NUMERICAL SIMULATION OF THE AIR FLOW FIELD IN THE FOREIGN FIBER SEPARATOR

by

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The air flow field of a foreign fiber separator is simulated numerically. Effects of design parameters such as the nozzle diameter and entrance width of the noil box on the air velocity along nozzle axis, turbulence intensity, and jet deflection distance are studied. Larger nozzle diameters and larger entrance widths of the noil box are advantageous to the elimination of foreign fibers. The results provide a theoretical basis for the design of foreign fiber separators.

Key words: *foreign fiber separator, air flow field, numerical simulation*

Introduction

Usually, there are foreign fibers such as nylon, polypropylene fibers, and hairs mixed with cotton fibers in bales. Foreign fibers are difficult to be eliminated in the common spinning process. However, foreign fibers will deteriorate the yarn quality. Therefore, various foreign fiber separators have been developed to eliminate foreign fibers [1]. Pneumatically operated devices are adopted in most foreign fiber separators. The principle of pneumatically operated devices is to control the discharge flow of the high pressure air by momentarily turning on and turning off the electromagnetic valves and the air streams flow out of the nozzle to eliminate the foreign fibers [2]. Different design parameters will cause different air flow fields inside the foreign fiber separator, therefore will influence the elimination efficiency. In this paper, the air flow field of a foreign fiber separator is simulated numerically by using a CFD method. Effects of design parameters such as the nozzle diameter and entrance width of the noil box on the air velocity along nozzle axis, turbulence intensity, and jet deflection distance are studied.

Numerical simulation

Figure 1 is the schematic diagram of the foreign fiber separator. The CFD software FLUENT is utilized to simulate the air flow field. The simulated domain comprises the conveying pipe, nozzle, and noil box as shown in fig. 2. The width of the conveying pipe, nozzle diameter, and entrance width of the noil box are 8 cm, 1 cm, and 4 cm, respectively. The nozzle inlet pressure is high pressure. The inlet pressure of the noil box is a little higher than normal pres-

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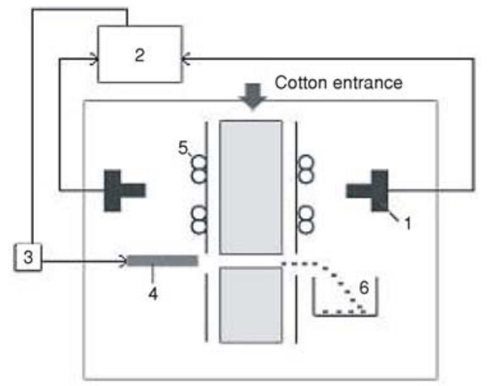

Figure 1. Schematic diagram of the foreign fiber separator
1 – Charge-coupled device camera, 2 – Computer, 3 – Control module of foreign fiber separator, 4 – Jet array of electromagnetic valves, 5 – Lighter, 6 – Noil box

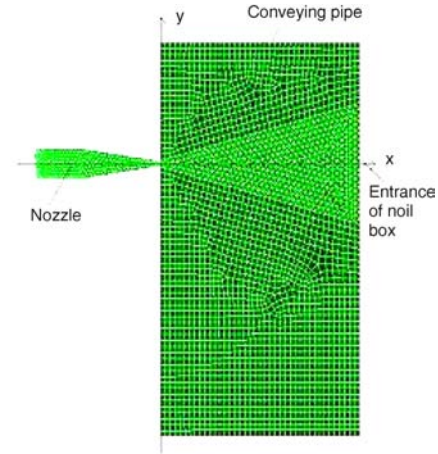

Figure 2. Computation grids

sure. The solid walls are set as non-slip boundaries. There are altogether 6981 computation grids.

Results and discussions

Effects of the nozzle diameter

Figure 3 shows the relationship between the air velocity along nozzle axis and the nozzle diameter. In fig. 3, *s* is the distance between the nozzle and entrance of the noil box, *d* – the nozzle diameter, *v* – the air velocity along nozzle axis, and v_0 – the air velocity at the entrance of the noil box. It can be found from the figure that the dimensionless air velocity v/v_0 increases with the increase of the nozzle diameter. When the nozzle diameter is larger than 0.7 cm, the air velocity increases steeply. The reason is that larger nozzle diameters cause larger air flow rates and thus higher air velocities.

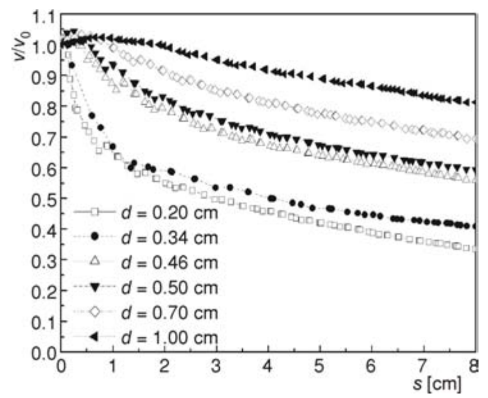

Figure 3. Relationship between the air velocity along nozzle axis and nozzle diameter

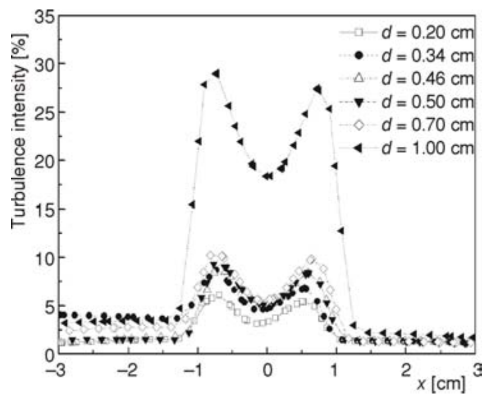

Figure 4. Relationship between the turbulence intensity along conveying pipe axis and nozzle diameter

Figure 4 illustrates how the nozzle diameter influences the air turbulence intensity. The air turbulence intensity also increases with the increase of the nozzle diameter. The air turbulence intensities have "M" distributions and the left peaks are higher than the right peaks, which indicates the air turbulence intensity in the conveying pipe below the nozzle axis is larger than that above the nozzle axis. The probable reason is that the increased air velocities induce drastic changes of the air flow field inside the conveying pipe and thus produces larger air turbulence intensity. When the nozzle diameter exceeds 0.7 cm, the air turbulence intensity strengthened remarkably.

The relationship between the jet deflection distance of maximum air velocity at the entrance of the noil box and the nozzle diameter is given in tab. 1. Larger nozzle diameters yield smaller jet deflection distances of maximum air velocity at the entrance of the noil box and thus smaller jet deflection angles because of the larger air velocities at the jet core area. Therefore, larger nozzle diameters are able to reduce impurity deflections, which is in favor of the elimination of foreign fibers.

Table 1. Relationship between the jet deflection distance of maximum velocity and nozzle diameter

Nozzle diameter [cm]	0.2	0.34	0.46	0.5	0.7	1.0
Jet deflection distance [cm]	0.6	0.6	0.2	0.2	0.2	0

Effects of the entrance width of the noil box

Figure 5 gives the relationship between the air velocity along nozzle axis and the entrance width of the noil box. In Figure 5, d_1 is the entrance width of the noil box. It can be observed from the figure that the dimensionless air velocity increases with the decrease of the entrance width of the noil box. The reason is that smaller entrance width of the noil box decreases the flowing region and thus increases the air velocity. However, it is difficult for foreign fibers to drop into the noil box through a too narrow entrance so that the elimination efficiency decreases.

Figure 6 gives distributions of the air turbulence intensity along the conveying pipe axis when the entrance width of the noil box changes, where D is the axial position. As the figure illustrates, with the increase of the entrance width, the air turbulence intensity decreases. The

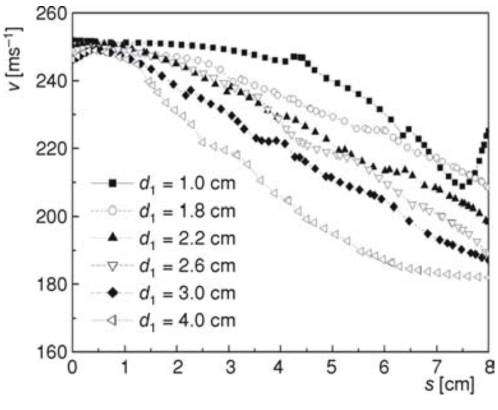

Figure 5. Relationship between the air velocity along nozzle axis and entrance width of noil box

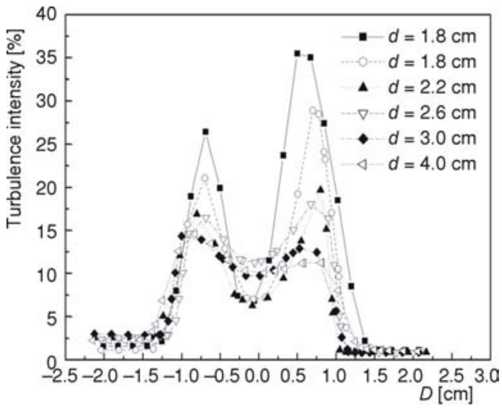

Figure 6. Relationship between the air turbulence intensity and entrance width of noil box

probable reason is that most air streams flow into the noil box and little back flow is formed near the entrance of the noil box, which is favorable for the elimination of foreign fibers.

Conclusion

The air flow field of a foreign fiber separator is simulated numerically by using a CFD method. Effects of design parameters such as the nozzle diameter and entrance width of the noil box on the air velocity along nozzle axis, turbulence intensity, and jet deflection distance are studied. With the increase of the nozzle diameter, the air velocity along the nozzle axis increases whereas the jet deflection distance decreases, which helps to eliminate foreign fibers. With the increase of the entrance width of the noil box, both the air velocity along nozzle axis and air turbulence intensity decrease, which is advantageous to the elimination of foreign fibers. The results provide a theoretical basis for the design of foreign fiber separators. The nozzle diameter and entrance width of the noil box should be considered simultaneously to design an efficient and energy-saving separator.

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