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Attrition Characteristics of Alumina Catalyst for Fluidized Bed Incinerator

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Abstract–Attrition characteristics of alumina catalyst for catalytic incineration have been studied in a fluidized bed cold mode combustor (Φ10 cm, 160 cm height). The particle size and density of alumina catalyst were 1.4-1.7 mm and 1.13 g/cm^3. As operating variables, excess gas velocity ($U-U_{mf}$) and bed weight (W_b) were selected. The experimental results show that attrition rate of alumina catalyst increased with excess gas velocity and bed weight due to intensive rubbing and collision caused by bubble coalescence. The size of the entrained particles collected in cyclone ranges over 0.5 to 100 μm, and the mean size for number base increases with an increase of excess gas velocity.

Key words: Fluidized Bed, Catalytic Combustion, Alumina Catalyst, Attrition Rate, Attrition Ratio

INTRODUCTION

Catalytic incineration enables fuel burning under the condition of lower temperature and density compared to the conventional ones. It also decreases the NO_x emission and has better combustion efficiency under an operating temperature much lower than the flame temperature. It has flexibility in the choice of combustibles, and thus can treat a large amount of harmful waste materials in a relatively small sized incinerator. Therefore, as a new concept of combustion, catalytic incineration is under active development in a number of countries [Kang et al., 1992, 1993].

It is important to choose a process that is superior in heat and mass transfer in a reactor and can keep a uniform temperature during the operation. The fluidized bed complies with the above criteria well since it has outstanding mixing effects and longer solid retention time; thus it can burn low-grade fuel with high moisture and low heating value. It especially shows excellent performance in burning viscous materials such as the sludge of waste water and sewage. Therefore, developing the fluidized bed catalytic combustion process is a good prospect [Park, 1994]. However, attrition loss of the catalyst during the fluidized bed process decreases the reactivity and requires frequent supplementing of the catalyst. Thus, it is important to check out its characteristics relating to the stable operation for a long period [Arena et al., 1984; Kono, 1981].

This study has been carried out to obtain the long term attrition characteristics such as the attrition rate and the attrition ratio associated with the process of catalytic incineration by using a cold mode fluidized bed using alumina particles as catalyst.

EXPERIMENTAL

The experimental equipment used in this study is described in Fig. 1. The fluidized bed is made of an acrylic cylinder with 10 cm diameter and 160 cm length. The gas distributor plate is a perforated one, with an orifice diameter of 0.12 cm, pitch of 1.1 cm, and opening area ratio of 1.0%. The entrained particles are collected in the first and second cyclone in series and then they are stored in each hopper, in the bottom of the cyclones.

Air is supplied from the oilless compressor (pressure 7 kg/cm^2, the capacity 27 Nm^3/hr), and the dryer is attached for drying the moisture from incoming air. The pressure regulator and flow meter are installed in the air supply tube for control of the air flow rater and pressure. In addition, five pressure taps are installed at the air plenum and the fluidized bed zone for the measurement of pressure of the inlet air and the fluidized bed, and they are connected to U-manometers in the control panel.

In catalytic incineration, alumina particles are used as a ca-

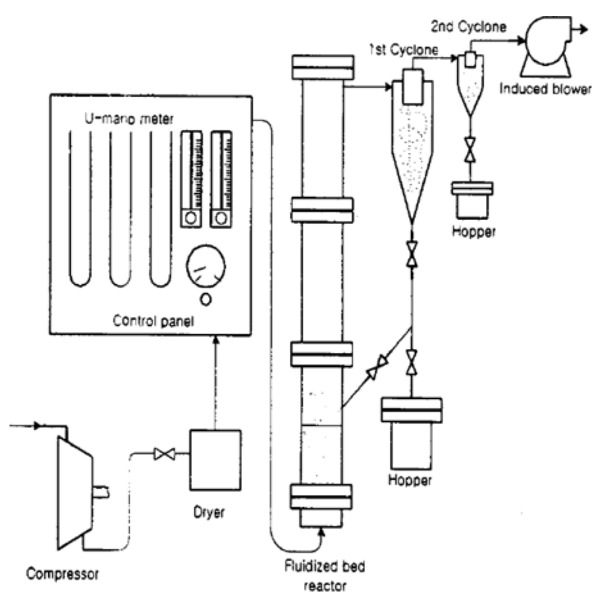

Fig. 1. Fluidized bed cold mode combustor.

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Table 1. Physical properties of alumina particle

Item	Values
Particle size	1.4-1.7 mm
Density	1.13 g/cm^3
Average crush strength	45 Newton/grain
Specific surface area	205 m^2/g
Pore volume	0.51 cc/g
Average pore diameter	99 Å

talyst or used as a support material for impregnation of precious metals like palladium or platinum on its surface. The alumina particles made in SSang Young Institute are used as a test sample for attrition experiment. The range of the particle diameter is 1.4 to 1.7 mm. The physical properties of the alumina particle are presented in Table 1. A predetermined amount of the sample is charged in the fluidized bed and the compressed air is supplied into the lower part of the fluidized bed through the air plenum, and a fluidized bed is formed.

The fine particles formed by attrition are collected at the cyclone and API Aerosizer-LD V7.04 is used for the size analysis of the collected particles. The following formulas are used to calculate the attrition rate and the attrition ratio through the experiment.

$$\text{attrition rate (mg/hr)}=\left(\frac{\text{cumulated attrition loss}}{\text{operating time}}\right)=\left(\frac{W_a}{t}\right)$$

$$\text{attrition ratio (\%)}=\left(\frac{\text{cumulated attrition loss}}{\text{initial bed weight}}\right)=\left(\frac{W_a}{W_b}\right)$$

In order to compare the change of the size of bed materials, the reduction of particle diameter is compared with the initial diameter of alumina particle, using the following formula. The parameters of the bed weight (W_b) and the excess gas velocity ($U-U_{mf}$) are used in the experiment of attrition in the fluidized bed. The experimental conditions including these are shown in Table 2.

$$W_b-W'_b=\frac{\pi}{6}\rho_s N(d_p^3-d_p'^3)$$

RESULTS AND DISCUSSION

Fig. 2 shows the dependence of attrition rate on the operating time with 1,400 g of the bed weight (W_b). For a given time, the attrition rate exhibits a larger value as the excess gas velocity becomes higher. However, with passing time the attrition rate decreased. It is found that under the given excess gas velocity, attrition was rapid in the initial stage of operation, then in 20

Table 2. Experimental condition

Variables	Operation range
Bed material type	Alumina
Fluidizing velocity (U)	50-95 cm/sec
Excess gas velocity ($U-U_{mf}$)	5-50 cm/sec
Air supply	200-450 l/min
Bed weight (W_b)	600-1,400 g
Static bed height	11-25 cm

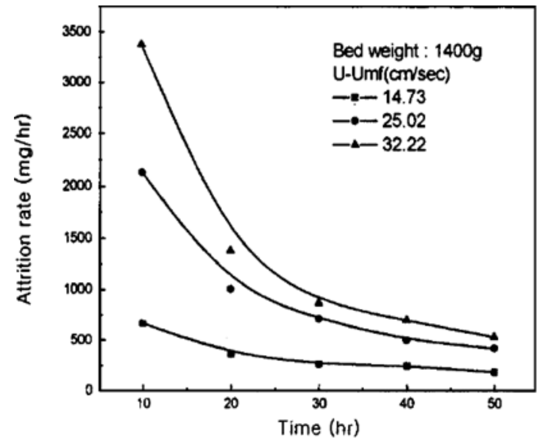

Fig. 2. Attrition rate as a function of time for different excess gas velocities.

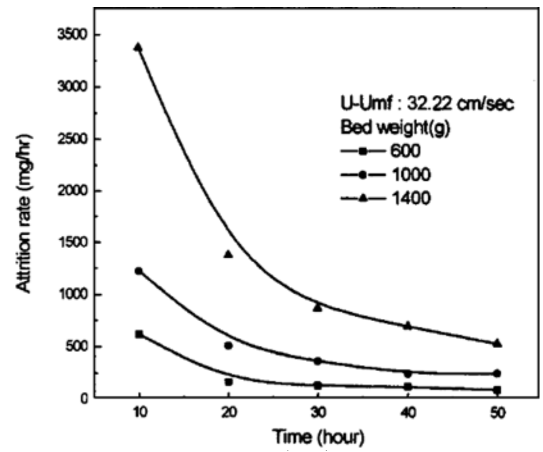

Fig. 3. Attrition rate as a function of operating time for different bed weights.

minutes the attrition rate dropped rapidly, and by degrees it decreased slowly owing to the reduction of the rough surface of the alumina particles. This result is equal to that of Park and Son's study [Park and Son, 1990] about the attrition characteristics through a coal burning experiment at 800-900 °C.

Fig. 3 shows the attrition rate as a function of operating time for different bed weights. It appears that for the same operating time, the attrition rate becomes larger with increased bed weight, even though the attrition rate decreased more rapidly with passing the time as the bed weight became higher.

Fig. 4 shows the attrition ratio according to the bed weight in operation time of 50 hours based on the condition when the excess gas velocity is different. In the case that the excess gas velocity was low, the attrition rate was almost regular according to the bed weight, but it was increased greatly as the bed weight increased when the excess gas velocity was higher. In this way, the excess gas velocity and the bed weight are important factors affecting the attrition ratio because intensive rubbing and collision of bed materials occurred as the excess gas velocity increased, and also, as the bed weight increased in the given gas velocity, the attrition operation of the particles in the fluidized bed was promoted due to the rapid bubble movement by

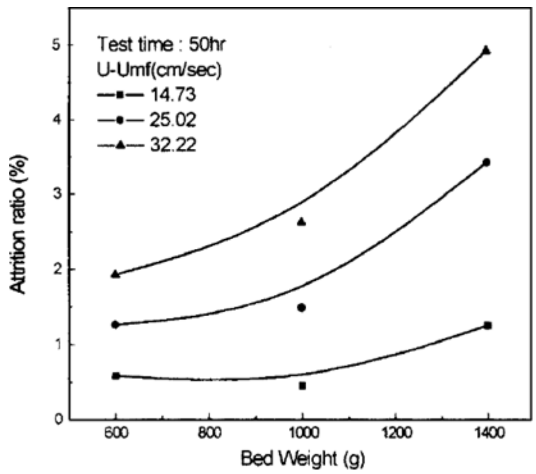

Fig. 4. Attrition ratio as a function of bed weight for different excess gas velocites.

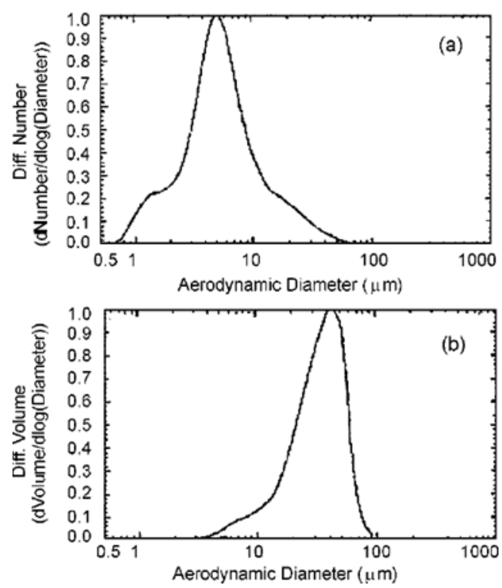

Fig. 5. Size distributions of attritted particles (a) number base, (b) volume base.

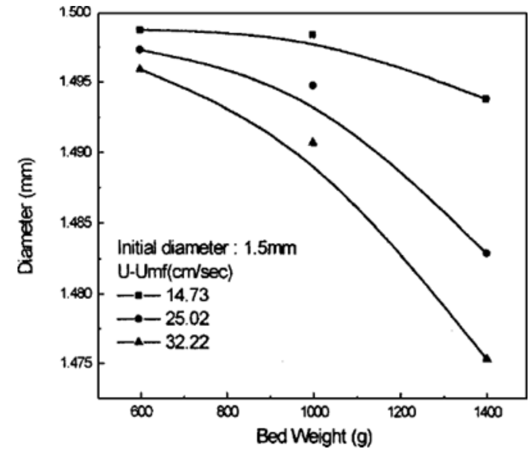

Fig. 6. Diameter change as a function of bed weight.

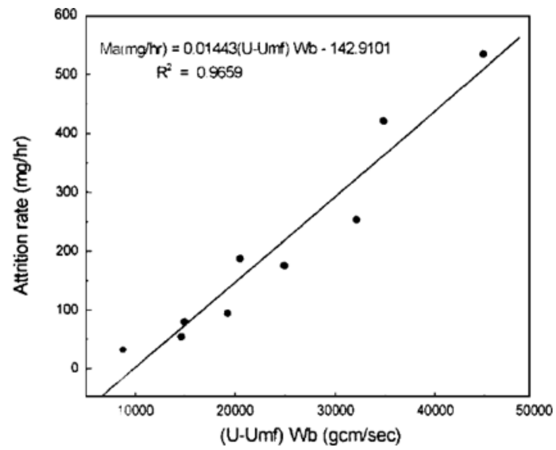

Fig. 7. Correlation of attrition rate as a function of $(U-U_{mf})W_b$.

the coalescence of the bubbles [Donsi et al., 1980, 1981; Arena et al., 1983, 1986].

Fig. 5 shows the size analyses of the attritted fine particles collected at the cyclone. The size distribution of the elutriated particles is 0.5-100 μm, which indicates that wide ranges of particle size are formed by attrition. a) is the size distribution of number base and b) is the size distribution of volume base. Each average size is 3.236 μm, 29.87 μm so that the average diameter of volume base is large at 10 times compared with the average diameter of number base.

Fig. 6 indicates the change of diameter of bed particle according to the change of the excess gas velocity and bed weight after 50 hours. In the given gas velocity, as the weight increased the diameter of bed materials decreased. It was also found that the influence of excess gas velocity becomes larger with increasing the bed height. Therefore, the bed height and the excess gas velocity are considered as very important factors in the fluidizing operation because the reduction of diameter based on initial diameter was 4.2 times when the excess gas velocity in- creased 2.2 times. As mentioned above, when the bed height increased the particle collision became more intensive.

Fig. 7 shows dependence of the attrition rate on $(U-U_{mf})*W_b$ which is the product of excess gas velocity and bed weight. The attrition rate is evaluated on the basis of operational data for 50 hours. As $(U-U_{mf})W_b$ has increased, the attrition rate has rapidly increased. The interrelating formula derived from this data is $Ma=0.01443\cdot(U-U_{mf})W_b-142.91$, which indicates that the attrition rate can be estimated within the operating range at a high coefficient of the determination the ($R^2=0.965$). Because parameters such as excess gas velocity and bed weight highly influence the attrition, the attrition characteristics should be considered sufficiently when the commercial process of the catalytic combustion of fluidized bed is utilized, especially for the case of high bed weight and the excess gas velocity.

The attrition rate is shown in Fig. 8, measured every 10 hours for a 250 hour run. The rate was the highest for the first 10 hours run, then it was rapidly decreased during next 30 hours. After that the decrease of the rate has slowed down and almost lined out by the end of the 250 hour run. Based on the results of this study, the decrease rate of the diameter of the catalytic particle, such as the alumina particle, can be estimated. Thus, this

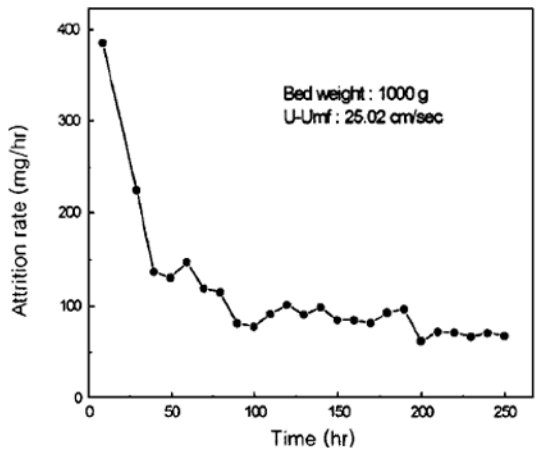

Fig. 8. Attrition rate for long time operation.

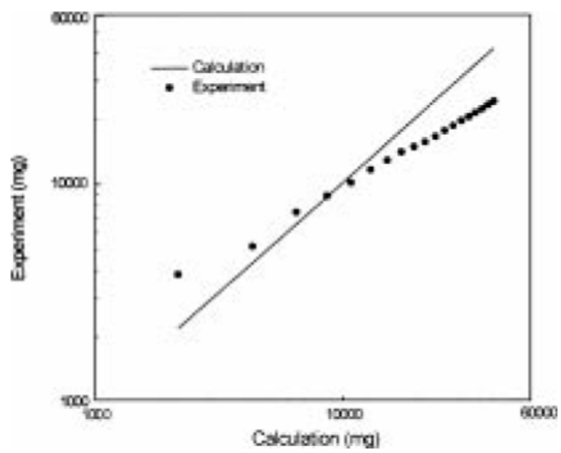

Fig. 9. Comparison between calculated attrition loss and measured one.

data can be used to determine the exchanging time of the catalyst and the supplementary amount of the bed materials to maintain a uniform bed level.

Fig. 9 indicates the comparison of the cumulated attrition calculated by the obtained formula and the cumulated attrition measured practically in operation for 250 hours. The long operating is limited to forecast because the derived formula is based on the data for 50 hours, but it can be estimated in a similar range. In the initial step of the fluidizing operation, the estimated data is presented as the lower estimation value because the practical attrition rate has some higher value. However, the estimated data is presented as the upper value because the practical attrition rate becomes slightly lower with passing time.

CONCLUSIONS

1. Attrition rate of alumina catalyst in fluidized bed increases with excess gas velocity and bed weight due to intensive rubbing and collisions caused by bubble coalescence.

2. The main factors affecting the attrition of bed materials in the fluidized bed are proven to be the excess gas velocity and bed weight in the catalytic fluidized bed. Based on these parameters, the estimation formula of attrition rate is $Ma=0.01443(U-U_{mf})W_b-142.91$ in the given operating conditions.

3. The attrition characteristics of the alumina catalyst in the fluidized bed for long hours indicate that the attrition rate is high in the initial period but decreases a little and has a regular attrition rate by the duration of time. Based on this fact, the reduction rate of diameter of the alumina particle can be estimated and also can be used to determine the exchanging time of the catalyst and the supporting amount of the bed materials.

NOMENCLATURE

d_p : particle diameter of initial bed material [mm]
d_p' : particle diameter of bed material after operation for given time [mm]
Ma : attrition rate [mg/hr]
N : number of particles charged in bed
t : operating time [hr]
U : fluidizing velocity [m/sec]
U_{mf} : minimum fluidizing velocity [m/sec]
W_a : total elutriation by attrition for given time [g]
W_b : initial bed weight [g]
W_b' : bed weight remaining after operation for given time [g]

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