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DETERMINATION OF PERFORATED SURFACE PARAMETERS FOR FIBER MASS CLEANING FROM DUST IN AN AERODYNAMIC CLEANING MACHINE

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Annotation
This article explores the effective cleaning process of fibers from dust and debris using aerodynamic cleaning machines. The study presents results on the impact of perforated hole sizes, the discharge zone, and air velocity modes on technological processes. It demonstrates the potential to improve the efficiency of the cleaning process by determining the optimal hole diameter. These methods can be applied in the textile industry to enhance fiber quality and make production processes more efficient.
Keywords: aerodynamic cleaning machines, fiber cleaning, separation of dust and debris, perforated surface parameters, discharge zone, fiber, debris, spinning machines, perforated surface, pneumomechanical, yarn, length, aerodynamic, grid, cleaning.

Introduction

It is well known that fine debris and dust associated with fibers accumulate on the rotor walls of pneumomechanical spinning machines, leading to serious difficulties in forming yarn spun by the pneumomechanical method. In modern spinning enterprises, every technological operation in yarn production is accompanied by the generation of new free dust particles (due to fiber breakage and damage) [1]. This is facilitated by the intensive mechanical impact of machine working elements on the fibrous material, which, on one hand, ensures significant cleaning efficiency but, on the other hand, leads to a decrease in fiber strength, shortening of fiber length, crushing of solid particles, and an increase in fine debris and dust. The fiber cleaning process must be of high quality and multi-stage, requiring the processing of fiber mass through various technological transitions, mainly during the opening and cleaning stages. In this regard, it is necessary, first and foremost, to replace the mechanical impact of working elements with an alternative influence that reduces fiber damage and dust formation starting from the initial processing stages [2]. Technological operations for cleaning fine debris and dust have been developed based on aerodynamic laws. These operations are based on the principle of passing part of the airflow through a perforated grid covering the working sector into a vacuum chamber. Such technological operations have been applied in axial cleaners, inclined cleaners, inclined opener-cleaners, and horizontal openers [3]. Experimental studies of the technological operations introduced in laboratories and enterprises showed improvements in all physical and mechanical properties of intermediate products and yarn. In particular, contamination levels decreased and yarn quality improved by 7–9%. Dust sedimentation in the spinning chamber tube was reduced by an average of 10%. Yarn breakages during spinning decreased by 10–15%. The proposed technical solutions involve performing the cleaning operation in areas between the working elements equipped with pins or knives and the perforated surface. In this case, the perforated surface is arranged concentrically relative to the working element, with a gap of 10–15 mm between them [4]. The gap between the working elements and the slatted grid is recommended based on literature sources.

In this way, cleaning from dust is ensured through the vacuum created on the opposite side of the perforated surface. Due to the vacuum, suction airflow is generated on the surface of the perforated material. In the fiber processing zone, over the entire area of the perforated grid, a discharge field shaped as shown in Figure 1 is formed [5].

The airflow generated by the suction removes dust and fine debris from the fiber processing area, directing them into the vacuum chamber and then through a pipeline to the filters.To successfully separate dust and fluff, it is necessary to know the optimal parameters of airflow velocity regimes and the parameters of the perforated surface in the discharge zone.

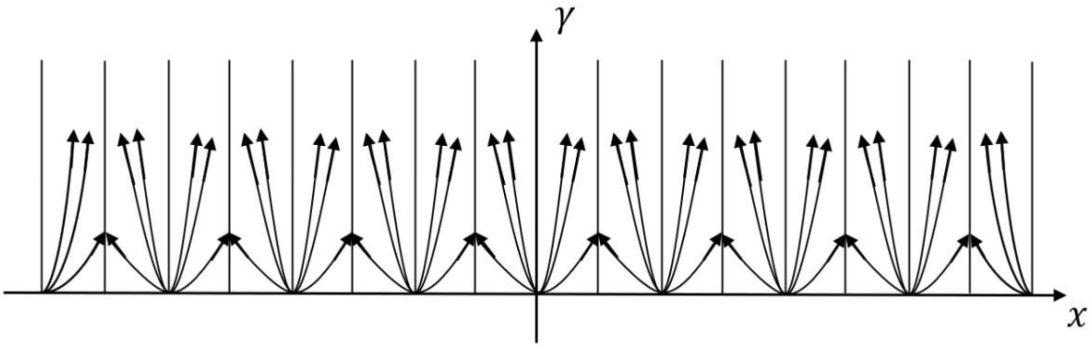

Figure 1. Suction Zone

In this case, the appropriate and uniform air velocity range must be determined within the zone of fiber flying velocity. One can reason as follows: if the air velocity V_{air} in the suction device slightly exceeds the fiber flying velocity V, then the aerodynamic forces are sufficient to control the movement of fibers, lint, dust, and small debris, and to direct these fractions through the perforated surface holes into the vacuum chamber.

For cotton fibers with a length of 25.4 mm and a linear density of 196 ktex, the flying velocity is approximately V=0.06 m/s. It should be noted that cotton lint is a shorter fraction with a lower linear density, thus its flying velocity is even lower. Therefore, for safety and reliability, the control flying velocity for lint separation through the perforated surface is also taken as V=0.06m/s.

As known from aerodynamics, the airflow velocity in the suction device decreases rapidly with increasing distance from the perforated surface holes. Therefore, to maintain at least V=0.06 m/s a short distance from the holes, the air velocity directly at the hole surface must be significantly higher [6].

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One of the main characteristics of the perforated surface is the shape and size of the holes. Aerodynamics shows that circular holes along the suction axis better maintain airflow velocity compared to rectangular ones. Hence, circular holes are preferred for the perforated surface design. As the diameter of the hole increases, the effective height of the suction device also increases, which is a favorable factor for efficient removal of dust, lint, and waste particles.

However, it must be emphasized that increasing the hole diameter in the perforated surface leads to:

A higher risk of long fibers being removed along with waste materials;

A sharp increase in air consumption, resulting in unnecessary energy expenditure;

Excessively strong suction forces pressing the fiber mass too tightly against the perforated surface holes, which disrupts the technological fiber cleaning process.

To determine the optimal hole diameter, perforated plates with hole diameters of d_0=3, 4, and 5 mm were prepared. These plates were tested on a GR-8 horizontal opener. The tests showed that with 5 mm hole diameters, almost all spinnable fibers of various lengths were being removed along with waste and dust [7].

Figure 2 presents the diagram showing the proportion of spinnable fibers lost to waste. The amount of spinnable fiber in the waste reached 50%, which is unacceptable. Therefore, perforated plates with 5 mm hole diameters are deemed unsuitable.

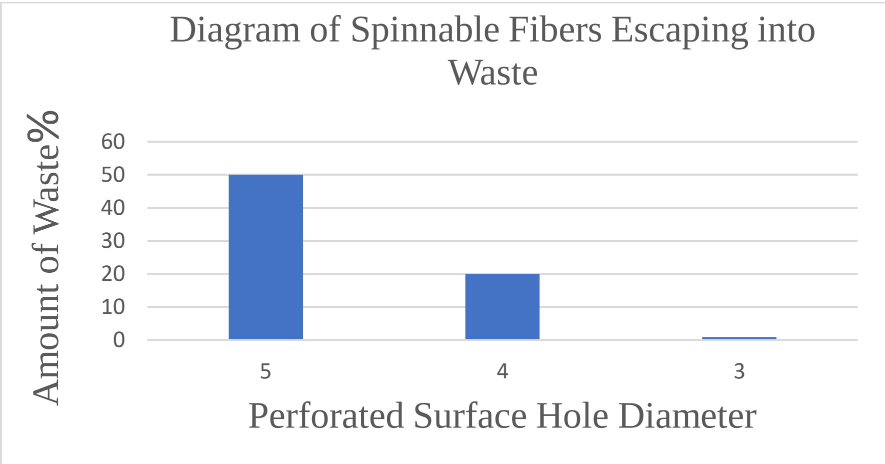

Figure 2. Diagram of Spinnable Fibers Escaping into Waste

Testing the perforated sheet with 4 mm hole diameter produced the following results: a small amount of spinnable fibers was observed to escape into the waste. Spinnable fibers accounted for about 20% of the total waste. Such a result is also considered unsatisfactory. Therefore, it is not recommended to use perforated sheets with 4 mm hole diameters.

Testing the perforated sheet with a 3 mm hole diameter showed that no spinnable fibers were found in the waste. This result is positive, thus perforated sheets with 3 mm hole diameters were used in subsequent tests.

For effective dust removal, the discharge (vacuum) zone created on the surface of the perforated sheet by the suction device plays a significant role. It is clear that if the holes on the surface of the perforated sheet are denser and more evenly distributed, the discharge field becomes more stable and uniform. However, the proximity of the holes to each other should not compromise the mechanical strength of the perforated sheet [8].

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Calculations of the perforated sheet's strength showed that with a hole diameter of 3 mm and a center-to-center distance of 5 mm, the holes can be arranged in a staggered (chessboard) pattern (Figure 3. Perforation Scheme).

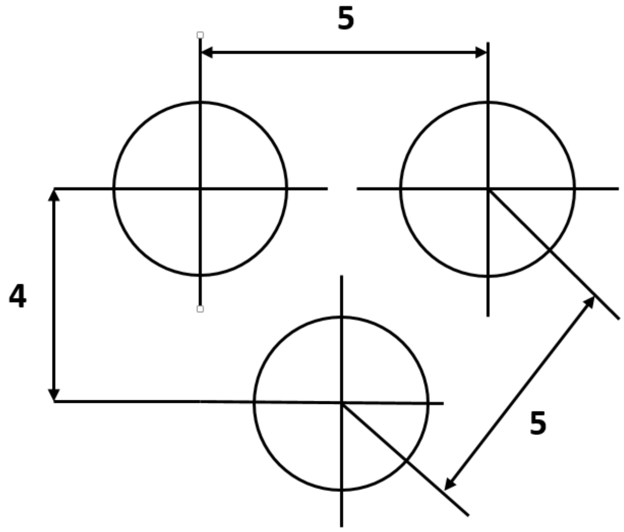

Figure 3. Perforation Scheme

In this case, the distance between the rows of holes is 4 mm, and the distance between adjacent holes is 2 mm. For this perforated sheet configuration, the cross-sectional area was calculated. For the calculation, a square area of 10 × 10 mm was considered.

Where:

d_o – diameter of a hole;
b_o – distance between the centers of adjacent holes;
h_o – distance between the rows of holes;
n_b – number of holes per row;
N_h – number of rows;
n_o – total number of holes;
S – area of the square;
S_{o1} – total area of the holes;
S_j – effective cross-sectional area;
f_m – effective cross-sectional coefficient;
$S_{f\%}$ – effective cross-sectional area percentage.

Based on the above parameters, the calculation of the effective cross-sectional area of the perforated sheet is presented in Table 1.

Table 1. the calculation of the effective cross-sectional area of the perforated sheet

Properties of the perforated Sheet	d_o mm	b_o mm	h_o mm	n_b	n_h	n_o	S mm^2	S_{o1} mm^2	S_{jo}	f_m	$S_{j\%}$

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Parameter Values	3	5	4	20	25	500	10^4	7,065	3532,5	0,35	35

Thus, the effective cross-sectional coefficient of the selected perforated sheet surface is 0.35. The perforated surface was calculated according to the specifications and is presented in **Figure 4**.

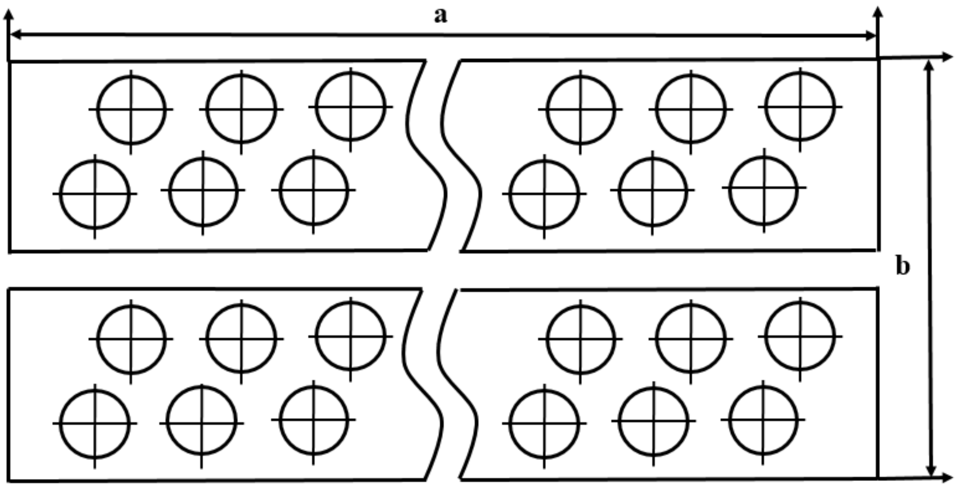

Figure 4

Based on the working width of the machines ranging from 1000 to 1600 mm, the perforated sheet width was assumed to be 1000 mm. The length of the vibrating organ's working surface is determined by the machine's design and the air flow capacity, and it is calculated based on further studies.

Conclusions

This article explored the effective methods of cleaning fibers from dust and fine fragments using modern aerodynamic cleaning machines used in textile industries. The parameters of the perforated surface and their impact on the technological processes, as well as the air speed regime in the discharge zone, were determined. The research results led to the identification of the optimal hole diameter and the necessary parameters to ensure effective cleaning. With the help of these technologies, the cleaning process of fibers was significantly improved, and the physical-mechanical properties of the yarn were enhanced.

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