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HYDRAULIC DESIGN OF INDUCER

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Abstract: *The paper deals with hydraulic design of an inducer. The mathematical model based on the Lagrange coordinates is presented. It is based on a choice of trajectory of a fluid particle in accordance with the continuity equation. Given the trajectory shape, it is possible to determine the specific energy of an inducer. The inducer blade is then determined by the family of these trajectories.*

Key words: ***Inducer, Euler equations, Continuity equation, Lagrange coordinates***

1 Introduction

When designing an inducer, the main criteria are high suction performance, high head rise and a positive pressure gradient. Currently, the design methods to avoid cavitation in inducers are becoming a major concern. This article provides relatively quick and easy methodology to do the preliminary blade design satisfying demanded parameters, while focus is put on suitable specific energy and pressure gradient. Cavitation in inducers is studied in the papers (Rebattet et al 2001; Acosta et al 2001; Wegner et al 2003). No attempts to improve the cavitation performance have been made here.

2 Liquid Motion on a Helical Surface

Let us consider the helical surface in the coordinate system $\mathbf{x} = [x_1, x_2, x_3]$. This surface rotates around axis x_1 with angular velocity ω. We connect the rotating coordinate system $\mathbf{y} = [y_1, y_2, y_3]$ with the helix. In the system y_i we may write down the general parametric helical surface as

$$\begin{aligned} y_2 &= F(a_1, a_3)\cos A(a_1, a_2, a_3) \;, \\ y_3 &= F(a_1, a_3)\sin A(a_1, a_2, a_3) \;, \\ y_1 &= G(a_3)\,, \end{aligned} \tag{1}$$

where $a_1 \in \langle a_{1\mathrm{i}}, a_{1\mathrm{f}}\rangle$, $a_3 \in \langle 0, a_{3\mathrm{f}}\rangle$ and a_2 is fixed in the interval $\langle 0, 2\pi\rangle$. In x_i this surface is given by

$$\begin{aligned} x_2 &= F\cos\,(A + \omega t) \;, \\ x_3 &= F\sin(A + \omega t) \;, \\ x_1 &= y_1 \,. \end{aligned} \tag{2}$$

Helix's shape is defined. To describe the motion of a fluid particle on this helix we choose the Lagrange coordinates, while this particle will be moving in the opposite direction of axis y_1. In general, this motion is described by

$$\begin{aligned} y_2 &= F(a_1, a_3, t)\cos A(a_1, a_2, a_3, t)\,, \\ y_3 &= F(a_1, a_3, t)\sin A(a_1, a_2, a_3, t)\,, \\ y_1 &= G(a_3, t) \end{aligned}$$

and in system x_i must satisfy the Continuity Equation (Brdička et al 2005), which in Lagrange coordinates takes the form $J(0) = J(t)$. Substituting from (2) and solving the determinant, we get

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$$J(t) = F\frac{\partial F}{\partial a_1}\frac{\partial A}{\partial a_2}\frac{\partial G}{\partial a_3} = J(0)\,. \tag{3}$$

2.1 Important Relations for the Inducer Design

With the defined motion in hand, we are ready to express some important quantities in terms of functions F, A and G. The circumferential velocity component v_u is given by

$$v_\mathrm{u} = F(\dot{A} + \omega) \tag{4}$$

and for the blade angle β, we have

$$\mathrm{tg}\,\beta = -\frac{\sqrt{\dot{G}^2 + \dot{F}^2}}{F\dot{A}}\,. \tag{5}$$

2.2 Pressure

The pressure field can be determined from the Euler equations, which in Lagrange coordinates take the form (Brdička et al 2005)

$$\rho\frac{\partial^2 x_1}{\partial t^2}\frac{\partial x_1}{\partial a_k} + \rho\frac{\partial^2 x_2}{\partial t^2}\frac{\partial x_2}{\partial a_k} + \rho\frac{\partial^2 x_3}{\partial t^2}\frac{\partial x_3}{\partial a_k} = -\frac{\partial p}{\partial a_k}\,, \qquad k = 1{,}2{,}3\,. \tag{6}$$

Using equations (2) in (6), we obtain equations describing the pressure field as

$$-\frac{\partial p}{\partial a_k} = \rho\left[\frac{\partial G}{\partial a_k}\ddot{G} + \frac{\partial F}{\partial a_k}\left(\ddot{F} - F(\dot{A} + \omega)^2\right) + \frac{\partial A}{\partial a_k}\left(2F\dot{F}(\dot{A} + \omega) + F^2\ddot{A}\right)\right]. \tag{7}$$

Now we are ready to design functions F, A and G such that the inducer satisfies demanded parameters. The inducer blade surface is then given by equations (1).

3 Conclusions

This paper presents the methodology to design an inducer blade. It is based on Euler equations together with the continuity equation in Lagrange coordinates. It can be used to perform the preliminary blade design and to predict its parameters (specific energy, pressure gradient, etc.). Several inducers were designed and compared to numerical computations. It was shown that these numerical results are in good agreement with the presented theory.

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References

Rebattet, C., Wegner, M., Morel, P. & Bonhomme, Ch. (2001) *Inducer design that avoids rotating cavitation.* CREMHyG's research report.

Acosta, A. J., Tsujimoto, Y., Yoshida, Y., Azuma, S. & Cooper, P. (2001) Effects of Leading Edge Sweep on the Cavitating Characteristics of Inducer Pumps. *International Journal of Rotating Machinery*, 7(6), pp.397-404.

Wegner, M., Acosta, A. J. & Tsujimoto, Y. (2003) Panel Discussions on Inducer Design Criteria. *International Journal of Rotating Machinery*, 9, pp.229-237.

Pochylý, F., Stejskal, J., Haluza, M. & Rudolf, P. (2011) *Hydraulický návrh induceru*. Brno University of Technology research report No. VUT-EU 13303-QR-20-11.

Brdička, M., Samek, L. & Sopko, B. (2005) *Mechanika kontinua*. Academia, Praha.