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Study on Characteristics of Pneumatic Nozzle and Blowing System

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Abstract. This paper addresses energy consumption of different blowing system with different nozzles by designing experiment device and building collection system and characteristics of nozzles are investigated by simulating actual conditions. For different conditions, if suitable nozzle was selected, the goals of reducing energy consumption and promoting production efficiency can be accomplished.

1. Introduction
Because of the process requirements of dust removal, drying and cooling [1-3], high pressure blowing has been widely used. However, energy loss of air compressor in the process of pressure conversion became increasingly prominent. According to statistics, air consumption of blowing system accounted for 50% to 70% of the total air consumption [4]. Therefore, it has great significance to research blowing efficiency and energy saving technology.

There are many reasons could make the blowing efficiency low, include unsuitable pressure, unreasonable gas path and so on [5]. Comparative study of several energy-saving nozzles and common nozzle has been made in this paper. The performance index, such as thrust, water removing area, has been detected by simulating actual conditions, to select suitable nozzles in different conditions.

2. Experiment device

2.1 Experiment subjects
Experiment subjects are three commonly used nozzles. KN-R02-200 single-hole nozzle, KNH-R02-200 high efficiency nozzle, ZH10-B-X185(small) and ZH20-B-X185(big) enhanced nozzle, as figure 1 and table 1 shows.

- a) Common Nozzle
- b) High-efficiency Nozzle
- c) Enhanced Nozzle

![Figure 1 Nozzle Shape](image)

| Table 1 Size of Nozzle |
|------------------------|
| Model                  | KN-R02-200 | KNH-R02-200 | ZH10-B-X185 | ZH20-B-X185 |
| Caliber (mm)           | 2          | 7           | 10          | 20          |
| Max Impact of Axis (kPa)| 175        | 60          | 1           | 1.2         |
Notes: The max impact of axis and flow are measured on the pressure of 200kPa.

2.2 Experiment device
1) Gas path
   The gas path is as figure 2 shown. Flowmeter and pressure sensors are installed to calculate pneumatic power. Besides, regulator and on-off valve are added to control the pressure.

   1-Air supply 2-Pressure sensor 3-Flowmeter 4-Ragulator 5-On-off valve
   6-Flowmeter 7-Pressure sensor 8-Nozzle

   Figure 2 Gas Path

2) Mechanical part
   A Multifunctional test platform has been designed to fix nozzle and experiment device, as figure 3 shown. A displacement was added to adjust the position of nozzle by a DC motor. Other element could be placed on the platform.

   Figure 3 Multifunctional Test Platform

3) Electrical part
   YanHua PCI-1710 data acquisition card was used to acquire signal of each sensor and control on-off valve as well as DC motor. Besides, control program which made by LabVIEW could meet the requirements of experiment, including initialization and detection.

3. Blowing system energy consumption

3.1 Process
   Connect gas path according to figure 2. Air supply is TYW-6A air compressor. Adjust outlet pressure to 200kPa. Measure the power of air supply and pneumatic power [6] of gas path upstream and nozzle. Compare and analyze these data. Look for energy loss law of blowing system.
3.2 Data and analysis

The electric power and pneumatic power of different nozzles is as shown in figure 4.

![Energy Consumption Comparison of Nozzles](image)

Figure 4 Energy Consumption Comparison of Nozzles

1) Single nozzle, high efficiency nozzle and small enhanced nozzle have essentially the same pneumatic power. Big enhanced nozzle’s pneumatic power is slightly larger than others because of its large flow.

2) Pneumatic power after regulator is about 60% of it before the regulator. Flow on the both sides of regulator are not much difference but change of pressure is large. So regulator consumes more energy in the blowing system.

4. Experiments

4.1 Thrust experiment

1) Process

   Thrust experiment device is as figure 5 shown. Fix a plate whose diameter is 50mm or 200mm on the force sensor and record the readings. Then blow the plate center. Record the reading of sensor and the distance between nozzle and plate.

![Thrust Experiment (200mm)](image)

Figure 5 Thrust Experiment (200mm)

2) Data and analysis:

   Thrust of different nozzles under 200kPa is shown as figure 6 and figure 7.
1) The thrust of different nozzles increase linearly with pressure.
2) With the increase of diameter of plate, thrust of small diameter nozzle changes little, but thrust of big enhanced nozzle is up 30%.
3) Comparing these nozzles, high efficiency nozzle and single-hole nozzle have essentially the same thrust. Thrust of big enhanced nozzle is maximal. It is twice as large as thrust of small enhanced nozzle and 1.5 times as large as single-hole nozzle.

4.2 Water removal experiment
1) Process:
As the figure 8 shown, a sink was added 2mm colored water. Blow the center of the sink and record the blowing process by a video camera. Estimate the maximum of water removal acreage by the video.
To estimate the acreage accurately, a 10mm*10mm square mark was as estimating reference. Process the video by threshold method. The ratio of total acreage and mark could be obtained. Then water removal acreage could be calculated.

2) Data and analysis
Water removal acreage is shown as figure 9 and figure 10.
If distance is constant, water removal acreage increased significantly with the increase of pressure. If pressure unchanged, the change of water removal acreage is not obvious.

2) Water removal acreage of single-hole nozzle and high efficiency nozzle is almost same. Big enhanced nozzle has the largest water removal acreage. It is about twice as large as single-hole nozzle. Area of small enhanced nozzle is 2/3 of single-hole nozzle.

4.3 Cooling experiment

1) Process
Keep temperature 20°C, pressure 1MPa. Place iron plate of different thickness (2mm/5mm/10mm) into boiling water for 3 minutes. Take out the plate and blow them. Record the change of temperature.

2) Data and analysis
Outlet pressure is 0.2MPa, distance is 5cm and range of temperature is 60°C-30°C.

1) Natural cooling time of plates whose thickness are 2mm 5mm and 10mm are 452s 1231s and 2010s. Cooling effect of blowing is notable.
2) Cooling effect of single-hole nozzle is best and energy consumption is lowest, because velocity of other nozzles decrease for inhaling air from outside.

4.4 Drying experiment

1) Process

Fix a square board on the force sensor and stick a piece of sponge (90mm*70mm*50mm) on the board as figure 13 shows. Soak the sponge and measure its weight (about 1.47N). Blow the sponge while pressure is 200kPa and distance is 5cm. Record the time during the weight of sponge change from 1.45N to 1.35N.

![Figure 13 Drying Experiment](image)

2) Data and analysis

To reduce the impact of jet, the on-off valve will close for 0.5s after every 10s to acquire valid data. The ambient temperature is 20℃. Air humidity is 10%.

Drying time of different nozzles is shown as figure 14.

![Figure 14 Dry Time of Different Nozzles](image)

1) The nature drying time is 3600s or more. So the drying effect of blowing is significant.

2) Comparing these nozzles, drying effect of big enhanced nozzle is the most notable. Its drying time is about 2/3 of single-hole nozzles'. Considering the work condition, diameter of nozzle and flow are more important than pressure.

5. Conclusion

Energy consumption of blowing system with various nozzles with different structures has been detected by data acquired system. Characteristics of the Pneumatic Nozzles are looked into by different experiment.

Suitable nozzle should be selected for particular condition. For example, big enhanced nozzles should be used to push and remove water while single-hole nozzles perform better on cooling. Only choose appropriate nozzle, can the purpose of reducing energy consumption and promoting efficiency be
realized.

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