Effect of temperature on oxidation reactivity and nanostructure of particulate matter from a China Ⅵ GDI vehicle

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Introduction

- Particulate matter (PM) emission becomes the most concerned topic in China, the hazardous impact of PM2.5 on human's health.
- The demand for GDI vehicles has been increasing, which derive more PM than traditional PFI gasoline vehicles.
- Gasoline powered vehicles face the stricter limitations of PM and PN .
- Analyze the oxidation reactivity and nanostructure of PM could provide a theoretical basis for gasoline particulate filter regeneration further.

Methodology

- The vehicle used for this study meet the China Ⅵ emission standard, which is equipped with a 1.4 L, 4-cylinder, turbo charged GDI engine.
- The tested vehicle was mounted on the chassis dynamometer for running WLTC (Worldwide harmonized Light vehicles Test Cycle).
- The test system includes the chassis dynamometer, jet diluter, single channel particle collection device, and the offline analysis equipment includes TGA and TEM.
- The sample was heated from 30 ℃ to 800 ℃ at a heating rate of 5 ℃/min in TGA. The nanostructure of PM is determined by TEM analysis.

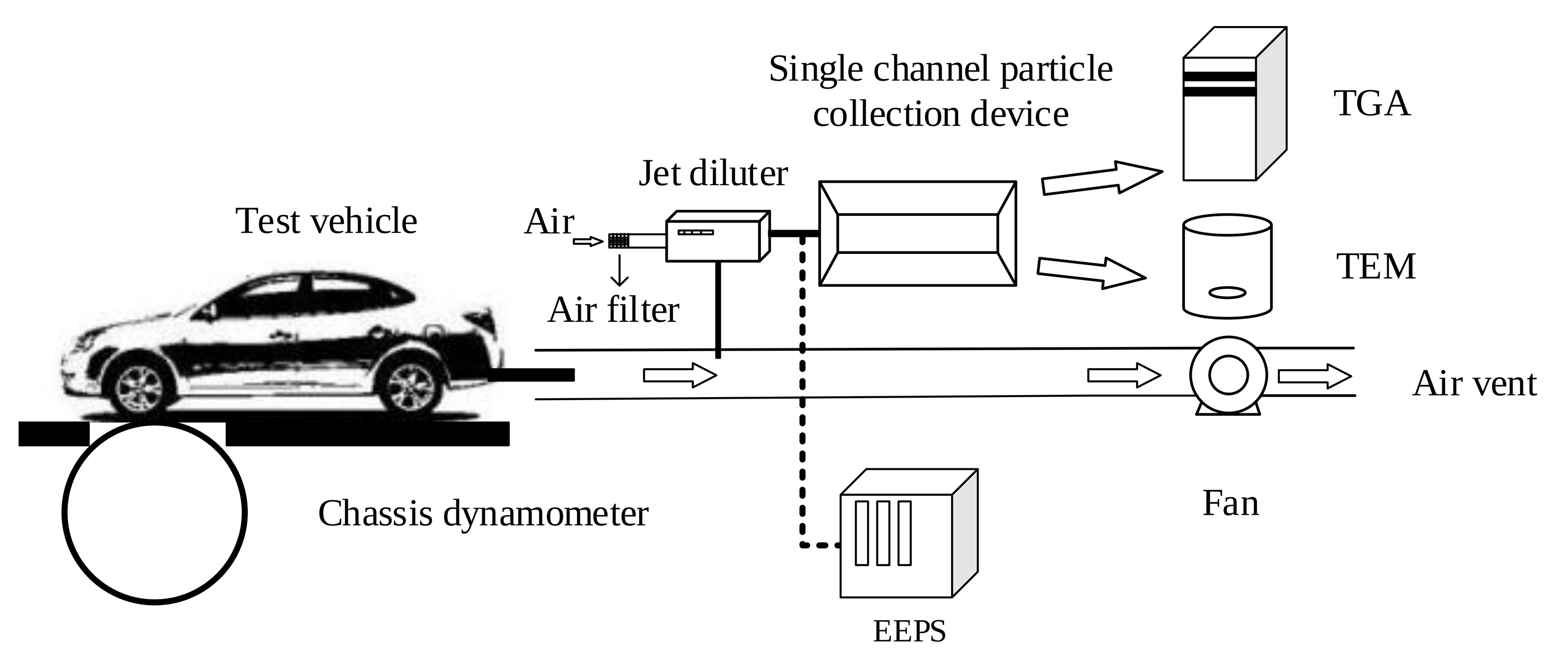

Fig.1 Schematic of the experimental setup

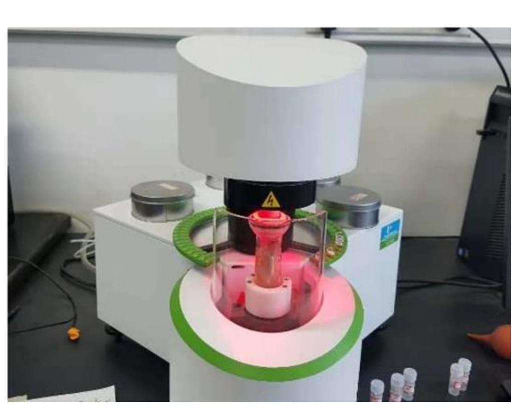

Fig.2 TGA and TEM

Oxidation kinetic calculate formulations:

① **Arrhenius:** $\ln\left(-\frac{1}{m}\frac{dm}{dt}\right)=\ln[k(T)]=-\frac{E}{R}\left(\frac{1}{T}\right)+\ln A$

② **Coats-Redfern:** $\ln\left[\frac{1-(1-\alpha)^{1-n}}{(1-n)T^2}\right]=\ln\left[\frac{AR}{\beta E}\left(1-\frac{2RT}{E}\right)\right]-\frac{E}{RT}$

③ **ABSW (Achar-Brindley-Sharp-Wendworth):** $\ln\left[\frac{d\alpha}{(1-\alpha)^n}\right]=\ln\left(\frac{A}{\beta}\right)-\frac{E}{RT}$

Results

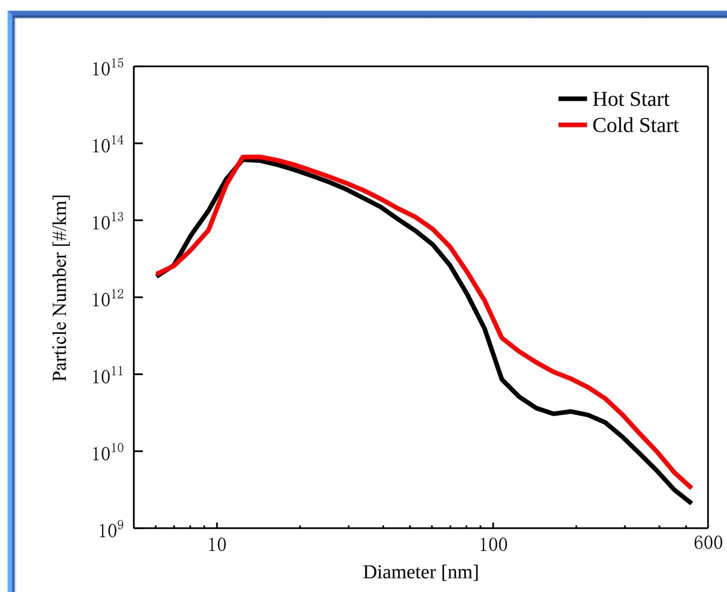

Fig.3 Size-number distributions of particles

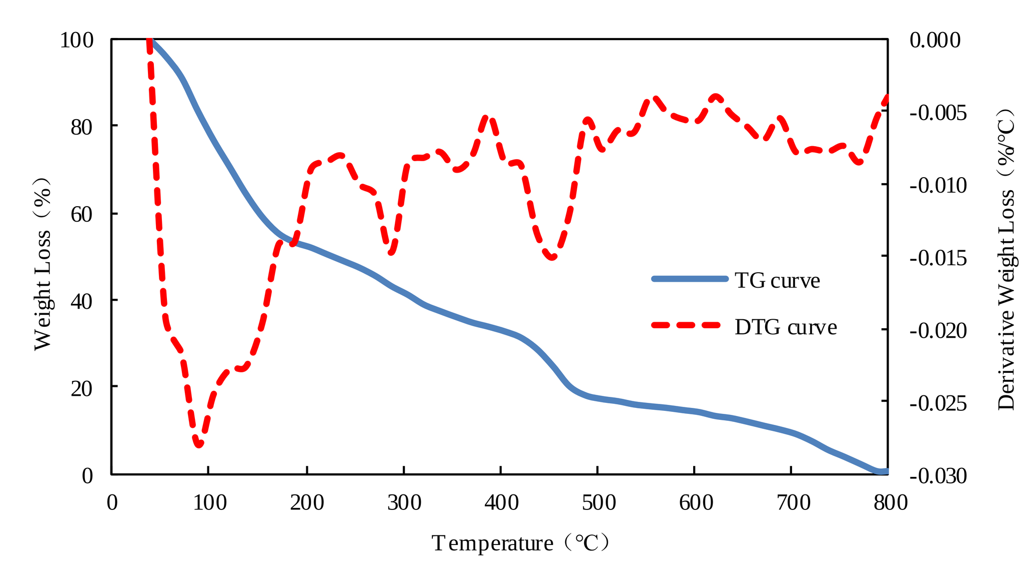

Fig.4 Thermogravimetric analysis of particles

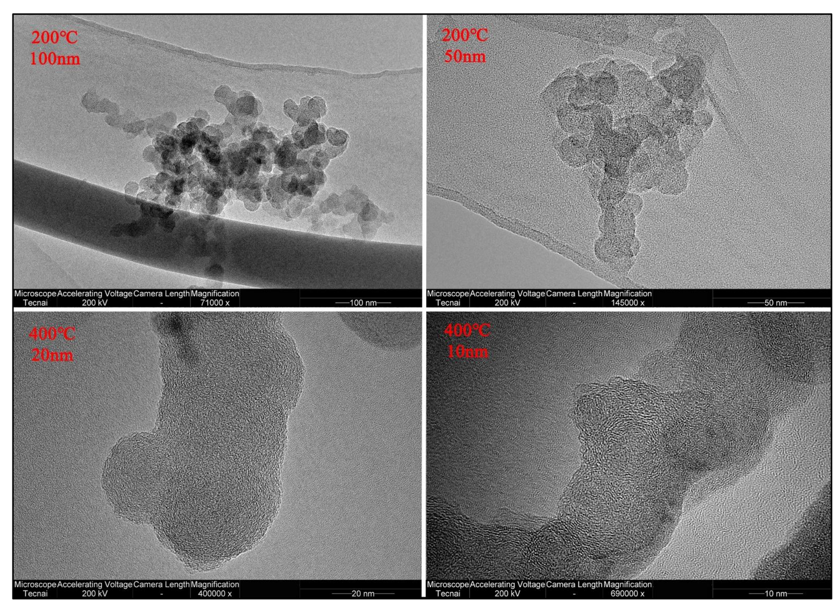

Fig.5 TEM microphotographs of oxidized particles

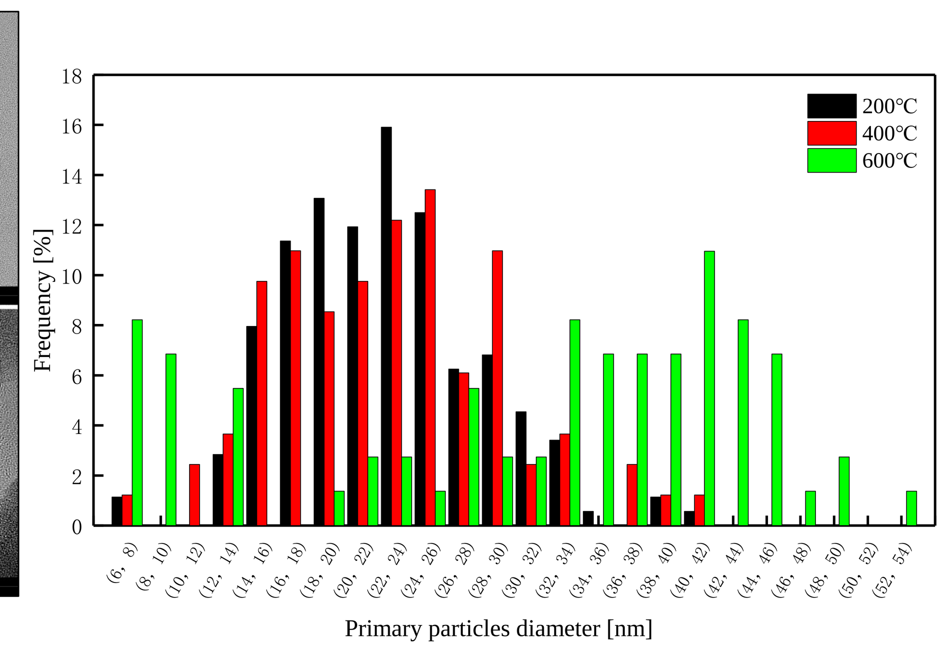

Fig.6 Primary particles size

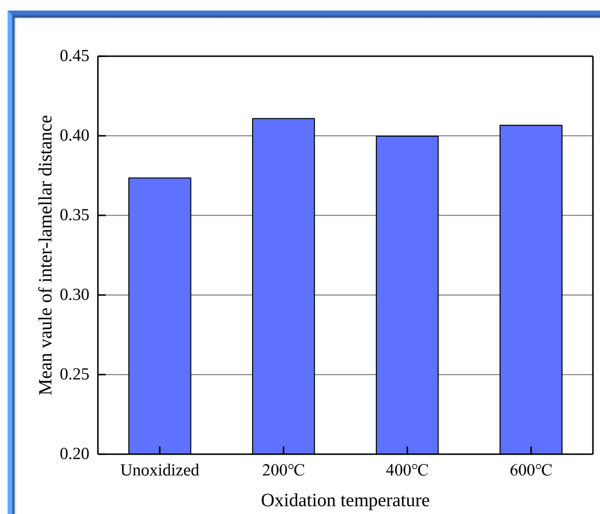

Fig.7 Inter-lamellar distance

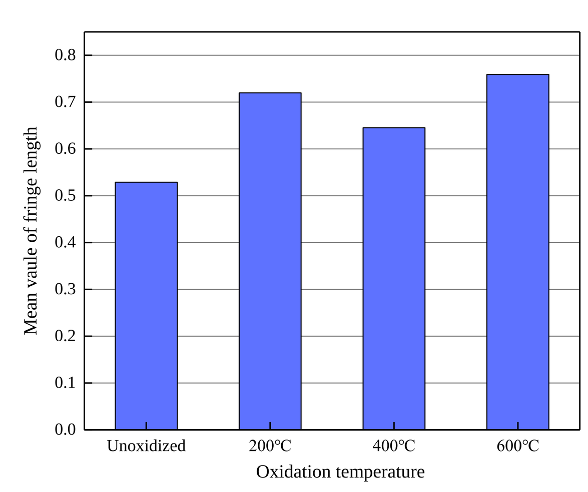

Fig.8 Fringe length

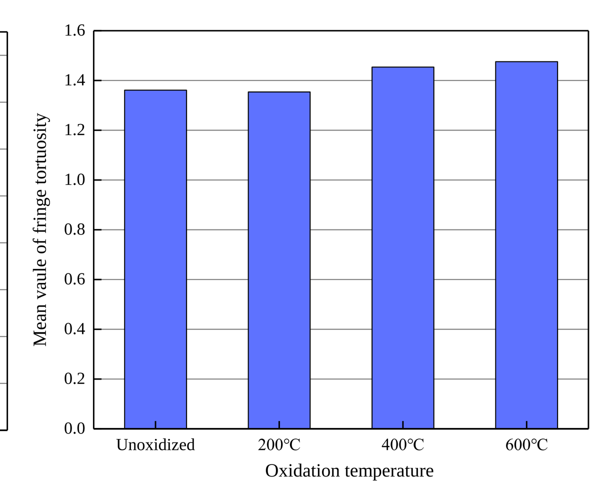

Fig.9 Fringe tortuosity

Table.1 Kinetic parameters of oxidized particles

Temperature	Methodology	E($kJ\cdot mol^{-1}$)	A($Pa^{-1}\cdot s^{-1}$)	R^2
400-600℃	Coats-Redfern	91	5.88×10^{16}	0.88
	ABSW	114	1.9×10^{7}	0.97
600-800℃	Coats-Redfern	133	7.52×10^{10}	0.91
	ABSW	170	8.86×10^{7}	0.85

Table.2 Fractal dimension of oxidized particles

Temperature	Fractal dimension
200℃	1.886
400℃	2.2
600℃	2.104

Conclusion

- The peak of particles number is 1.49 x 10^{12} for cold-start cycle, which is located about 15 nm, a number decrease presents between 12 nm and 143 nm during warm-start cycle.
- Oxidation reactivity of particles is measured by activation energy (E) which is found to be in the range of 114-173 $kJ\cdot mol^{-1}$ with different preexponential factors (A) for two temperature sections. Nanostructure is presented as the microphotographs and structural parameters under different oxidation temperatures.
- With the increase of oxidation temperature, the activation energy of particulate matter increases and nanostructure becomes denser, the optimum oxidation temperature range is between 400 and 600℃.

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