THE INVESTIGATION ON PARTICLE AND WATER REMOVAL EFFICIENCY BY IMAGE METHOD

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ABSTRACT

In mechanical manufacture, air jet is often used to remove the water droplets, particles and residues from workpieces. However, an obvious disadvantage has shown in the energy dissipation caused by the vast flux of air supply. With the purpose of protecting environment and saving the energy, the removal efficiency of water and particle has been concerned.

In this paper the image method of evaluating particle removal and water removal efficiency are presented. Influence of impinging angle, supply pressure, nozzle-plate distance (between the exit of nozzle and impinging plate) on removal efficiency is studied systematically. The results of our experiments show that the efficiency of particle removal and water removal increases with increasing supply pressure. The efficiency of particle removal varies with impinging angle and nozzle-plate distance, optimal ranges can be obtained from these experiments. However the efficiency of water removal is not sensitive to the impinging angle and the nozzle-plate distance

KEYWORDS

air-jet, image processing, particle removal efficiency, water removal efficiency

INTRODUCTION

Pneumatic nozzles are widely used in the processing of manufacture and machining process. The compressed air flow with high speed from nozzle can be used to remove residues, particles and water droplets on work-pieces or to cool off work-pieces. Therefore, improving the design of nozzle and enhancing its working efficiency are of most significance for saving the energy and protecting the environment. How to evaluate the efficiency of particle or water removal in investigating nozzle is a more important problem. If we can directly and quantitatively measure the efficiency of the nozzle, we can easily understand the influence of various factors on removal dust or water efficiency of nozzle.

Previous studies of particle removal and water removal show that the efficiency of particle removal or water removal are dependent on supply pressure(p), impinging angle(θ) and the nozzle-plate distance(L). The purpose of this paper is to investigate the relationship between the efficiency of the particle removal and water removal and mentioned parameters systematically.

Masuda, H (1990) studied particle removal efficiency by using microscope to count particles in small region before and after jet blowing. It is obvious that this method is not convenient to implement. Therefore we develop an image method to investigate particle removal and water removal efficiency.

The design goal of an image measuring system is to obtain quantitative nozzle efficiency of removal dust or water under various parameters, such as supplying pressure, impinging angle, and nozzle-plate distance.

EXPERIMENTAL SYSTEM AND THE PRINCIPLE OF IMAGE METHOD FOR PARTICLE REMOVAL EFFICIENCY

Figure 1 Schematic diagram of image method for particle removal efficiency

The schematic of experiment setup is shown in Fig. 1. It consists of a plate(350mm X 480mm), a jet with a 3mm diameter smoothly contoured contraction nozzle, a lighting lamp and an image acquisition system consisting of a CCD camera (748 X 566 pixels) and a PC interfaced by a frame grabber board.

The experiment procedures were as follows:

First of all, the mixture of glycerin and water with ratio 1: 1 was atomized and then deposited on a black plate with horizontal position. The second procedure was that the uniform particles were sprayed on the plate to form a thin layer of particle. The particles are made of glass sphere with about $38\mu\text{m}$ diameter, whose backscatter light is more intense. The third procedure was the same as the first procedure to deposit atomized mixture on the

plate again. In order to keep the same agglutination force of particle layer, we must control fixed supply pressure and operating time under each procedure. All of these operations should be done in a closed box to prevent pollution.

We suppose that the size of particles is small enough and the distribution of particle is uniform. Therefore the light intensity of scatter light from the plate is proportional to density of particle under the same condition of illumination.

The relationship between the light intensity of scatter light and the density of particle in each point on the plate is as follows:

$$\sigma = \sigma_1 \frac{(I - I_0)}{(I_1 - I_0)} \quad (1)$$

Where σ_1 is the particle density when the plate is

suffused by particles, accordingly,

I_1 is the light intensity of scatter light

from the plate in the case of σ_1 .

I_0 is the light intensity of scatter from the

plate without particles.

The efficiency of particle removal is defined as,

$$\lambda = \frac{\sigma_1 - \sigma}{\sigma_1} \times 100\% \quad (2)$$

Therefore, substitution of Equation (1) into (2)

yields:

$$\lambda = \frac{I_1 - I}{I_1 - I_0} \times 100\% \quad (3)$$

The experiment was carried out with supply pressure 0.15 Mpa, nozzle-plate distance $l=40\text{mm}$ and impinging angle $\theta = 45^\circ$.

First of all initial two images were recorded without particle deposit (black plate) and with full particles. The third image was recorded after jet blowing shown in Figure 2. According to calculation by equation (3) the contour of particle removal efficiency is shown in Figure 3.

Fig. 2 The image after particle removal by jet blowing

For each point (small area) the mean of physical value is following,

$$[A] = \frac{\iint_s A(x, y) dx dy}{\iint_s dx dy} \quad (4)$$

Where $S = 16 \times 16$ pixels

$A(x, y)$ is I, I_0, I_1 , respectively.

Fig. 3 The contour map of particle removal efficiency after air jet blowing

THE EXPERIMENTAL RESULTS OF PARTICLE REMOVAL EFFICIENCY

Figure 4 The removal area of particle as distance

Fig. 4 shows the relationship between removal area and nozzle-plate distance under the supply pressure 1.0 Mpa and the impinging angle 30° . In Fig. 4, the curve on the top with label 0.9 represents the particle removal efficiency is equal to 90%. The particle removal efficiency increases quickly with distance from 20mm to 40mm, and then it is almost constant with distance from 40mm to 60mm. After that it will decrease with distance longer than 60mm. Therefore the best range of nozzle-plate distance for high particle removal efficiency is from 13d to 20d.

Fig. 5 The area of particle removal efficiency as impinging angle

Fig. 5 shows the relationship between the removal area and the impinging angle under supply pressure 1.0 Mpa and nozzle-plate distance 30mm. Obviously the particle removal efficiency in 45° is less than 30° or 60° . This result is a coincidence of previous study(Wang,W.C.1990). Therefore it should be avoided to operate in impinging angle about 45° when the particle is removed by air jet.

Fig. 6 The area of particle removal as supply pressure of jet

Fig. 6 shows the removal area with supply pressure of jet. The higher the supply pressure of jet, the larger the removal area,. However if higher pressure is used, the consumption of energy will be higher. Therefore, the suitable supply pressure should be chosen when jet is working.

THE EXPERIMENT RESULTS OF WATER REMOVAL EFFICIENCY

Comparing with the image method of particle removal efficiency, these two experimental setups are very similar. The only difference from the image method of particle removal efficiency is the plate with fender around four sides in order to avoid water effusion when the air jet is blowing.

The process of water removal is longer than particle removal. After a period of jet blowing, the area of water removal will not change. The very thin layer of water was left when the water was pushed away by air stream in process of water removal as shown in Fig. 7. This layer of water will be evaporated and quickly dry. The remaining water layer was thicker. Therefore the image formed after jet blowing was a binary image if the initial plate is painted with white color and water is dyed by black color.

Fig. 7 The schematic diagram of water removal processing

The process of water removal can be divided into three stages

A, The dyed water was quickly removed by jet air blowing. The very thin layer of water was remained and the area of relative "clean" was formed shown in Fig. 8 the area labeled "a".

B. After a period of time, the water dyed of area "b" (area between white line and black line) was removed slowly and non-uniformly. A lot of

isolated water spots dyed left.

Fig. 8 The image of water removal ("+" in image is the intersection of axial line of nozzle and plate)

C. After a period of time, the area removed kept constant or very slowly increased.

In these experiments the key problem is to control viscosity of liquid(water dyed) in order to keep repeatability.

As mentioned before, the supply pressure, impinging angle and nozzle-plate distance are main factors on water removal efficiency shown in Fig 9,10,11 However the impinging angle from 15° to 60° and nozzle-plate distance from 30mm to 140mm seem not to be an important factor for water removal to compare particle removal.

Fig. 9 The area of water removal under different supply pressure

Fig. 10 The area of water removal as impinging angle

Fig. 11 The area of water removal as nozzle-plate distance

SUMMARY AND CONCLUSION

In this paper we developed two image methods to evaluate particle removal efficiency and water removal efficiency of jet nozzle. These methods are relatively simple and effective. The results of influence of supply pressure, impinging angle and the nozzle-plate distance on particle removal efficiency and water removal efficiency are discussed. For particle removal efficiency, there are optimum range of distance L , such as $13d$ - $20d$, and impinging angle, such as 10 degree. In contrast, for water removal impinging angle and nozzle-plate distance affect on the efficiency only a little. Increasing the supply pressure of jet can increase the efficiency of both

particle removal and water removal but consume more energy. The selection of supply pressure of jet should be considered between energy consumption and overall efficiency.

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