Research and optimal design of an energy efficient axial fan

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Abstract. Ventilator, as a fluid machine, is widely used in many areas of national life, he has high efficiency, high flow, small volume and low pressure, etc., in daily life, mining and metallurgical industry and other fields have a wide range of applications. In this regard, efficiency and noise are two important indicators of fans, so for the existing fans, there is a need for a design that optimises the efficiency and noise of axial flow fans.

Keywords: axial flow ventilator, fluid mechanics, optimal design

1. Design background
Although future energy development will increase the country's energy reserves, relying on domestic resources alone will not solve the problem at its root.

Figure 1. Chart of total energy consumption in China
The fan is a general-purpose machinery widely used in various sectors of the national economy, it is widely used in various fields such as petroleum, chemical industry, metallurgy, water conservancy and electric power. Information shows that the proportion of energy consumption of fans accounts for about 12% of coal consumption. At present, the total installed power of China's fans is about 0.49 billion kilowatts, and the annual power consumption accounts for about 30% of the country's total mechanical power consumption. Fans are widely used in various industries of the national economy and in people's daily lives. According to the latest statistics of the third industrial census, the total number of various types of fans used in China is about 21 million units, of which the electricity consumption of metal mines accounts for 30% of the electricity consumption of mining, the electricity consumption of fans in the iron and steel industry accounts for 20% of its production, and the electricity consumption of fans in the coal industry accounts for 17% of it. On this basis, the actual operation of China's fans than the efficiency of the Western developed countries about low about the annual waste of electricity in more than 10 billion degrees, therefore, the energy-saving potential of fans is very large, improve the level of fan research and design, the national economic development, energy saving and environmental protection will have an important impact, so this paper based on the information and knowledge learned, the existing fans to carry out a certain study and research, try to A more efficient axial fan optimization and energy saving design is proposed.

2. Current status of domestic and international research
Axial fans have many advantages such as high adaptability and efficiency, so they are widely used as supply and induced fans in large workstations and other important places. But at the same time the pneumatic noise it produces during operation is becoming a problem that cannot be ignored, deteriorating the working environment and endangering the health of the surrounding residents. In addition, according to the "China fan industry development analysis report" recommended: to improve the efficiency of the fan and reduce the noise of the fan, is currently one of the most important tasks of China's fan industry. Therefore, it is necessary to carry out research on how to improve the efficiency of fans and reduce pneumatic noise.

The following is a brief description of the development of axial fans at home and abroad, designed and analysed the impact of four hub options on the performance of cooling tower type axial fans, four hub options are shown in the figure.

![Figure 2. Four types of wheels](image)

Through CFD simulation, the axial fan characteristics such as shaft power, full-pressure efficiency and full pressure were extracted. In terms of full-pressure efficiency, solutions A and D have higher full-pressure efficiency than B and C at the same flow rate, and also have a higher stable operating range than the latter two, indicating that the increase of the rectifier hub can play a role in improving the full-pressure efficiency and stabilising the flow field. Luo Song, Xiang Yi et al. conducted full-pressure
efficiency experiments and flow-pressure experiments on rotary axial fans with three different wing types: Clark Y for the flat-bottom wing type, FMIA for the full-curved wing type and C-4 for the full-curved symmetrical wing type, and the three wing types are shown in Fig. 3.

The full pressure efficiency experiments show that all three blades have a high full pressure efficiency, all above 80%, but also have a tendency to reduce the full pressure efficiency as the installation angle increases, and pointed out that as the installation angle increases the radial clearance between the blade and the inner wall of the wind cylinder increases leakage is the cause of this trend. Compared to other airfoil types, the FMIA airfoil has the highest full-pressure efficiency. Flow-pressure experiments showed that the aerodynamic performance of the three airfoils was good, but the area of the high efficiency zone of the FMIA airfoil was larger than that of the other two airfoils. At the same time, the Jilin University team studied the application of bionic coupling technology to axial wind vortex drag, which in turn reduces aerodynamic noise, and to end saw noise reduction. This further reduces the aerodynamic noise across the wing surface. The team applied the special structure of the long-eared owl's plumage to an axial fan blade by machining a striped structure on the blade and serrated the blade edges, as shown in the figure.

A. Maaloum et al. from the Ecole Nationale Supérieure Technologique d'Ingénieurs (France) analysed the influence of axial fan inlet duct profile and cap shape on axial fans. It was found that the turbulence intensity of the inlet duct has a strong influence on axial fan noise, especially broadband noise. Cengiz Cemci and Ali Akturk of the University of Rome, Italy, proposed five different solutions for extending the blade tip platform based on the basic blade tip profile, and obtained six different blade tip particle motions by means of 3D particle image velocimetry. The tests show that the extended blade tip platform reduces tip leakage by reducing the tangential velocity of the airflow in the tip region, and that the appropriate choice of the position of the pressure side bump and its width are two key factors in reducing tip leakage.
3. Overall structure

3.1. Design objectives

1. Master the relevant principles of aerodynamics and pneumatic acoustics of axial fans, and train the ability to analyse and solve engineering problems by participating in the project students through the design work of axial flow.

2. Independent design of the experimental test platform to test key parameters such as speed, pressure, power, efficiency and noise of axial fans.

3. Compare numerical predictions and experimental test results, and on this basis carry out multi-objective aerodynamic optimization design of axial fans, cultivate the innovative ability of all participating students and strive to achieve good optimization and improvement results.

4. Based on the above work, a low noise, high efficiency axial fan was finally designed.

3.2. Technical lines

The optimisation and design done in this paper is a theoretical calculation of the given data (flow rate Q, pressure P, media parameters, inlet state): determination of the specific speed, blade outlet mounting angle, impeller circumferential speed, impeller outer diameter, blade inlet diameter, impeller diameter of the ventilator, number of blades, blade inlet and outlet width, blade inlet mounting angle and other key data of the fan. The drawings are drawn, the pneumatic design is carried out, the blades are selected and the blades are designed, then numerical simulations are carried out and the results of the theoretical calculations are checked. 3D drawings are scanned and physical objects are made and tested in the laboratory. The numerical analysis is checked and, after the required operating conditions are met, the product is optimised to improve efficiency and reduce noise.
3.3. Overall design

Based on the above research, this project is based on a one-dimensional design concept, combined with a multi-objective optimisation design approach, taking into account both noise and efficiency factors, to develop a high efficiency, low noise axial flow fan design.

![Non-uniform rotor](image1)
![Non-uniform rotor](image2)
![Prototype impeller](image3)
![Optimised impeller](image4)

Figure 7. Non-uniform rotor  
Figure 8. Non-uniform rotor  
Figure 9. Prototype impeller  
Figure 10. Optimised impeller

4. Summary

In the traditional fan design, there are some key parameters often set by experience, sometimes even within a certain range of arbitrary selection, it is difficult to design the ideal axial fan, but this paper introduces a different approach to the traditional design is expected to optimise the design, so that the axial fan with higher efficiency and lower noise is the main goal of this design.

For example, air conditioners in household appliances, range hoods, aero engines, factory ventilation, petrochemicals, etc. In these applications, high efficiency and low noise are usually the two core objectives of the fan. Therefore, this project is based on a one-dimensional theoretical design to optimise the design of a high efficiency and low noise axial fan for a given parameter. The main idea is to combine theoretical design, numerical simulation and experimental testing to develop a new type of highly efficient, low-noise axial fan and to apply it in real industry.

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