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Generation of Combustion Soot Particles for Calibration Purposes

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Introduction

Soot particles from combustion are detrimental for the health and have negative influences on the environment. The controlling of particulate emission and immisson has become an important public concern which makes intensive studies of soot particles and the improvement of soot measuring techniques more necessary.

To study the characteristics of soot particles and for the calibration of soot measuring devices, diesel engines have been often used as "soot generator". As the characteristics of soot particles from diesel engine cannot sufficiently adjusted by controlling the engine parameters, the reproducibility of the soot generation from diesel engine is not steady. To improve the study of soot particles and to develop a calibration basis for soot measuring instruments there is a demand on the development of a new method for generating combustion soot particles of definite particle characteristics, e.g. the particle size distribution and the number concentration of particles etc., with good stability and reproducibility. The new soot generator must be able to provide possibilities for varying the characteristics of the output soot particles. With regard to the practise applications, the yield of soot particles must be high enough to meet the field situations. Such soot generators can also be used for testing soot filter or to simulate emission and immission situations.

Construction of the new soot generator

The initial idea how the new soot generator should work is based on the following considerations:

1. Soot formation occurs when hydrocarbons are pyrolysed by heating without oxygen.
2. Based on the new hypotheses [1] for soot formation in diffusion flames and on the experimental observations [2] [3], the conclusion can be made that the soot formation in a diffusion flame extends toward oxygen.
3. Soot particles formed on the fuel side of a diffusion flame follow the gas-phase streamlines. They are decomposed and subsequently oxidised while passing through the flame surface.

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1. L. Jing, Charakterisierung der dieselmotorischen Partikelemission, Dissertation, 1997
2. J. Zhang and C. M. Megaridis, Soot Microstructure in Steady and Flickering Laminar Methane/Air Diffusion Flames, Combustion and Flame 112: 473-484, 1998
3. K. T. Kang, J. Y. Hwang and S. H. Chung, Soot Zone Structure and Sooting Limit in Diffusion Flames: Comparison of Counterflow and Co-Flow Flames, Combustion and Flame 109: 266-281, 1997

The principle of the new soot generator is demonstrated in Figure 1. A co-flow diffusion flame is used to pyrolyze the fuel gas in order to form soot particles. A steel tube is co-axially inserted into the flame to form a cylindrical flame between the burner and the steel tube (called soot collector). The soot collector stops the oxygen supply for the covered part of flame. Soot particles formed in the flame follow the upward streamlines and enter the soot collector. Due to the lack of oxygen and the falling temperature in the soot collector, soot particles passing through it are prevented from further oxidation.

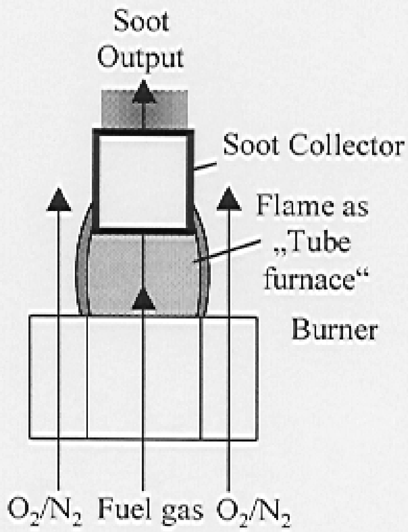

Figure 1 Soot generation principle

To get controllable flame conditions a linear stage is used to locate the co-flow burner and the soot collector (Figure 2). The burner is installed on the platform of the linear stage. As fuel gas, propane-nitrogen mixture is supplied through the inner tube and oxygen-nitrogen mixture is supplied through the outer tube of the burner. Flows are adjusted using mass flow controllers.

The distance between the burner and the soot collector is adjusted using the linear stage to maintain the cylindrical flame shape. A restrictor is placed in the soot collector to reduce the suction effect occurred by pressure differences between the inlet and the outlet of soot collector. Besides, the soot collector is isolated thermally from ambient conditions.

The soot generation on the new principle depends on the flame condition, which can be adjusted by the following parameters:

- Dilution ratio of fuel gas;
- O_2 ratio in air flow;
- Fuel velocity and air velocity;
- Fuel quality;
- Distance between soot collector and burner;
- Geometry of soot collector (length, diameter);
- Thermal condition of soot collector.

These parameters have influences on the fuel pyrolysis and the soot formation progress in the flame and can be used as single or in combination to adjust the characteristics of output soot particles.

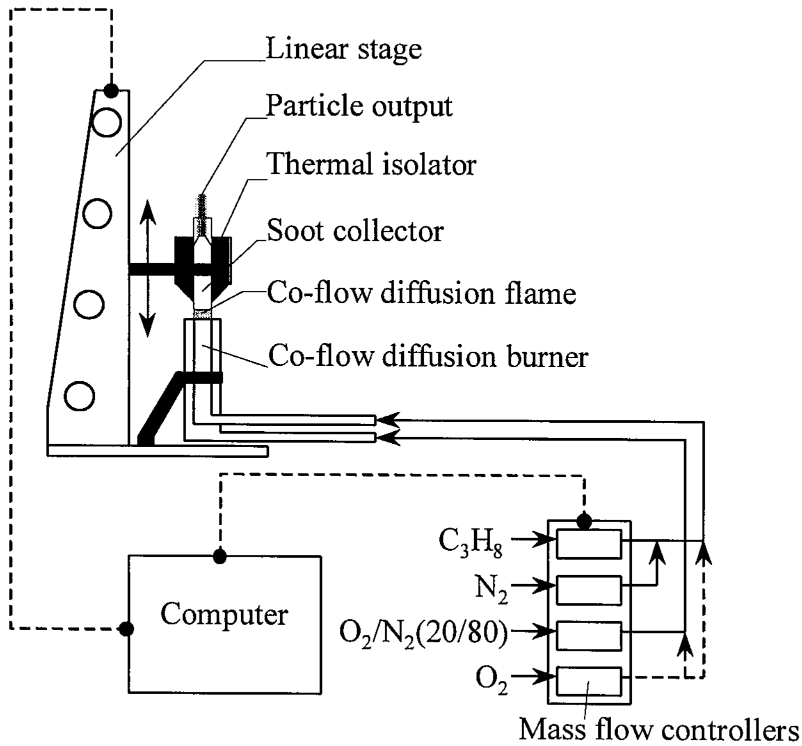

Figure 2 Experimental installation of the new soot generator

Result and discussion

Although several parameters are available to adjust the flame condition and the soot generation respectively, in practice it is not necessary to vary each. The following example shows how efficient the size distribution of output soot particles can be adjusted just by diluting the fuel gas with nitrogen while other parameters are kept unchanged.

As the dilution of fuel gas leads to a reduction of intermolecular impact and coagulation of soot particles, the size and the concentration of output soot particles can be varied using this parameter.

In Figure 3 size distributions of output soot particles from the new soot generator are presented. As comparison a size distribution of soot particles from diesel engine is presented in the same figure. As one can see in Figure 3, soot particles from the new soot generator are in the same size range of soot particles from diesel engine. With increasing dilution ratio of fuel gas, soot particles become smaller and their size distribution shifts significantly toward smaller particle diameters. The particle concentration from the new soot generator is more than 1000 times higher than the particulate emission from diesel engine.

Conclusions

The new soot generator presented here produces real combustion soot particles. Due to the precisely adjustable parameters of the new soot generator, soot generation can be achieved with good reproducibility and stability. With regard to the possibilities for the continual adjustment of flow conditions, particle size distribution can be varied easily and continually. The high yield of soot particle meets the demands in field situations and allows further dilution for different applications. In comparison to diesel engine, the operation of soot generator is simple and easy.

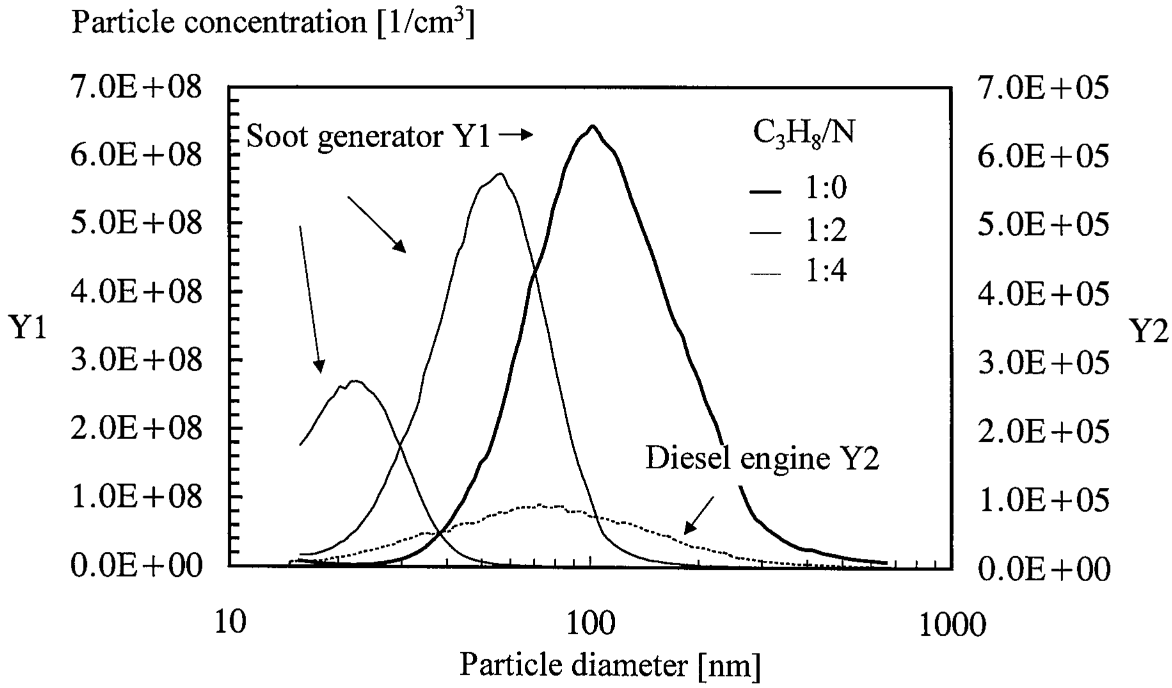

Figure 3 The size distributions of soot particles from the new soot generator driven at different C_3H_8/N_2-ratios.

Acknowledgements

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