Size Dependence of Morphology and Nanostructure in Ultrafine Particles Emitted by a GDI Engine Operated with Various Fuel Injection Strategies

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Introduction and Motivation

The gasoline direct injection (GDI) engine is a becoming an increasingly popular power plant choice for light-duty vehicles, owing to the concept's increased power density and fuel economy. However, GDI engines have been observed to emit large numbers of particles, with a large fraction below 100 nm in mobility diameter [1]. In effort to reduce these emissions and to further improve efficiency, manufacturers will likely move to multiple fuel injection strategies, following the advancements made in diesel engine technology. The size-specific structure of the particles is often overlooked in studying IC engine combustion, but health effects research has shown that size and structure are indeed important factors to consider [2]. Therefore, there is a need to understand how the operation strategy of future GDI engines will affect particle structure, which will benefit the aerosol, combustion, health effects, and regulatory communities.

Experimental and Data Analysis

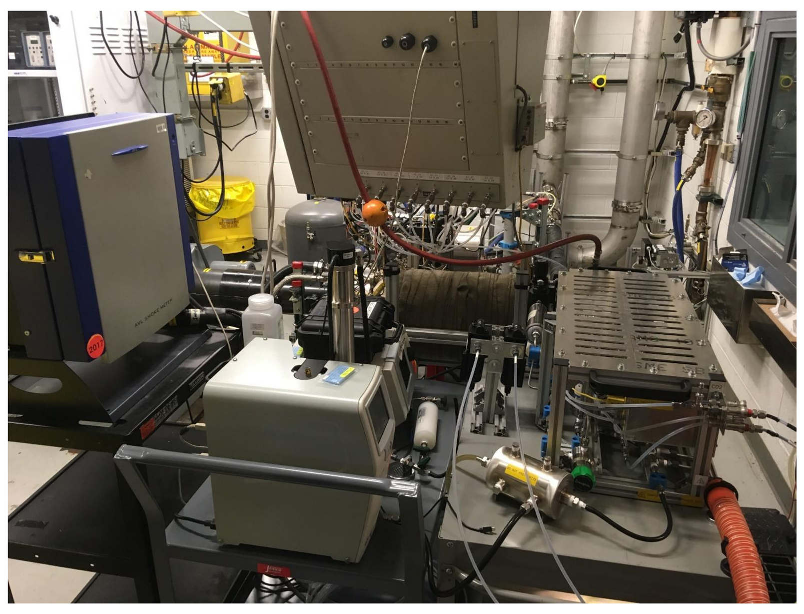

Fig. 1: Test Article.

The test article was a single-cylinder research engine (SCRE) comprising an FEV Systemmotor crankcase and a stock 1.6L Ford EcoBoost cylinder head (see Fig. 1). The engine management was provided by the RPECS system from Southwest Research Institute (SwRI). The test matrix is shown in Table 1.

Particle size distributions (PSDs) were taken with a TSI 3082 electrostatic classifier and 3776 CPC, and these PSDs were used as a guide to select the specific sizes to examine. Five size cuts were taken (mode, ±30 nm from the mode, and ± 60 nm from the mode), using the classifier and a Naneos Partector TEM sampler.

	Injection timing [CAD BTDC]								
Injection pressure [bar]	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
50	330	270	200	270	200	120	180	120	60
200	330	270	200	270	200	120	180	120	60

8 bar Triple 1	8 bar Triple 2	8 bar Triple 3	8 bar Triple 4	8 bar Triple 5	8 bar Triple 6

Table 1: Test Matrix.

The size-selected particle samples were first imaged in both low resolution (LR) and high resolution (HR) on a JEOL 3011 TEM at the Michigan Center for Materials Characterization, (MC)[2]. For LR analysis, images were prepared using proprietary code and the FRAKTAL fractal dimension analysis program [3]. HR images were processed using modified codes developed by Kuen et al [4].

Selected Results

Mode – 60 nm	
Mode – 30 nm	
Mode	
Mode + 30 nm	
Mode + 60 nm	

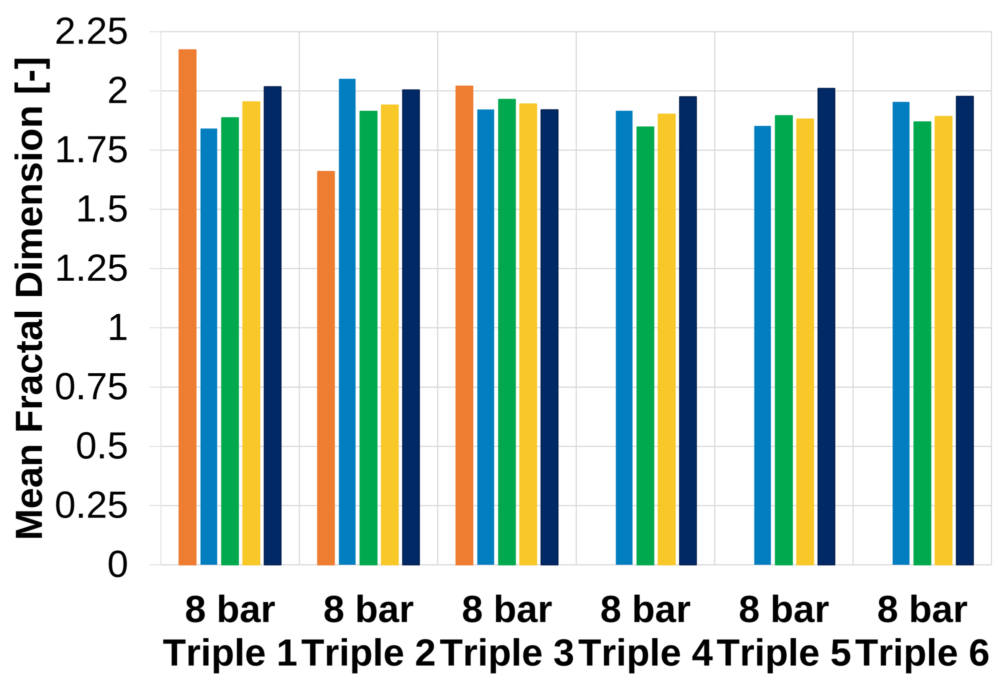

Fig. 2: Mean fractal dimension

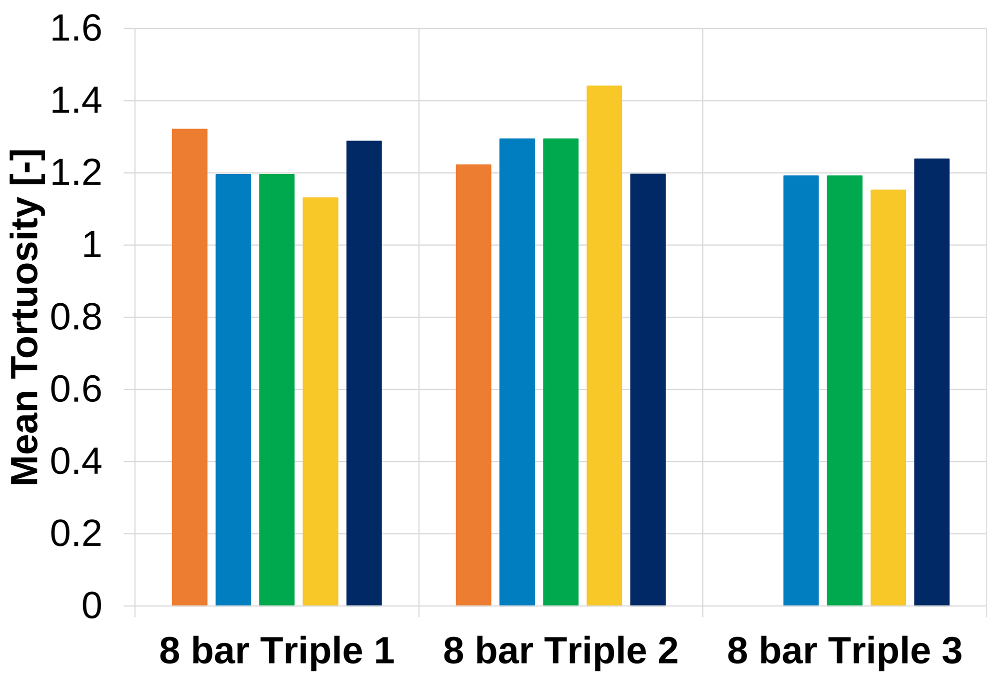

Fig. 3: Mean tortuosity for test points 1 - 3

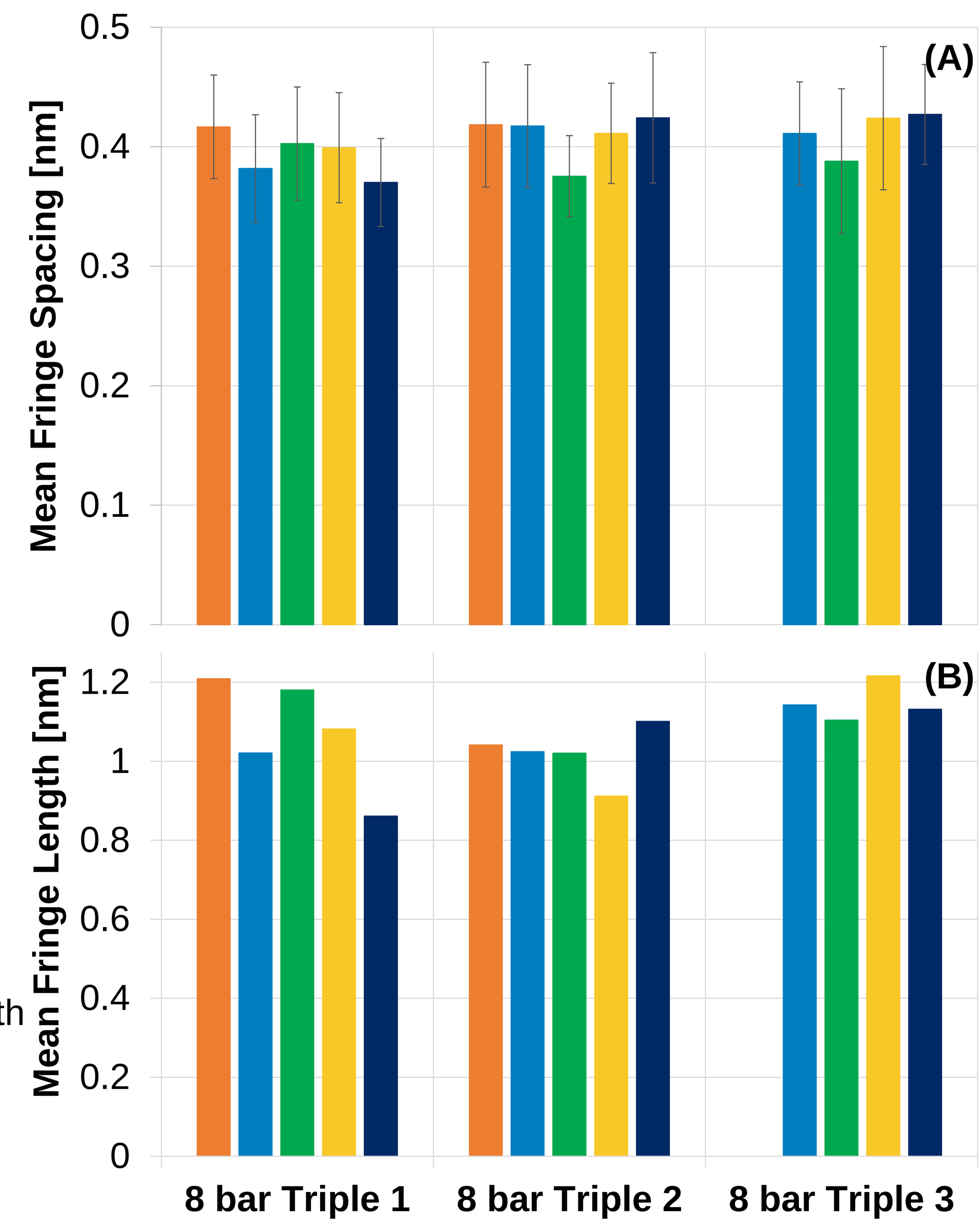

Fig. 5 (right): Histograms for test points 1 - 3
(A): Mean fringe spacing (top)
(B) Mean fringe length (bottom)

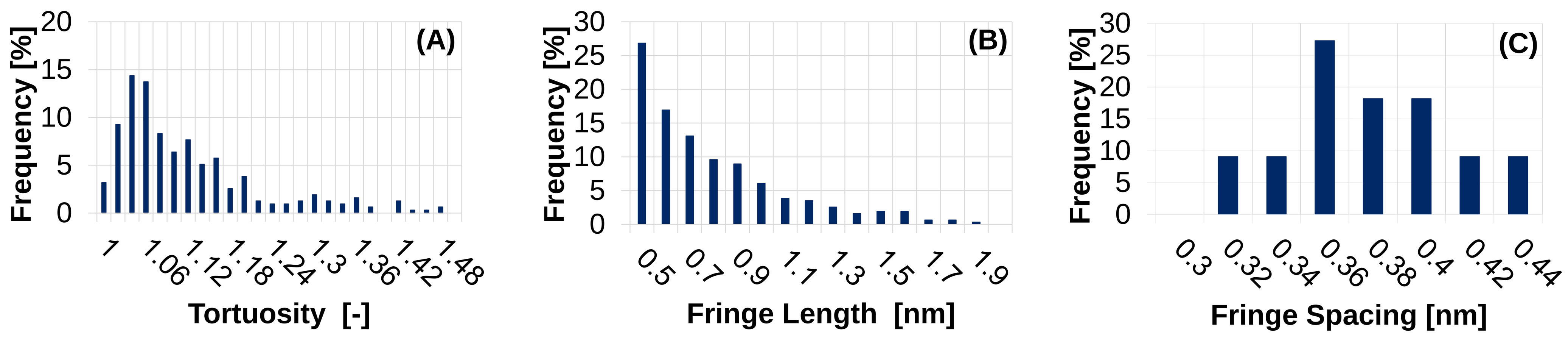

Fig.4 Example histograms for 8 bar triple 1, 150 nm (mode + 60 nm cut):
(A): Tortuosity histogram (left) (B) Fringe length histogram (center) (C) Fringe spacing histogram (right)

Conclusions

- There were few clear tends, indicating a low sensitivity to the injection strategy that were selected
- The small fringe lengths and tortuosities indicates that, on average, there was a lack of long-range order in the soots
- The mean fraction dimensions around 2 suggest that the particles were very likely to be branched rather than linear
- Large standard deviations in the measurements (30 % or more) suggest that one number (e.g., the mean) is not optimal to summarize the results

References and Acknowledgements

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