Filter-based Aerosol Measurement Experiments using Spherical Aerosol Particles under High Temperature and High Pressure

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1. INTRODUCTION

FNC Technology Co., Ltd has been developed test facilities for the aerosol generation, mixing, sampling and measurement under high pressure and high temperature. The aerosol generation system is connected to the aerosol mixing system which feeds aerosol/ethanol mixture. Aerosols inject into the two-fluid nozzle with nitrogen. In the sampling system, isokinetic sampling ensures that sampling gas entering the sampling probe has a representative aerosol concentration and distribution between free-stream and sampled gas.

Two types of measurement devices were used for the experiment. Optical Particle Counter (OPC) is used to provide real-time measurement of aerosol concentration and size distribution. Glass fiber membrane filter also be used to measure average mass concentration.

Three tests (MTA-1, 2 and 3) have been conducted to study thermal-hydraulic effect, a filtering tendency at given SiO_2 particles. Based on the experimental results, the experiment will be carried out further with a main carrier gas of steam and different aerosol size. The test results will provide representative behavior of the aerosols under various conditions.

2. THE EXPERIMENTAL TEST

The aerosol species used in these tests is SiO_2 as a mixture, which is AMMD (Aerodynamic Mass Median Diameter) of 3 micron and spherical shape. MTA(Micrometer (1-10 ㎛ by definition) Aerosol Test with Main Carrier Gas of Air) -1, 2 and 3 were carried out at different pressure and temperature. Table 1 shows summary of aerosol test conditions for MTA-1, 2 and 3. Mass fraction of SiO_2 in the feed liquid is 20% at all experiments. To ensure complete evaporation of the spray droplets, the entire system including a mixing tank was heated above ethanol evaporation point.

The insoluble SiO_2 is stirred continuously to avoid settling of the aerosol particles on the bottom of stirred tank. The feed liquid temperature entering the two-fluid nozzle stays below the evaporation temperature of the ethanol.

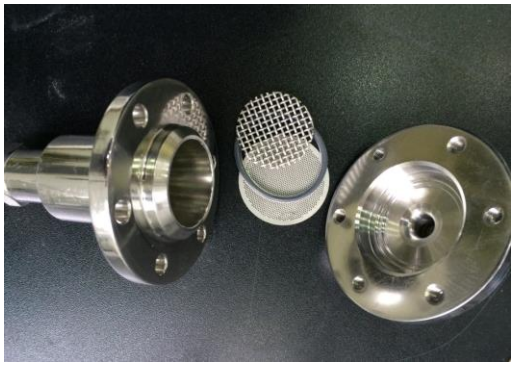

Fig.1: The filter holder including O-ring, Mesh Plate and Perforated Plate designed for high temperature and high pressure.

Due to aerosol deposition on the mixing tank and piping wall, all systems were cleaned out after conducting each test. Aerosols sampling duration at steady conditions was approximately 30 minutes and the time needed to collect enough aerosol particles on membrane filter may vary from aerosol concentration and test conditions. The sampling probe is installed at pipe diameter of 3 inches aerosol sampling section from the downstream of mixing tank and is used to connect the main pipe with the membrane filter and Optical Particle Counter (OPC). The sampling nozzle is attached by nozzle tip to the 3 inches main pipe. The size of sampling nozzle tip is exchangeable to adjust the sampling velocity to be equal to the free-stream gas velocity for isokinetic sampling conditions.

Table 1: Summary of Thermal-hydraulic and Aerosol Test Conditions for MTA 1, 2 and 3

Test No.	Pressure	Temperature	Sampling Time	AMMD	Aerosol Mass Fraction	Main Carrier Gas
	bar(g)	℃	Sec	㎛	-	-
MTA-1	1.0	118.0	2060	3	0.2	Air
MTA-2	2.4	121.3	2990	3	0.2	Air
MTA-3	4.0	126.5	1813	3	0.2	Air

For measuring average mass concentration, glass fiber membrane filter (Whatman™ GF/F, pore size of 0.7 micron) with a diameter of 47mm is used for these tests. The filter holders also have been designed to be applied at high temperature (up to 200℃) and high pressure (up to 10 bar(a)) conditions.

The filter holder has a conical flow path including perforated support plate for the filter and O-ring for sealing. It is designed for a commercial filter size of 47mm and any types of filter, which shown in Figure 1.

3. TEST RESULTS

The filter was heated up prior to the measurement in an oven to a temperature about 120℃ for 24 hours to evaporate moisture captured in the fiber. The filter was loaded in the filter holder, aerosol particles was collected and weighed when test is terminated. The filter handled with care not to lose aerosol particles was weighed by a microbalance with O-ring and Perforated plate to avoid particle losses. The sampled net aerosol mass of MTA 1, 2 and 3 are 0.58109g, 0.64820g and 1.93038g. Figure 2 shows aerosol cake collected on the glass fiber filter after terminating MTA-3.

Fig.2: The Aerosol Cake Collected on Glass Fiber Membrane Filter on MTA-3.

The sample was first observed under membrane filter, following this measurement, analysis by Scanning Electron Microscopy (SEM) to obtain collected aerosol size and filter behavior. Figure 3 provides SEM images of the glass fiber membrane filter on MTA 1 and 3.

The spray droplets injected into the mixing tank cannot be evaporated if system temperature is not maintained above evaporation point of ethanol (Figure 4(a)). Aerosols suspended in the mixing tank considerably are affected by the liquid droplets and captured in droplet, settling on the bottom. Hence, to reduce transport losses, it is important to provide stable tiny droplets from two-fluid nozzle and sufficient heat.

a

b

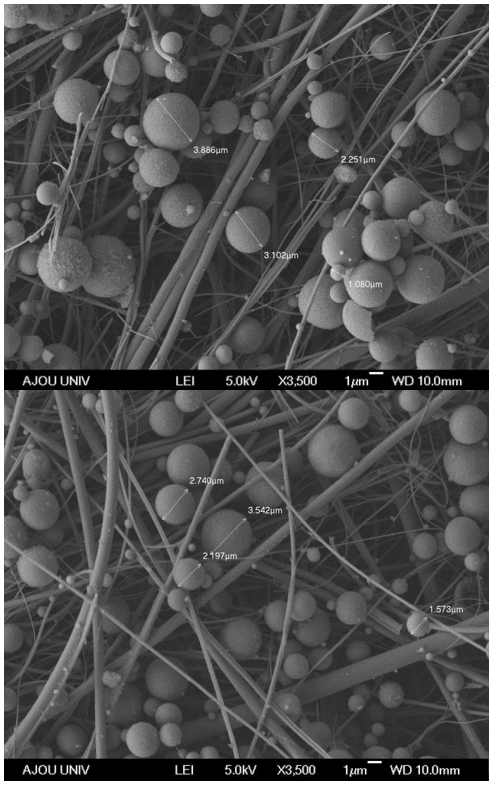

Fig.3: Scanning Electron Microscope (SEM) Photograph of Aerosols Collected on the filter on test (a) MTA 1 and (b) MTA 3.

a

b

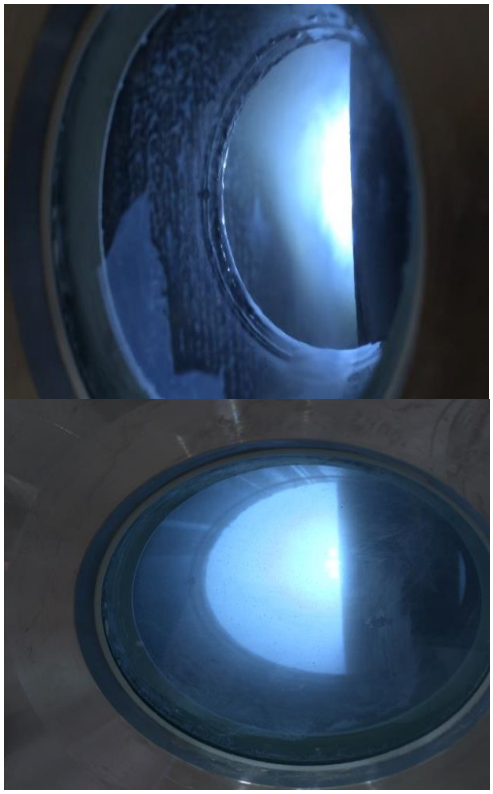

Fig.4: The SiO2/Ethanol spray in mixing tank with (a) incomplete evaporation and (b) fully evaporated droplets.

4. CONCLUSIONS

FNC Technology Co., Ltd. has been developed the experimental facilities for aerosol generation, mixing, sampling and measurement under high temperature and high pressure. The aim of the tests, MTA 1, 2 and 3, are to be able to 1) establish the test manuals for aerosol generation, mixing, sampling and measurement system, which defines aerosol preparation, calibration, operating and evaluation method under high pressure and high temperature 2) develop commercial aerosol test modules applicable to the thermal power plant, environmental industry, automobile exhaust gas, chemical plant, HVAC system including nuclear power plant and 3) investigate aerosol behaviors and removal mechanisms under these conditions.

The MTA 1, 2 and 3 were conducted with main carrier gas of air under different pressure and temperature. Based on the test results, sampled aerosol particles in the filter indicate that important parameters affecting aerosol behavior aerosols are 1) system temperature to keep above a evaporation temperature of ethanol and 2) aerosol losses due to the settling by ethanol liquid droplet. The removal mechanisms and transport losses in the experimental facilities will be discussed further.

ACKNOWLEDGEMENT

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