MODERN DEVELOPMENTS OF HIGHPERFORMANCE INDUSTRIAL FANS

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Modern centrifugal and axial impellers were developed on the basis of domestic and foreign experience. Highly efficient centrifugal and axial fans of different aerodynamic schemes for different practical applications were designed on the basis of those impellers. Optimal technological solutions allowed to master the serial production of the developed fans in short time. Realized technical decisions will allow to reduce energy consumption of ventilation systems of modern buildings and structures.

Introduction

The main directions of the development of general industrial fans are:

- increase in energy efficiency,
- expansion of the working area for air flow rates at specified dimensions and speeds,
- noise reduction,
- optimization of design performance in accordance with classes of tasks to be solved.

The most significant fact is that, firstly, fan science has been developing for a long time and high levels of efficiency have been achieved (up to 92%), there¬fore, every step in its development requires more and more efforts. Secondly, today the development is, as a rule, at the junction of directions, when it is necessary, for example, not only to reduce the power consumption of the fan, but also to reduce its noise. Or increase the pressure of the fan while increasing the temperature of the pumped medium. One can cite other examples of concrete tasks at the junc¬tion of two or three different branches of science. We strive to be at the level of modern requirements and we are engaged in research, development and practical implementation of new promising technical solutions in the field of ventilation equipment. In this article, we will offer several technical solutions for radial and axial general industrial fans from the spectrum of problems we solve.

Centrifugal fans

Aerodynamic scheme "free impeller"

The last 20 years, the development of fans with the aerodynamic "free impeller" principle has been devel-oping. This principal is based on a scheme of a radial impeller with backward curved blades and an inlet cone on the frame, without a housing. The impeller can be located either directly on the shaft of the electric motor or connected to it via a pulley-belt transmission. It should be noted that this scheme has been used for a long time, for example, in roof fans. Today - this is one of the most used schemes in supply and exhaust systems.

The outlet of the flow from the impeller occurs in the volume of the casing of sufficiently large dimen¬sions [1,2] and the velocity head is lost, the impeller operation is estimated on basis of static parameters. In accordance with modern energy saving trends, research and development work is conducted in the direction of increasing the static efficiency of such impellers by optimizing their geometry.

Currently the upper limit of the capabilities of such an aerodynamic scheme seemed to be reached. The problem solving has an optimum: to increase the static efficiency of the impeller, it is necessary to reduce the angle of the blades at the outlet, however, in order to increase the flow and pressure coefficients it is neces¬sary to increase the angle of installation of the blades at the impeller outlet and its width. A number of other factors are also of influence. The actual efficiency for static pressure corresponds to approximately FEG71 (Fan efficiency grade 71) see[3,4]. Obviously, further improvement of the "free impeller" scheme will be very difficult and may prove to be economically unjus¬tified, since it will not be possible to completely get rid of the lost dynamic pressure at the outlet of the free impeller.

Regarding the modern impellers with backward curved blades, it is worth mentioning the impellers of the companies "Ziehl-Abegg", "EBM Papst", "Flakt Woods", "Comfrey" (see, for example, [5]). These impellers were designed, according the aerodynamic scheme of the fan "free impeller", for application in supply and exhaust systems. In our country schemes such as "free impeller" began to be used in the early 2000s. At the same time, the most popular were centrif¬ugal impellers with backward curved blades having a flat front disc of an enlarged diameter (in comparison with the blades) with a smooth turning radius at the impeller inlet (Figure 1).

In this article, we want to demonstrate the basics of aero¬dynamics of the best foreign and domestic centrifugal impellers with backward curved blades. This to identify opportunities, generalize their advantages and minimize shortcomings. Our experiments showed the dependence of the aerodynamic performance and efficiency

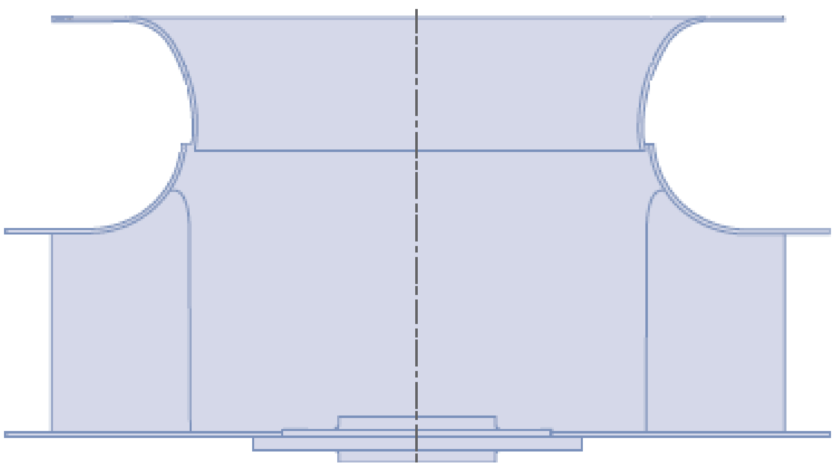

Figure 1. The basic unit of the "free impeller" scheme.

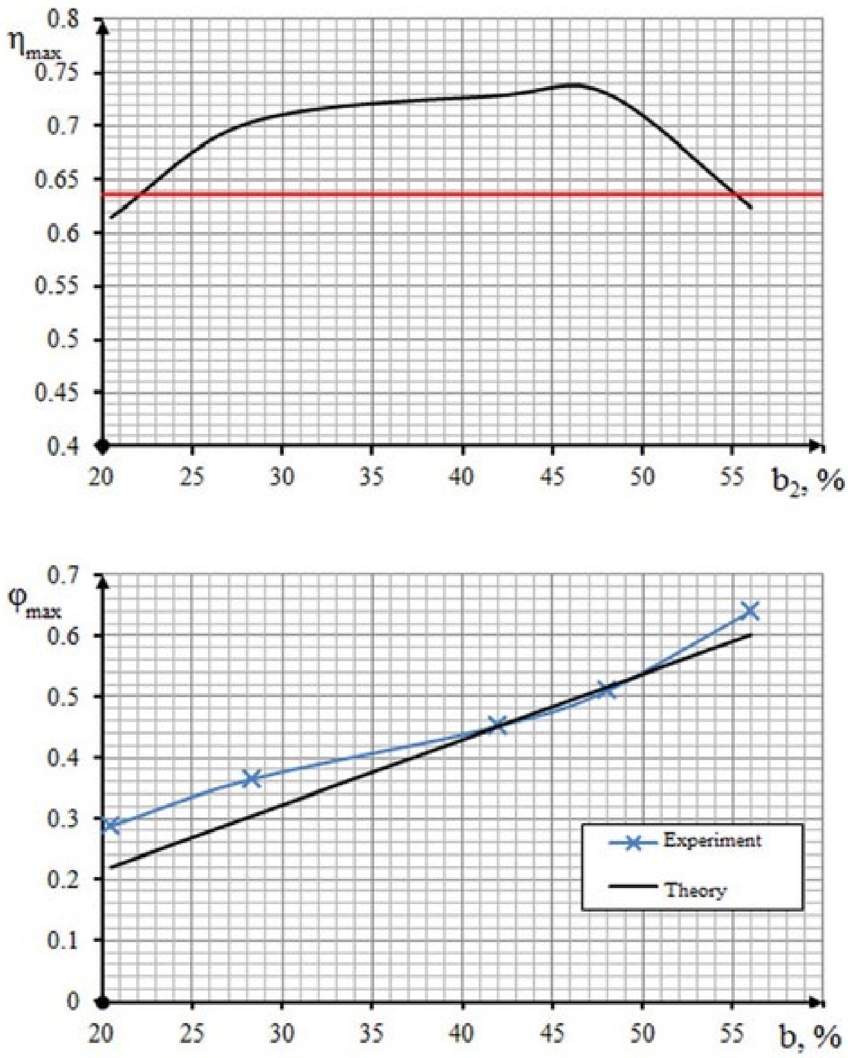

Figure 2. Dependence of the maximum efficiency and the flow coefficient on the width of the impeller divided by blade system diameter.

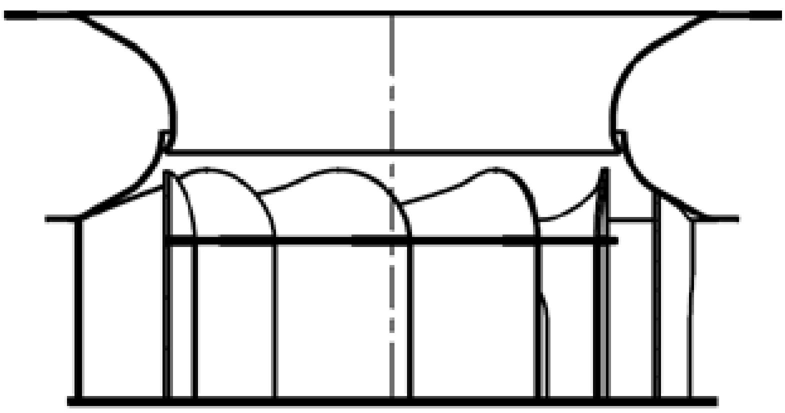

Figure 3. The newly developed basic unit of the “free impeller” scheme.

on the width of the impeller (Figure 2), with other geometric parameters of the impeller also affecting its efficiency, but the main effect is on the width. As the width of the impeller increases, the flow in it loses stability, there is a flow separation near the front disc, which leads to a decrease in the aerodynamic parameters and efficiency, volume flow growth is disproportionate to the width of the impeller. The best impellers with a flat front disc have optimum performance at widths of about (25 ... 28%) of the diameter of the blade system. For smaller widths, efficiency also falls off rather quickly, which is already associated with a suboptimal relation¬ship between the inlet diameter and the width of the impeller. For example, in the book [6], one can find the results of work related essentially to the effects observed in a centrifugal impeller with a change in its geometry.

These results were obtained from the results of a cycle of experiments to optimize the geometry of the impeller, including the shape and relative dimensions of the front disc, the shape of the blade and the angles of its instal¬lation at the inlet and outlet of the impeller, the shape of the rear disc (Figure 3). In addition to the tests, estimates of the aerodynamics of impellers were made for a deeper understanding of the influence of the basic geometric dimensions and parameters.

The smooth inlet cone, in combination with the conical front disk of the impeller and the curvilinear shape of the sheet blades, made it possible to obtain aerody¬namic, power and noise characteristics similar to the best “free impeller” schemes. It should be noted that there is a significant difference: the developed aerody¬namic scheme allows creating impellers of greater width, providing a significant expansion of the aerodynamic characteristics of the “free impeller” without loss of pres¬sure and, accordingly, the efficiency of the fan (Figure 4).

The developed scheme can be used without a noticeable reduction in efficiency to impeller widths of at least 25% of the diameter of the blade system. At smaller widths, the efficiency of the circuit decreases and it is necessary to apply other aerodynamic parameters of the "free impeller" principle.

Volute casing

The need for unification led us to inspect the perfor¬mances of new impellers as part of a fan with a volute casing. As the width of the impeller widens its working zone by the volume flow rate of air, it is necessary to change the geometry of the volute casing accord¬ingly. For unification reasons, it was decided not to change the front and rear walls of the volute casing. The effect of the change in the spiral wall of the casing (its axial extension) proportional to the width of the impeller was studied. The completed cycle of works allowed designing two types of fan, differing in width (axial extension) of impeller and the volute casing correspondingly. One fan made it possible to obtain wide aerodynamic characteristics corresponding best industrial centrifugal fans and is distinguished by the reliability and stability of these characteristics. The second fan has a wider impeller, a wider volute casing and its aerodynamic performance is significantly wider, while maintaining high efficiency values (Figure 5). An essential advantage of the second scheme is a high proportion of the static pressure in the total pressure of the fan, which simplifies its matching with the ventilation systems.

Tubular fan

For practical applications of considerable interest are radial ducted direct flow fans with a cylindrical casing (for example, [7]). In our country, fans of this type started to be studied in the fifties [8], but unlike at the foreign market where they were widely spread are called "tubular fan", they have not yet been applied. These fans are close to fans with a volute casing, but smaller in size, having a larger static pressure part in total pressure, higher static efficiency, strait direction of flow, which in some cases sim-

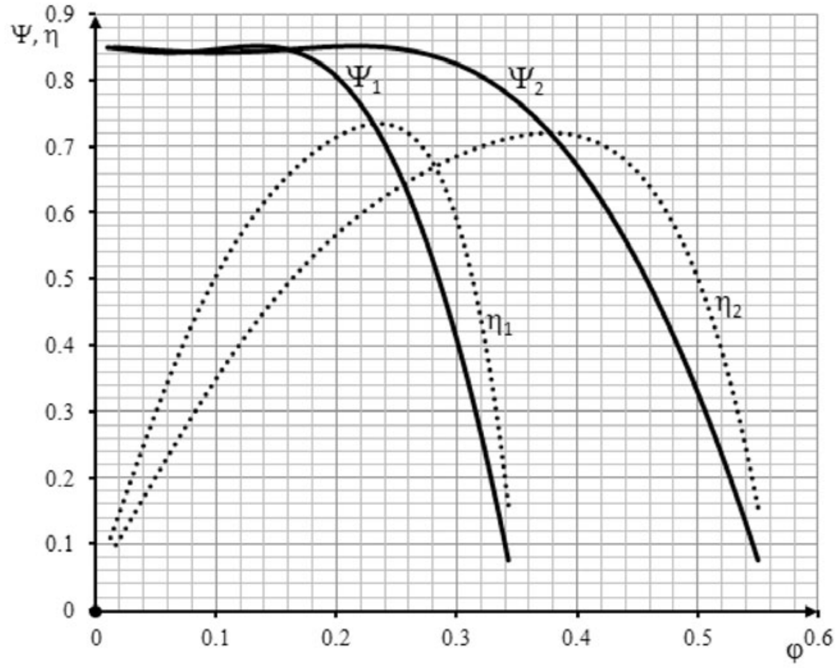

Figure 4. Dimensionless operating characteristics of the developed "free impeller" scheme for two impeller widths (here $\varphi = L / (FU)$; $\psi = \rho U^2/2$; $U = \pi Dn/60$; $F = \pi D^2/4$; D-diameter of the impeller blade system, m; n-impeller speed, rpm; η - fan efficiency).

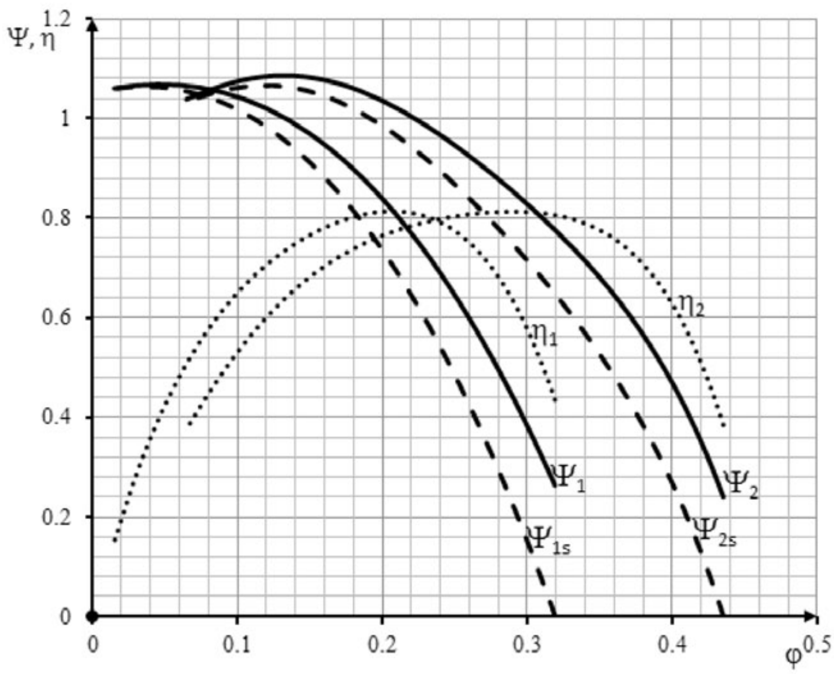

Figure 5. Dimensionless performance of two fans with a volute casing, differing in the width of the impeller and volute.

plifies the connection of the fan with the network with lower noise levels. Such fans can successfully replace corresponding fans with a volute casing. The impeller can be centrifugal, centrifugal with profile blades, mixed flow, or mixed flow with profile blades.

At the same time, the centrifugal impeller with backward curved blades is characterized by higher pressures than the mixed flow impeller, but the use of a mixed flow impeller makes it possible to expand the performance zone (with other things being equal).

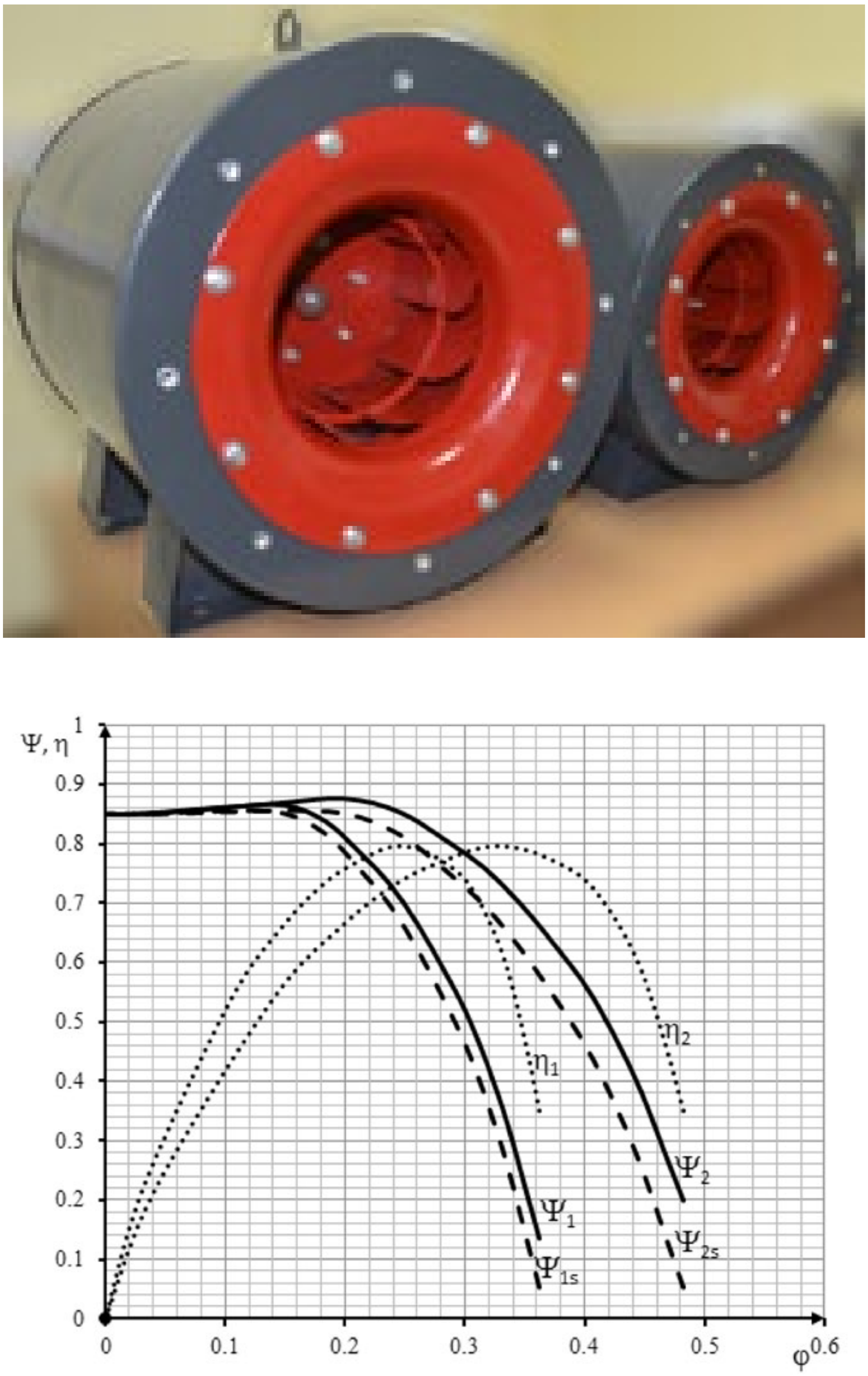

Figure 6.Centrifugalin-line fan with a round casing. Performance data are given for two impeller widths.

The possi¬bility of changing the width of the centrifugal impeller in a large range allows you to combine the advantages of mixed flow and centrifugal impellers. (Figure 6).

As a result of a series of experiments, the aerodynamic characteristics of the created fan were confirmed, providing a sufficiently wide aerodynamic characteristic for air volume flow coefficient. At the same time, it was possible to regulate the working volume flow area by changing the width of the impeller, without changing the fan casing. According to aerodynamic parameters and efficiency, the fan replaces the corresponding fans with a volute casing, but with higher static parameters. According to aerodynamic and power characteristics, the fan is at the level of the best analogues and exceeds in the width of the flow rate working zone.

Thus, the new centrifugal impeller has allowed to a significant extent, to unify the technology and design of several types of centrifugal fans, and to obtain new high-efficiency low-noise general industrial fans for modern ventilation systems of energy-efficient build¬ings, structures and technologies.

Axial fans

Unlike the radial fans calculation methods, which are mostly based on semi-empirical and empirical dependencies and require experimental investigation and refinement of each individual design, the calcula¬tion methods of axial fans have theoretical design bases which allows providing a set of accurate, specific design parameters.

One of such methods is the technique developed in Central Aero-hydrodynamic Institute (TsAGI) (for example [9,10]). This technique allows determining all the optimal parameters, starting with the maximum allowable diameter of the axial fan hub (the works of Brusilovsky I.V. and Mitrofovich V.V.) and ending with the prediction of aerodynamic characteristics (the works of Brusilovsky I.V., Gegin A.G., Kolesnikov A.V., Dovzhik S.A., and others). The developed technique also allows you to design an axial vane diffuser under an existing axial impeller blade system.

Unfortunately, the forms of the blades obtained as a result of calculations by this method as, indeed, for any other, are quite complex and usually have the form of a saddle surface. This makes it impossible to fabri¬cate them with simple technological operations such as bending and rolling, not to mention profile blades. For this reason, some manufacturers either manufacture sheet blades with forms just like the calculated geometry (with several bends or along a cylindrical surface). Some users acquire blades of known companies specialized in axial blades manufacturing with known characteris¬tics in a wide range according to angles of installation, number of blades as well as changes when pruning blades and installing on hubs of different diameters. It is obvious that the blade rings made by geometry only approximate to the optimal and have much reduced levels of efficiency and pressure. Impellers with several types of blades used for all applications cannot have high efficiency in all designs due to too wide unification. In addition, axial vane diffuser has to be coordinated with impeller geometry if not, most part of dynamic pressure associated with swirling the flow at the outlet of the impeller will be lost and consequently with increased pressure coefficients, the efficiency will decrease.

To solve problems in which high flow rates, medium and low-pressure coefficients are required at high efficiency values, fan blades with sheet blades were designed with observance of the calculated geometric parameters corresponding to the optimal aerodynamic scheme (Figure 7). The technology of such blades avail¬able in applications has been developed which allows creating dimension rows of fans.

A wide dimensions range and the possibility to use fans with or without axial vane

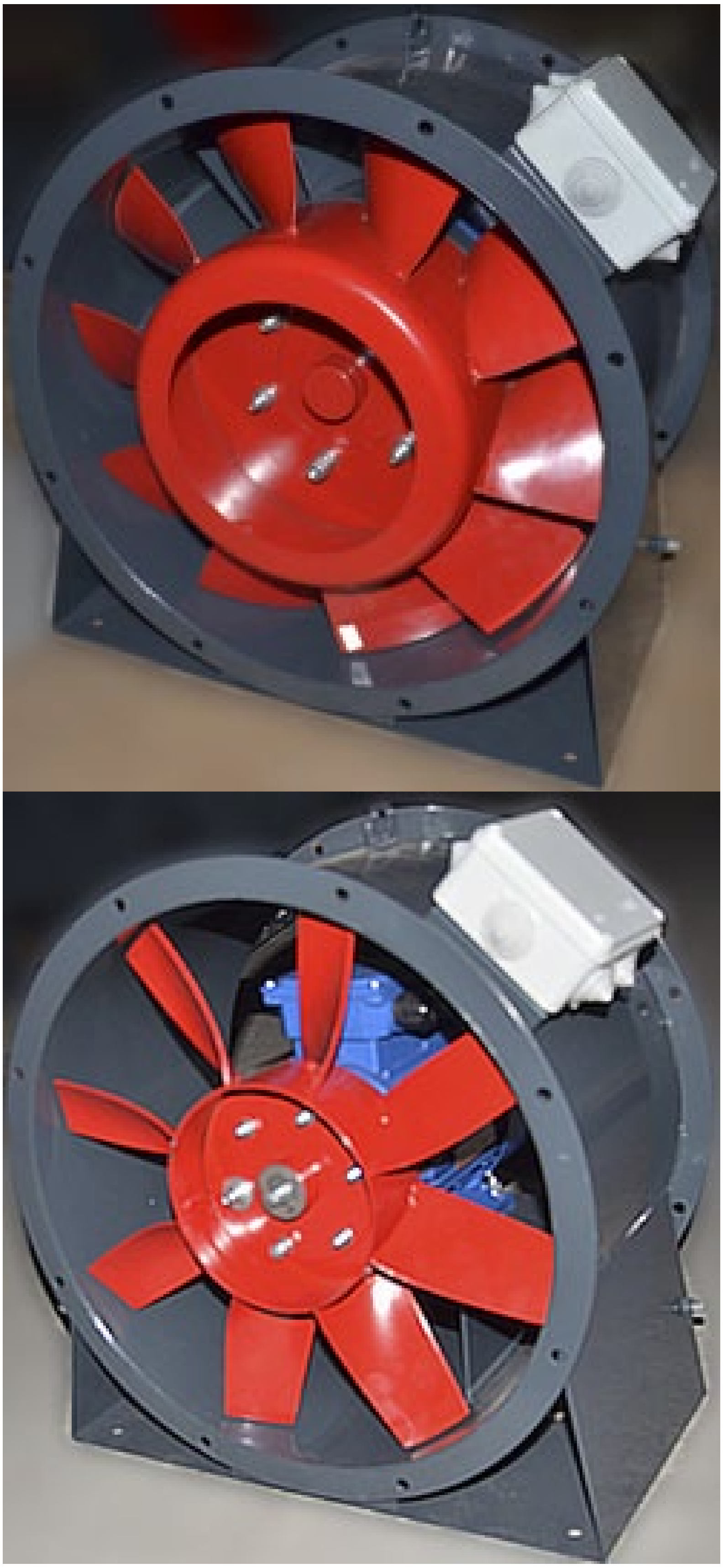

Figure 7. Axial fans according to the scheme “impeller + axial vane diffuser” and scheme “impeller” with sheetblades of spatial curvature.

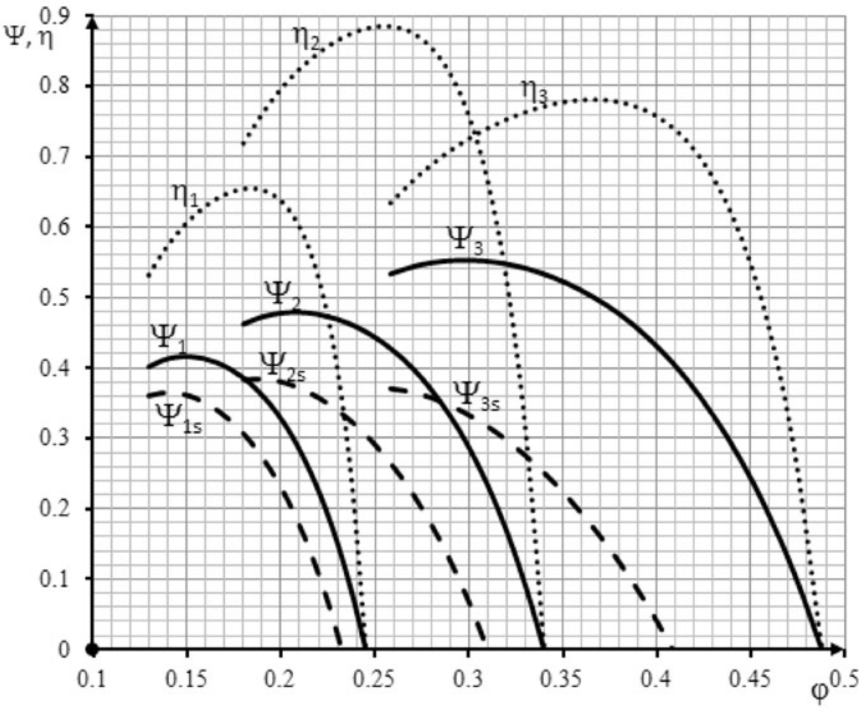

Figure 8. Dimensionless aerodynamic characteristics of a medium-pressure fan according to "impeller + axial vane diffuser" scheme.

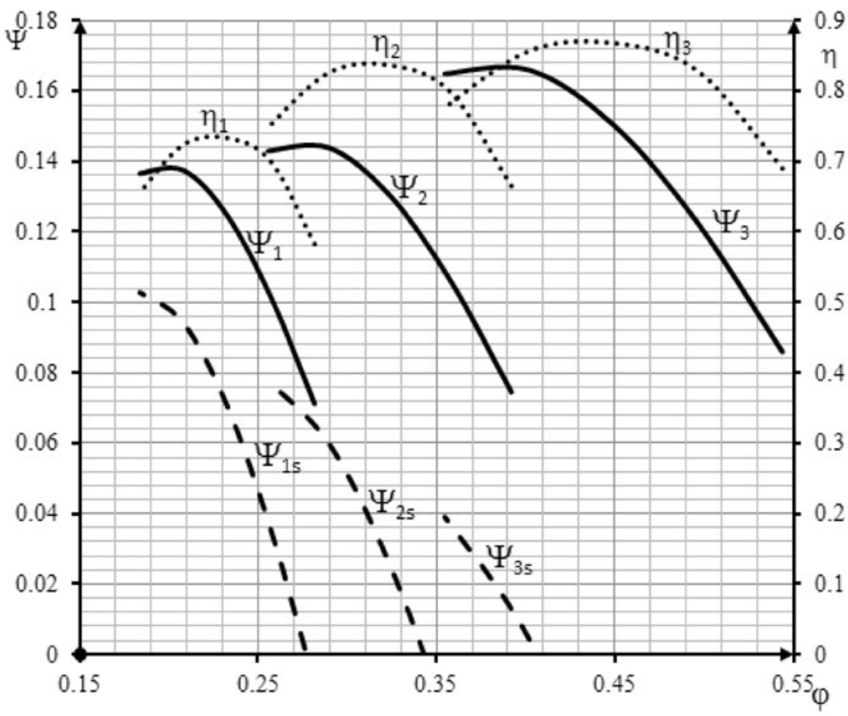

Figure 9. Dimensionless aerodynamic characteristics of a low-pressure fan according to the "impeller" scheme.

diffuser, as well as, in some cases, the creation of a complete system with axial guide vanes for regulation, allow solving a wide range of problems with high efficiency levels (Figure 8 and Figure 9). Such fans can successfully compete with the best samples of other companies. High levels of efficiency allow them to be used in the construction of ventilation systems of energy-efficient buildings and structures.

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