nucleatin mode particles are emitted from vehicles into the atmosphere under the condition of idling, high speed, fuel cut period i.e. shift change, engine breaking from diesel engines without after treatment.

2. Plume mixing of gasoline vehicle with diesel vehicle does not form distinguished nano- particles.

reference

1)S.Sasaki et.al,8th ETH nanoparticle conference

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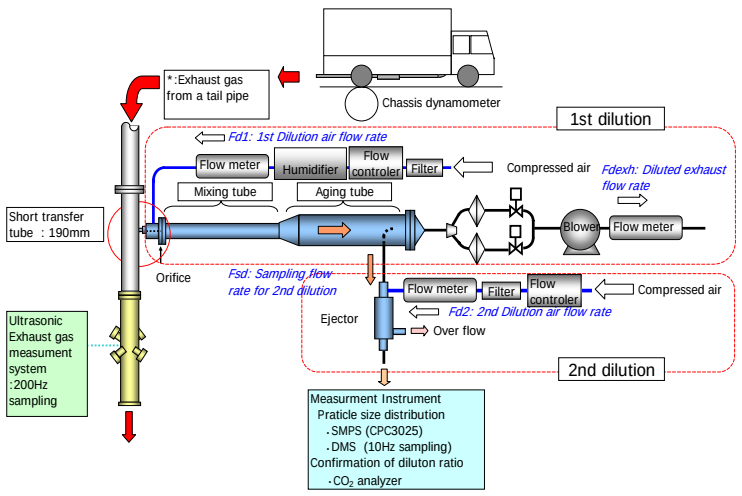

Fig.1 Experimental setup for C/D and E/D test

Fig.2 Experimental setup for plum mixing

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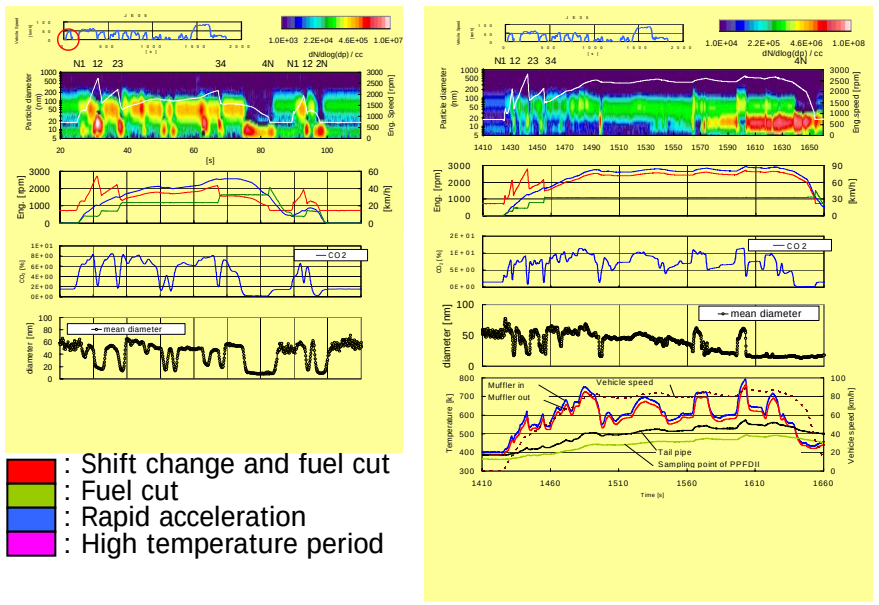

Fig.3 Nano-particle formation during transient cycle

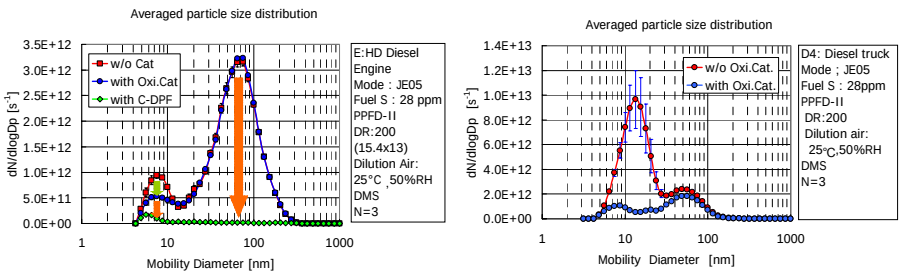

Fig.4 Reduction of nano-particles by after-treatment

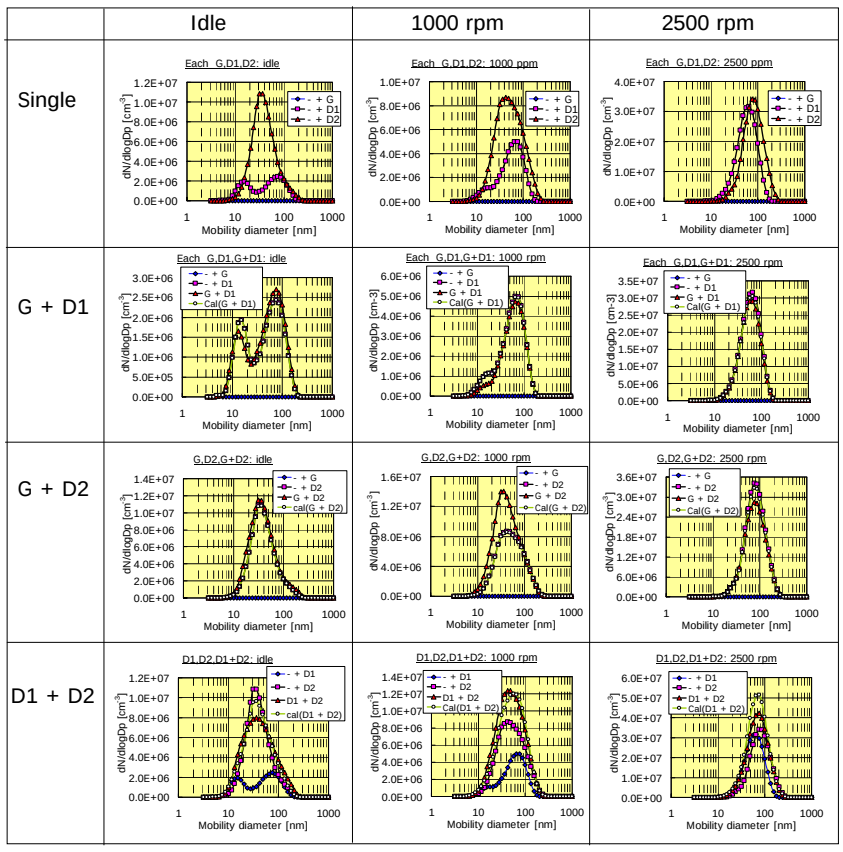

Fig. 5 Plume mixing of gasoline vehicle with diesel vehicle

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- Deceleration with fuel cut (shift change, accelerator off, engine braking etc). (D4, E)(Fig. 3).These particle can be reduced by after- treatment

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