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FLOWING OF THE SYSTEM THE UNDERWATER VEHICLES HULL THE NOZZLE OF PUMP-JET PROPELLER WITH ANGLES OF ATTACK

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ABSTRACT : Results of a numerical simulation of a flowing of the underwater vehicles hull with the pump-jet nozzle are presented. It was calculate velocity distributions and coefficients of the lift force and the longitudinal moment of the hull with the pump-jet nozzle and isolated hull for some values of angle of attack. It was shown that the area of the influence of the nozzle on the velocities distribution of the hull and character of changing of coefficients of the lift force and the longitudinal moment and their derivatives depending on angle of attack.

1. Introduction

To calculate maneuverability of an underwater vehicle with a pup-jet propeller it is necessary to know the character of change of effective forces when it moves on a curvilinear trajectory [2]. These forces depend from geometrical parameters of the system the hull the pump-jet nozzle (the hull form, relative length of the nozzle, its location, distance between the hull surface and the nozzle), the value of angle of attack, Reynoldss number and some other. Results of investigations of these problems are presented in this article.

A pump-jet propeller is a similarity of the turbine consisting of two blades systems, placed in a cylindrical (conical) pipe (the nozzle). One blade system is moving and named as a rotor or an impeller. The fixed system can be located both before impeller, and behind this. In the first case it is called as a stator in second - as a rectifying device. The pump-jet nozzle is placed in the stern of the UVs body and on a majority of a length it is located near to a body surface. Impeller is biased to the rearmost edge of the nozzle concerning its midship.

The object of these investigations was the body of revolution, which had the relative length $L/B = 7{,}7$ and there was the nozzle in the bodys stern (Fig. 1). I was used some variants of the nozzle with relative lengths from $l/L = 0{,}05$ to $0{,}11$ (base variant). The foil of the nozzle is cited on pic. 2. The distance between first edge of the nozzle and the hull surface $\triangle/L$ (the gap) was considered from 0,005 to 0,009. It was used connected coordinates: the coordinate origin was disposed in the middle of the axis line, x-direction was against the flow and its values are [-1..1], y-direction was up, z-direction was on the right board. Abscissa of the first edge of the nozzle in first variant was from $\bar{x}$

= 0,780 to $\bar{x}$ = 0,90. Values of angle of attack were α = 0; 4; 8; 10°. Fluid is assumed ideal and non-limited, motion of fluid was supposed steady.

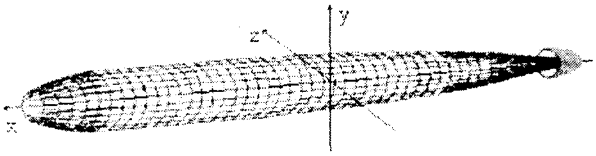

Fig. 1. The system " the hull - the nozzle"

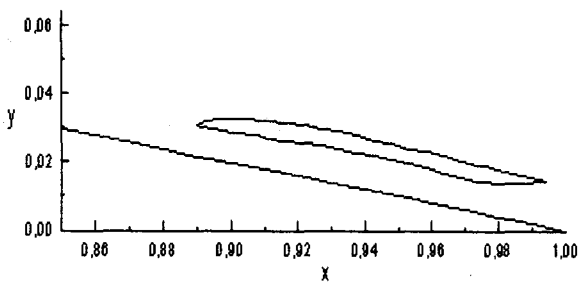

Fig. 2. The foil of the pump-jet nozzle

2. Discrete vortexes method for determination of hydrodynamical forces and moments

This investigation was performed with help of software complex "Wings" . In the base of this complex it is discrete vortexes method (panel method) [1, 3]. Vortex system was located on the surfaces of bodies, which belong to the system. These surfaces were divided into quadrangular areas (panels) used longitudinal and diametral lines. The influence on flow from each panel was replaced by vortex segment, which lies in the same plane with the panel. For each panel condition of zero flow normal to the surface is applied at the center of the panel, therefore this complex allows to take into account non-linear effects connected with forms of bodies and their orientation in space. The Zhukovsky-Chaplygin condition about velocity on the rear edge is fulfilled with help of the vortex sheet line. The line leaved the body generates the vortex wake consisting of free vortex with axis, which collinear to velocity vector of approach flow. The condition results in set of linear equations relatively unknown circulations of vortexes and their derivatives. After determination of these circulations it is possible to calculate induced local velocities in every panel.

Forces of each vortex segment were calculated using Zhukovsky theorem. Forces and moments of all bodies in the system are results of summation. Values of moments were calculated relative the center of coordinates. It was assumed the typical length $V^{\frac{1}{3}}$, where V is volume displacement of the hull of the vehicle.

We may write main vector of hydrodynamical forces $\vec{R}$ and main moment $\vec{M}$ in this form:

$$\vec{R}=(C_x\vec{i}+C_y\vec{j}+C_z\vec{k})\frac{\rho v_0^2}{2}V^{\frac{2}{3}},$$

$$\vec{M}=(m_x\vec{i}+m_y\vec{j}+m_z\vec{k})\frac{\rho v_0^2}{2}V$$

where C and m - coefficients of forces and moments, ρ- density of fluid, v_0 - velocity of approach flow, $\vec{i}, \vec{j}, \vec{k}$ - basis vectors of connected coordinates.

These coefficients were determined after expansion in Taylor's series accurate to linear members:

$$C=C^0+\sum_{k=1}^{5}C^{qk}q_k+\sum_{k=1}^{5}C^{\dot{q}_k}\dot{q}_k$$

$$m=m^0+\sum_{k=1}^{5}m^{qk}q_k+\sum_{k=1}^{5}m^{\dot{q}_k}\dot{q}_k,$$

where. q - generalized kinematical parameters, q1 = α, q2 = β, q3 = ω_x, q4 = ω_y, q5 = ω_z, $\dot{q}=\frac{dq}{dt}$

For problems of maneuvering of underwater vehicles it is the most important to know transversal components of the force and longitudinal components of the moment. We have the hull in form of body of revolution, therefore we may consider one projection of the force and one projection of the moment. The projection of the main vector of the forces on the ordinate axis y is named the normal force, which may be determined by these expressions:

$$C_y=\frac{R_y}{\frac{\rho v_0^2}{2}V^{2/3}}$$

here R_y - normal force.

Coefficient of longitudinal moment is:

$$m_z = \frac{M_z}{\frac{\rho v_0^2}{2} V}$$

3.The normal force and longitudinal moment of the system

As results of calculations it was received distributions of velocities on the surfaces of bodies of the system the hull the nozzle and values of coefficients of the lift force and the longitudinal moment and their angle of attack derivatives for all bodies separately and for the system as whole. The velocity distributions on the hull with the base variant of the nozzle are presented on Fig. 3 and 4. We may see the influence of the nozzle on flowing of the hull is extend on one length of the nozzle upstream from its first edge. As a result of this influence we can see a decrease of velocity near the nozzle besides velocities of flowing of the isolated hull (without the nozzle). By the way this decrease on the upper generator is more then on the lower.

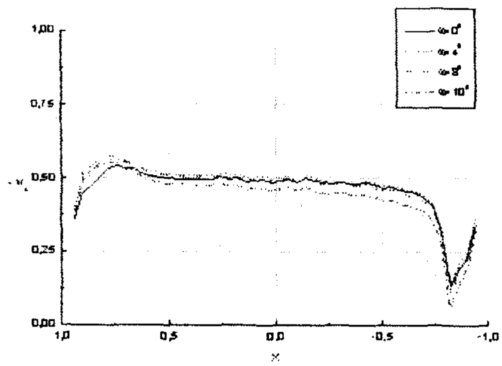

Fig. 3. Longitudinal velocity distribution on the upper generator of the hull

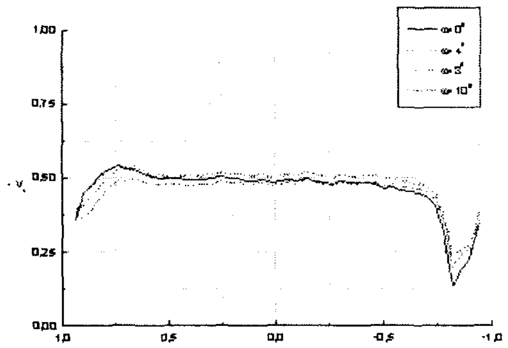

Fig. 4. Longitudinal velocity distribution on the lower generator of the hull

In consequence of this strong decreasing of the scalar of velocity in the area of the first edge of the nozzle there is quicker increasing of the pressure, therefore a flow separation from the drag surface of the hull is possible in this area. After changes of relative length of the nozzle and the distance between its first edge and the surface of the hull the character of flowing of the internal and external surfaces of the nozzle is not changed, and we may see changes of values of velocities only. Moreover velocities on the lower surface of the hull are higher the velocities of lowing of lower surface. Coefficients of the normal force and the longitudinal moment and their angle of attack derivatives are presented on diagrams 5 8 depending on angle of attack for base variant of the nozzle.

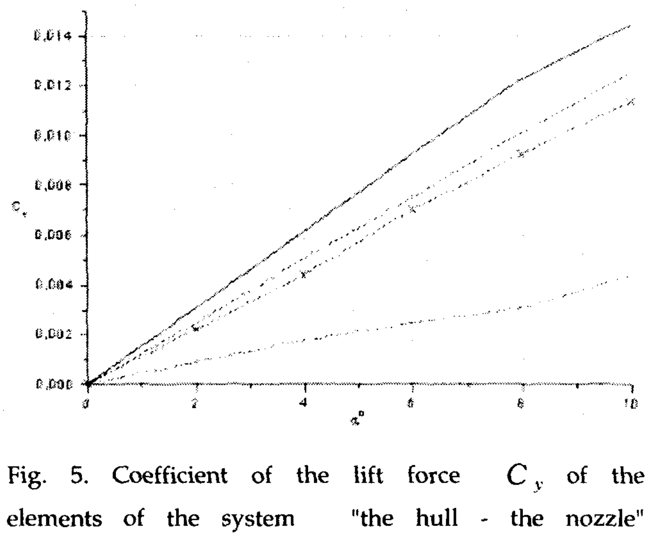

Fig. 5. Coefficient of the lift force C_y of the elements of the system "the hull - the nozzle" depending on angle of attack α; - - - - - isolated hull; ------- the system; - - x - - the hull as a part of the system; -- - -- - the nozzle as a part of the system

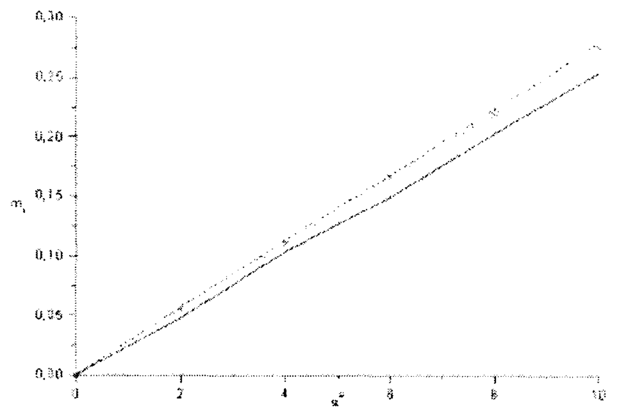

Fig. 6. Coefficient of the longitudinal moment of the elements of the system "the hull - the nozzle" depending on angle of attack α; - - - - - isolated hull; ------- the system; - - x - - the hull as a part of the system;

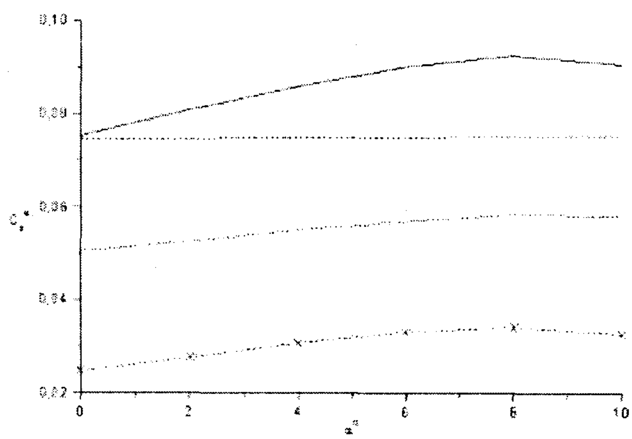

Fig. 7. Angle of attack derivative of the normal force coefficient

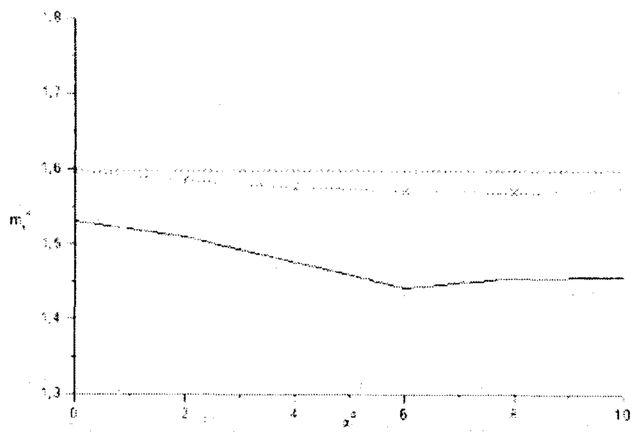

Fig. 8. Angle of attack derivative of the longitudinal moment coefficient

As a result of the influence of the nozzle the dependence became non-linear, initial values C_y for isolated body and for the system are the same, initial values of m_z, C_y^a and m_z^a are different. Coefficient of the normal force of the hull and its angle of attack derivative is decreasing in consequence of this influence; the full value of the normal force is increasing. Abscissa of the center of pressure of the hull is increasing and the moment is increasing too, the abscissa of the center of pressure of the system is decreasing. The influence of the nozzle on the normal force coefficient of the system can amount to 10% in comparison with the coefficient of the isolated hull.

On diagrams 9-12 it was showed coefficients of the normal force and longitudinal moment depending on relative length of the nozzle l/L and the relative gap (the distance between the first edge of the nozzle and the surface of the hull) △/L. It is possible to see that when values of the relative gap and angle of attack the normal force has a negative value, i.e. the influence of the nozzle reduces to a decrease of stability of the underwater vehicle. It is necessary to consider this to choose geometrical parameters of the pump-jet nozzle.

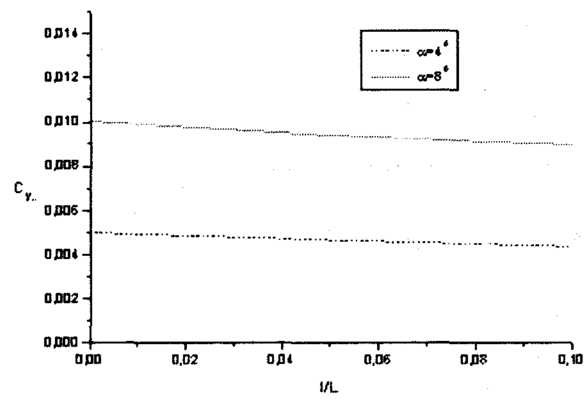

Fig. 9. Coefficient of the normal force of the hull consisting on relative length of the nozzle when △/L = 0,009

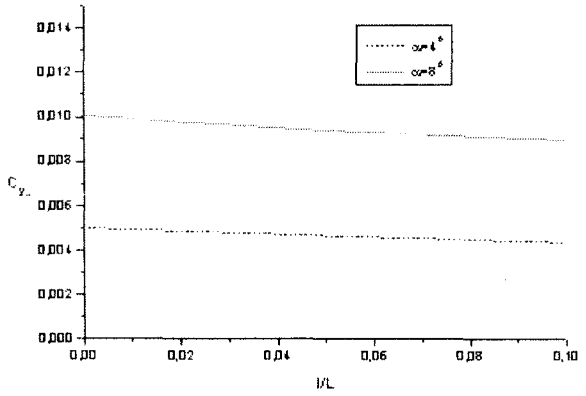

Fig. 10. Coefficient of normal force of the nozzle depending on its relative length for △/L = 0,005

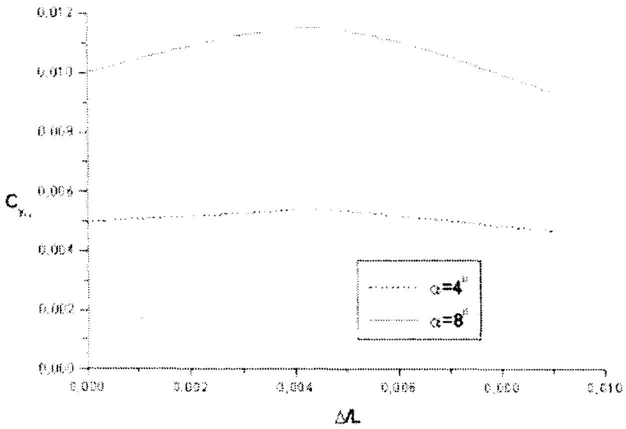

Fig. 11. Coefficient of normal force of the hull depending on the gap △/L when l/L = 0,05

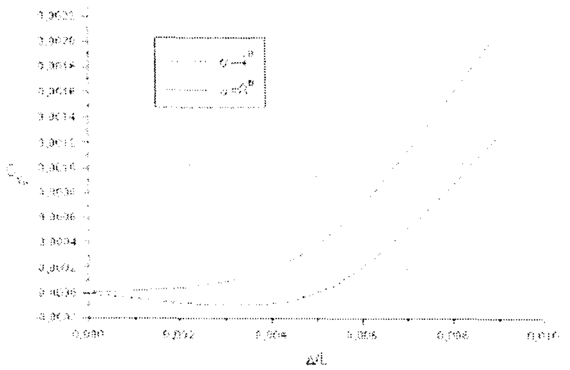

Fig. 12. Coefficient of normal force of the nozzle depending on the gap △/L when l/L = 0,05

As a result of the influence of the nozzle the coefficient of longitudinal moment of the hull as a part of the system is changed within the limits of (-20..30) % in comparison with its value for the isolated hull depending on angle of attack, relative length of the nozzle l/L and the gap /L, and the coefficient of the full moment of the system decrease by (10..80) %.

Moreover the first edge of long nozzles have is located in area of forming of vortex sheet in the stern of the hull, therefore it is possible a displacement of the vortex sheet line downstream, thus the coefficient of the normal force will decrease when values of angle of attack are small. When angle of attack is large it is possible a displacement of the vortex sheet line upstream. To determine the change of the vortex sheet line it is necessary to calculate of viscous flowing of the system with angles of attack. But there are some problems with this calculation. In first it is difficult to find a mathematical model of such flowing, in second there are problems with model tests of the system because the hydrodynamic parameters of the UV's body with the pump-jet nozzle, determined as a result of tests of scale models, are depended on scale effect, and it is necessary to recalculate them on actual Reynolds numbers. However such recalculation by present procedures does not allow receiving correct outcomes, because the flow in the stern of model with a nozzle differs from flow in the stern of full-scale object.

4. Conclusions

As a result of this investigation we may make these conclusions:

1. The influence of the nozzle on velocity field of the hull extends to one length of the nozzle upstream from its first edge.
2. As a result of this influence a dependence of the coefficients of the normal force and longitudinal moment and their derivatives from angle of attack becomes non-linear strongly.
3. The normal force increase in comparison with the normal force of the isolated hull and this increase may be to 20%.

5. References

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