Effect of pressure on thermal accommodation coefficient

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The thermal accommodation coefficient, α, for carbon black in air was measured for various sub-atmospheric pressure levels. Surprisingly, it was found that α is dependent upon pressure, increasing from ~0.1 at 1 atm. to ~0.5 at 0.18 atm.

Introduction

The thermal accommodation coefficient, α, is an important parameter in predicting the cooling rate of nano-sized particles in the free-molecular regime. Its value, which can theoretically range from 0 to 1, is critical in calculating particulate fineness from LII data. In the literature of LII modeling, reported values of α have varied widely, from a low value of 0.26 to a high value of 0.9 [1].

Experimental Details

LII measurements were performed on carbon black sampled from a process stream at a manufacturing plant. The sampling process dilutes and cools the stream, such that the LII measurements are performed on a stream of ambient temperature. For this particular set of experiments, the pressure in the optical cell was reduced to sub-atmospheric levels by "sucking" the aerosol stream through a small orifice using the vacuum generated by a venturi eductor. A diagram of the setup used is shown in Figure 1.

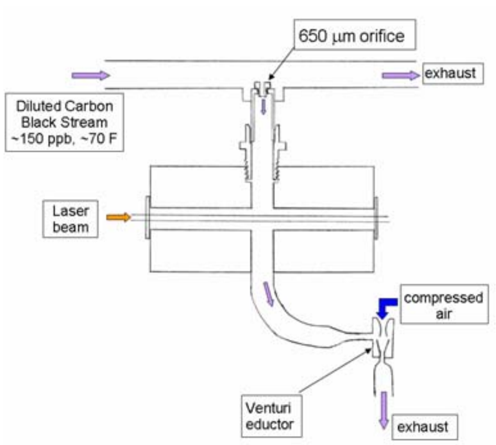

Fig. 1: Experimental Setup

Data Analysis and Results

In the free-molecular regime, the temperature decay rate measured with LII can be related to the particulate fineness as [2]

$$\frac{d}{dt}\left\{\ln\left(T_c - T_g\right)\right\}\Big|_{t=0} = -\frac{\theta}{D_{32}} \quad , \tag{1}$$

where T_c is the "effective" temperature of the polydisperse group of particles determined by LII measurements, D_{32} is the Sauter Mean Diameter of the particle distribution, and θ is given as

$$\theta = \frac{3\alpha\, p_g}{4\rho\, c_s T_g}\sqrt{\frac{8k_B T_g}{\pi\, m_g}}\left(\frac{\gamma^* + 1}{\gamma^* - 1}\right) \quad . \tag{2}$$

As seen from these equations, the measured temperature decay rate can be used to calculate either D_{32} or α, but not both simultaneously. For this series of measurements, a sample of the carbon black was collected for nitrogen adsorption measurements. The external surface area was found to be 91 m^2/g, giving an SMD value of D_{32} = 35.6 nm. With this value for SMD, the values of α calculated from LII are shown in Fig. 2, where it is seen that α has a value of ~0.1 at 1 atm. of pressure and increases to ~0.5 as pressure decreases to 0.18 atm.

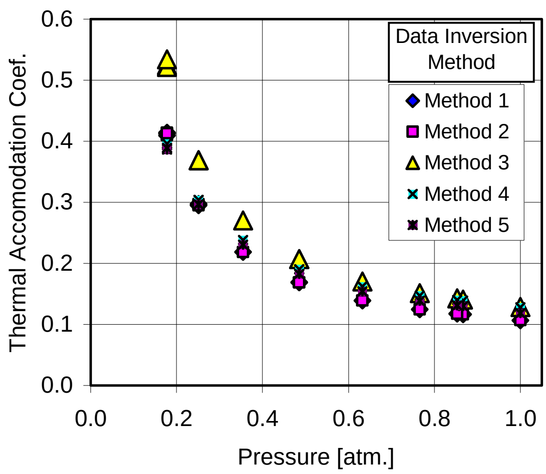

Fig. 2: Inferred α Values

[1] D. Snelling, F. Liu, G. Smallwood, O. Gulder, Combustion and Flame, 136, 180 (2004).
[2] F. Liu, B. J. Stagg, D. R. Snelling, G. J. Smallwood, IJHMT, 49, 777-788 (2006).

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