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Analytical analysis of hydrodynamics of the perforated Rankine oval

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ABSTRACT

Design of a tunnel submarine to perform controlled maintenance and service duties within pipes, tunnels and sewers, such as water tunnels, water and oil pipelines containing hydraulic liquid substances, is proposed to extend the life span of those systems. For instance, beetle submarines may be used to carry out maintenance and repair work. In this study, two dimensional hydrodynamic design of a submarine of single perforated Rankine oval shape has been analyzed analytically by applying the solid modeling methods of two dimensional potential flow theory in the environments that accommodate velocity, pressure, and force field around them. General flow has been modeled using source-well doubles and the stream function of the flow around the perforated Rankine oval is obtained. Thus, the effect of the size of the interior hole of the Rankine oval, the effect of the channel size and, in case of drift or deviate from the centerline, the effect of the pressure changes have been obtained and solutions have been visualized through Matlab program. It has been concluded that the axial perforation of the oval positively contributes to the drag resistance of the designed submarine.

1. Introduction

Matters such as water, water usage and utilization of water have often become preliminary hottest issues among people. Such problems have always kept people busy throughout the history of mankind. Gradually more complicated and sophisticated systems have been invented in order to improve and enhance the welfare of people and enable them to benefit from water much more effectively day by day, and thus many unsolved problems have been dealt in various ways within this respect. Water channels and water tunnels are utilized to meet the needs for water. Discharge and transport of waste water works are carried out via sewer systems or tailing lines. The significance of these problems originating from water is vital since four-fifths of our world is covered with water. Consequently, systems that can perform the duties of care-maintenance-control and thus capable of prolonging their life are needed to solve the problems in such cases with movable hydraulic liquids as in water tunnels, water pipes, sewers, tailing lines, oil and natural gas pipelines and so on. Within this context, it has been considered that designing a tunnel submarine in the shape of perforated Rankine Ovoid will provide us with many effective technological benefits. Jobs regarding the care-maintenance-control of such huge tunnel systems are often quite difficult and expensive to carry out. Meanwhile, fulfilling such duties often results in failure, or the system is disabled altogether. These problems are quite big and they also hinder the operation of the systems for a long time. Therefore, some solutions that will not hinder operating the system efficiently must be produced in order to maintain the performance of the system. A few restricted numbers of publications have drawn our attention and some of those studies that are closely related to the subject matter are summarized within the scope of this Research Paper.

Blair and others explained the construction and manufacture steps of the new sort of submarine bearing a fish cage system that can turn on the surface so as to eliminate biological contamination and pollution as well as for other purposes (Blair et al., 1982). During a survey conducted by Djerid et al. (2003), they examined the turbulence properties of the flow around the cylinder of the Reynolds number 140,000. During his doctoral thesis study, Durgun (1983) examined and reviewed the effects of interior side walls and the bottom resistance of a free surfaced rectangular channel. In other words, he studied the blockage effect and considered how to calculate ΔV the rates of velocity increase of those geometrical shapes, such as ellipsoid, oval, Rankine ovoid for the shape of the ship both theoretically and experimentally. In their research, Gilmanov and Sotiropoulos (2005) developed a hybrid cartezian control method for the simulation of the flows in three dimensional complicated geometrical shaped substances and they utilized the Navier Stokes's equation to solve the problems regarding movable three dimensional substances in irregular incompressible fluids. Hsu et al. (2005), in their study, an opened shallow

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Symbols and nomenclature

a	the distance from the axis of the source and wells, (m)
b	wide length of channell, (m)
C	the distance of doubles from the x-axis, (m)
d	size of hole of Rankine oval, (m)
D	submarine body outer size, (m)
D_0	channel size, (m)
F	force, (N)
F(z)	complex potential function, (m^2/s)
$\dot{I}$	the number of the intervals used in the series sum of the solid surface, (dimensionless)
j	the number of channels used to perform rigid channel of the solid surface, (dimensionless)
m	the number of parts of on the side wall of body between the two end points, (dimensionless)
n	cider on the wall between the two end points of the number of parts, (dimensionless)
$\vec{n}$	unit vector normal of the the surface, (dimensionless)
q	magnitude of a two-dimensional double, (m^2/s)
P	pressure, (kg/ms^2)
P_0	ambient pressure (N/m^2)
u	components of velocity on the x-axis, (m/s)
V	velocity, (m/s)
v	components of velocity on the y-axis, (m/s)
$y(\dot{I})$	position of double on y axis, (m)

Greek letters

μ	the fluid dynamic (absolute) viscosity, (kg/ms)
ρ	density of the fluid (kg/m^3)
σ	surface area in the normal direction, (m^2)
φ	potential function, (m^2/s)
ψ	stream function, (m^2/s)
∇	gradient operator

Sub-indices

D_0C	channel wall
DC	the outer wall of Rankine oval
dC	interior wall of perforated Rankine oval
ROC	the surface of Rankine oval

Abbreviations

AUV	Autonomous Underwater Vehicle

cylindrical shell and deep-diving submersible vehicle GUPPY was adopted to investigate . Another research on how to determine the size of an adjustable vehicle was conducted by Huggins and Packwood (1994). Janson (1997) calculated forces of lifting and forces of free surface flows by making use of potential flow panel methods during one of the studies, and thus he developed and introduced a method to optimize the shapes of the bodies of ships automatically. Kauh and Suen (2001) studied on issues based on the three dimensional potential flow theory by taking high level panel method as the basis of their research, and thus they made the dual distribution and Guasian field measurement suitable for the potential flow problem. In their study regarding similar matters, Li and Lee (2005) designed an inspector that is applicable to a nerve network for the submerging behavior of an autonomous (AUV) underwater vehicle. During their research studies, by Zh et al. (2012), they did experiments on propellers to control those varying forces propellers and they put a barrier in the middle in order to evoke those eddy flows so that they can test and measure the characteristics of their motion. In another study conducted by Madsen et al. (2000) the design of a submarine vehicle and management duties of the system were explained. As a result of that research, the model of a mini submarine was constructed on the objective result pedigree, basic plan and logical diagram. During the research conducted by Mahfouz and Haddara (2003), the impact of total predictions of hydrodynamic parameters and by accelerating and slowing down of an underwater robot vehicle floating on the level of the sea surface with random sea waves were examined. During still another study (Mraccek et al., 1992), the amount of unpressured potential flow on the closed substances was predicted by adopting an alternative approach. During the research conducted by Niazmand and Renksizbulut (2003), the viscouse flow around a rotating globe shaped object submerged into water was examined. During another survey (Ohring and Telste 1980), direct matrix and replacement technique was utilized in order to solve its potential of speed by using normal gradient while examining a 2-dimensional submerged vessel. A study to provide us with the combination of versatile dynamic problems bearing vital importance, such as controlling of a modern submarine, its static stationary, its hydrodynamic performance control system, were explained and exposed by Papoulias et al. (1995). Perrault et al. (2003) tested the sensitivity to the changes in the hydrodynamic parameters of a typical AUV response characteristics. Rapoport and Rubin (2009) showed that for penetration velocities V below a critical value Vs, the target material maintains full contact with the projectile's surface, the drag force is due solely to the resistance of plastic flow in the target and it is independent of the velocity V. In another research (Goel Gang, 1995) examined Rankine and similar geometrical shapes, the pressure and speed around the Rankine oval by utilizing a general computer assisted method. During a research (Reynolds et al., 1973) the analysis of the body weight of a pressure resistant submarine, its structural properties, vibration, tension, analysis of its stationary state and the analysis of its structural fatigue reality were done by means of a computer program. During a research conducted by Rubin (2012), he developed an analytical formula to display the cavitation effect distribution on a long rigid Rocket which contain the impact of cavitation. During their study, Sahin and Hyman (1993) calculated the flow around the Rankine Ovoid that moves at a certain depth under free water surface by benefitting from the theory of potential flow. In an essay published by Sahin et al. (1994), the three dimensional flow around an asymmetrical object submerged into water at a certain depth was calculated by making use of the theory of three dimensional flow and by means of analytical and numerical method comprised of the Green Function. The losses of stationary state at high and medium speeds were calculated in the research by adopting method of the non-linear Hopf Forking Analysis. Best fit sizes were found for a submarine that submerges into the depths of the Atlantic Ocean autonomously bearing slow drift coefficient. Another research conducted by Szymzak et al. (1993) indicated the analysis of the body weight of a submarine, its structural properties, vibration, tension, analysis of its stationary state and the analysis of its structural fatigue reality by means of a computer program. The survey conducted by Virgin and Erickson (1994) was performed in order to reveal and introduce the dynamic motion of those floating substances much more definitely and accurately. In their study, Wu and Chwang (2001) suggested a hydrodynamic underwater system attached to a primary wire a two-piece vehicle capable of doing easy maneuvers, towed actively in horizontal position and vertically bearing control surfaces and they discovered mass of the vehicle by making use of the three dimensional potential flow theory. In the research conducted by