Smoke particle morphology for different fire types determined by equivalent ratio tube furnace method

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The adverse health effects of smoke are associated with the inhalation of smoke particles, and depend on the amount and location of their deposition within the respiratory tract. The characteristics of the penetration and deposition of smoke aerosols into the lungs that determine the adverse health effects are related to the morphology and the size distribution of smoke particles (Hertzberg and Blomqvist, 2003).

Most cases of smoke inhalation involve smoke from compartment fires, and the time-varying size distribution of the smoke particles is an important factor in lung deposition. Several researchers measured the size distributions of smoke particles generated in typical test fires, but the information derived about the morphology of smoke particles was insufficient for examining lung deposition (Hertzberg and Blomqvist, 2003; Blomqvist *et al*, 2007). Recently, Goo (2012) calculated the development of the size distribution of smoke particles in a compartment fire using an analytical method.

The present work investigates the morphology of smoke particles for different fire types, in order to determine the initial conditions for calculations related to the development of particles in a compartment fire. The steady-state tube furnace method given in ISO/TS 19700 (2009) is used for the generation of smoke particles. The size distribution of the particles is measured for different fire types using a cascade impactor, and the morphology of the particles for each stage of the impactor is analyzed using transmission electron microscope (TEM).

The tube furnace used has a maximum set temperature of 1,100 ^{o}C, a 600-mm heating zone, and a total length of 700 mm (AHI Co. Ltd.). The quartz tube of the furnace has an inlet length of 900 mm and an outlet length of 85 mm. The outer diameter of the tube is 48.0 mm, and the wall thickness is 1.5 mm. Strip specimens or pellets are spread in a quartz sample boat over a length of 800 mm at a loading density of 25 mg/mm. An induction motor (DKM, 9IDG3-200FP) is used for introducing the sample into the quartz tube with a typical advance rate of 40 mm/min. Primary air is introduced into the quartz tube with a maximum flow rate of 20 L/min using an mass flow controller (MFC: KOFLOC, 3660) and a readout (MJT, MR300).

The mixing chamber is made of 5-mm-thick polystyrene and 1-mm-thick stainless steel plates, with the inner dimensions of 310 mm (depth) × 310 mm (width) × 340 mm (height). Secondary air is introduced into the mixing chamber with a total flow rate of 50 L/min with the primary air using a flow meter (KFM, PA-20).

Table 1. Test conditions.

Stage	1	2	3	4
T (^{o}C)	350	650	650	825
Qp (L/min)	2	-	-	-
Equ. ratio (ø)	-	< 0.75	2	2

The furnace temperature (T) and the flow rates of primary air (Qp) are changed for each fire type, as shown in the Table 1. TEM (HITACHI, H-7650) is used to examine the morphology of the particles (Figure 1) by collecting smoke particles on the TEM Grid (TedPella, 01800-F) from the mixing chamber through the impactor, with a flow rate of 1 L/min controlled by the MFC. Typical materials, such as polyethylene, PVC, polyprophylene, polyurethane, and wood, etc. are used for the experiment.

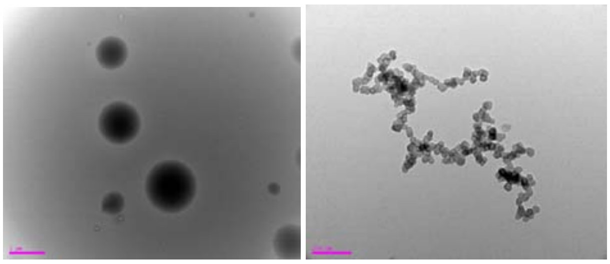

Figure 1. Typical TEM images of wood smoke for stage 1 (left, 2 μm scale), and stage 2 (right, 200 nm scale)

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