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工业生态与节能——面向工业车间非均匀热环境营造的低碳空调系统

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Summary. *The problem of indoor heat supply in industrial workshops in high latitude areas in winter is complex. The energy consumption of air conditioners used in most workshops is huge. In this paper, an innovative industrial low carbon air conditioning design based on the concept of "non-uniform thermal environment" is proposed. Through orthogonal experiment and three-level evaluation, the best operating parameters and energy-saving effect of air conditioning are obtained.*

The indoor temperature of workshops in high latitude areas in winter is often close to 0 ℃. The workshop has scattered personnel and numerous equipment, which makes the heating problem in winter complex. The traditional air conditioning systems used in most factories are committed to creating a uniform thermal environment. They not only consume huge energy, but also have a poor heating effect, which affects the working efficiency of workers.

In order to ensure the normal development of production and maximize energy conservation, we based on the concept of "non-uniform thermal environment", has made improvements in the traditional air conditioning system, and proposed an industrial air conditioning system design for industrial workshops, to improve the industrial production environment and production efficiency, reduce power consumption, and save energy.

After preliminary investigation and study, we chose an industrial workshop in Shenyang, China, with a specification of 50 m × 30 m × 5 m. The internal lathes are arranged in two parallel rows, with three lathes in one row. 6 windows are evenly distributed on each side above the lathe, and the specification of each window is 1.5 m × 1.5 m, normally closed in winter.

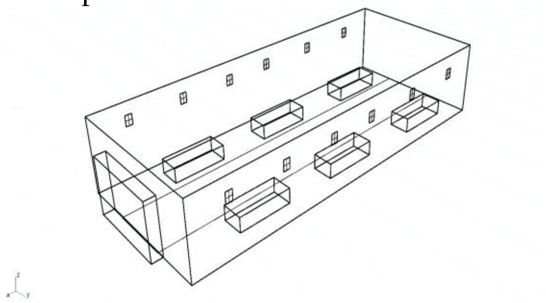

Figure 1 – Workshop model

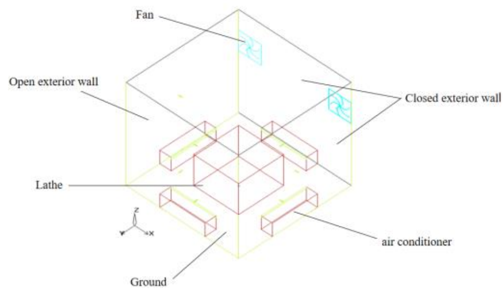

Figure 2 – Airpak Modeling

As the lathes in the workshop are evenly distributed and the influence between stations is small, one of the stations is selected for this research. In order to carry out the simulation experiment smoothly, we simplified the model as much as possible on the premise of ensuring the calculation accuracy, and used Airpak software to carry out the following modeling.

Based on the concept of "non-uniform thermal environment", we put "people-oriented" and "energy conservation and emission reduction" in the first place, so the evaluation indicators are not limited to the temperature, speed and other parameters of traditional air conditioners. we had selected the following parameters to build a new three-level evaluation system:

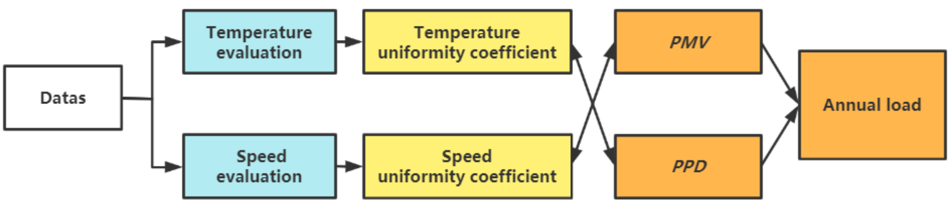

Figure 3 – Three-level evaluation system

The evaluation system of this project is complex, and there are many air conditioning operating parameters. To reduce the workload of simulation experiment and ensure the accuracy of experimental data, we took the orthogonal experimental design as the main idea and obtained the best condition parameters by comparing the influence importance of various factors.

According to the number of factors and the level of factors in the experiment, we designed the orthogonal test table and conducted the experiments. Then we calculate K_{ij} (K_{ij} represents the average value of the experimental results when the factors in column i are taken as level j) and r_j (r_j represents the range of K_{ij} in the column j). We judge the importance of different levels of the same factor by K_{ij}, and judge the importance of the best levels of different factors by r_j.

Table 1 – Levels of influencing factors

Level	Temperature(/°C) A	Speed (m/s) B	Air outlet angle(°) C	Air outlet height (m) D	Air outlet area(m²) E
1	20	1.2	0	0.45	2*0.05
2	25	1.5	15	0.75	2*0.15
3	30	1.8	30	1.05	2*0.25
4	35	2.1	45	1.35	2*0.35
5	40	2.4	60	1.65	2*0.45

Table 2 – Importance ranking table of influencing factors

Evaluation conditions	Impact importance(primary←secondary)
Temperature	C2←E4←D1←A5←B3
Temperature uniformity	D5←C5←A2←E1←B2
Speed	E5←D1←C1←B5←A3
Speed uniformity	D1←C3←A3←B3←E5
PPD	B2←C1←D2←A3←E3
PMV	C1←D1←E5←A5←B3

According to the influencing factors and their respective levels, 25 groups of orthogonal experiments were designed. By calculating K_{ij} and r_j values, the order of influencing factors of different evaluation conditions in tab. 2 is obtained. We can get the best three groups of operating parameter 1) A3-B2-C2-D1-E5; 2) A2-B3-C1-D2-E4; 3) A3-B3-C2-D1-E4. According to the experimental parameters selected by the three groups of schemes, the simulation experiments were carried out respectively to compare the temperature, speed nephogram and the annual load.

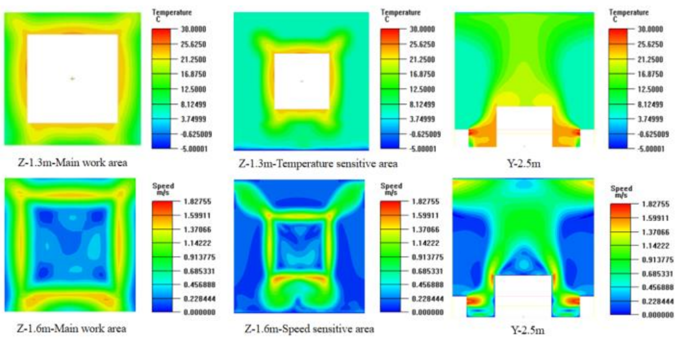

Figure 4 – Scheme temperature nephogram and speed nephogram

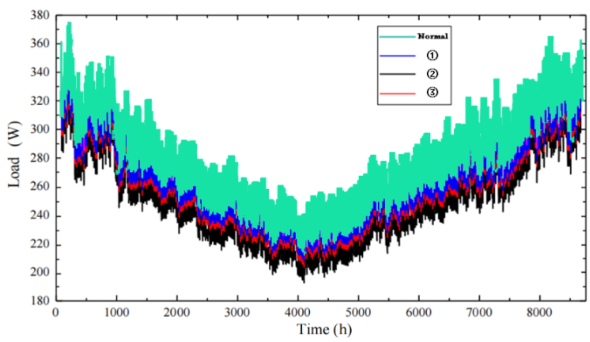

Figure 5 – Annual load comparison under various working conditions

Among them, the maximum values of group 2 are lower than those of the other two schemes in the temperature and speed nephogram, the uniform coverage area is similar, the *PPD* and *PMV* change little, and both are within the reasonable requirements. In terms of annual load consumption, it is 28.4 % lower than that of traditional air conditioners, 11.2 % lower than that of 1, and 6.8% lower than that of scheme 3. Therefore, Scheme 2 is the best operating parameter of low-carbon air conditioners in industrial workshops: Temperature 25 ℃, Speed 1.8 m/s, Air outlet angle 0°, Air outlet height 0.75 m, Air outlet area 2 0.35 m^2.