PREPARATION OF ULTRAFINE CALCIA POWDER BY AIR PLASMA

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ABSTRACT

Ultrafine calcia powders were prepared by air plasma using $CaCO_3$ powders as raw material. Composition and morphology of powders had been studied by electron microscopy and X-ray diffraction. The results showed that mean particle size was about 100nm to 150nm. The shape was sphere. The main composition of ultrafine powders was calcia involving a little undecomposed calcium carbonate.

INTRODUCTION

The problem of environment pollution caused by sulfur dioxide after coal combustion caught considerable attention. Many effective methods to control and reduce the exhaust pollution had been studied. One of which was clean combustion technology which is now developing. Ultrafine calcia powders were the important material in this technology.

Ultrafine calcia powders have advantages such as large specific surface area, small particle size, good diffusion and high chemical activity. As desulphurization sorbent, it is easy to react with SO_2 in the exhaust. The reaction leads to formation of calcium sulfate ($CaSO_4$) and reduces sulfur dioxide content in the exhaust obviously. Moreover, ultrafine calcia powders are source of additive of calcium activator in food industry. So preparation of ultrafine calcia powders lead to considerable interest for researchers.

NUMERICAL SIMULATION OF REACTOR

To prepare ultrafine powders effectively, the field of temperature, velocity and particle's resident time in reactor should be known. Before experiment, numerical simulation had been used, temperature and velocity field in reactor were obtained.

The following assumptions were made when formulating the transport equations for the system under study.

i) the gas flow in reactor is steady and axially symmetrical.
ii) the k-ε model may be used to represent the turbulent viscosity and differential kinetic energy of turbulence and dissipation rate of turbulence equations.

The conservation equations of the axial, radial momentum ,the enthalpy , the kinetic energy of turbulence and its dissipation rate can be written in general form.

$$\frac{\partial}{\partial z}(\rho u\phi)+\frac{1}{r}\frac{\partial}{\partial r}(\rho r v\phi)=\frac{\partial}{\partial r}(\Gamma_\phi\frac{\partial\phi}{\partial z})+\frac{1}{r}\frac{\partial}{\partial r}(r\Gamma_\phi\frac{\partial\phi}{\partial r})+S_\phi \qquad (1)$$

Here ϕ is an index that may represent the velocity components, the enthalpy, the kinetic energy and its dissipation.

Γ_ϕ and S_ϕ represent the transport coefficients and source terms respectively. These transport coefficients and source terms are given in table 1

table 1 The transport coefficients and source terms

Φ	Γ_ϕ	S_ϕ
u	μ_t	$-\frac{\partial P}{\partial z}+\frac{1}{r}\frac{\partial}{\partial r}(r\mu_t\frac{\partial u}{\partial z})+\frac{\partial}{\partial z}(\mu_t\frac{\partial u}{\partial z})$
v	μ_t	$-\frac{\partial P}{\partial r}-\frac{2\mu_t v}{r^2}+\frac{1}{r}\frac{\partial}{\partial r}(r\mu_t\frac{\partial v}{\partial r})+\frac{\partial}{\partial z}(\mu_t\frac{\partial v}{\partial r})$
h	μ_t/σ_h	0
k	μ_t/σ_h	$G_k-\rho\varepsilon$
ε	μ_t/σ_h	$\frac{\varepsilon}{k}(C_1G-C_2\varepsilon)$
1	0	0

$$G_k=2\mu_t\{(\frac{\partial u}{\partial z})^2+(\frac{\partial v}{\partial r})^2+(\frac{v}{r})^2+\frac{1}{2}(\frac{\partial u}{\partial r}+\frac{\partial v}{\partial z})^2\}$$

$$\mu_t=C_D\rho k^2/\varepsilon \;,\; C_D=0.09, C_1=1.43, C_2=1.92\ \sigma_k=1, \sigma_\varepsilon=1.22, \sigma_h=0.9$$

The method of solution followed the "SIMPLE" procedure, which essentially involved several iterative cycles. Temperature and velocity fields were obtained, Average temperature and velocity in reactor were calculated by integral method. Results was :

$$T_m \approx 3400\ K\ ,\ V_m \approx 46\ m/s$$

The resident time of particle in reactor was: $t \approx 3.3\times10^{-3}$ (s)

When the particle size of $CaCO_3$ was about 200 μm , fully evaporating time under the plasma was: $t_1 \approx 13.7 \times 10^{-3}$ (s)

When the particle size was about 100 μm: $t_2 \approx 3.43 \times 10^{-3}$ (s)

From the calculation, fully evaporating time of raw material was larger than resident time in reactor when the particle size was about 200 μm. It resulted that raw material decomposed incompletely which was verified by experiment results. The particle size should be less than 100 μm in order to prepare pure ultrafine calcia powders.

EXPERIMENTAL

The experiment system consisted of four components: plasma generator reactor , powder feeder and powder collector. A schematic diagram was shown in Fig. 1

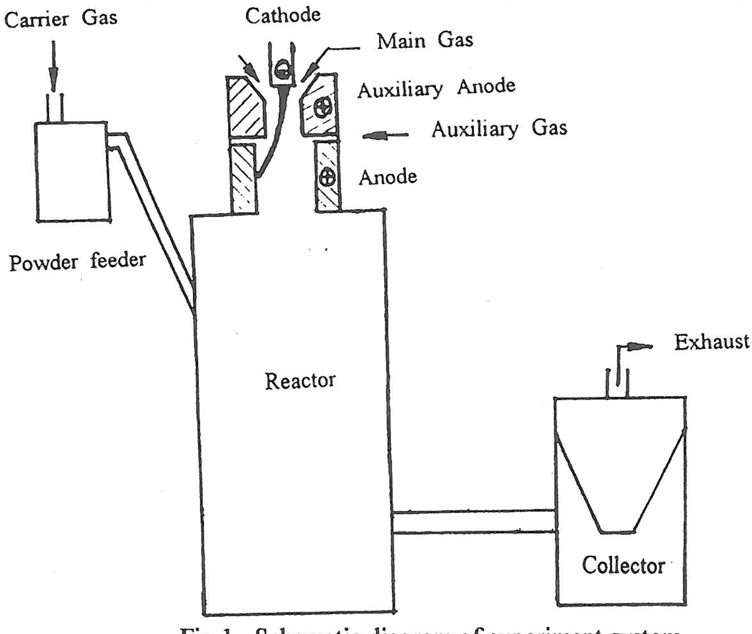

Fig. 1 Schematic diagram of experiment system

The mean size of raw material was about 200 μm .In experiment, powders fed directly to the plasma reactor with carrier gas, plasma working gas and carrier gas of powders was air . Plasma generator was double anode plasma torch . Power of generator could be adjusted from 40 kw to 80 kw. Total flow rate of generator was from $8m^3/h$ to $12m^3/h$. The carrier gas flow fate of feeder was from 1.5 to 3 m^3/h . Voltage of vibration feeder was from 50v to 150v which could control the flow rate of powders. $CaCO_3$ decomposed into CaO and CO_2 very quickly under high plasma temperature . Through fast cooling, ultrafine CaO powders were formed.

RESULTS AND DISCUSSION

Ultrafine calcia powders had been prepared by air plasma in laboratory scale. The powders had been analyzed by x-ray diffraction ,TEM and BI-XDC equipment.

1. Composition analysis

Ultrafine calcia powders were measured by x-ray diffraction. Results showed that main phase of powders was calcia. Each characteristic peak was obvious. Meanwhile powders involved a little undecomposed calcium carbonate . The result of x-ray diffraction analysis was shown in Fig.2

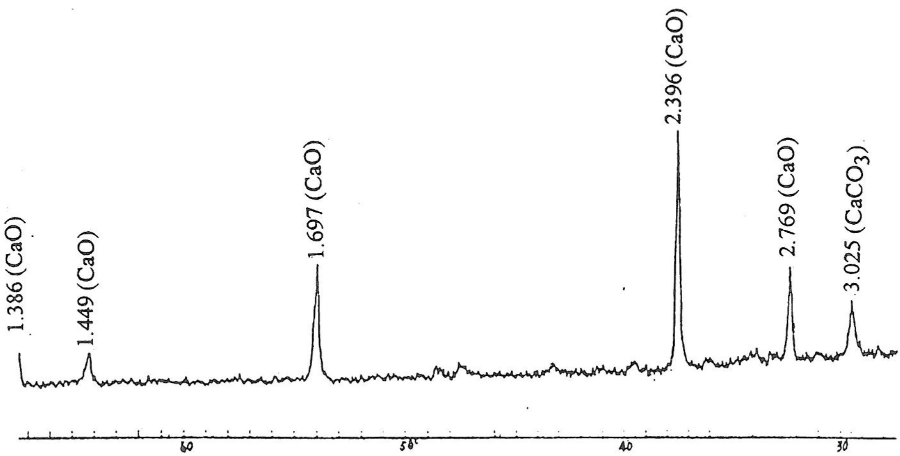

Fig.2 Result of X-ray analysis

2. Particle size analysis

Ultrafine powders were measured by BI-XDC equipment first. Because CaO is soluble in water. The solution selected had great influence on analysis . In test, the solution was pure ethyl alcohol. It volatilized very quickly and influenced the result. Meanwhile calcia powders could reunite . The scattering results influenced directly on accurate of particle size. So the results by BI-XDC could only provide an qualitative analysis. It's not accurate in value. The result showed that the size of great majority of particles was very small. The curve was shown in Fig.3

Because of the error of BI-XDC analysis, the same powders had been measured by TEM . TEM results showed the shape of ultrafine powders was sphere and means particle size was about 100nm to150 nm. TEM photographs were shown in Fig.4

3. Discussion

(1) Calcia powders prepared by air plasma involved a little undecomposed calcium carbonate . The reason should be

a) Particle size of raw material was too large to decompose completely.

b) Resident time of raw material in reactor was short

(2) When using BI-XDC equipment to analyze the distribution of particle size, scattering result and solution had important effect on measurements.

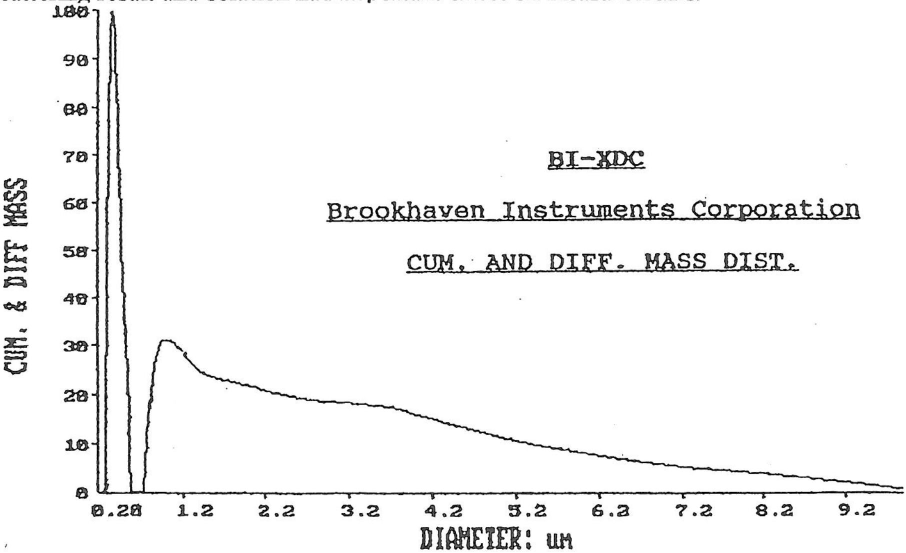

Fig.3 Curve of particle size distribution

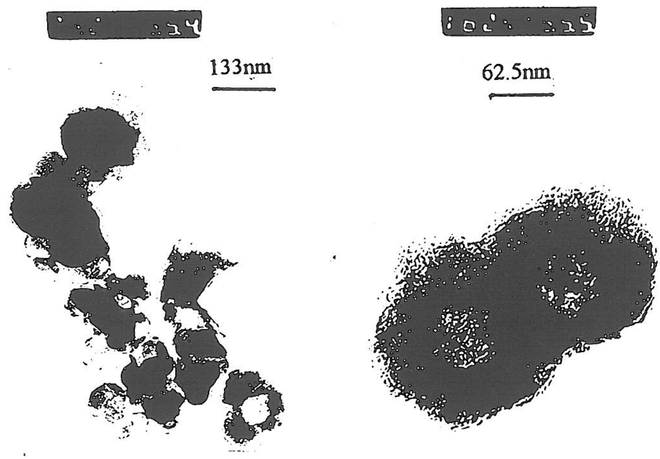

Fig.4 photographs of TEM

CONCLUSION

1. Preparation of ultrafine calcia powders using air plasma was effective.

2. The mean particle size of calcia powders was about 100nm to 150nm. The shape of calcia powders was sphere

3. If the distribution of temperature was improved or the resident time of raw material in reactor was enhanced , it should be good for preparation of pure calcia powders.

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