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Motion parameters analysis of the atmospheric diving suit

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Abstract

The paper presents an atmospheric diving suit (ADS) designed to provide a practical and economical mean of conducting effective work at depths up to 300 meters. The model examination has been carried out in the aerodynamics tunnel. The main aim of the examination has been to recognize suit movements and the resistant forces.

The numerical analysis of the computational model has been carried out as well. The convergence has been obtained for the case of the air environment. Additionally, the computer simulation has been performed for the water environment.

1 Introduction

A human being has tried to exploit sea and oceans for his own and necessity for ages. Explorers are interested in underwater technology and they are interested in mineral resourses which may be found on and under bottom of the sea. It is neccesity that somebody have to go underwater. Besides different underwater vechicles the new generation of underwater objects appears during the past twenty years. They have got an antrophomorphic shape. In such objects called atmospheric diving suits a diver is fully isolated from ambient water pressure. These suits may be equipped with propulsion systems allowing the diver to move fastly underwater. They are capable of; underwater inspection, research works, resquing underwater vehicles and submarines, underwater documentation. ADS creates a complicated underwater hydrodynamics system. An analitical description of the system and its solution is possible only at neccesary assumptions. Considerable simplify phenomena which are taken place during the motion. An evaluation ADS of underwater is indispensable to make a prognossis of the operating range which it is capable of doing and to make a choice for the propulsion system. Taking into consideration advantages mentioned above the authors made a decision to carry out motion parametres analysis of the atmospheric diving suit.

2. The model examination of atmospheric diving suit in an aerodynamics tunnel

Because of the absence research possibilities of a real object a model of the atmospheric diving suit has been produced. Trating motion of the ADS model as a hydrodynamics problem nonsatisfactionary and non-linear three dimensional question is obtained.

In order to select suitable propulsion system for the ADS model and for real object particular resistant force of motion had to be recognized. Authors of this paper assumed, in a stage of design model examinations allow carrying out an effectivity comparison between different alternatives objects. They are neccesary to estimate propelling forces at assumed operation speed. Regarding possibilities of the model, tunnel costs of trial model examinations has been carried out in wind tunnel [2]. During model testing are measured the components of forces affected on the model in the adequate direction to the tunnel axes and yawing moment related to the werticale axis of aerodynamics balance in three positions of the model related to an inflowing air stream.

As a result of measurements and calculations values of resistance coefficients and moment coefficients have been obtained. These results are measurement from an angle of incidence of the model for its particular positions. In position 1 the model has been situated as for the motion in a vertical - longitudinal plane. Results of model testing have a dual meaning. Firstly, they have been used as a data to formulate a mathematical model of the ADS model motion (treating as a testing result of the real object). Secoundly, they have been used as a real a model examinations to estimate ADS resistance.

3. Computation of velocity potential and pressure on surface of laminar flow around the atmospheric diving suit

In this paper friction forces are formulated with - the aid of resistant ceoefficints and apparent mass forces are formulated with - the aid of coefficient apparent inertia mass. A solution for a real liquid has been searched on the bassis of solutions for an ideal liquid.

Equation solution of the ADS model flow reduces to the solution of a boundary value problem determinated by Laplaces equation:

$$\Delta\varphi = 0 \tag{1}$$

A - differential operator of Laplace;

with adequate of boundary conditions:

$$\frac{\partial\varphi}{\partial n} = V_n \tag{2}$$

on the surface of the hull;

$$\frac{\partial\varphi}{\partial n} = 0 \tag{3}$$

in infinity;

where:

n - direction of the normal towards the boundary that limits the liquid space.

Foregoing boundary - value problem may be easily solved by the application of boundary element metod. It means, equations matrix should be solved as follow:

$$H\,U = G\,Q \tag{4}$$

where:

U - vector of potential node value;

Q - vector of node value of deriverate of the potential in the normal direction towards the boundary;

H and G - are expressed respectively by integrals calculated for the boundary elements.

In order to simplify the problem, symetry of ADS related to XOZ surface has been applied. A half of the ADS model surface has been devided into boundary elements. Description of ADS geometry has been obtained by usage of node coordinates and elements [7].

Velocity potential has been computated for air silt velocity of $V_o = 41$ m/s of eleven values of the incidence angles.

Distribution of velocity potential on the surface of the discrete model presents Figure 1.

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4. Motion resistant forces doing on the descrete model of atmospheric diving suit

Resisting forces occur in a viscous fluid. An elementary hydrodynamics resistance affects an optional surface element of the ADS model. It represents a sum of normal resistance related to surface S_i which is called an elementary reaction of pressure and tangential resistance, it is called an elementary reaction of surface frictiones as well. This reaction results from operating of tangential stress [1].

The pressure resistance is caused by prssure differents resulting from a boundary layer separation. It is different from zero. The angle separtion at $\tau = 0$ has been calculated in examinatons. Upon assumed condition resistant forces are equal to forces obtained from model examination. There has been noticed during calculations that the results accuracy depends on transformation accuracy from the real object into discrete model.

The corection of discrete model was executed during calculations. It concerned the regularity of the elements. After calculating the results set of forces Rx and Rz acted on the discrete model were compared to the results obtained from the model. It presents Figure 2 [7].

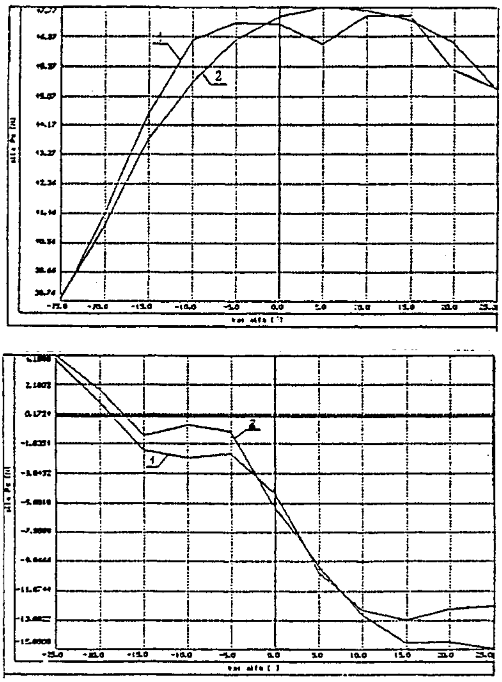

Figure 2. Component of forces Rx and Rz in terms of the aqngle of incidence α for air: 1) numerical calculations; 2) model testing.

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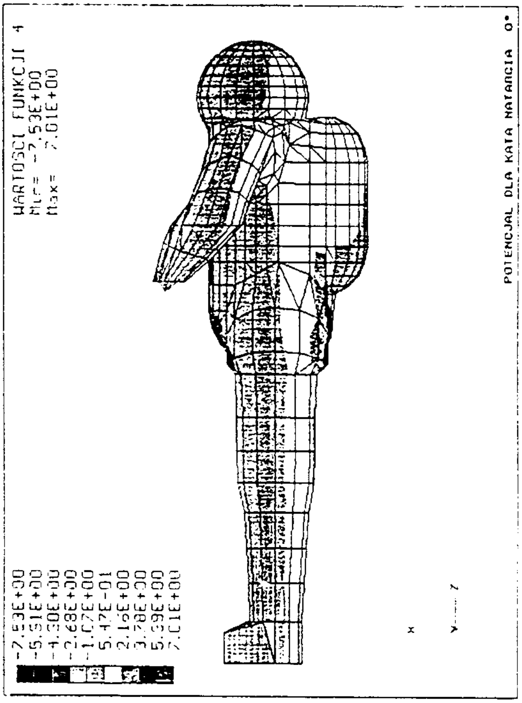

Figure 1: Velocity potential on the surface of discrete model of Atmospheric Diving Suit for angle of incidence $\alpha = 0°$

Pressure in an optional point for this determinated potential may be obtained by usage of Bernouli equation:

$$P = P_o + \rho V_o grad\varphi - \frac{\rho}{2}(grad\varphi)^2 \qquad (5)$$

where:

$P_o(x,y,z)$ - static pressure in distributed flow;
p (x,y,z) - pressure in the region of included flow;
ρ - density of water.

The pressure as a continous load has been reduced to nodes. It enable to determine forces acting in nodes. It was noticed that the sum of forces projections an optional selected axis is equal „0" for ideal liquid. d`Alembert`s paradox confirms this theory.

The accuracy of numerical calculations related to model testing for component resistant forces Rx within angle of inclination limits is 3% however for component forces Rz, for seven measuring points is 9%. The results have been accepted to next calculation [7].

Setting together results received from discrete model and results from model examinations enable us to make a conclusion about the correctness of computational algoritm used in this paper.

5. Motion of atmospheric diving suit underwater

The model of ADS is in plane motion. It is assumed in this paper. The velocity energy of apparent inertia mass is evaluated by formula:

$$T_w = \frac{1}{2} U^T \wedge U \tag{6}$$

where:

$$U = \begin{bmatrix} V_x \\ V_y \\ V_z \\ \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

$\wedge = \lambda_{ik}$ for i, k = 1, ...6 is matrix coefficient of apparent inertia designed water innertia mass describing a water inertia teaking part in motion of the atmospheric diving suit:

$$\lambda_{ik} = -\partial \iint \frac{\partial \varphi_i}{\partial n} \varphi_k dS \tag{7}$$

where:

φ_i, φ_k - are potentials from elementary velocity in direction i, k.

Both resistant coefficients and coefficient of apparent innertia mass depend on the propeller force. They are changeable in time.

A differential equation of motion describing behaviour of ADS underwater is as follow:

$$[A]\,[U] + [K]\,[U] + [M]\,[U] = [Q] \tag{8}$$

where:

[A] - matrix innertia;
[K] - matrix contain mass, advance velocity and anglar velocity;
[M] - matrix contain resistanct coefficient and moment coefficient;
[Q] - matrix contain components of exiciting forces;.

The foregoing equation has been approximated by Euler method with step forward. Then the equations have been obtained:

$$\dot{U} = \frac{1}{\Delta t}(U^{t+\Delta t} - U^{t)}; \tag{9}$$

and

$$A(U^{t+\Delta t} - U^{t})\frac{1}{\Delta t} + MU^{t+\Delta t} = Q^{t+\Delta t} \tag{10}$$

from

$$A(\frac{1}{\Delta t} + M)U^{t+\Delta t} = Q^{t+\Delta t} + \frac{1}{\Delta t}AU^{t}; \tag{11}$$

or

$$CU^{t+\Delta t} = P;$$

where:

$$C = \frac{1}{\Delta t}A + M; \qquad P = Q^{t+\Delta t} + \frac{1}{\Delta t}AU^{t};$$

The set of equations is nonlinear, because matrix C and vector P depend on the solution. That`s why, in accordance with the left and right part of equations has been searched in every stage of iterative method.
Lack of adequate data concerning exciting forces of the ADS motion (from the propeller), and exciting forces of the model motion, coused that in these paper the invers problem has been soluted.

The changeable velocity of ADS has been assumed hipoteticaly and forces which are necessity to input this motion have been determinated. The speed alteration of the ADS model has been carried out parabolically or lineary.

Motion of the model has been analised 20 secound period at incidence angle $\alpha = 0°, 20°, -25°$. The speed alteration i turns of time has had identical character for the all analysed case. The component of exciting forces Qx and Qz efferting the ADS motion were estimated during the ADS motion.

In order to evaluate the computation accuracy the model of ADS has been immersion into the water. Then the model has been moved many times in specific lenght of way. The time of the model displacement has been measured. The component resistant force Rx for acceleration equal „0"has been measured as well.

The resistance which the ADS model has got underwater in terms of velocity has been estimated in the experiment. Criterion of similarity is fulfilled for velocity of the model underwater V = 2,98 m/s. Difference between the calculated of component forces Rx and measured in this experiment, for angle of incidence $\alpha = 0°$, related to the measured value is 14%. This experiment should be treated as a hipotetical, novertheless it has been capable of preliminary selection for the ADS propulsion system.

6. Conclusions

Results presented in this paper have got a cognitive character, because research experiments were carried out for only hipotetical motion of atmospheric diving suit.

In order to improve an utylity value of the results precisle characterisation of propulsion system ADS should be known.

The requirements of the ADS motion character during underwater operation should be known as well. Practical applications of the ADS should be advanced with computational model revision. It schould be carried out on the basis of resistant examinations in cavitational tunnel for underwater motion and in the ship model basin taking into consideration a free surface of liquid.

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