Heat conduction issues in laser-induced incandescence

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Uncertainties in modelling heat conduction in connection with the application of laser-induced incandescence (LII) to primary particle sizing are discussed. Besides a comparison between commonly used models an experimental study employing specified carbon blacks was performed. An overall good correlation of LII-values and those from electron microscopy has been found. Based on these data an effective accommodation coefficient of α = 0.23 is determined and the influence of aggregate size on primary particle sizing has been quantified.

Introduction

In the time interval evaluated for primary particle sizing by laser-induced incandescence (LII) heat conduction is the dominant cooling mechanism. Thus uncertainties in modelling this process may result in considerable errors in the sizes determined. It is the aim of the present paper to critically assess two models on heat conduction widely used and to experimentally provide quantitative information both on the thermal accommodation coefficient α and on the influence of aggregate size on primary particle sizing.

Numerical

Modelling the heat conduction between primary particles and the surrounding gas, different approaches are compared, namely the most widely used formula proposed by McCoy and Cha [1] and the approach developed by Fuchs [2]. Based on numerical implementations it is shown that considerable differences may occur depending on relevant temperatures and particle sizes. The models may be reconciled, however, with proper choices of "effective" thermal accommodation coefficients.

Experimental

Systematic measurements on re-dispersed carbon blacks with specified primary particle sizes were carried out. To that end a carbon black aerosol was produced by dispersing powders, spraying the dispersion into a carrier gas by means of an aerosol generator and flowing it through a heating section. Pointwise experiments were performed using a Nd:YAG laser at 532 nm and a standard detection scheme with a photomultiplier.

Results

When LII results, employing a typical primary particle size distribution, are related to the carbon black manufacturer's data determined by transmission electron microscopy (TEM) an effective accommodation coefficient can be obtained. Using a value of α = 0.23 (based on the model of McCoy and Cha) for the accommodation coefficient delivers an overall good correlation.

Generally, aggregate size is expected to influence heat transfer from primary particles, mainly due to shielding effects. Numerical analyses on this issue were recently performed by Filippov et al. [3] and Liu et al. [4]. In order to experimentally address this question residual deviations in the above correlation of LII- and TEM-results were linked to aggregate sizes determined by two independent methods. Thus it could be shown that these deviations in LII-values are directly correlated to the number of primary particles per aggregate. These results may contribute to check the numerical models developed and to provide a guideline for the inclusion of aggregate effects in practical applications of LII for primary particle sizing.

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