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THE EVALUATION OF YARN MOVEMENT IN THE SPIN BOX

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Abstract
The rotor plays a crucial role in the spinning process, responsible for transporting the fibres in the airflow channel, transferring the fibres to the inside of the rotor, and helping to collect the fibres in the rotor shaft. At the same time, the airflow can also interfere with fibre orientation, resulting in poor yarn quality. In the article, research on the movement of yarn in the spinning chamber is studied and analyzed.

Keywords: airflow field, optimization of rotor spinning, computational fluid dynamics, spinning machine, camera.

Introduction
Rotor spinning is the most widely used new spinning technology for the commercial processing of fibres into yarns and has the advantages of low production cost, high productivity, process automation, and flexibility to produce a variety of new yarns [1-4]. The rotor plays a crucial role in the spinning process, responsible for transporting the fibres in the airflow channel, transferring the fibres to the interior of the rotor, and helping to collect the fibres in the rotor shaft. At the same time, the airflow can also interfere with fibre orientation, resulting in yarn quality deterioration [5]. Therefore, airflow studies can provide key criteria and useful insights for understanding and optimizing the rotor spinning process, for example, the characteristics of the airflow field and the effect of geometrical and spinning parameters on the airflow in the rotor spinning assembly and thus on the yarn properties [6].

Literature Review
Many studies have focused on the airflow field in the rotor spinning unit using computational fluid dynamics techniques. In 1996, Kong and Platfoot [7] developed a two-dimensional (2D) computational model and simulated flow patterns in the conveying zone of a rotor-spinning machine. Their results showed that airflow patterns can be affected by changing the

configuration of the fibres after changing the geometric dimensions of the baffle or the speed of the discrete drum. Yang and et al. [8] conducted a numerical simulation of three-dimensional (3D) flow in a transfer channel and a rotating rotor, and the results showed that the vortex formed in the rotating rotor, the airflow velocity decreased at the slip wall, and the high-pressure regions caused slippage. showed that it is on the wall and the rotor shaft. Further understanding of the 3D airflow characteristics in a rotor spinning unit can be found in the studies of Lin et al [9] and Xiao [10]. They simulated 3D airflow in a rotor spinner and studied the effect of important geometrical and rotational parameters on the airflow patterns. Their research and results provide key guidelines for selecting and optimizing rotor design and spinning parameters.

Some researchers have conducted experimental studies to understand the effect of airflow on fibres and yarns. Zeng and Yu, [11] Guo and Hu, [12] and Pei [13] adopted high-speed imaging to capture and analyze the fibre movement in the airflow field under different operating conditions of air-jet spinning. Seyedi [14] used the trace fibre technique to investigate and analyze the fibre migration in the airflow field of a novel rotor-jet spun yarn with variable rotor-jet spinning parameters.

Seyed [15] and Lin [16] conducted a spinning test to compare yarn quality and thereby confirmed the effect of optimized baffle airflow area on yarn properties. Akankwasa [17] also evaluated blended yarn quality to support simulated results of airflow characteristics in conventional and two-feed section rotor spinning machines.

There are many simulation studies of airflow in a rotor spinning machine and some experimental methods to determine and investigate the effect of airflow on fibres and yarns. However, there are no visual experimental results on the airflow in the rotor spinner under industrial conditions.

The rotor spinning process is mainly controlled by the air suction mechanism and the rotation mechanism, that is, the air suction at the exit of the rotor and the high-speed rotation of the rotor. Based on these two working conditions, an appropriate airflow field is generated in the rotor spinning device, so that the transmission, transfer and collection of the fibre are achieved. Several publications have investigated the effect of two operating conditions on the airflow field in a rotor spinner.

Xiao [10] studied the effect of rotor speed on airflow, and their results showed significant changes in the flow structure in the rotor as the rotor speed changed.

The research of Lin [18,19] showed that more vortices around the rotor tube can be formed at a lower rotor speed and can cause more yarn breakage when the rotor speed is much higher. Their research on rotor exit pressure showed that threading is useful for reducing rotor exit pressure. However, the vorticity intensity at the entrance of the confucor can increase, which leads to a decrease in fibre straightening and yarn properties [20-24]. However, no previous studies are focusing on these two operating conditions and experimental investigations focus on their contribution to airflow field generation, i.e., the mechanism of airflow field formation in the rotor spinning unit.

Analysis and Discussion

This work aims to experimentally and numerically investigate the dynamic and static characteristics of the airflow field (i.e., airflow motion and air pressure) in a rotor spinning unit. The formation mechanism of the airflow field in the rotor spinning unit is also analyzed by comparing experimental results and simulation results in three cases with two operating conditions changed. Our work provides further insight into the characterization of the airflow field from a practical perspective, and the technique used in this work can be widely applied to other flow problems.

The general rotor spinning unit of air-sucking pneumo-rotor spinning is shown in Fig. 1. An air pump is connected to the aspiration hole and sucks air from the spinner. The air in the rotor is also sucked from the rotor outlet, and then two airflows are supplied to the rotor from the baffle and the threading tube, respectively. At the same time, the rotor rotates at high speed. Thus, a specific airflow field and twisting environment of rotor spinning are formed.

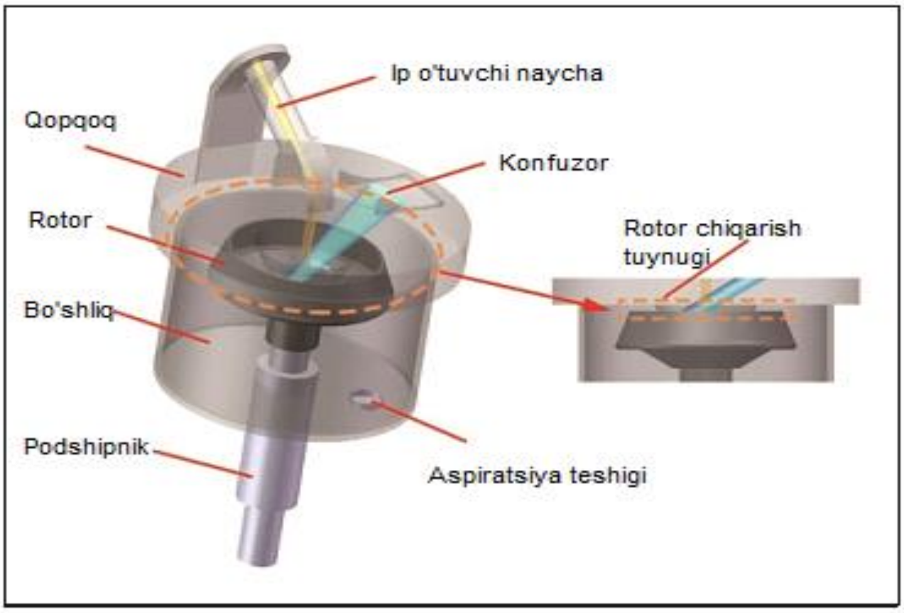

Figure 1. Schematic diagram of the rotor spinning unit.

Because the rotor spinning unit is opaque and fixed in the actual spinning position, it is difficult to observe the movement of the airflow and obtain the characteristics of the airflow field in the rotor spinning unit. To solve this problem, a model rotor spinning device (in short, a rotor spinning device with a model block) was set up based on the geometric parameters of the real rotor used in open-ended spinning (Fig. 2). The model unit consists of a rotor, a cover, and a cavity, all of which are made of plastic, transparent polycarbonate, and resin, making it easy to see the inside of the rotor (Figures 2(a) and (c)). The dimensions of the model block are given in Figure 2(d). In addition, our device used an air pump to perform air suction, which provides the negative pressure necessary for spinning. The rotor model was driven by an electric motor through a flat belt to realize high-speed rotation.

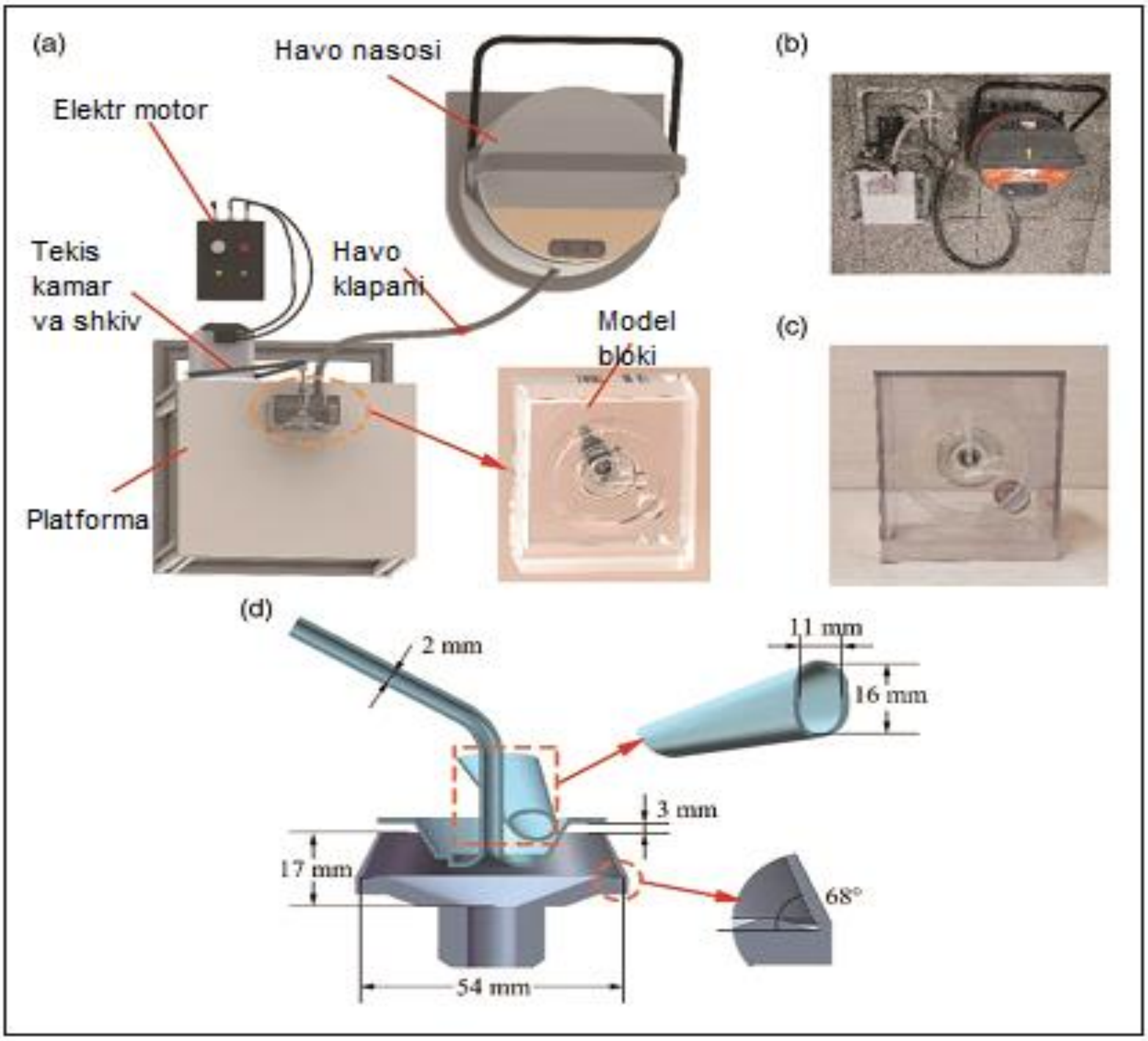

Figure 2. (a) Schematic diagram of the experimental setup; (b) Model rotor spinning device; (c) Model block; (d) Basic dimensions of the model block.

To obtain the dynamic and static characteristics of the airflow field in the rotor spinning unit, we observed the movement of the airflow and measured the air pressure in the model unit. In addition, three case conditions were developed to study the formation mechanism of the airflow field in the rotor spinning unit based on the air suction mechanism and the rotation mechanism. Case 1 was under the actual operating conditions of the rotor spinner, with air being sucked into the rotor outlet and the rotor rotating at high speed. Cases 2 and 3 were performed with the rotor rotating at high speed and with no air suction at the rotor outlet. The discharge pressure was measured with a digital pressure gauge with a resolution of 1Pa.

The air suction mechanism provides the primary airflow - the airflow rate necessary to achieve fibre acceleration, transmission and alignment. The rotating mechanism can eliminate the airflow caused by the geometrical restrictions of the rotor due to air suction at the rotor outlet in a counter-clockwise direction, which helps the fibres to be transferred smoothly from the confusor to the rotor wall. At the same time, the high-speed rotation of the rotor can also contribute to the transfer of fibres suspended in the rotor to the sliding wall of the rotor and fibres collected in the rotor shaft.

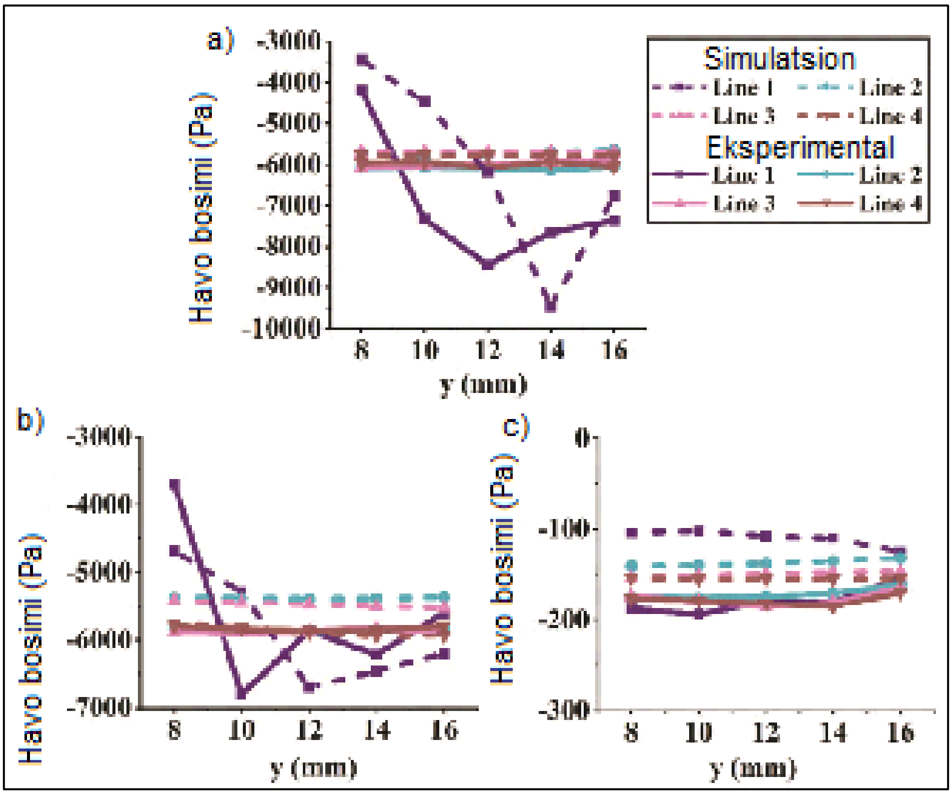

Figure 3. Comparison of simulated pressures with experimental results for (a) Case 1 (suction and rotation), (b) Case 2 (no rotation), and (c) Case 3 (no suction).

In addition, it can be found that the numerical simulation results of the airflow motion are in good agreement with the corresponding experimental results in all three cases.
Based on the numerical simulation of the airflow field in the rotor spinning unit, the simulated pressure can also be obtained. To further validate the simulation results, the simulated pressure values were compared with the measured data in three cases.
As shown in Figures 3(a) and (b), the results of comparing the simulated pressures with the experimental data for the four lines in Cases 1 and 2 are similar. In two cases there is a deviation between the two results in row 1. However, the overall trend of the two results in row 1 is the same, first decreasing and then increasing as y increases. There are two reasons for the deviation: firstly, row 1 is opposite to the exit part of the confusion, where the airflow changes most sharply and complexly; second, the distance between adjacent measurement points is too short, which may cause measurement errors. As for the other lines in cases 1 and 2, the simulated negative pressure of each point is slightly lower than the measured result due to measurement errors. In case 3 (Figure 3(c)), the deviation between the simulated and experimental pressure values in line 1 is larger than that in the other three lines due to the unique position of line 1. However, the airflow field and the pressure in the negative rotor spinning unit are generated by the high-speed rotation of the rotor in case 3, and the negative pressure is small, and the simulations on four lines and the experimental results are generally

consistent. In general, the simulation values in cases 1–3 are justified to match the experimental data quantitatively. the airflow field and the pressure in the negative rotor spinning block are generated by the high-speed rotation of the rotor in case 3, and the negative pressure is small, the four lines are simulated and the experimental results are generally consistent. In general, the simulation values in cases 1–3 are justified to match the experimental data quantitatively. the airflow field and the pressure in the negative rotor spinning block are generated by the high-speed rotation of the rotor in case 3, and the negative pressure is small, the four lines are simulated and the experimental results are generally consistent. In general, the simulation values in cases 1–3 are justified to match the experimental data quantitatively.

Conclusion

We have developed a new experimental technique to make visible the movement of the airflow in the spinning chamber. The experimental results are in good agreement with numerical simulation data and related literature. In addition, we measured the air pressure inside the rotor and analyzed the measured values as well as the simulated results quantitatively. The technique used in this study can predict and analyze the rotor spinning process in more detail.

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