THE DESIGN OF AXIAL PUMP ROTORS USING THE NUMERICAL METHODS

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Abstract: *The researches in rotor theory, the increasing use of computers and the connection between design and manufacturing of rotors, have determined the revaluation and completion of classical rotor geometry. This paper presents practical applications of mathematical description of rotor geometry. A program has been created to describe the rotor geometry for arbitrary shape of the blade. The results can be imported by GAMBIT - a processor for geometry with modeling and mesh generations, to create a mesh needed in hydrodynamics analysis of rotor CFD. The results obtained are applicable in numerical methods and are functionally convenient for CAD/CAM systems.*

Keywords: rotor theory, diameter, distribution, CAD/CAM.

1. Introduction

The researches in rotor theory, the increasing use of computers and the connection between design and manufacturing of propellers, have determined the revaluation and completion of classical rotor geometry.

The rotor geometry is defined by diameter, number of blade, radial distributions of pitch, skew and rake, radial distribution of chord length - which together with skew gives the contour of the blade, type of camber and thickness distribution, radial distribution of maximum thickness and camber, hub shape. The rotor blade shape is defined by a series of cylindrical blade sections, each of which is positioned relative to pitch line and rake line.

Knowing the geometrical parameters of rotor blade is important for numerical calculations, drawings and manufacturing work. This paper presents practical applications of mathematical description of rotor geometry. A program has been created to describe the rotor geometry for arbitrary shape of the blade. The coordinates of cylindrical sections in rotor blade are given in Cartesian and Cylindrical coordinates. The results can be imported by GAMBIT - a processor for geometry modeling and mesh generations, to create a mesh needed in hydrodynamics analysis of rotor with CFD.

The results obtained are applicable in numerical methods and are functionally convenient for CAD/CAM systems.

2. Theoretical Aspects Regard Rotor Geometry

A screw rotor has a complex geometry, given in technical drawings following a special convention. The rotor geometry is usually characterized by: rotor diameter, hub diameter, number of blade, rotor pitch, expanded blade area, skew, rake, and profile shape [1], [5].

The classical screw drawing comprises four parts: a developed blade, the blade sections, a blade sweep and boss shape, together with a table of dimensions. The blade shape is defined by a series of cylindrical blade sections, positioned relative to pitch line and rake line.

During the last years there have been a considerable change in rotor design and manufacturing.

The increasing use of computers and modern milling machines, the connection between design and manufacturing of rotors, has determined the revaluation and completion of classical rotor geometry.

The complex rotor geometry is given in thousand of offset points or spline surface descriptions. When the radial distribution of pitch, skew, rake, chord lengths, chamber, thickness and profile shape have been fixed numerical interpolation tools can be used to compute the coordinates of any point of the blade.

A Cartesian (x_0,y_0,z_0) and a cylindrical (x_0,r_0,e_0) coordinate system are fixed to the ship and a Cartesian (x,y,z) and a cylindrical (x,r,θ) are fixed to the reference blade (fig.1).

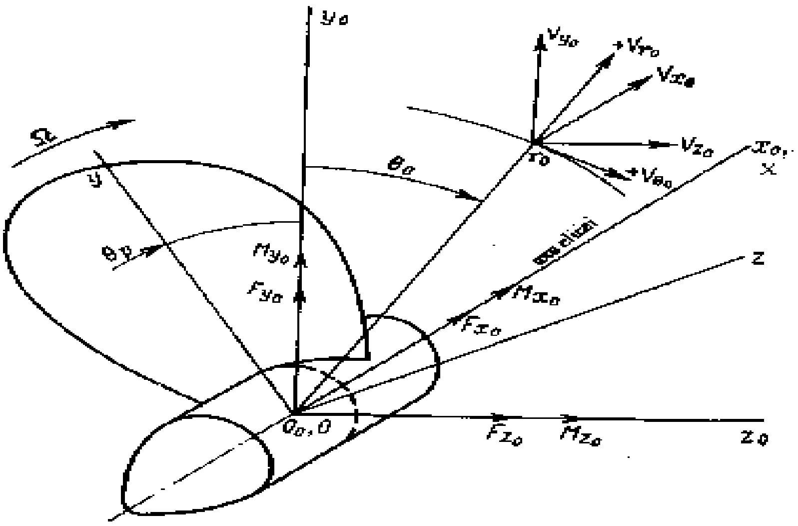

Fig. 1 Cartesian and Cylindrical Coordinate Systems of pump rotor [1]

A local Cartesian coordinate system (fig.2) is used to represent the cylindrical blade section geometry (φ is the pitch angle).

Two non-dimensional function are used to describe the geometry of a cylindrical blade section:

camber function $F_c = \eta_c / f_M$

thickness function $F_T = \eta_t / e$ where $e = \max \eta_t(\xi)$ and $f_M = \max \eta_c(\xi)$

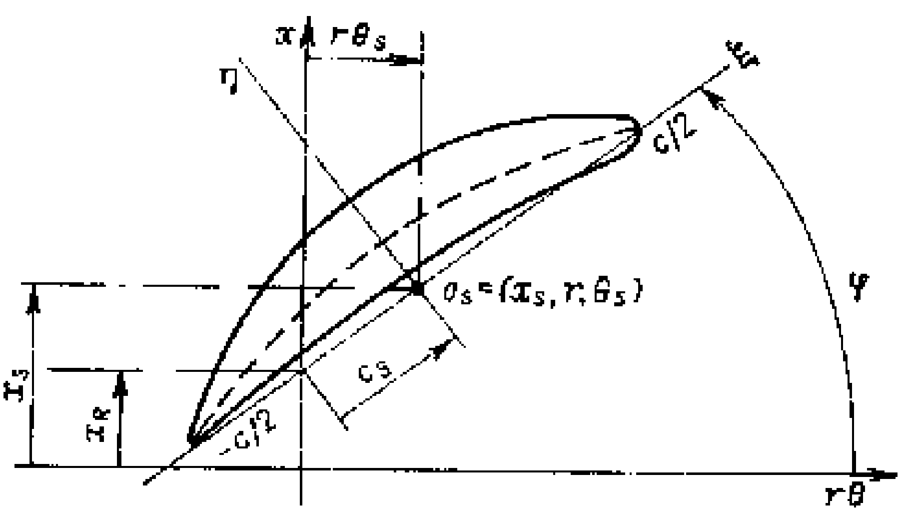

Fig. 2 Local Cartesian Coordinate System for a Cylindrical Blade Section [1]

Knowing eight main geometrical parameters which define completely the rotor blade geometry: Radial distribution of pitch P(r); Radial distribution of chord length c(r); Radial distribution of maximum chamber f_M(r); Type of chamber distribution F_c (ξ, r); Radial distribution of maximum thickness e(r); Type of thickness distribution F_T(ξ,r); Radial distribution of skew C_S(r); Radial distribution of rake x_R (r) [2], [5].

The equations of the blade surface in cylindrical coordinates are:

- for the upper side:

$$\bar{x}^{+} = \overline{x_R} + (\overline{c_s} + \bar{c}\cdot\xi\%)\sin\varphi + (\overline{f}_M \cdot F_C + \bar{e}\cdot F_T)\cos\varphi$$

$$\theta^{+} = \frac{1}{r}[(\bar{c}_s + \bar{c}\cdot\xi\%)\cos\varphi - (\overline{f}_M \cdot F_C + \bar{e}\cdot F_T)\sin\varphi \qquad (1)$$

- for the lower side:

$$\bar{x}^{-} = \overline{x_R} + (\overline{c_s} + \bar{c}\cdot\xi\%)\sin\varphi + (\overline{f}_M \cdot F_C - \bar{e}\cdot F_T)\cos\varphi$$

$$\theta^{-} = \frac{1}{r}[(\bar{c}_s + \bar{c}\cdot\xi\%)\cos\varphi - (\overline{f}_M \cdot F_C - \bar{e}\cdot F_T)\sin\varphi \qquad (2)$$

The relationships between the cylindrical and Cartesian coordinates are:

$$x = x \;,\; y = r\cos\theta \,,\; z = r\sin\theta \qquad (3)$$

The most usual type of section for axial pump rotor is NACA 66 a = 0,8 [4]. In next table the non-dimensional distributions of thickness and cambers is given.

Table 1 The non-dimensional distributions of cambers and thickness for NACA 66 a = 0,8

$\xi\%$	$\frac{(1-\xi)}{2}\%$	F_C (ξ%)	F_T (ξ%)
1(LE)	0	0	0
0.995	0.0025	0.0235	0.0445
0.99	0.005	0.0423	0.0665
0.985	0.0075	0.0595	0.0812
0.975	0.0125	0.0907	0.1044
0.95	0.025	0.1586	0.1466
0.9	0.05	0.2712	0.2066
0.85	0.075	0.3657	0.2525
0.8	0.1	0.4482	0.2907
0.7	0.15	0.5869	0.3521
0.6	0.2	0.6993	0.4000
0.5	0.25	0.7905	0.4363
0.4	0.3	0.8635	0.4637
0.3	0.35	0.9202	0.4832
0.2	0.4	0.9615	0.4952
0.1	0.45	0.9881	0.5000
0	0.5	1	0.4962
-0.1	0.55	0.9971	0.4846
-0.2	0.6	0.9786	0.4653
-0.3	0.65	0.9434	0.4383
-0.4	0.7	0.8892	0.4035
-0.5	0.75	0.8121	0.3612
-0.6	0.8	0.7027	0.3110
-0.7	0.85	0.5425	0.2532
-0.8	0.9	0.3586	0.1877
-0.9	0.95	0.1713	0.1143
-00.95	0.975	0.0823	0.0748
-1(TE)	1	0	0.0333

3. Results

A computer program has been created to describe the rotor geometry for arbitrary shape of the blade.

Knowing the eight main geometrical parameters, which define completely the rotor blade geometry, the coordinate of any points of the blade can be computed.

The coordinates of cylindrical sections in rotor blade are given in Cartesian and Cylindrical coordinates. The Cartesian Coordinates form a file which can be imported by GAMBIT, a processor for geometry modeling and mesh generations, to create a mesh needed in hydrodynamics analysis of rotor with CFD [3].

Rotor blade modeling with GAMBIT has five stages:

- Importing the coordinates vertex data file;
- Creating the edges which represent the cylindrical blade sections (fig. 3);
- Creating the blade surfaces (fig.4);
- Creating the blade volume (fig.5);
- Creating the rotor volume (fig.6).

The illustrations plotted outputs from the program are given in fig. 3-6 for a high skew rotor, and in fig.7-8 for a rotor with a symmetrical blade distribution.

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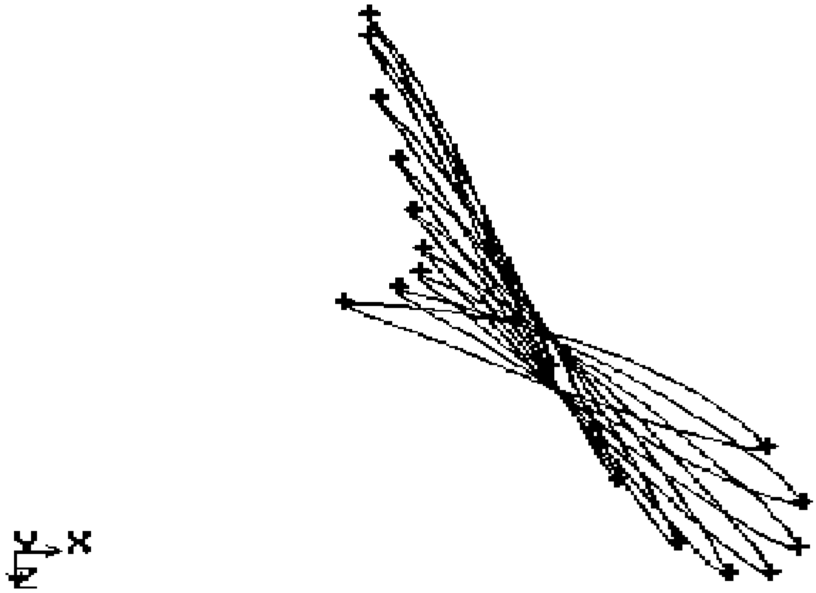

Fig. 3 Views of blade sections

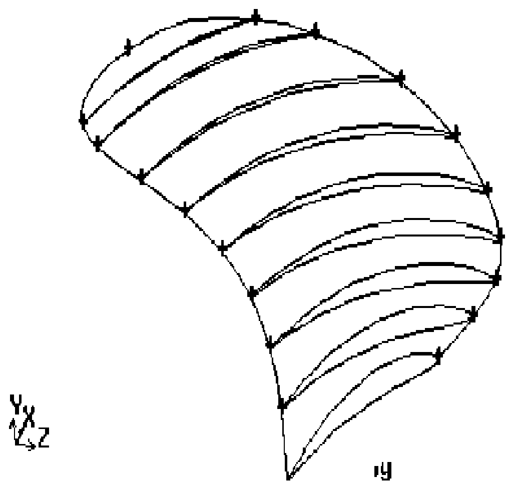

Fig.4. Blade surfaces (upper side and lower side)

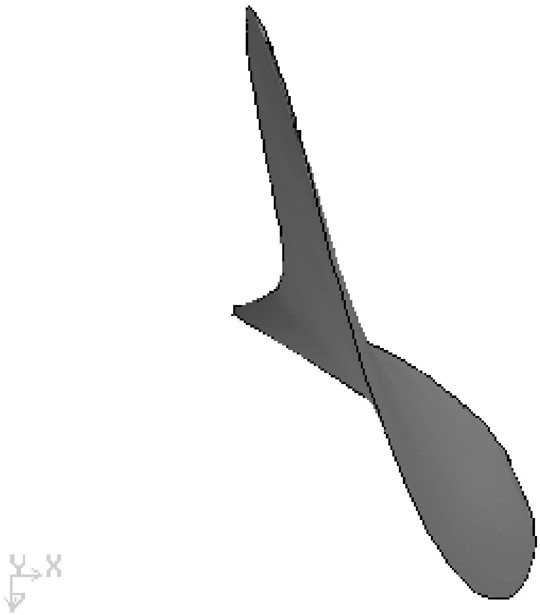

Fig. 5 Rotor blade (volume)

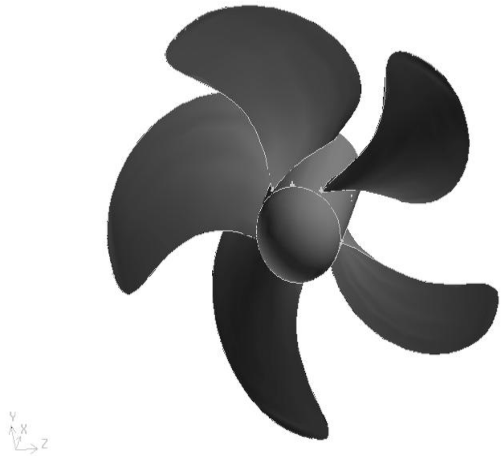

Fig. 6 High skew rotor

Fig. 7 Rotor blade (symmetrical blade distribution)

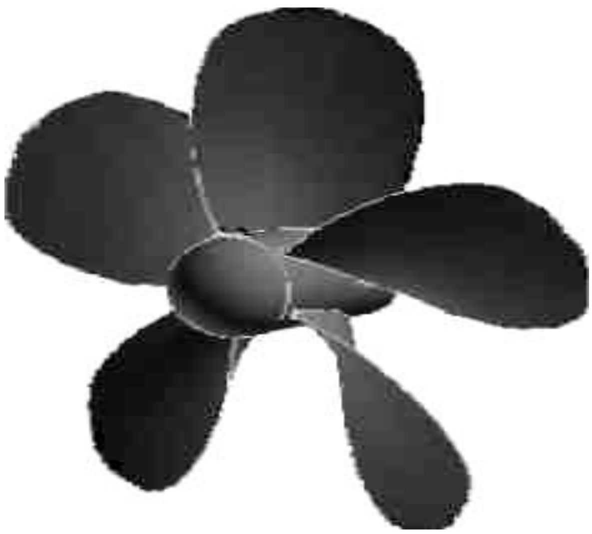

Fig.8 Rotor with symmetrical blade distribution

4. Conclusions

Knowing the geometrical parameters of rotor blade is important for numerical calculations, drawings and manufacturing work.

The complex rotor geometry can be given in thousand of offset points and the results obtained are applicable in numerical methods and are functionally convenient for CAD/CAM systems.

The program created is able to construct the rotor surfaces which are used for mesh generations needed in hydrodynamic rotor analysis with CFD methods.

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