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The Effect of Swirling Flow in the Mixing Chamber of Atomizer and the Length/Diameter Ratio of Atomizer Exit on the Distribution of Coal Particles in CWM Spray.

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This research is aimed to investigate how the swirling phenomena in an atomizer and the ratio of length/diameter of the atomizer exit affect the size distribution of coal particle in spray. CWM slurries are injected by a swirling twin-fluid atomizer. Five different caps and a swirler are designed and fabricated into an existing twin fluid atomizer. The droplets are sampled by test tubes and microscope slides coated with magnesium oxide. The data analysis are done by photo technique and Malvern particle sizer. The experimental results reveal that there are many droplets which do not have any coal particles. Those are simply water droplets. The population ratio of droplets without coal particles to total sampled CWM droplets is increased as the sampling position moves outward in the radial direction from the axis of spray. The length/diameter ratio of an atomizer exit and the swirling phenomena in an atomizer affect a lot the spray pattern and the spray angle but they make no noticeable effects on the size distribution of coal particles in droplets and spray.

Key Words : CWM Atomization, Swirling Flow, Distribution of Coal Particle

1. Introduction

CWM(coal water mixture) has been considered as an alternative to reduce high tensions from energy crisis because of relatively abundant coal resources in the world. COM(coal oil mixture) or COWM(coal oil water mixture) also were considered in past as other alternatives but their cost of energy production per Btu is higher than that of CWM. It is well known that the quality of atomization governs the most of combustion processes. The atomization mechanism of CWM must be fully understood to use CWM efficiently. The combustion processes of CWM are quite different from those of liquid fuel because of the presence of coal particles in CWM droplets. The distribution of coal particles inside CWM droplets is believed to be one of very important controlling factors of the combustion phenomena of CWM. Most of previous researches of CWM atomization, however, have been focussed mainly on the size distribution of CWM droplets in spray. There are no research reports on the size distribution of coal particles in spray except something done in this laboratory.

It is known that the length/diameter ratio of an atomizer exit strongly governs atomization processes such as the break-up length and the spray angle, which make a great effect on the spatial distribution of fuel droplets and the formation of the fuel-air mixture in a combustor (Lefevre, 1989 ; Ruiz, 1991). But there have been no studies on how the length/diameter ratio influences the coal particle distribution in spray. The purpose of this study is to investigate how swirling flow in the atomizer and the length/diameter ratio of the atomizer exit affect the distribution of

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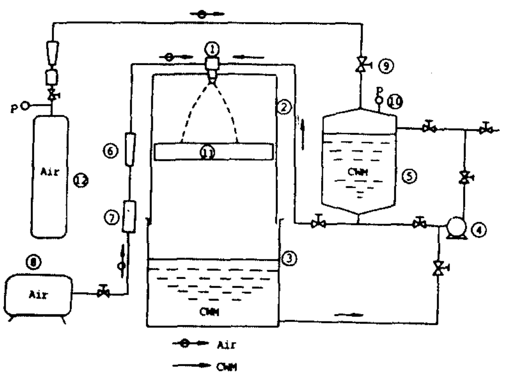
coal particle in CWM spray.

2. Experimental System

An experimental system shown in Fig. 1 is designed, manufactured and fabricated. It has two main functions. One is to atomize CWM slurry by an atomizer and the other is to sample CWM droplets from spray by a sampling shutter. The main parts of the experimental rig are CWM tank, spray chamber, air compressor, compressed air bottle, flow meter, air pressure regulator and atomizer.

A swirler and five differents caps are designed, manufactured and fabricated into the existing twin-fluid atomizer (Model B1/4J - SS + SU22 - SS)(Spray System, 1988). The brief structure of a swirling twin-fluid atomizer is shown in Fig. 2. A swirler has four equally spaced slots of which width and depth are 0.8 mm and 1.8 mm, respectively. The angle of slot is 33 degree. These dimensions are determined after considering the maximum size of coal particle to avoid plugging of slot by coal particles. Five different length/diameter ratios are summarized in Table 1. The exit diameter of cap is 2.7 mm.



① Atomizer
② Spray chamber
③ Collection tank
④ Rotary pump
⑤ Mixing tank
⑥ Flow meter
⑦ Air pressure regulator
⑧ Air compressor
⑨ Ball valve
⑩ Pressure gage
⑪ Impression sampling shutter
⑫ Air bottle

Fig. 1 Schematic of CWM atomizer facility

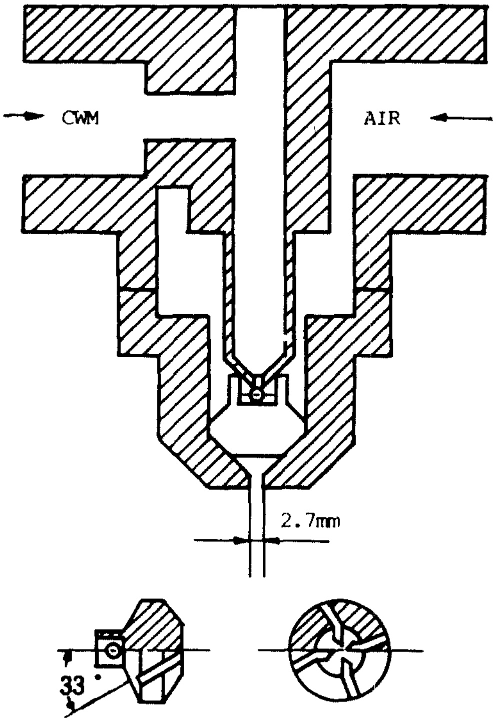


Fig. 2 Structure of swirling twin-fluid atomizer

Table 1 Length/diameter ratio of atomizer exit

Length of atomizer exit(mm)	2	3	4	5	6
Length/diameter ratio	2	3	4	5	6
	2.7	2.7	2.7	2.7	2.7

* Dimeter of atomizer exit is 2.7 mm

3. Data Sampling and Analysing Method

CWM droplets from the spray are sampled by test tubes to measure the variation of slurry flow rate and coal particle size along the radial direction in the spray. Test tubes, of which diameter is 10 mm, are distributed from the axis of spray to the circumference of it at 60 cm downstream from

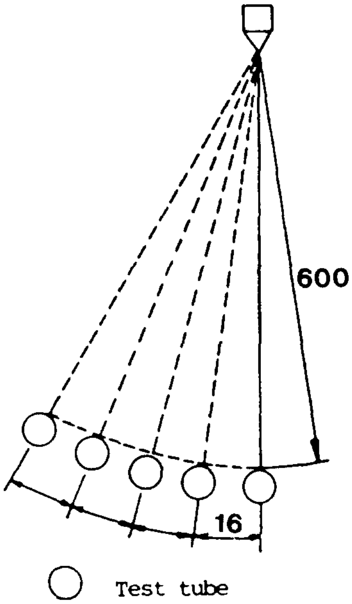
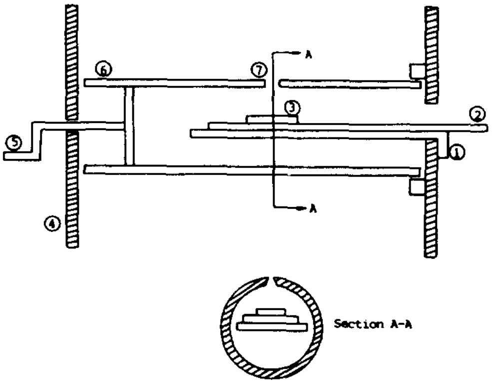


Fig. 3 Sampling position of test tube sampling method



① Fixed plate
② Sampling Plate
③ Slide glass coated with MgO
④ Wall of the spray chamber
⑤ Turning handle
⑥ Rotating cylinder
⑦ Slit

Fig. 4 Impression sampling shutter

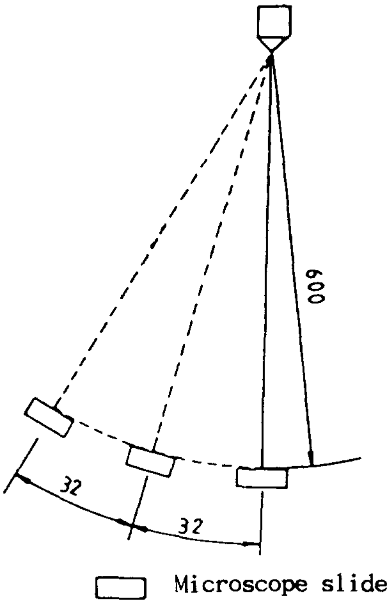


Fig. 5 Sampling position of impression sampling method

the exit of atomizer. Every tube is distanced by 1. 6 cm from the axis of spray to the circumference of it. The radial sampling positions of test tubes are shown in Fig. 3.

An impression sampling method is adopted to get data on the presence of coal particles inside droplets. It is a combination of emergency sampling shutter (Karasawa, 1982; Kim, 1990) and magnesium oxide method (May, 1950; Kim, 1990). It uses microscope slides coated with magneisum oxide where CWM droplets are sampled. Figure 4 shows the brief cross sectional view of emergency sampling shutter and the lay of microscope slide inside the sampling shutter. The impression sampling method removes some disadvantages of immersion sampling method (Aihara, 1985) which uses silicon oil baths. There are no coalescences between sampled droplets and no dissolutions of droplets after sampling in the impression sampling method. It may keep droplet impressions on magnesium oxide layer forever unless any outside disturbances happen an microscope slides. Magnesium oxide layer is white contrary to the color of coal particles. It is very easy to notice the presence of coal particles in the impressions of droplets on the white magnesium oxide layers.

Every sampling position is distanced by 3.2 cm in the radial direction of the spray. The sampling positions of impression sampling method are shown in Fig. 5.

Impressions of CWM droplets on magnesium oxide layers are pictured by a camera mounted on a microscope. The magnification ratio on a film is 5 to 10. These negative films are developed and become positive photographs of which images are 50 to 100 times of the actual size of droplets. The presence of coal particles in CWM droplets is identified by the eye inspection. It is very easy to distinguish droplet impressions wihthout coal particles from droplet impressions with coal particles because coal particles are black contrary to white magnesium oxide layers. Figure 6 is a typical photograph of droplet impressions on magnesium oxide layers.

In a photograph, droplet impression (a) is a typical CWM droplet with coal particle. Droplet impression (b) is a droplet without coal particles. It is actually a simple water droplet, not CWM droplets, which may act as a strong heat sink in combustion process. (c) is a single coal particle which may have water film on the surface. The size distribution of coal particles in CWM droplets and spray are analysed by the Malvern laser particle sizer.

(a) CWM droplets with coal particles
(b) CWM dorplets without coal particles
(c) Coal particles

Fig. 6 Impression of CWM droplets on magnesium oxide layer

4. Result and Discussion

The bulk of coal is dried, crushed and pulverized. Coal particles have 4.2 micron of SMD(Sauter Mean Diameter). Coal particles are mixed with water to get slurries. The coal particle loading in CWM slurries is 10 percent in mass. CWM slurries are injected by the prepared atomizer. The atomized droplets are sampled by an impression sampling method and the impressions on magnesium oxide layers are analysed by the photo technique. The presence of coal particles in droplet impressions is investigated by the photo technique. There are a lot of droplet impressions without any coal particles, which result in very similar to that of twin fluid atomization without swirling flow (Kim, 1990; Kim, 1991). The number of droplet impressions without coal particles is counted and summarized in Table 2. The percentage of droplet impressions without coal particles among total number of counted droplet impressions is increased as the sampling position moves in the radial direction from the axis of spray to the circumference of it. There are no sufficient explanations on the occurrence of this phenomena but it may be considered that this is

Table 2 Percentage of droplets without coal particles

Sampling position(cm)	0.0		3.2		6.4		Total	
Classification Atomizing conditions	A	B	A	B	A	B	A	B
Atomizing air pressure : 2.0(kg_f/cm^2) Slurry supply pressure : 5.5(kg_f/cm^2)	1746	142	580	114	246	86	2500	342
$\frac{B}{A+B}(\%)$	7.81		16.4		25.9		12.0	

A : Number of droplets with coal particles
B : Number of droplets without coal particles

due to aerodynamic response of injected droplets.

The five different length/diameter ratios are adopted for this experiment. The atomizing air pressure and slurry supply pressure are kept constant, 2 kg_f/cm^2 and 5.5 kg_f/cm^2, respectively.

The variations of slurry flow rate along sampling positions at each length/diameter ratio are shown in Figs. 7 and 8. CWM slurries are sampled by test tubes for 20 seconds. The slurry flow rate becomes more uniform across the sampling positions at the particular length/diameter ratio of 3/2.7. The uniformity becomes worse as the length/diameter ratio be smaller or greater than 3/2.7.

Total sampled slurry flow rate at each length/diameter ratio is shown in Fig. 9. The amount of slurry flow rate becomes the smallest value at the length/diameter ratio of 3/2.7 and the flow rate are increased as the length/diameter ratio becomes smaller or bigger than the length/diameter ratio of 3/2.7. It is believed that these phenomena come from the change of spray pattern. The spray angle is changing with length/diameter ratio. The length/diameter ratio of 3/2.7 has the biggest spray angle among the five ratios. The cross sectional diameter of spray is varing according to spray angle. Smaller spray angle means smaller diameter of cross sectional area of spray. All of sampling positions are located within 6.4 cm from the axis of spray. Broader spray has a lot of droplets not collected by test tubes.

The coal particles collected in tubes are analysed by Malvern laser particle sizer (Malvern, 1989). SMD of sampled coal particles at each sampling position is shown in Fig. 10. Figure 11 shows the averaged SMD variation of coal particles along sampling position. There are some variations of SMD of coal particles along the sampling position. The circumferential zone of spray has a little bit bigger particles than the core zone of spray, which is almost same result as that of twin fluid atomization without swirling (Kim, 1991) shown in Fig. 12. These experimental results show that there are no appreciable differences between the size distribution of coal particle of a swirling atomization and that of non-swirling

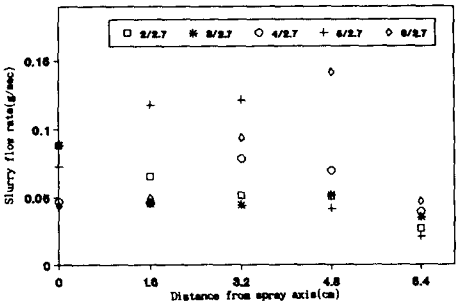


Fig. 7 The variation of slurry flow rate along sampling position

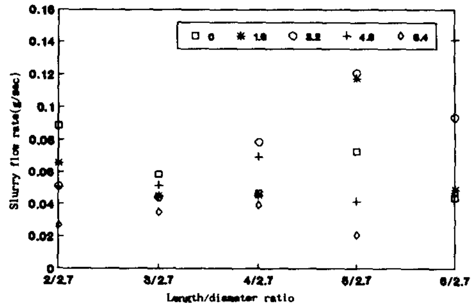


Fig. 8 The variation of slurry flow rate with length/diameter ratio

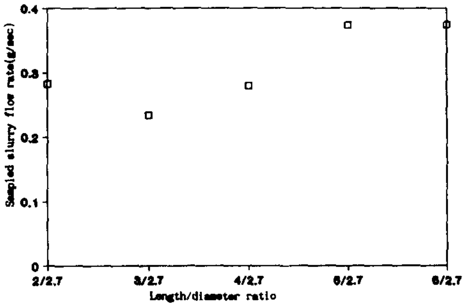


Fig. 9 The variation of sampled slurry flow rate with length/diameter ratio

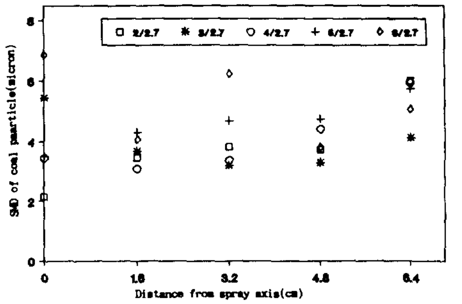


Fig. 10 The variation of SMD of coal particle along sampling position

atomization.

The distribution of SMD of coal particles at each length/diameter ratio is shown in Fig. 13. The difference between the maximum SMD and the minimum SMD at each length/diameter ratio is quite uniform with respect to the change of length/diameter ratio, which also means that there are no noticeable effects on the coal particle distribution by the variation of length/diameter ratio of atomizer exit.

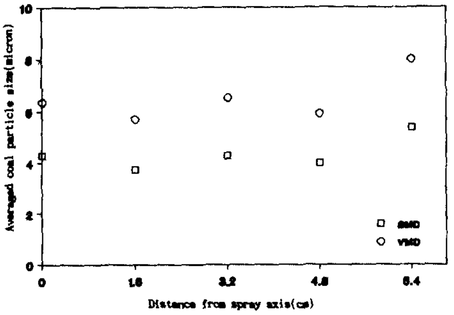


Fig. 11 The variation of averaged SMD and VMD of coal particle along sampling position

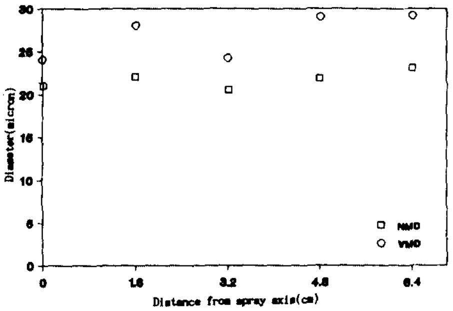


Fig. 12 The variation of mean diameter of coal particles inside spray on sampling position

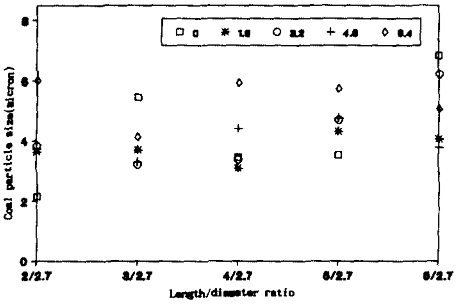


Fig. 13 The variation of SMD of coal particles with length/diameter ratio

5. Conclusion

CWM slurries are atomized by a twin fluid atomizer with swirler. The atomized droplets are sampled by test tubes and impression method. The impressions of droplet on the magnesium oxide layers and the sampled coal particles are analysed by the photo technique and a Malvern laser particle sizer. The experimental results are summarized as follows.

(1) There are quite many droplets which do not have any coal particles. The population ratio of droplets without coal particles to total sampled drplets is increased as the samlpling position moves outward in the radial direction from the axis of spray.

(2) Spray pattern is influenced a lot by the change of length/diameter ratio. The spray angle becomes the smallest value at a particular length/diameter ratio but there are no appreciable effects on the distribution of coal particle by the change of length/diameter ratio.

(3) The distribution of coal particles of a swirling atomization is similar to that of non-swirling atomization.

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