

Design of an External Centrifugal Fan for the Cooling System of an Electrical Machine

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Abstract. Air cooling systems for electrical machines still do not lose their relevance. Especially noteworthy here is the aviation industry, in which special attention is paid to the weight and size of all systems, as well as the high density of equipment layout, which can interfere with the implementation of other types of cooling. At such times, only air cooling can be used to ensure the optimum operating temperature of the electrical machine. This article presents a research work on the profiling of blades for an external centrifugal fan of the air-cooling system of an electrical machine. The study is based on 3D numerical calculations using computational fluid dynamics software. Based on the results obtained, a design option was chosen that provides maximum performance.

1 Introduction

The losses that occur during the operation of the electrical machine are converted into thermal energy, which causes heating and an increase in the operating temperature of the parts of the electrical machine. In the stator part of an electrical machine, the most vulnerable part in terms of operating temperature is the winding of the electrical machine. Exceeding the operating temperature above the maximum temperature that the winding insulation can withstand leads to degradation of materials and may also cause failure. Ensuring the optimal operating temperature is one of the main and most important tasks in the design of electrical machines, which determines the performance of the proposed design [1].

When designing electrical machines, air [2], liquid [3] and cryogenic [4] cooling systems are actively considered. Despite the clear superiority in heat dissipation in liquid and cryogenic cooling systems, air systems still do not lose their relevance. First of all, this is due to the fact that the air-cooling system is the least demanding from the weight and size point of view, due to which it is actively considered for use in areas where special attention is paid to weight and size characteristics. For example, in the aviation industry [5-8].

This article presents the process of designing an external centrifugal fan for an electrical machine, performed using the computational fluid dynamics software package.

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2 Design algorithm

In general, the sequence of work when designing a fan in terms of gas-dynamic characteristics consists of 4 stages (Fig. 1).

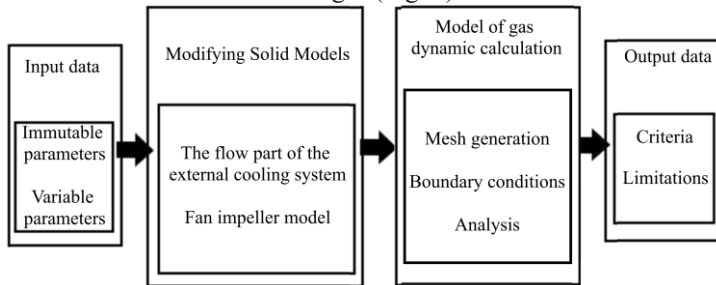


Fig. 1. Algorithm for working with the calculation model.

The algorithm shown in Fig. 1 describes an approach to design using computational fluid dynamics software packages.

The input data block contains immutable and variable parameters, which are due to design considerations.

In the block for modifying solid models, a geometric change in the design and its subsequent analysis are carried out. Previously, in this block, you can use an analytical calculation in a one-dimensional setting.

In the gas-dynamic calculation block, a grid model is generated, the selected boundary conditions are set, and the calculation results are analyzed.

In the output data block, an analysis is made of the contribution of various parameters to the final operation of the system.

3 Description of the design and research method

In general, the design of the studied air cooling system with a centrifugal fan is shown in Fig. 2. Centrifugal fans of low and medium pressure are widely used. The following is a medium pressure fan.

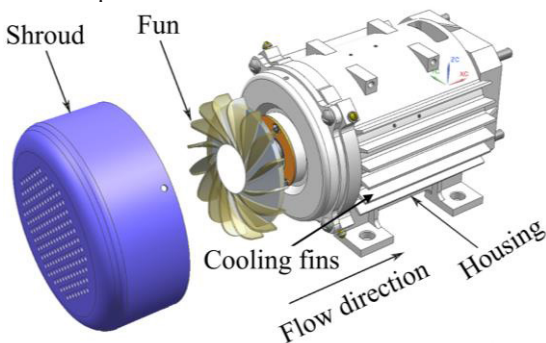


Fig. 2. The design of the electrical machine under study from the point of view of the cooling system.

The system consists of a perforated fan shroud, a centrifugal fan and a housing with cooling fins. The fan is located on the same shaft as the rotor of the electrical machine and has a similar rotation speed.

The main characteristics of the fan are presented in Table 1.

Table 1. Cooling fan specifications.

Parameter name	Value	Dimension
Required capacity, Q	120+	m ³ /h
Temperature, T	25	°C
Shaft speed, n	6000	rpm

The parameters are determined by the terms of reference from the industrial partner. The choice of forward-curved blades is due to the large capacity of this type of blades, due to which it is possible to use small impellers and create cost-effective designs.

The cooling system is studied using the computational fluid dynamics software package, which makes it possible to simulate the flow of gases taking into account various turbulence models.

Initially, designs with straight blades are calculated, where the dependence of performance and power consumption on the number of blades is determined. Then, on the basis of the most efficient solution with straight blades, the effect of the rotation of the blades (Fig. 3) is investigated to reduce power consumption while maintaining the performance of the fan assembly. The angle of entry and the angle of exit of the air flow from the impeller are changed.

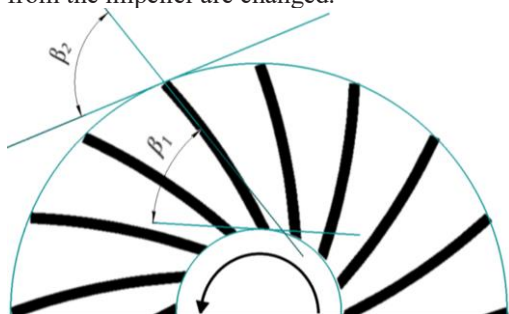


Fig. 3. Changing the angles of entry and exit of the air flow.

4 Description of the design and research method

4.1 Straight blades

Initially, the calculation is carried out for straight blades. We consider the range of 10-24 blades with a step of 1 blade. The influence of the number of blades of the proposed design on the performance and on the power expended is determined (Fig. 4).

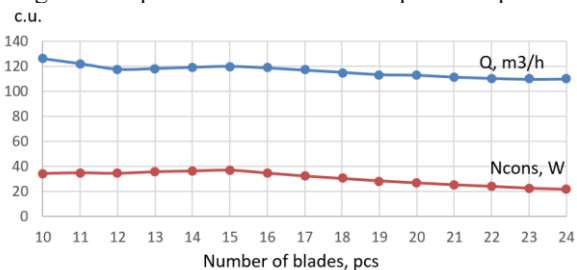


Fig. 4. Dependence of performance and power costs on the number of blades.

Fig. 4 shows that up to a certain point (15 blades) there is an increase in the energy expended on the fan drive. Further, with an increase in the number of blades, the power

expanded decreases. The highest performance is observed for the case with 10 blades, then the performance decreases.

Fig. 5 shows a plot of velocities and velocity vectors for one of the calculations. Fig. 6 shows the pressure diagram.

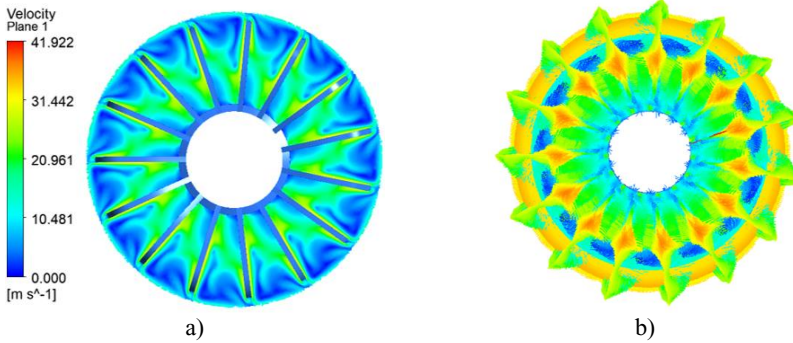


Fig. 5. Plots of velocity and velocity vectors on the example of calculation with 15 blades (a) velocities (b) velocity vectors.

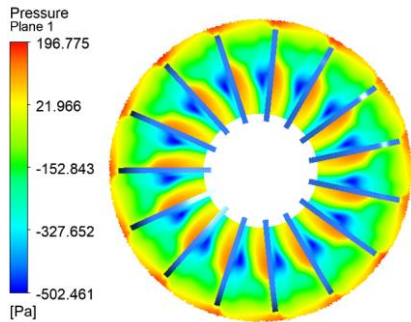


Fig. 6. Plot of pressure on the example of calculation with 15 blades.

A number of structures with forward-curved blades are calculated in a similar way. Further calculation is carried out for the most productive solution - 10 blades. The range of angles of airflow entry into the wheel β_1 (30-60°) and exit from the wheel $-\beta_2$ (40-70°). The results are presented in Table 2. The calculations are sorted by column with performance, starting from the most productive design.

Table 2. Calculation results for forward-curved blades.

$\beta_1, ^\circ$	$\beta_2, ^\circ$	m ³ /h	Ncons, W
30	70	124.763	26.7851
40	70	124.07	26.925
50	70	120.346	26.5867
60	70	118.522	26.7579
40	60	118.503	34.6327
60	60	117.459	23.9034
50	60	117.237	23.3114
30	60	117.094	23.4017

50	50	112.447	21.0821
40	50	112.172	20.717
30	50	111.998	20.3495
50	40	110.523	18.5739
60	40	110.188	19.0217
40	40	110.022	17.9828
60	50	109.461	22.834
30	40	109.278	17.4635

As can be seen from the presented table, the most productive ratio is $\beta_1 = 30^\circ$ and $\beta_2 = 70^\circ$. The power input dropped to 20 straight blades (more than 25% compared to 10 straight blades). At the same time, this solution is almost in no way inferior in performance to the solution with 10 straight blades (the difference is less than 1%, which can also be explained by small errors in the calculation model caused by the mesh).

5 Conclusion

This paper presents a research work devoted to profiling the blades of a centrifugal fan of an electrical machine with forward-curved blades. A series of calculations were carried out to determine the effect of the number of blades on the performance of the fan and on the power consumed by the fan. Then a series of calculations was carried out with the swirling of the blades, where, with the ratio of the inlet flow angle = 30° and exit angle = 70° the performance of the fan remains virtually unchanged from the original design, however, the power consumption of this solution is reduced by more than 25%.

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