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Optimal Design of Fan Airflow Guiding Device in the Wood Drying Kiln

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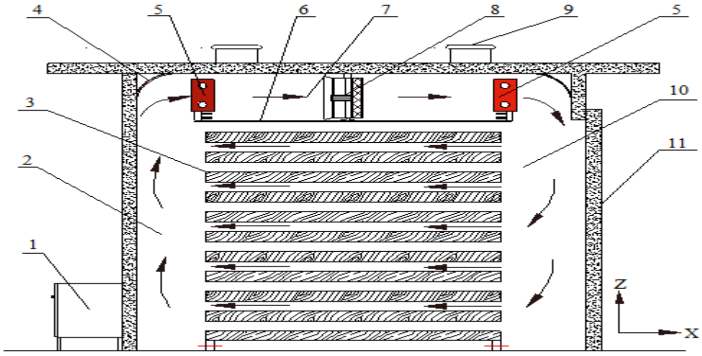
Abstract: Wood drying chamber is the most conventional equipment used for drying wood, within the wood drying chamber on fan airflow guiding device for optimization design research, making the heat air supply uniform, and improve the drying efficiency, reduce drying costs. This paper through improving the airflow guiding device, add the designed device for uniform flow to flow distribution. Finally through the SC-Tetra simulation showing that improved fan airflow guiding device can achieve the purpose of different thickness of wood drying at the same time, improve the economic benefic.
Key words: wood drying chamber; airflow guiding device; numerical simulation

I. PREFACES

The conventional wood drying room is a kind of building or metal container to dry materials by controlling the temperature, humidity and air velocity of drying medium air flow, taking advantage of convection heat transfer of the hot air flow. Drying room is one of the main energy consuming equipments in wood processing, whose energy consumption accounts for about 60% - 70% of the total energy consumption of enterprises [1]. The uniformity of heated air circulation in drying room is the key to drying efficiency improvement, energy saving, and product quality guarantee. It is thus clear that the hot air cycle of drying medium is not only an important factor affecting the final quality of wood drying, but also a critical technical index for the performance of drying equipment.

In the wood drying house, as shown in Figure 1, when the woods are transferred into the room for drying, the horizontal air supplied by fan 6is produced to be hot air flow after passing through the front lateral heat sink 9, and then comes from the front lateral vertical air flue 10 after turning 90 degree, and that it comes to the horizontal air duct among the wooden materials. The hot air passes would cool and humidify by the absorbing the moisture in timbers when passing though the horizontal air duct among the timbers, then the hot air with low temperature and high humidity hot would flow back to the top at the rear side of the drying room through vertical air duct 1, and back to the inlet of fan through the rear lateral heat sink 2. Then the whole air clockwise cycling is over; After drying the timbers for about 2-3 hours in line with the timber drying process, the driving motor 5 would drive the rod gear combination mechanism, making the various fans in the drying room rotary synchronously for 180 degrees and realizing the counterclockwise circulation flow. The air flow in the drying room would repeat above process until the wood is dried uniformly. In case of the humidity elimination stage, the front and rear roof outlets are open at the same time. The front side flows in while the rear side exhausts. The outside air flows into the drying room through the rear fan inlet to mix with the high-humidity hot air and then comes to the fan inlet. The high-humidity hot air flow would exhaust from the outlet 7 in the front lateral positive-pressure end of the fan to take out the moisture, drying the woods.



1 Rear vertical air duct 2 Arc guide plate 3Rear heat sink 4 Horizontal braced frame 5 Driving motor 6 Fan 7Front air outlet 8Horizontal air duct 9 Front heat sink 10Vertical air duct 11Timbers 12Lifting door

Fig. 1 schematic diagram of Timber Drying Room

1. Existing Problems in Drying Room and Solutions

The forward and reverse circulation in the air drying room can make the wood drying, but there is uniformity of air due to situation such as vortex, collision etc in some areas for the hot circulating airflow. Reasons are as follows: (1) The horizontal air injected by the fan become hot air after passing through the front heat sink 9, which then changes the original direction after meeting the front vertical wall in the top of the drying room and then turn to the vertical air duct 10 by getting down 90 degree. But there are extrusion, entrainment and eddy when the hot air in the horizontal and vertical steering resistance encounters extrusion, so that the vertical duct air distribution is not uniform; (2) for fan equipped with impeller in unidirectional rotation, the originally designed four link mechanism can make the various fans in the drying room rotary forward and reverse synchronously for 180 degree. Though such mechanism can make the fan realize forward and reverse blowing, there are dead point for the four linkage, which makes it easily blocked during the forward and reverse rotating, so that the wind turbine cannot complete the rotation of 180 degrees. As a result of the deviation of the angle of the fan rotation, the deviation of the direction of the air supply airflow is generated, and the air circulation is not uniform.

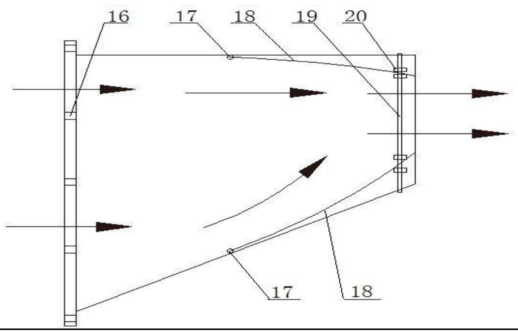
Thus, the uniformity of circulating air flow inside the drying room and the optimization design of air guiding device for fan is of great importance for improving the dryness of timbers.

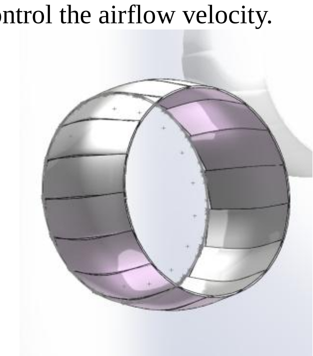
II. OPTIMIZATION DESIGN OF AIR-GUIDING DEVICE FOR FAN AND AIR INLET CONNECTING DEVICE

2.1 Design of Air-guiding Device for Fan

In order to improve the problems of non-uniform air velocity distributed, hot air jet beyond control and inflexible drying process for the conventional drying room, it is designed the wind turbine guide air supply device. The software modeling outlet is shown in the Figure (2), as well as the guide send wind device in figure (3); the outlet is designed to be a cylindrical shell, an inverted horn shape, and the circular outer bolt of guide send wind cove r is connected to the fan to send wind port. 18 upper and lower two arc guide tongue plates are designed at the guide send wind cover,; the roots of the diversion tongue plate is hinged with hinge 17 to the guide air cover on the inner wall.

The air guiding cover is a foldable cylindrical port as shown in Fig. (3), whose dimension can be adjusted accordingly, so as to change the sectional area of air outlet and control the airflow velocity.





16- Bolt Hole 17- Hinge 18-Arc guide tongue piece 19- Adjustable positioning screw 20-Tight nut

Fig 2-6 Two-dimensional Plan View of Adjustable Air Guide Cover

2.2 Optimization Design of Air Inlet Connecting Device

The air outlet and air-guiding device is connected through the knuckle bearing shown in Fig. (4) A outer bearing to fix the knuckle bearing is installed in the outlet of the air-guiding cover and fix the air-guiding cover as the inner bearing of the knuckle bearing. Then it is ok to achieve adjustable air flow in different directions.

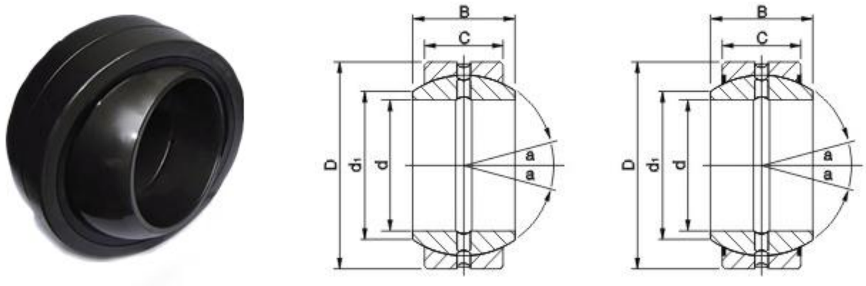


Fig 2-6 knuckle bearing

III. OPTIMIZATION ANALYSIS OF AIR FLOW ORGANIZATION

In the actual production, two stacks of timers of the same species and the same thickness are subject to dying by a 20M^3 conventional wood drying room and one optimized respectively, using the same drying process. The wood initial moisture content is 40%. The conventional wood drying oven is aired with three sets of impeller blower fans, whose each typhoon machine power is 2.2kW. The drying period is 30 days, and finally the wood moisture content is 11.8%; while the drying room equipped with the connecting rod mechanism to realize reverse air flow only needs three sets, whose power is 0.75kw. The drying cycle is shortened to 28 days, and the wood moisture content is 11.5%. Visibly, the drying period is shortened 2 days. In accordance with the currently used industrial electric price of 1 yuan/degree, for wind machine running 24 hours/day with full load, without considering the ladder electricity price, the drying costs would be reduced optimize the airflow drying room due to save electricity, drying cost will be decreased by 68% due to less electricity fees for drying room. In addition, the fact that the drying period is also shortened 2 days also means the annual operation costs are reduced and improves the factory profits.

Tab1: the contrast of normal oast and within airflow guiding device

Type of tuyere	Volume of oast （m^3）	Drying cycel （day）	Power of fan（kW）	Quantity Of fan （units）	Electric charge （RMB/time）
normal	20	30	2.2	2	3168
With airflow guiding device	20	28	0.75	2	1008

When calculating with the SC/tetra from numerical simulation, the structure size of a laboratory drying room with Pro/E: 4.8m in length, 3.6m in width, and 3.1m in height. The drying room is equipped with two typhoon machines, and the wood thickness is 40mm, whose interval size is 40mm. The boundary condition of the device is model Standard k-EPS, and the drying room circulation flow attribute is defined as compressed gas. Without considering the airflow gravity, the fan out tuyere is applied with velocity boundary conditions, and the exit velocity is set at 2.2m/s and the return air to the pressure boundary conditions, and the set static pressure is set at 0Pa. The drying room walls and obstacles are applied with no-slip adiabatic wall boundary condition; the relaxation factor is set as the default, and the setting calculation step is 300 steps automatically grid, whose number is approximately three million [6]. The simulation results are shown in figure (7) and (8). Figure (7) is the conventional wood drying room. The simulation results show that there is obvious vortex at the corner of the fan chamber of the fan, causing the airway ventilation between the upper and lower wood stacking not uniform. In particular, the air velocity of the top 4 stacking wood layer is obviously low, as well as poor drying effect; As shown in Figure (8), above problems disappears after adding air-guided device in the fan out and the airing uniformity of the vertical wind duct horizontal airflow is better. In addition, the horizontal airflow out can flow more into the vertical duct. The airflow is assigned by the arc guide plate, among which some are distributed to the upper of the timber stack, and others are to the lower, allowing to improve the efficiency of airflow uniformity among the whole timbers.

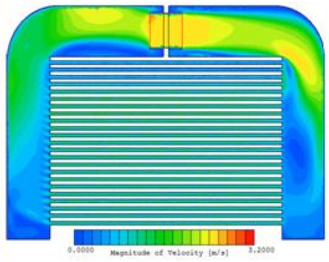


Fig. 7 Velocity Field Distribution of The Conventional Drying Room

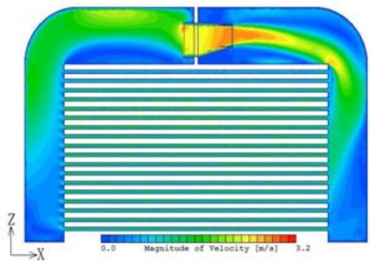


Fig. 8 Velocity Field Distribution After Being Optimized

The Monitoring Points Analysis:

In order to know about the velocity field distribution between the stacking timbers before and after the installation of arc guide plate in drying room, 23 monitoring points are selected in turn from the wood stack top to the bottom. The monitoring points' locations are shown in Fig. (9), so does the speed distribution of the monitoring point Fig. (10). From the monitoring points of the velocity distribution, it can be found that after applying the guided air supply device, the speed rate 1-4 layer above the stack of wood is remarkably improved and the uniformity of airflow velocity field in the whole drying room is effectively improved. And there is no obvious mutation rate between the monitoring points, improving the drying uniformity of the whole stack wood.

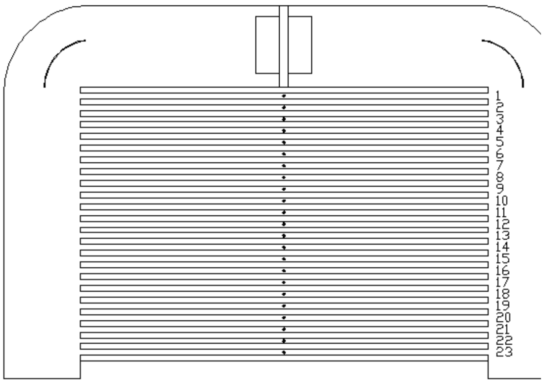


Fig. 9: Distribution Diagram of Monitoring Points inside the Drying Room

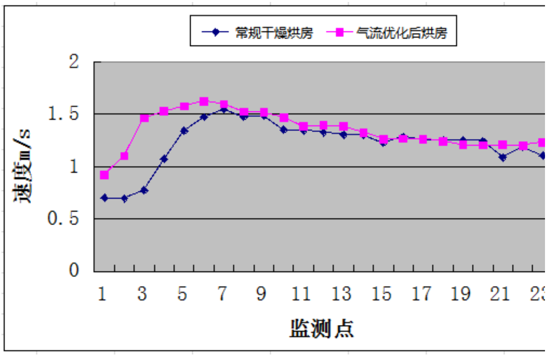


Fig. 10: Distribution of Velocity of Monitoring Points inside the Drying Room

IV. CONCLUSIONS

Following conclusions can be reached after optimizing the design of the existing conventional wood drying room, so as to perfect the air flow in the drying room, and using SC/Tetra to simulate the numerical simulation:

1. After using the air supply device guided with draught fan, the uniformity of air speed between the wood stacks is improved remarkably, so does the flow velocity in upper timber stacking, allowing to dry the timbers evenly. Thus the problem of different dryness among the upper and lower timers in the same drying room, which extends the drying circle, is removed, improving the drying efficiency of drying room.

2. The use of joint bearing mechanism can effectively achieve adjustable wind direction in the drying room as well as improve the uniformity of air circulation, improving the drying efficiency, shortening the drying cycle, reducing drying costs, improving product added value, and saving energy.

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