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Influence of wall pressure on power reduction of plug conveying by ultrasonic

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Abstract: Ultrasonic was applied to the horizontal line in plug conveyance of granular particles, and pressure drop was measured. As the result of this experimental research, pressure loss became smaller linearly with increasing of ultrasonic amplitude regardless of kinds of particles and flow conditions. Therefore, ultrasonic can cut the frictional resistance between packed particles and wall surface. The relationship of average pressure to the pipe wall and pressure loss reduction effect by ultrasonic was investigated. As a result, the pressure loss could not be reduced by ultrasonic as pressure of particle bed against the pipe wall become larger. This was assumed that it's hard to float particles as particle pressure to the wall become larger and a lot of particles contact with pipe surface.

1. INTRODUCTION

The plug transportation which is one of the pneumatic transportation systems has many advantages compared with other systems, but it has the demerit to which transportation power becomes large due to frictional resistance. As one of the method to remove this matter, Dr. Kano proposed to apply mechanical vibration for pipe lines[1]. However, this has some lacks. Therefore this method has not been realized. Dr. Kofu proposed the application of ultrasonic for plug conveying line because device is easy and cheap, generation power is low. Then it has been revealed experimentally that ultrasonic wave can get the friction reduction effect in the horizontal plug transportation line in spite of kinds of granular particles. Moreover, it was shown by using theoretical equations that the reduction effect becomes small when wall pressure becomes large because it's hard to float particles. But it hasn't be validated experimentally. Then, the purpose of this study is to clarify the relationship between reduction effect and wall pressure experimentally.

2. EXPERIMENTAL DEVICE AND METHOD

The experimental device for plug conveying is shown in figure 1. In this experiment, a compressor is positioned at the initial point, and positive pressure system was employed. The air chamber is used for accumulating the compressed air. A transport pipe is made of acrylics, entire length is 13m and inner diameter is 50mm. The vibration pipe is installed in the horizontal pipe line. The pipe inside diameter was 50 mm, the outer diameter was 58.56 mm, the length was 200 mm. The vibration pipe which material is juralmin was designed to resonate at 20.5 kHz similar to piezoelectric ceramics. Figure2 shows the vibration amplitude measured by laser Doppler vibrometer A_m in the longitudinal direction L_0 and angle θ.

In order to measure pressure loss in the plug $\Delta P/L_P$ in the vibration pipe, two pressure taps are attached at both end of the vibration pipe. Moreover, in order to measure the pressure which acts on pipe wall, eight button sensors was attached on the inner pipe wall at every 45 degrees in peripheral direction as shown in figure 3. Furthermore, in order to measure the particle velocity u_s, laser Doppler velocimeter was installed. Then, in order to obtain the plug velocity W_P, two photoelectric sensors which this intervals is 1m were positioned.

As conveyed particles, four kinds of granular particles are employed, Polystyrene pellet, Nipolon hard, Polyethylene pellet and Plastic pellet.

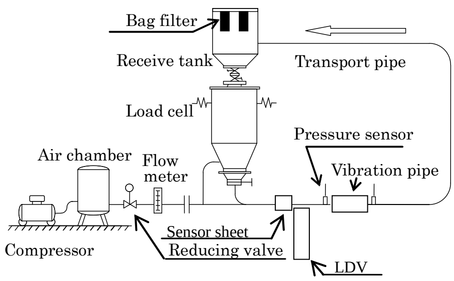

Fig.1 Experimental apparatus

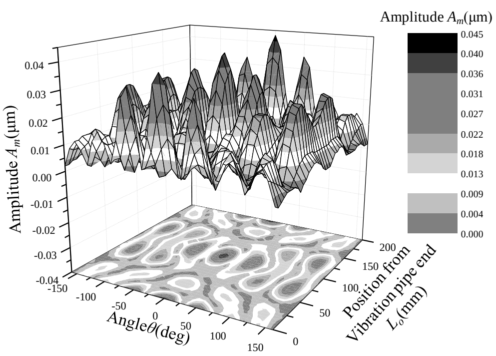

Fig.2 Vibration mode

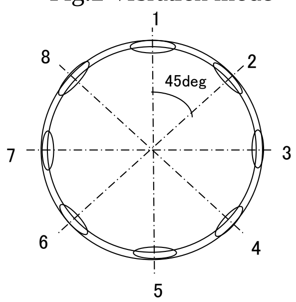

Fig.3 Position of sensor sheet

3. EXPERIMENTAL RESULTS AND DISCUSSION

A relationship between pressure drop ratio α and Am *in* Nipolon hard is shown in figure 4 representatively. α is the ratio of $\Delta P/L_P$ with ultrasonic vibration to it at A_m=0. Therefore small value on α means large reduction effect on pressure drop by ultrasonic. Figure 4 shows that α is related to the particle velocity u_s, and the power reduction effect becomes larger with decreasing of u_s. This cause is considered as the pressure affecting on the pipe surface by the particles. This pressure increases when u_s becomes faster

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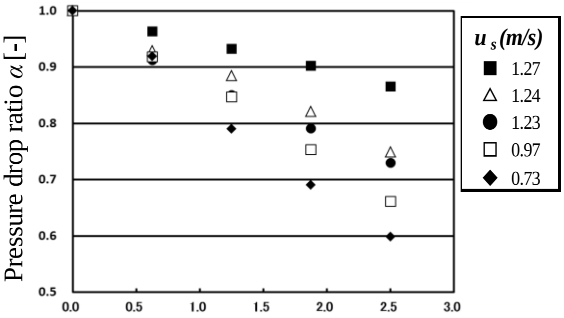


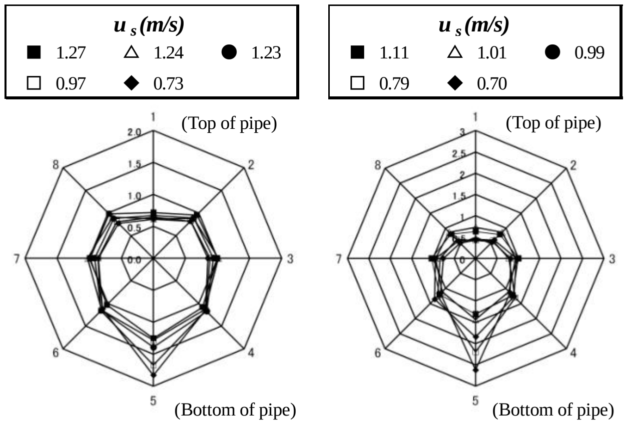
Fig.4 Relation of amplitude on pressure drop ratio (Nipolon hard)

because particles are pushed hard and spread to the pipe wall. In this time, it is hard to float particles with large u_s, and large reduction effect can't be obtained.

Next, measurement of wall pressure by eight button sensors in Nipolon hard and Plastic pellet is shown in figure 5. These figures show circumferential directions pressure distribution. The rise of wall pressure per the unit time in the plug is divided by plug velocity W_P. This means the exchange to the pressure per lengths. Then, ratios of each sensor to the mean value on obtained wall pressure per length is calculated, and figures 5 were drawn. It turns out that the wall pressure in the perpendicular direction maximizes at the bottom of a pipe, and upper part is the minimum in spite of flow condition. This is considered as the gravity force. From this result, reducing effects on friction resistances can be enlarged by enlarging ultrasonic of the underside of vibration pipe.

Figures 5 also reveals that wall pressure ratios in lower part of pipe became smaller and approach to one as u_s becomes faster. Powder pressure can be considered as this cause. The gravity force of particles and powder pressure are main stress concerning the wall surface. Powder pressure against the wall becomes large, u_s becomes large [2]. Therefore, the effect of gravitational force becomes small compared with pressure by pushed particles, and wall pressure distribution becomes small while u_s becomes large.

Next, the relationship between the wall pressure P_w and the pressure loss reduction effect R_p are investigated. In figure 4, the approximation straight lines on decreasing α with A_m at each condition is drawn, and the obtained gradient is set to R_p. The relationship of this R_p and P_w is shown in figure 6. In figure 6, when P_w becomes large, R_p becomes small. The amount of floating particles by the ultrasonic decreases as wall pressure becomes large. It's hard to float particles by ultrasonic, many particles contact with pipe wall and friction can't be reduced if particle pressure to the wall is large. In short, it can be said that the reduction effect by ultrasonic becomes small with increasing of wall pressure. Additionally, this experimental result agrees with theoretical speculation by Dr. Kofu[3]. Moreover, this relationship can be expressed as linear approximation line not related to kinds of particle. Therefore pressure reduction effect by ultrasonic can be estimated on wall pressure by figure6.



[a]　Nipolon hard　　　　[b]　Plastic pellet

Fig.5　Distribution of wall pressure rise ratio

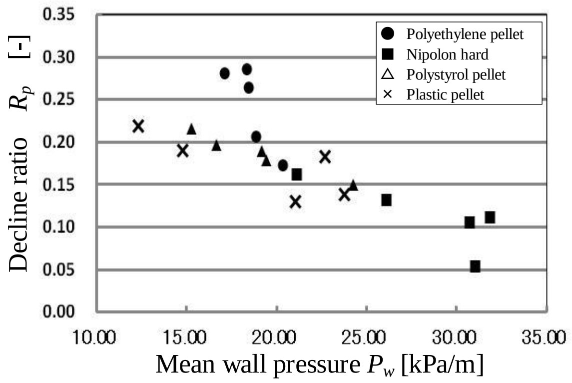


Fig.6 Relation of wall pressure on decline

4. CONCLUSION

(1) The pressure loss $\Delta P/L_P$ was able to be reduced by pipe generating ultrasonic vibration. And α became small as u_s became large.

(2) Wall pressure ratio at bottom of pipe is maximum. And, this ratio becomes large when u_s becomes small.

(3) It turned out that R_p becomes small as P_w became large from the relationship between R_p and P_w.

5. REFERENCES

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