Studies on Central Cleaning System (Part 4)

Design of Cyclone Gate

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INTRODUCTION

In the Central Cleaning System, a simplicity mechanism which some uniform dusts in a home are vomited automatically, was designed and manufactured by way of trial. In this paper, we report the mechanism and the results obtained by our experiment.

MECHANISM AND PRINCIPLE OF THE GATE OF CYCLONE

The fundamental structure of the gate of our cyclone is shown in Figure 1.

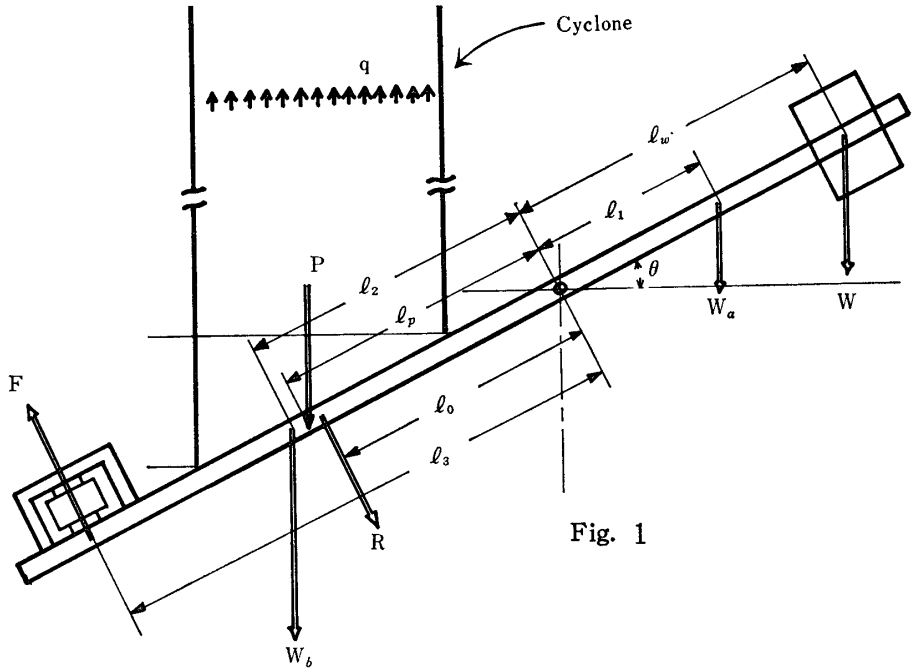


Fig. 1

W_a : weight of the beam on the right side about the fulcrum
W_b : weight of the beam on the left side about the fulcrum
W : wieght of the weight
R : reaction force
P : weight of the dust in the cyclone
F : adsorption force by the electromagnet

When some dusts are gathered at the hight of $l \sim h$ on the bottom of cyclone, from the moment about the fulcrum, force R is shown as follows.

$$R=\frac{\cos\theta}{l_0}(Wl_w+W_al_1-Pl_p-W_bl_2)+\frac{1}{l_0}(Fl_3+Ql) \cdots\cdots (1)$$

In this place, F is a adsorption force by the electromagnet, and the friction about the fulcrum is omited. As regard Wl_w, W_al_1 and W_bl_2, we can see their relation in the next equation.

$$Wl_w+W_al_1 \gtrless W_bl_2 \text{ or } l_w \gtrless \frac{W_bl_2-W_al_1}{W}$$

The more the pile of dust enlarges, the more force P increases. When the reaction force R is changed from plus to negative, the gate of cyclone is opened slightly, the switch of electromagnet is turned off, and force F and force Q are equal to zero. Then,

$$Wl_w+W_al_1-W_bl_2 \ll Pl_p$$

therefore the gate is turned to the left by moment M, and the dust is excluded. The moment of the time is shown as follows.

$$M=\frac{\cos\theta}{l_0}(Wl_w+W_al_1-Pl_p-W_bl_2)$$

When the exclusion of dust is finished, P is equal to zero. Returned by the moment $Wl_w+W_al_1-W_bl_2 \gtrless 0$, the gate is pushed on the bottom of cyclone, and the cyclone is made airtight. The then force R is as follows:

$$R=\frac{\cos\theta}{l_0}(Wl_w+W_al_1-W_bl_2)+\frac{1}{l_0}(Fl_3+Ql) \cdots\cdots (2)$$

Let d and ρ denote the diagram of cyclone and the specific gravity of dust, in the case of $\theta=\frac{\pi}{4}$, the volume of solids in the part A is $V_1=\frac{1}{8}\pi d^3$, its weight is $P_1=\rho V_1=\frac{1}{8}\pi\rho d^3$, the volume of solids in the part B is $V_2=\frac{1}{4}\pi d^2h$, its weight is $P_1=\rho V_2=\frac{1}{4}\pi\rho d^2h$, therefore the whole weight is as follow.

$$P=P_1+P_2=\frac{1}{8}\pi\rho d^2(d+2h) \cdots\cdots (3)$$

As is evident from Figure 2, from $Pl_p=P_1l_x+P_2l_0$, the central position of the gravity of collected dust is shown as follows.

$$l_p=\frac{dl_x+2l_0h}{d+2h} \cdots\cdots (4)$$

In the preceding equation, in the case of $\theta=\frac{\pi}{4}$

$$l_x=\sqrt{2}(l+x), \quad \text{here } l=\frac{1}{\sqrt{2}}l_0$$

And x is obtained by solving the next equation ($d=2a$).

$$ax\sqrt{a^2-x^2}-\frac{x^3}{3}+a^3\sin\frac{x}{a}=\frac{\pi d}{2}(a^2+1)-\frac{a^3}{3}$$

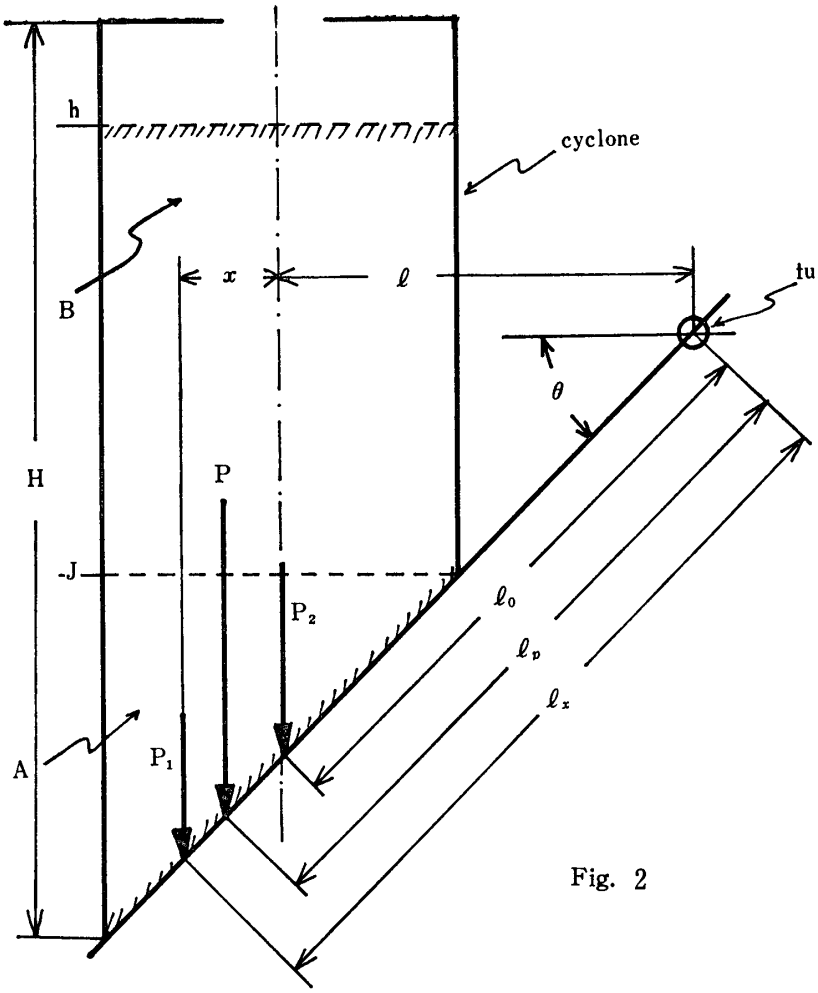


Fig. 2

Dimension

θ	45°
ℓ_0	22.3cm
ℓ_w	16.5cm and 9.5cm
ℓ_1	20.3cm
ℓ_2	23.1cm
ℓ_3	41cm
ℓ	15.8cm
w	1277 g
w_a	548 g
w_b	985 g
d	20cm
H	106cm

The height of cyclone is designed less the dust should be pile over the entrance of cyclone ; that is, in the equation (1), the height H must be greater than h when $R=0$.

$$(Wl_w+W_al_1-W_bl_2-Pl_p)\cos\theta+Fl_3+Ql=0$$

Furthermore, we obtain a following equation by substituting equation (3), (4) and $Wl_w+W_al_1-W_bl_2=S$ into the preceding equation.

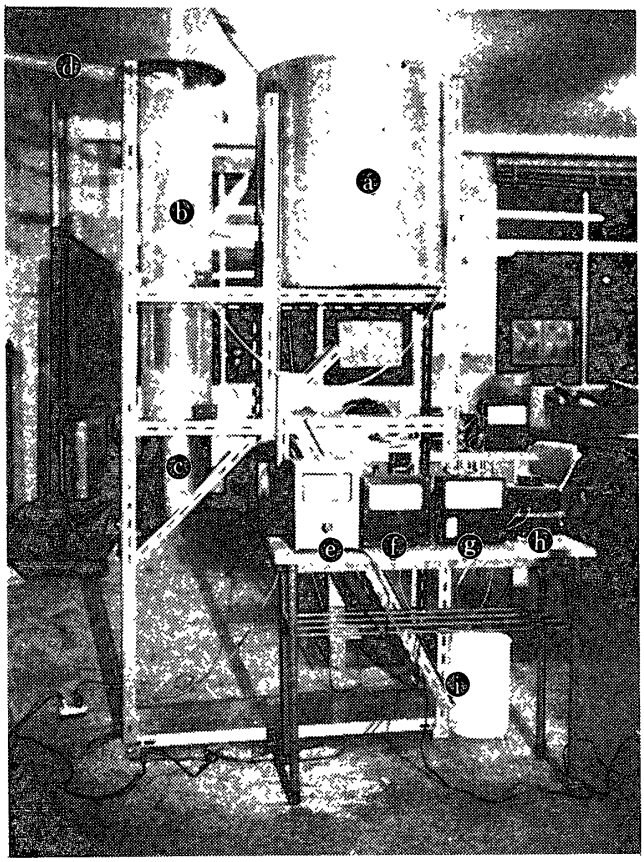
$$h=\frac{1}{l_0}\left[\frac{4}{\pi\rho d^2}\left(S+\frac{Fl_3+Ql}{\cos\theta}\right)-\frac{dl_x}{2}\right]<H \quad \cdots\cdots(5)$$

Certainly the smaller the specific gravity of dust is, the greater the height of cyclone H is.

When the electric current of magnet is equal to zero, or when the magnet is not used, the reaction force R and the height of cyclone H are obtained by substituting $F=0$ into the equation (1) and (5). When the weight is set in the condition $S=0$, R and H are obtained also by substituting $S=0$ into the equation (1) and (5).

EXPERIMENTAL RESULTS AND CONSIDERATIONS

Our cyclone and experimental installation are shown in Figure 3.



ⓐ Blower
ⓑ Cyclone
ⓒ Gate
ⓓ Pipe
ⓔ Hot wire anemometer
ⓕ Voltmeter
ⓖ Ammeter
ⓗ Transformer
ⓘ Aquatic manometer

Fig. 3

The electric vacuum cleaner of 100volt-600watt is used for a blower in our experiment. The relation between the voltage of blower and first the suction pressure q_0 of blower, second the negative pressure q in the cyclone which had a suction pipe of 31 mm in diameter, and third the velocity v of air in the pipe are shown in Figure 4.

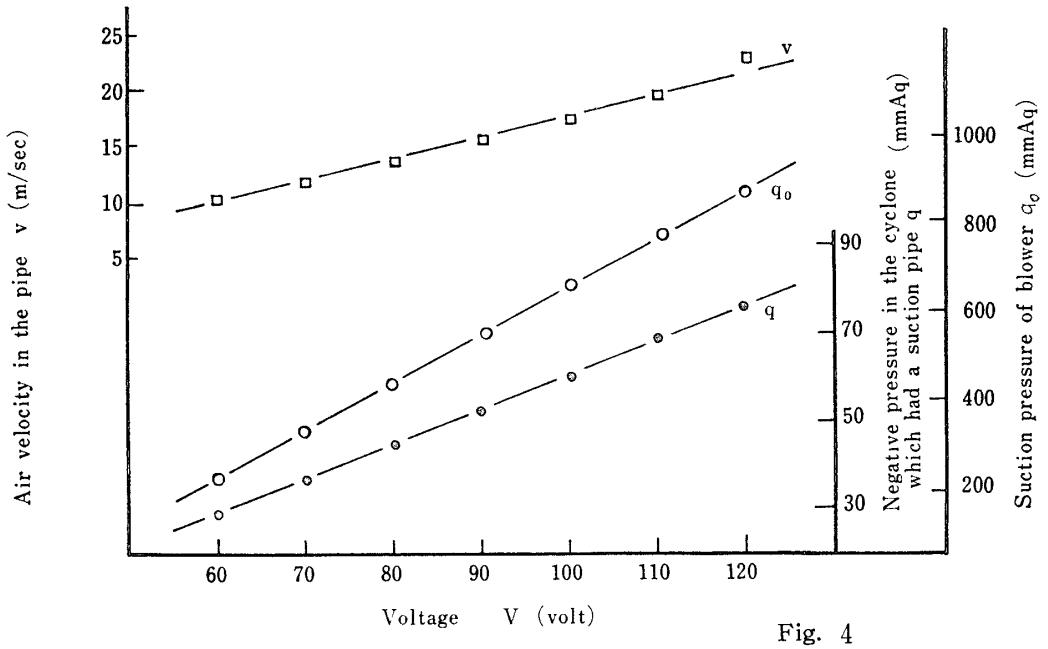


Fig. 4

The negative pressure is measured by a aquatic manometer, and the air velocity in the pipe is measured by a hot wire anemometer.

In the equation (1), Q is caluculated from the next equation.

$$Q=\frac{1}{4}\pi d^2 q$$

The relation between the suction force by our electromagnet and the then exciting current is shown as Figure 5.

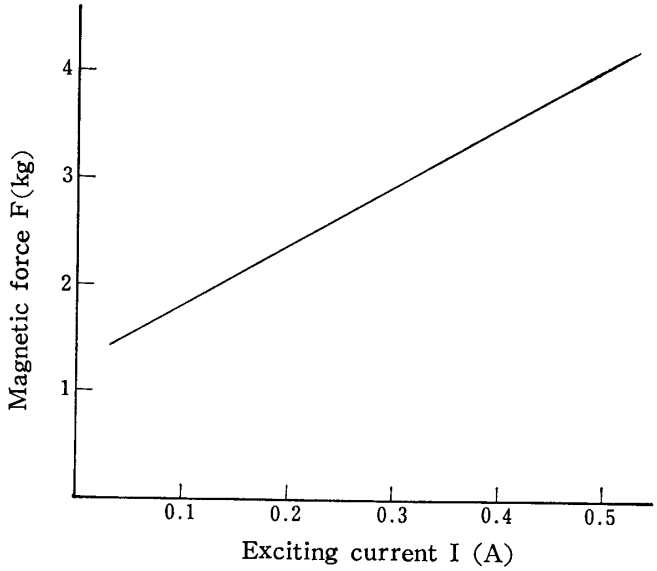


Fig. 5

As the transported material equivalent to some dusts, we used some uniform unhulled rice (specific gravity $\rho=0.51$) and rice hulls ($\rho=0.14$) in this experiment. As the specific gravity is very great in the case of unhulled rice, the volume of rices excluded at a time is small enough, and the height of cyclone H may be designed small, as it is shown in equation (5). In the case

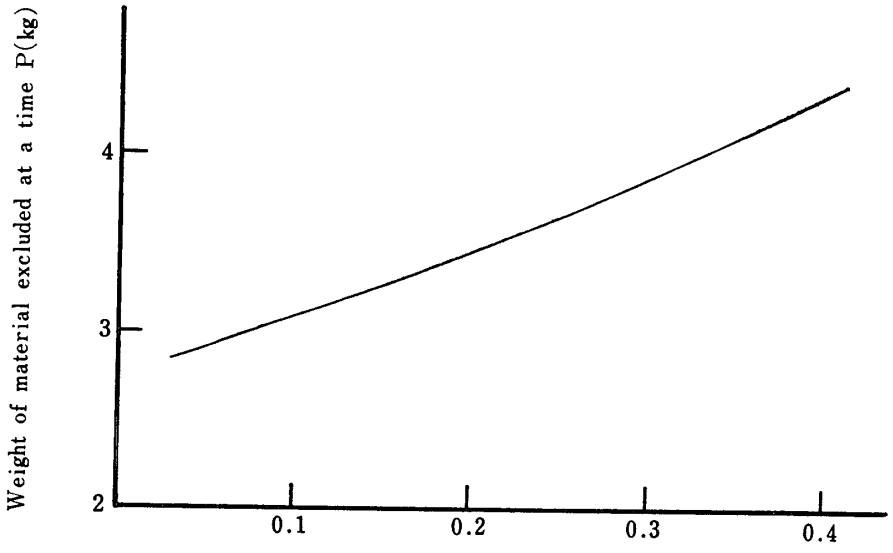


Fig. 6

of l_w=16.5 cm, the relation between the exciting current of electromagnet and the weight of rice excluded at a time is shown in Figure 6. The then negative pressure in the cyclone is about 50 mmAq in the case of no-load and about 70 mmAq in the case of load (when the vacuum cleaner is used).

In our experiment, even if the electromagnet is not used, or in the case of F=0, when the dust of regular weight is piled up in the cyclone, the gate of cyclone is openod speedily and the dust is excluded completly. The then weight of dusts can be calculated by substituting R=0, F=0 into the equation (1).

When we transport dusts of which specific gravity is small, the negative pressure q or Q in the cyclone is so great and the volume of the dust excluded at a time is so great that the hight of the cyclone H must be designed to be very great. Even if dusts of the constant volume are not piled, when we finish the cleaning, and when the blower is stopped, Q is equal to zero. And if the weight is set on the position of $S=Wl_w+W_al_1-W_bl\fallingdotseq 0$, even a few dusts can be excluded, the cyclone is prepared for the next cleaning.

In our experiment, in the case of l_w=9.5 cm ($S\fallingdotseq 0$), F=0 and the specific gravity of the transported material ρ=0.14, the weight of dust P excluded at a time is 2510g. The then negative pressure in the cyclone is q=55 mmAq in the case of no-load, and about q=70 mmAq in the case of load. When the blower of electric vacuum cleaner is stopped, even if the weight of dust P is 10g, the dusts are compltely excluded.

SUMMARY

A simplicity mechanism which some un-uniform dust are vomited automatically, was designed and manufactured by way of trial.

The height of cyclone is designed less the dust should be pile over the entrance of cyclone, that is, in the equation (1), the height H must be greater than h when R=0.

(1) As the specific gravity is very great in the case of rices, the volume of rices excluded at a time is small enough, and the height of cyclone H may be designed small.

(2) When we transport dusts of which specific gravity is small, the negative pressure q or Q in the cyclone is so great and the volume of the dust excluded at a time is so great that the hight of the cyclone H must be designed to be very great.

Even if the electromagnet is not used, or in the case of F=0, when the dust of regular weight is piled up in the cyclone, the gate of cyclone is opened speedily and the dust is excluded completly. Even if dusts of the constant volume are not piled, when we finish the cleaning, and when the blower is

stopped, Q is equal to zero. And if the weight is set on the position of $S = Wl_w + W_a l_1 - W_t l \fallingdotseq 0$, even a few dusts can be excluded, the cyclone is prepared for the next cleaning.

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