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CONSTRUCTION OF A COMPRESSOR STAGE BLADE ROW ACCORDING TO THE GAS-DYNAMIC CALCULATION

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Наведено методику побудови лопаткового вінця ступені осьового компресора за даними. Методика газодинамічного розрахунку дає змогу в першому наближенні отримати координати поверхні і спинки та корита лопаткового вінця з урахуванням кутів установки кривизни, відносної товщини профілів вінця по висоті.

Ключові слова: осьовий компресор, лопатковий вінець, товщина профілю, координати поверхні вінця, проектування ступені.

In research presented methodology of blade nm construction according to the gas-dynamic calculation. This methodology permit at first approximation obtain coordinate of section face and tray of blade row subject to angles of setting, profile curature, profile thickness ration by height o blade row.

Keywords: Axial-flow compressor, blade row, profile thickness, coordinate of profile row. stave designing.

Introduction

This article tells us about one of the approaches of axial flow compressor blade row construction. The idea of the analytical method of calculation is the geometry of given profile specified with the help of some primary profile size definition. By blade row height calculation data made primary profile geometry calculation, subject to angles of setting, profile curvature, profile thickness ratio by height of blade row.

Analysis of researches and publications

Up-to-date methods of blade rows flow calculation of axial-flow compressor allows basically define only qualitative figure of process that take in channel of interscapular row. That's why definition of inverse problem on basis of gas-dynamic calculation data doesn't allows getting a scape of blade row that satisfied actual aerodynamic properties.

Data of gas-dynamic calculation, for example, by the help of finite-difference equation is used in general for the account some physical events those are difficult and sometimes impossible to investigate by experiment. Practically in all cases are required an experimental researches for finishing prototype models of impeller machine elements.

Pretty much all optimization problem of axial-flow compressor air-gas channels design consist of at the prime with inverse one-dimensional calculations and radius calculations of blade row parameters with the subsequent organization of blade row. At the heart of axial-flow compressor blade row profile geometry organization as often as not base original profile with task geometry that profile can be symmetrical or asymmetrical [1].

Methods of blade row profiles design considered in works [1, 2 and 3] and others. All of them are based on graphic and grapho-analytical methods of axial-flow compressor stage can be based summarized characteristics of axial-flow compressor planar gratings or mode stage. Also provide blades smoothing blade rows geometry during the research. In any cause for take an experiment we need to have blade rows with technical characteristics satisfied the performance specification. Profiling of blade rows could have done by gas-dynamic calculation of axial-flow compressor, by arbitrary diameter and calculation of the flow parameter by blade height.

During a blades design we can take as design section (fig. 1) at the blade tips and at the root usually take section that locate on 2…4 mm by the exit edge of blade from radial flow section to the direction of pitch diameters [1].

Centerline of reference profile bent so that bend angles leading and trailing edges χ_1 and χ_2 (fig. 2) are fit with calculation. The bent of centerline can be performed on a circle arch, a parabola or some other selected law.

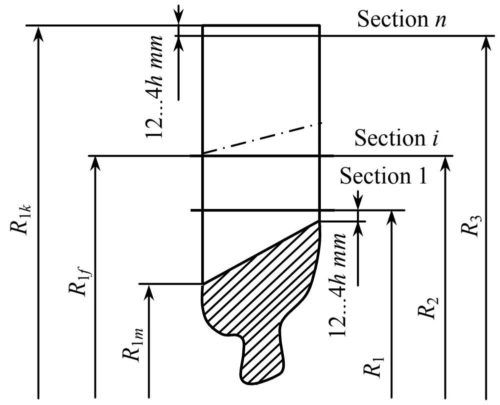


Fig. 1. Calculation scheme of blade row

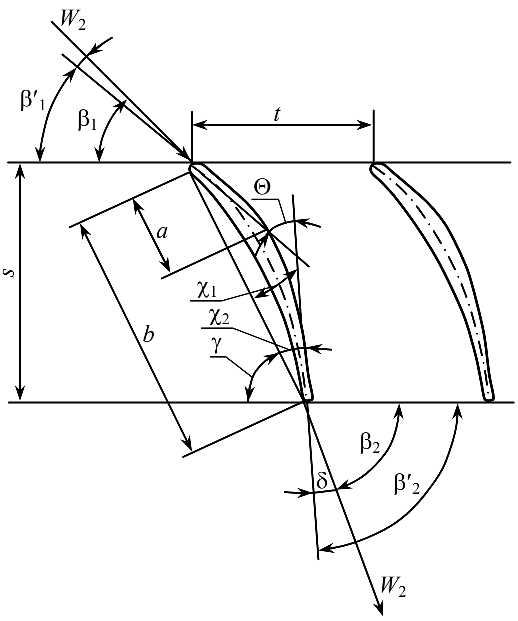


Fig. 2. Gas-dynamics and kinematics parameters of plane grating

In elementary compressor blade rows with consists of profiles, distinguish the following angles:

- constructive angle at the inlet, β_1';
- inlet flow angle, β_1;
- constructive outlet angle, β_2;
- outlet flow angle, β_2;
- bend profile angle, Θ;
- delay profile angle, δ;
- angle of flow alteration in row, $\Delta\beta$;
- angle of profile setting, γ;
- attack angle, i;
- angle between tangent to the profile centerline at the leading edge and chord, χ_1;
- angle between tangent to the profile centerline at the trailing edge and chord, χ_2.

Also the important parameters of a cascade are:

- profile chord, b;
- array spacing, t;
- distance between grate forward and back front edge, S.

Problem statement

The idea of analytical method of calculation lies in the fact that geometry of desired profile defined by the way of some desired profile size recalculation.

Task solution

The task of preliminary profiling of compressor blades with the help of reference aerodynamic profiles could be divided on two parts: profile centerline construction and blade row construction at its height. Analytic construction of blade profile centerline that curved along the arc of parabola is done using the equation

$$y(i) = \frac{bx(i) - x(i)^2}{2Ax(i) + c}, \qquad (1)$$

where $A = 0,5(\text{ctg}\chi_2 - \text{ctg}\chi_1)$, $c = b\,\text{ctg}\chi_1$, i — the number of original symmetrical profile sections to coordinate χ.

In some cause of blade centerline design provide by circular arc with the help of equation

$$y(i) = a\left(x(i) - x(i)^2\right), \qquad (2)$$

where $a = \text{tg}\left(\frac{\Theta}{2}\right)$, Θ — angle of centerline profile.

Next, we need to specify the reference symmetrical profile. For example, on fig. 3 showed reference symmetrical profile № 2 $\left(\bar{C}_{\text{пр}} = 12\,\%\right)$ [1].

Coordinate of section face of profile and profile and profile tray can calculate, using following procedure.

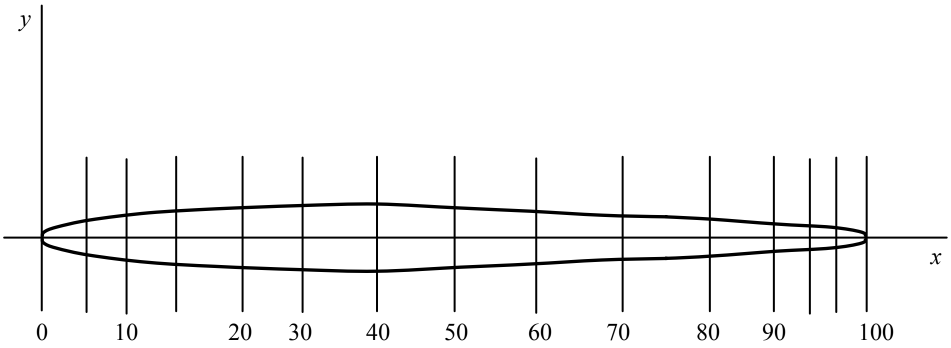
Definition of profile suction face and profile tray possible by the way of normal equation using to curve in points $\{x(i); y(i)\}$

$$y - y(i) = -\frac{x - x(i)}{f'\,x(i)}, \qquad (3)$$

where y, x — straight line current value that is normal to profile centerline in point $\{x(i); y(i)\}$.

The first derivative of equation (2) will have the appearance

$$f'(x) = a\left(1 - 2x(i)\right). \qquad (4)$$



x	y_c	y_x	y_{cp}	h
0	0	0	0	0
1,25	1,89	–1,89	0	5,78
2,5	2,62	–2,62	0	5,24
...	...	...	...	...
...	...	...	...	...
90	1,45	–1,45	0	2,90
95	0,81	–0,81	0	1,62
100	0	0	0	0

Fig. 3. Scheme and geometry characteristics of original symmetrical airfoil section

Then equation (3), take, $b = 1/\left(a\left(2x(1)-1\right)\right)$ have another view

$$y - y(i) = b\left(x - x(i)\right). \qquad (5)$$

Distance from centerline along the normal to profile section face (fig. 4) could define from equation

$$y_s(i)^2 = \left(y - y(i)\right)^2 + \left(x - x(i)\right)^2, \qquad (6)$$

where $y_s(i)$ — value of i^{th} ordinate of symmetrical profile.

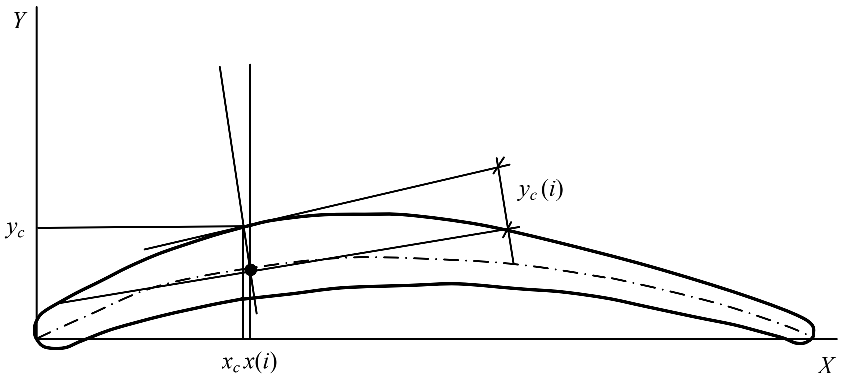


Fig. 4. Scheme of arc-shaped airfoil profile

In cause when an original profile is asymmetrical, then perpendicular to the chord isn’t simultaneously a perpendicular to the centerline.

This observation is easily taken into account during arc-shaped airfoil profile design.

Solving the equations (5) and (6) we can obtain a value of arc-shaped airfoil profile suction and tray coordinate

$$x_k(i) = \left(x(i) \mp y_s(i)\Big/\sqrt{1+b^2}\right);$$

$$x_c(i) = \left(x(i) \pm y_s(i)\Big/\sqrt{1+b^2}\right);$$

$$y_k(i) = \left(y(i) - y_s(i)\Big/\sqrt{1+b^2}\right);$$

$$y_c(i) = \left(y(i) + y_s(i)\Big/\sqrt{1+b^2}\right).$$

After transfer coordinate system in the center of gravity of arc-shaped airfoil profile (fig. 5) or axis system, that is used during blade machining, suction face and tray define like

$$x'_k(i) = x_k(i) - x_{\text{ЦТ}};$$

$$x'_c(i) = x_c(i) - x_{\text{ЦТ}};$$

$$y'_k(i) = y_k(i) - y_{\text{ЦТ}};$$

$$y'_c(i) = y_c(i) - y_{\text{ЦТ}}.$$

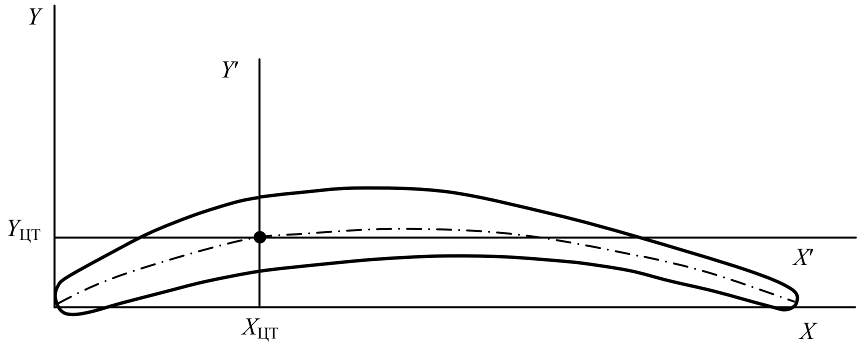


Fig. 5. Scheme of coordinate grid transfer

Knowing the angles of setting of the height blade rows profiles, coordinates suction faces and trays sections of blade rows define with the help of equations

$$x''_k(i,j) = x'_k(i,j)\cos\gamma(j) - y'_k(i,j)\sin\gamma(j),$$

$$x''_c(i,j) = x'_c(i,j)\cos\gamma(j) - y'_c(i,j)\sin\gamma(j),$$

$$y''_k(i,j) = x'_k(i,j)\sin\gamma(j) - y'_k(i,j)\cos\gamma(j),$$

$$y''_c(i,j) = x'_c(i,j)\sin\gamma(j) - y'_c(i,j)\cos\gamma(j)$$

where $\gamma(i)$ — angle of setting of a profile on blade row height; j — number of section of blade row on a height.

If thickness of blade row profile changes in blade height, for example, by linear law

$$c(j) = \frac{\left(d(j)(c_k - c_{\text{вт}}) - c_k d_{\text{вт}} + c_{\text{вт}} d_k\right)}{\left(d_k - d_{\text{вт}}\right)},$$

then coordinates of symmetrical profile suction face and tray by the row section define from equation $y'_s(i,j) = c(j)\, y_s(j)/c_{\max}$ and should be accounted during the definition of profile coordinate on blade row height.

By the results of calculation in taken coordinate system could design blade row profile section on its height (fig. 6) with the account of angles of setting on each radius. Calculation results could also use during manufacture of the blade at the axis-controlled machine.

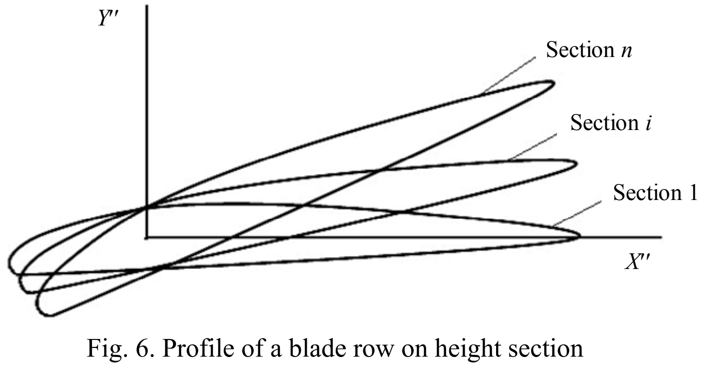


Fig. 6. Profile of a blade row on height section

Conclusion

Accordingly, the proposed method of blade row projection allows in the first approach give a coordinate of blade row suction face and tray with the account of angles of setting, curvature, thickness ratio of row profiles on height.

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