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On the Experimental Investigation for the Separation Characteristics of a Rotary Flow Dust Collector*

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The characteristics of a rotary flow dust collector for the dust separation process in connection with the flow pattern of air, pressure drop, total collection efficiency and the fractional collection efficiency η_x are made clear. The test dust is fly-ash which has mean diameter $x_{R50} = 12.44 \mu\text{m}$. Then the mechanically balancing particles $\bar{x}_{PB}$ which make a statistically stationary rotation in the collector are determined experimentally. And from the relationship between $\bar{x}_{PB}$ and η_x , the separation process of the dusts in the collector is investigated. Experimental equation of η_x is written as follows:

$$\eta_x = 1 - \exp\{(-\ln 2)(x/x_{c50})^m\}$$

where x is particle size and x_{c50} is a cut-size corresponding to x of $\eta_x = 0.5$ (50%). The exponents m of the separation are compared with the other types of cyclone, and m with x_{c50} is an index which shows the separation efficiency. And the results of experiments show that the collector can more easily attain a high collection efficiency than the ordinary type of cyclone.

1. INTRODUCTION

A rotary flow dust collector (Drehströmungsentstauber; D.S.E.) is a kind of equipment in the centrifugal dust collectors which produces a flow field of a strong centrifugal force. The flow mechanism is such that the dust-laden gas flow as a primary flow is introduced into a spiral vortex chamber from which the dust-laden rotational jet is spouted in the upward direction, and then in order to produce a stronger rotational flow of the dust-laden gas of primary flow, the secondary pure air is introduced tangentially to the main body⁽¹⁾⁽²⁾. The authors have done experiments on the total pressure drop, total collection efficiency and fractional collection efficiency. From the results of the experiments, the relationship between the cut-size of the separating particles and the fractional collection efficiency and also the characteristic value which represents the collection efficiency were made clear. In order to explain the physi-

cal mechanism of separating process of dusts, the distributions of the tangential and axial velocities of the mixing rotational air flow in main body of vortex chamber were measured. From these results, the equi-flow rate lines were calculated. Moreover, the size-distributions of particle clouds at various positions in the rotational air flow were measured. From these results, the mechanically balancing particle sizes on the arbitrary radius r were also calculated.

2. SYMBOLS

(gravitational units are used)

C	feed concentration of fly-ash (g/m ³)
D_i	diameter of the main body of cyclone (mm)
E	total consumed energy of fluid (Kg-m/sec)
$f(x)_n$	number frequency of fly-ash(%)
$f(x)_w$	weight frequency of fly-ash(%)
$f(x)_{we}$	weight frequency of fly-ash escaping from the dust collector (%)
H_i	effective height of the dust collector (mm)
g	gravitational acceleration (m/sec ²)
m	separation index of fractional collection efficiency (1)
n	velocity index of the tangential velocity distribution for the quasi-free vortex (1)
Δp_i	pressure drop of the primary

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- air flow (Kg/m^2)
- ΔP_{s1} difference of the static pressure between the inlet pipe and the outlet pipe for the primary air flow (Kg/m^2)
- ΔP_2 pressure drop of the secondary air flow (Kg/m^2)
- ΔP_{s2} difference of the static pressure between the inlet pipe and the outlet pipe for the secondary air flow (Kg/m^2)
- ΔP_c total pressure drop of the dust collector (Kg/m^2)
- Q_1 flow rate of the primary air flow (m^3/sec)
- Q_2 flow rate of the secondary air flow (m^3/sec)
- $R(x)_N$ cumulative residue distribution of numbers for fly-ash (%)
- $R(x)_w$ cumulative residue distribution of weights for fly-ash (%)
- $R(x)_{ws}$ cumulative residue distribution of weights for fly-ash escaping from the dust collector (%)
- Re_c cyclone's Reynolds number (1)
- r radius (mm)
- V_1 mean velocity of the primary air flow in the outlet pipe of the primary vortex chamber (inlet pipe of the main body of vortex chamber) (m/sec)
- V_1' mean velocity of the primary air flow in the inlet pipe of the primary vortex chamber (m/sec)
- V_{1e} mean exit velocity of the primary air flow in the outlet pipe of the main body of vortex chamber (m/sec)
- V_2 mean inlet velocity of the secondary air flow (m/sec)
- V_{2e} mean exit velocity in the outlet pipe of the secondary air flow (m/sec)
- V_θ tangential velocity of air in the main body of vortex chamber (m/sec)
- V_z axial velocity of air in the main body of vortex chamber (m/sec)
- x particle size (μm)
- x_{c50} cut-size corresponding to the particle size of $\eta_x = 50\%$ (μm)
- x_{R50} particle size corresponding to $R(x) = 50\%$ (μm)
- $\bar{x}_{PB}$ measured value of the mechanically balancing particle size (μm)

Fig. 1 Experimental apparatus.

Fig. 2 Particle size distribution of fly-ash as a test dust.

- z distance from the edge of the outlet pipe for the primary air flow in downward direction (mm)
- γ specific weight of air (Kg/m^3)
- γ_p specific weight of fly-ash (g/cm^3)
- η_c total collection efficiency (%)
- η_x fractional collection efficiency (%)
- ν coefficient of kinematic viscosity of air (m^2/sec)
- Ψ non-dimensional equi-flow rate line (1)

3. EXPERIMENTAL APPARATUS AND EXPERIMENTAL METHOD

As shown in Fig.1, an equipment of the rotary flow dust collector is made of a transparent synthetic resin and the main dimensions of this collector are: the outer cylinder diameter $D_1 = 150$ mm; the diameter of the inlet pipe where the dust-laden air flows into the main body of vortex chamber, 29.5 mm; and the

diameter of the outlet pipe from the main body of vortex chamber, 29.5mm. The tangential inlet pipe of the secondary air flow has the diameter 19.5mm and this pipe is installed with a slope of 45° to the collector center line and this pipe relative to the main body is inclined at 30° in the tangential direction. The secondary air flow streams into the main body of vortex chamber from the two inlet pipes which are installed symmetric with respect to the axis. The diameter of exit slit above the main body of vortex chamber for the secondary air flow is 80 mm. The exit pipe of primary air flow is installed passing through the center of this exit slit. The diameter of the exit pipe for the secondary air flow from the upper part of the collector is 42 mm. The diameter of the interruptive disc plate above the dust-bunker is 130 mm. The height of the outlet pipe from the primary vortex chamber is 32 mm. The secondary air flow re-circulating in the pipe is controlled by a heat-exchanger of volume 0.2 m^3 , through which the heated air flowing through the friction blower is cooled to the normal room temperature. In order to compare the effects of the effective height H_i on the performance of this collector, two kinds of H_i are employed: $H_i = 266 \text{ mm}$ and 466 mm .

The velocity distributions of the rotational flow in the case of $H_i = 466 \text{ mm}$ are measured by a cylindrical Pitot-tube of diameter 3 mm with a measuring hole of diameter 0.3 mm which is inserted perpendicular to the center axis of the collector and also which is variable to seven z places for the measurement. The measurable range of the velocity distributions of the rotational air flow in the collector is restricted to $V_1 = 10.1 \sim 33.1 \text{ m/sec}$ and $V_2 = 0 \sim 49.1 \text{ m/sec}$. Then from the results of the axial velocities, equi-flow rate lines are calculated. Each pressure drop for primary air flow and for secondary air flow of the collector is measured in the range of $V_1 = 6.1 \sim 42.3 \text{ m/sec}$ and $V_2 = 0 \sim 49.1 \text{ m/sec}$ and also the total pressure drop is calculated by considering the flow rate ratio Q_2/Q_1 and each dynamic pressure.

Then in order to measure the total collection efficiency, the fractional collection efficiency and the mechanically balancing particles, fly-ash is used as a test dust. The size distributions of fly-ash were determined by the Andreasen pipette method (by weight) and by the microscope method (by number) as shown in Fig.2. This dust is dried up in the desiccator, after which it is fed into the primary air stream from the electrical vibrator and then the dust concentration C in

Fig. 3(a) Distributions of tangential velocities.

Fig. 3(b) Distributions of axial velocities.

the primary dust-laden air flow becomes $C = 4.6 \sim 5.2 \text{ g/m}^3$.

The total collection efficiency is determined by the ratio of the total collected dust weight and the total fed dust weight. The fractional collection efficiency which is

Fig. 4(a) Non-dimensional equi-flow rate lines.

Fig. 4(b) Non-dimensional equi-flow rate lines.

derived from the method of K.R.Schmidt as described below is determined from the size distribution measured with a five-stage cascade-impactor, into which each escaping dust is sucked by an isokinetic sampling of each moving gas stream with a suction probe of inner diameter 7.5mm and outer diameter 9 mm located at each center of two exit pipes of the collector. Then the mechanically balancing particles on the arbitrary radius r are determined from the size distributions of dusts which are stuck on the adhesive tape on a piano steel wire of diameter 2 mm in the case of the feed concentration $C = 0.4 \sim 1.2 \text{ g/m}^3$. The ranges of the inlet velocities of these experiments for the total collection efficiency, the fractional collection efficiency and the balancing particle are $V_1 = 10.1 \sim 33.1 \text{ m/sec}$ and $V_2 = 11.1 \sim 49.1 \text{ m/sec}$.

4. EXPERIMENTAL RESULTS

4.1 VELOCITY DISTRIBUTION AND EQUI-FLOW RATE LINE

The tangential velocity contributing to the dust separation increased with an increasing velocity V_2 and then the velocity index n describing the distribution of the tangential velocities for the quasi-free vortex was less than about 0.5 and this index n became lower in comparison with the general rotational air flow. In addition to this, index n became lower than about 0.2 in the case of values larger than $Q_2/Q_1 = 1$. The decreasing tendency of this value n increased with an increasing value of V_2 . Especially the effect of decreasing tendency of index n was strongly influenced at the upper portion of $z \leq 200 \text{ mm}$.

In Fig.3(a) the distribution of the tangential velocities corresponding to the change of value of V_2 in the case of $V_1 = 25.8 \sim 28.4 \text{ m/sec}$ is shown at the position $z = 200 \text{ mm}$. In these results, in the range of $Q_2/Q_1 = 0.95 \sim 1.51$ the value of n became $n = 0.07 \sim 0.15$. And also in the case of $Q_2/Q_1 = 0.37 \sim 0.66$, the value of n became

$n = 0.23 \sim 0.41$. The distribution of the axial velocities corresponding to the values above mentioned range is shown in Fig.3(b).

The radial positions ($r = r_b$) where downward flow turned to upward flow (the axial velocity $V_z = 0$) were in the range of $50 \sim 60 \text{ mm}$, and these positions became about 50 mm with an increasing velocity of V_2 . These radial positions became $r_b = 30 \sim 40 \text{ mm}$, these were almost in the central part from the center axis of vortex chamber to the inner wall surface in the case of $V_1 = 14.9 \sim 17.0 \text{ m/sec}$ at $z = 340 \text{ mm}$ and also $r_b = 40 \sim 50 \text{ mm}$ in the case of $V_1 = 26.2 \sim 28.4 \text{ m/sec}$. Then at the axial position $z = 8 \text{ mm}$, r_b became $60 \sim 70 \text{ mm}$. Below the velocity of $V_2 = 15 \text{ m/sec}$ and above $V_1 = 30 \text{ m/sec}$, the radial position of r_b increased to $r_b = 70 \text{ mm}$ and showed a decreasing downward flow.

From these axial distributions of the axial direction, the non-dimensional equi-flow rate lines ψ were calculated as follows:

$$\psi = \frac{1}{Q_1} \int_0^r 2\pi r \cdot dr \cdot V_z \quad (1)$$

In the case of $Q_2/Q_1 = 0.80$ of Fig.4(a), the line of $\psi = 1.0$ returned to above the middle of the main body of vortex chamber, but in the

Fig. 5 Total pressure drop.

Fig. 6 Total collection efficiency for the secondary inlet velocity in the case of $H_i = 466$ mm. Fig. 7 Total collection efficiency for the secondary inlet velocity in the case of $H_i = 266$ mm.

case of $Q_2/Q_1 = 1.30$ of Fig. 4(b) the line of $\psi = 1.0$ extended to the bottom of the vortex chamber. So in the case of $Q_2/Q_1 = 1.30$ the inward drag acting on a separating particle which reaches the wall surface with an increasing downward flow tends to decrease in comparison with the centrifugal force by the tangential velocity V_θ . Therefore the separation efficiency becomes higher⁽⁴⁾.

4.2 TOTAL PRESSURE DROP

The pressure drop ΔP_1 of the primary air flow is defined as follows:

$$\Delta P_1 = \Delta P_{s1} + (\gamma V_1^2 / 2g) - (\gamma V_{1e}^2 / 2g) \quad (2)$$

and also the pressure drop ΔP_2 of the secondary air flow is defined as follows:

$$\Delta P_2 = \Delta P_{s2} + (\gamma V_2^2 / 2g) - (\gamma V_{2e}^2 / 2g) \quad (3)$$

Therefore considering the re-circulation of the secondary air flow, the total pressure drop ΔP_c is estimated as⁽⁴⁾

$$\Delta P_c = \Delta P_1 + (Q_2/Q_1) \Delta P_2 \quad (4)$$

The value of ΔP_c for the pure air flow calculated in the case of $H_i = 466$ mm is shown in Fig. 5. The corresponding minimum values of ΔP_c for various values of V_2 were about $Q_2/Q_1 \approx 1.2$. These values of ΔP_c were independent of the dust concentration $C = 4.6 \sim 5.2$ g/m³ of fly-ash.

4.3 TOTAL COLLECTION EFFICIENCY

The experimental values of η_c for V_2 are shown in Fig. 6 and 7 as a parameter of value V_1 . These values of η_c were very stable and also could reappear within the range of $\pm 3\%$. The value of V_1 increased with an increasing value of V_2 from the minimum value to the maximum value within each range of V_1 which is written in these figures.

In the case of $H_i = 466$ mm the value of η_c was more than $\eta_c = 95\%$ for the velocity higher than $V_2 = 20$ m/sec. Then the driving conditions for the collection efficiency corresponded to the velocity $V_2 = 42$ m/sec for the primary inlet velocities $V_1 = 28.2$ and 32.7 m/sec, therefore the values of Q_2/Q_1 were 1.30 in the former case and

Fig. 8 Equi-total collection efficiency lines and equi-total pressure drop lines in the case of $H_i = 466$ mm.

Fig. 9 Equi-total collection efficiency lines and equi-total pressure drop lines in the case of $H_i = 266$ mm.

1.12 in the latter case. The critical point of a sharply decreasing collection efficiency corresponded to the value $Q_2/Q_1 \approx 1.0$.

In the case of $H_i = 266$ mm which increases the value of V_1 from 26 m/sec to 33 m/sec, the value of η_c decreased about 5~10 %. The physical meaning of this result is based upon the short residual time of the fine solid particles, and in this case even if the same order of magnitudes of the centrifugal force in the case of $H_i = 466$ mm is given, the inward drag acting on the fine solid particles by the returned flow of the secondary air flow acts strongly.

Then the lines of the equi-total collection efficiency η_c are shown in Figs. 8 ($H_i = 466$ mm) and 9 ($H_i = 266$ mm) on the axes V_1 and V_2 as a parameter ΔP_c . In these figures the lines of the equi-total pressure drop as a parameter are shown. Then the domain of the total collection efficiency above $\eta_c = 99\%$ for $H_i = 466$ mm ranged in $V_1 = 13 \sim 35$ m/sec and in $V_2 = 25 \sim 53$ m/sec, in

this case the value of Q_2/Q_1 being above about 0.95 and the minimum value of ΔP_c being about 130 Kg/m^2 . And also in comparison with the case of $H_i = 466$ mm for the case of $H_i = 266$ mm, the domain exhibiting a high collection efficiency was narrower but kept about $\eta_c = 98\%$ even in the case of $\Delta P_c = 80 \sim 150 \text{ Kg/m}^2$.

In addition to this, the values of η_c for the total consumed energy $E = Q_1 \Delta P_c (= Q_1 \Delta P_1 + Q_2 \Delta P_2)$ Kg-m/sec of the pure air flow are shown as a parameter Q_2/Q_1 in Figs. 10 and 11.

In the case of $H_i = 466$ mm which increases the value of E , η_c developed until $E \approx 8 \text{ Kg-m/sec}$. For the case $Q_2/Q_1 \approx 1$, $\eta_c = 98\%$ was shown at about $E = 1.0 \text{ Kg-m/sec}$. And when the value of E was increased for $H_i = 266$ mm, the value of η_c did not increase proportionally to the value of E and also the maximum value of η_c at $E = 1 \sim 3 \text{ Kg-m/sec}$ was shown; then with a further increase of the value of E , the values of η_c decreased gradually.

4.4 FRACTIONAL COLLECTION EFFICIENCY

The value of the fractional collection efficiency η_x was calculated by the method of K.R. Schmidt from which the relationship between the distribution $f(x)_{we}$ of the escaping particles from the collector and the distribution $f(x)_w$ of fly-ash of the feed dust was determined by the experiments¹¹. This reciprocal relation among η_x , η_c , $f(x)_{we}$ and $f(x)_w$ is written as

$$\eta_x = 1 - (1 - \eta_c) [f(x)_{we} / f(x)_w]_x. \quad (5)$$

Figs. 12 (a) (b) and 13 (a) (b) show the experimental results of the fractional collection efficiency η_x for the case of $V_1 = 14.9 \sim 17.0$ m/sec and of $V_1 = 26.2 \sim 28.4$ m/sec, both of which are dependent on the change of V_2 . After arrival at $\eta_c = 99\%$, the value of η_x reached about 100 % for the particle size $x = 3 \sim 5 \mu\text{m}$ and also in the case of the maximum value of $\eta_c = 99.7\%$, η_x became about 100 % for about $x \approx 2.5 \mu\text{m}$. For $\eta_c = 95\%$, η_x became zero in the range of roughly $x = 1 \sim 1.5 \mu\text{m}$. In the case of finer particles than $x = 1 \sim 1.5 \mu\text{m}$, $[f(x)_{we} / f(x)_w]_x \geq 20$ was given from the results of experiments for $1 - \eta_c = 0.05$ in eq. (5) and then the values of η_x became up to the maximum of zero; therefore these calculated

Fig. 10 Total collection efficiency for the consumption of energy in the case of $H_i = 466$ mm.

Fig. 11 Total collection efficiency for the consumption of energy in the case of $H_i = 266$ mm.

Fig. 12(a) Fractional collection efficiency for the particle size in the case of $H_i = 466$ mm.

results indicate that these fine particles can not be collected. By observing under the microscope the fly-ash which was collected in the

dust-bunker, even the finer particles of lower size than $x = 1 \sim 1.5$ μm were confirmed sufficiently.

On the other hand, in the case of $\eta_c = 67.3$ % for $V_1 = 26.2$ m/sec, $V_2 = 11.1$ m/sec, $Q_2/Q_1 = 0.37$ and $H_i = 266$ mm, the value of η_x became zero for about $x \approx 4.2$ μm and reached $\eta_x \approx 96$ % for $x = 15$ μm.

4.5 CUT-SIZE AND INDEX OF SEPARATION

The experimental equation of the fractional collection efficiency η_x was written as follows:

$$\eta_x = 1 - \exp \left\{ (-\ln 2) \left(\frac{x}{x_{c50}} \right)^m \right\} \quad (6)$$

and then the collection efficiency was estimated by the factors of the cut-size x_{c50} and the index m of separation which indicates the sharpness of the separation. Both of the values x_{c50} and m become the characteristics of the collection efficiency, because of the estimation of the total collection efficiency only with the value of x_{c50} is very difficult in a wide range of distributions of η_x .

In order to compare with the experimental results of the fractional collection efficiency, the values calculated by eq.(6) are drawn by the solid lines in Figs. 12(a)(b) and 13(a)(b). From this comparison of the experimental values with those of eq.(6), this equation could describe the characteristics of the fractional collection efficiency of the experimental results especially in the region between $\eta_x = 20 \sim 30$ % and $\eta_x = 95$ %, but below $\eta_x = 20 \sim 30$ % and above $\eta_x = 95$ % there was a little difference between the calculated values of eq.(6) and the experimental results.

Fig.14 and 15 show the values of x_{c50} for $H_i = 466$ mm and $H_i = 266$ mm. In the case of $H_i = 466$ mm, the value of x_{c50} fell within $0.4 \sim 6.3$ μm and also in the case of $\eta_c \approx 99$ % the cut-size $x_{c50} \approx 1.1$ μm was reached. Then

Fig. 12(b) Fractional collection efficiency for the particle size in the case of $H_i = 466$ mm.

Fig. 13(a) Fractional collection efficiency for the particle size in the case of $H_i = 266$ mm.

Fig. 13(b) Fractional collection efficiency for the particle size in the case of $H_i = 266$ mm.

in the case of the value of $\eta_c = 99 \pm 0.5\%$, $x_{cso} = 0.7 \sim 1.4 \mu m$ was obtained. Above $V_2 = 25$ m/sec, the values of x_{cso} became below $3 \mu m$. In the case of $V_1 = 10.1 \sim 23.5$ m/sec, even

smaller than the values for $H_i = 466$ mm. Moreover, the experimental values of the secondary flow type dust collector by Ogawa et al. and of the ordinary type of cyclones by Hikichi

if the value of V_2 was $15 \sim 20$ m/sec, x_{cso} became below $3 \mu m$. These results for the case of $Q_2/Q_1 = 0.7 \sim 1.2$ suggest that the dust having the distribution of the fly-ash as a test dust is collected above $\eta_c \geq 90\%$. The value of x_{cso} for the case of $V_1 = 10.1 \sim 11.7$ m/sec was coincident with the value which was obtained by Ogawa et al. at $V_2 \div 15$ m/sec as shown in Fig. 14 and also this tendency was very similar to that of Ogawa et al.

In the case of $H_i = 266$ mm the values of x_{cso} were within $1 \sim 3.5 \mu m$ for $V_2 \div 30$ m/sec, and also these values showed the minimum values for various values of V_1 .

The values of m are shown in Figs. 16 and 17 for the values of x_{cso}/x_{rso} which are non-dimensionalized by $x_{rso} = 12.44 \mu m$. In the case of $H_i = 466$ mm for the range of $x_{cso}/x_{rso} = 0.05 \sim 0.2$, the values of m were $2.2 \sim 2.8$ for the condition of $V_1 = 10.1 \sim 11.7$ m/sec, and also $m = 1.8 \sim 2.3$ for $V_1 = 14.9 \sim 23.5$ m/sec, then $m = 1.3 \sim 1.7$ for $V_1 = 26.2 \sim 33.1$ m/sec. For the three regions of the inlet velocity, the calculated values of $Rec = (Q_1 + Q_2)/V H_i$ are corresponding to $(1.9 \sim 5.2) \times 10^3$, $(2.3 \sim 6.3) \times 10^3$ and $(3.4 \sim 7.3) \times 10^3$ respectively, but with an increasing value of Rec , the values of m decrease. On the other hand, with an increasing value of x_{cso}/x_{rso} , the values of m increase, the values of x_{cso}/x_{rso} became from 0.1 to 0.5, and the values of m became about $0.2 \sim 0.3$ in each case.

In the case of $H_i = 266$ mm, for respective ranges of values of V_1 , the values of m fall within the range of $1.5 \sim 2.5$. In this case the values of Rec are $(3.3 \sim 12.7) \times 10^3$, also the values of m become

Fig. 14 Particle size of $\eta_x = 50\%$ in the case of $H_i = 466$ mm.

Fig. 15 Particle size of $\eta_x = 50\%$ in the case of $H_i = 266$ mm.

Fig. 16 Separation index for x_{c50}/x_{R50} in the case of $H_i = 466$ mm.

& Ogawa are shown in Fig. 17⁽⁷⁾⁽⁸⁾. These values of η_c are corresponding to the former 75~88 % and the latter 95~97 %, then even if the values of x_{c50} for each case are nearly the same, the values of η_c are different largely depending on the grade of magnitude of m .

4.6 MECHANICALLY BALANCING PARTICLE SIZE

Collecting the particles (the mean space of particle is 90~150 times as large as $x_{R50} = 4.78 \mu m$ by number) in the main body of vortex chamber and calculating the mean size $\sum f(x_i) \cdot x_i$ as a symbol $\bar{x}_{PB}$ from the number size-distribution curve $f(x)$, the calculated results of values $\bar{x}_{PB}$ are shown in Fig. 18 (a) (b). These values are limited between $0.3 \mu m$ to $2.8 \mu m$ and in spite of the range of values $x_{c50} = 0.48 \sim 4.76 \mu m$, the change of these values becomes smaller. And with an increasing radius position from center, the collection of the solid particles increases, but the size-distributions of these solid particles at each radius position do not change so much except in the center core region.

5. CONCLUSIONS

As the separation characteristics of a rotary flow dust collector, the total collection efficiencies η_c and the fractional collection efficiencies η_x were measured by using fly-ash as a test dust, and then the relationships between the values of η_c and the total pressure drops ΔP_c were made clear. Then it was made clear by the experiments that the experimental equation of η_x could be expressed by eq. (6) and also that the values of x_{c50} and m characterized the performances of collection efficiency. Still more concerning the mechanism of separation, the equilibrium flow rate lines and the mechanically balancing particle sizes $\bar{x}_{PB}$ in the main body of vortex chamber were calculated. In the following these results are summarized.

- (1) The value of η_c can be obtained as more than $\eta_c = 99\%$. This collector shows a higher collection efficiency than the ordinary type of cyclone. The value of ΔP_c is $150 \sim 250 \text{ Kg/m}^2$ and the value of E is $1.5 \sim 5 \text{ Kg-m/sec}$.
- (2) The ratio Q_2/Q_1 which yields a high collection efficiency is limited to $Q_2/Q_1 = 1 \sim 1.9$.
- (3) Comparing the collection efficiency between $H_i = 466 \text{ mm}$ and $H_i = 266 \text{ mm}$, in the case of $H_i = 466 \text{ mm}$ a higher collection efficiency is obtained and its application is wide.
- (4) The minimum value of x_{c50} is $0.48 \mu m$ and the value of η_c is 99.7% for this case. Then it is easy to obtain a value of x_{c50} below $1 \mu m$.
- (5) The value of m is $1.3 \sim 2.8$, thus the value of m with the value of x_{c50} is an index which shows the separation efficiency.
- (6) The value of $\bar{x}_{PB}$ is $0.3 \sim 2.8 \mu m$ and except in the domain of the vortex core the value of $\bar{x}_{PB}$ increa-

Fig. 17 Separation index for x_{cso} / x_{R50} in the case of $H_i = 266$ mm.

Fig. 18(a) Mechanically balancing particle size in the rotational air flow.

Fig. 18(b) Mechanically balancing particle size in the rotational air flow.

ses slightly with an increasing radius.

(7) It is very difficult to infer the values of η_c and of x_{cso} with a weight method from the value of x_{pb} .

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