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RESEARCH ARTICLE

INVESTIGATION OF HYDRODYNAMIC FORCES FOR AUV BARE-HULLS BY USING SEMI-EMPIRICAL EQUATION AND CFD

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Abstract

This paper addresses the problem of autonomous underwater vehicle (AUV) modeling and parameter estimation as a means to predict the dynamic performance of underwater vehicles and thus provide solid guidelines during their design phase. The use of semi-empirical methods to estimate the hydrodynamic coefficients of a popular class of AUVs is discussed. A comparison is done with the results obtained by using a semi-empirical equation at different angles of attack with results obtained by using CFD and experimental results. Finally,it is in our interest to investigate the range of angle of attacks for which semi-empirical equations are valid. The semi-empirical method was originally developed to predict the aerodynamic coefficient onairships butwas later refined for underwater vehicles like submarine and AUVs. This paper describes different types of semi-empirical equations and provides comparative results obtained from these equations. This paper also indicates suitable semi-empirical equation will be more likely to be useful at large angles of attack. The information provided by this paper will be very much useful indesign stage of AUVs.

Introduction:-

Autonomous Underwater Vehicles (AUVs) are programmable robotic vehicles that, depending on their design, can drift, drive, or glide through the ocean without real-time control by human operators. Underwater vehicles are being used increasingly in a variety of applications such as survey, exploration, inspection, maintenance and construction, search and rescue, environmental and biological monitoring, military, undersea mining, and recreation. AUVs, have no physical connection to the surface. Power supply, underwater communication, intelligent mission planning and control, underwater navigation, and sensors are a few areas that arechallenging in the design and construction of an AUV.

Classification of AUV'S:

From the perspectives of drag reduction, a streamlined body (see figure below), which promotes the laminar flow within the boundary layer, is the best choice.

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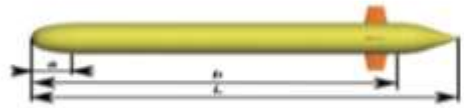
Laminar form hull



Torpedo shaped AUV

A simpler alternative to the laminar flow is commonly called the "Torpedo body". The torpedo body has a nose cap followed by a parallel mid-section and a tapered tail section.

Objectives of the Paper:-

1. Investigates the range of angles of attack for which the semi-empirical equations are valid.
2. Validate the results obtained from the semi-empirical method with CFD and previously published experimental results.

Methodology:-

Predict the value of hydrodynamic coefficient –drag, lift, and pitching moment coefficients using semi-empirical methods by generating a MATLABcode at varying pitch angles (0-45 degrees) in 5-degrees intervals. Semi-empirical methods have beendeveloped by many researchers; the most promising ones are byAllen and Perkins (1951), Hopkins (1951), and Jorgensen (1973). In this paper,wehave compared the hydrodynamic coefficients obtained from the above mentioned equations with the results fromCFD and experiments.

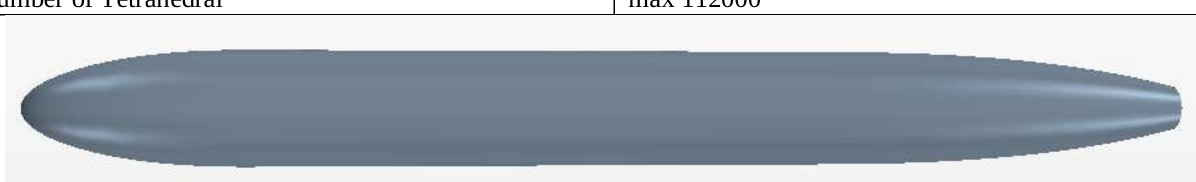
At this point, analyses based on CFD methods provide an interesting visualization and an important reference for the semi-empirical estimation. CFD,adoptedto calculate the hydrodynamic coefficients,was performed at the same angle of attack as those in theprevious semi-empirical treatments.

This type of information will certainly play a major role during the vehicle design phase to meet the open-loop requirement. The paper guides the reader through estimation of the hydrodynamic derivatives of cylinder type AUVs using information available from several sources, mainly the aircraft Datcom (Hoak and Finck, 1978) handbook and missile-related literature (Pitts et al., 1957; Nielsen, 1960; Jorgensen, 1977).

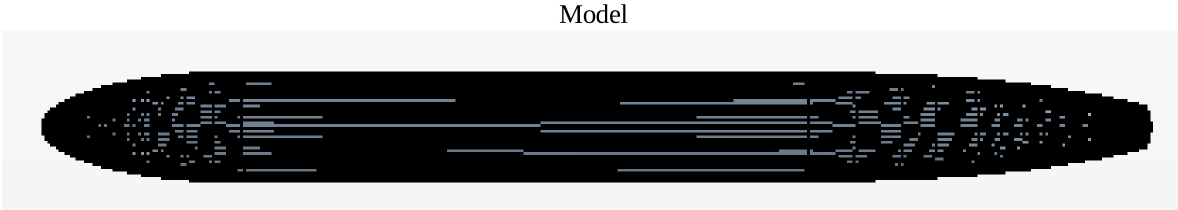
Results And Discussion:-

Principle condition employed in the numerical computation:

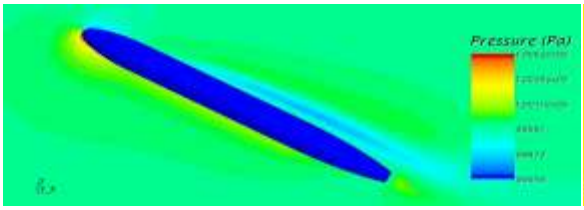
TANK SIZE	2100×980×980 mm^3
Turbulence model	k-ε model, shear stress transport
Reynolds number	1.05× 10^5 -3.06× 10^5
Radius, Length of the AUV	0.14 m, 1.4 m
Angle of attack of the nozzle	0 - 30 degree
Total number of elements (nods)	110,000- 120,000
Number of Tetrahedral	max 112000



Model



Mesh representation



Pressure distribution at 30° angle of attack

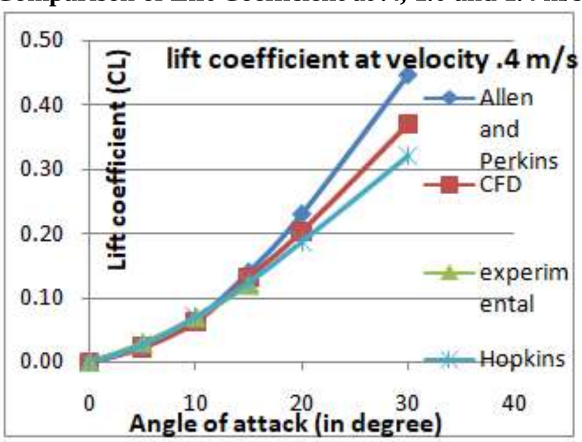

Velocity distribution at 30° angle of attack

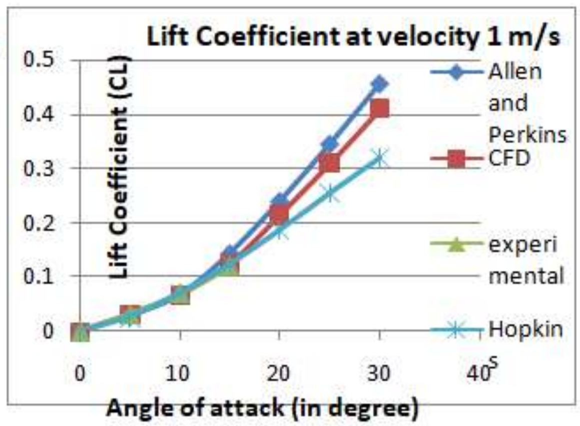
All the results are obtained according to the methods like semi-empirical. These methods are finally compared with the published experimental results. Since, our main aim is to investigate the range of semi-empirical methods for a bare hull AUVS, for that purpose, we have to compare oursemi-empirical results with CFD and experimental results. In our case,the experimental results are given up to 15-degree angles of attack after which we compare oursemi-empirical results with the computational ones. The calculations were done till 30-degree angles of attack.

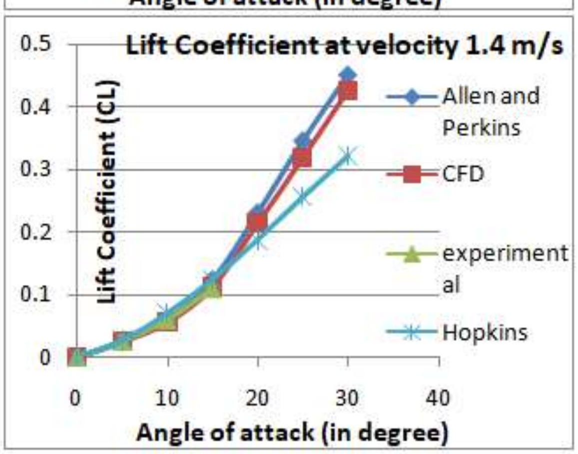
Comparison:

Note that wehave calculated the lift coefficient, drag coefficient, and moment coefficient for ourbase model using the semi-empirical methods as well asthe computational method. Finally, to investigate the range of angles of attack for which the semi-empirical methods are valid, wehave compared my semi-empirical and computational results to the experimental results as shown below.

Comparison of Lift Coefficient at .4, 1.0 and 1.4 m/s:

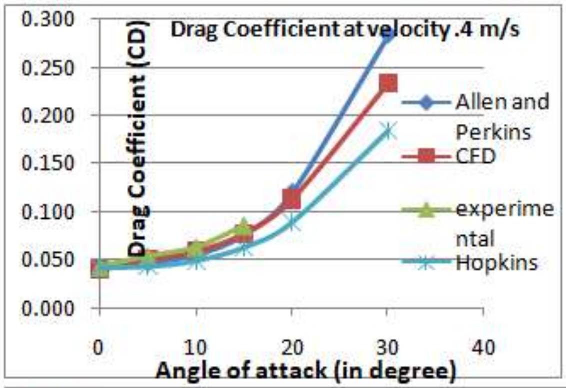


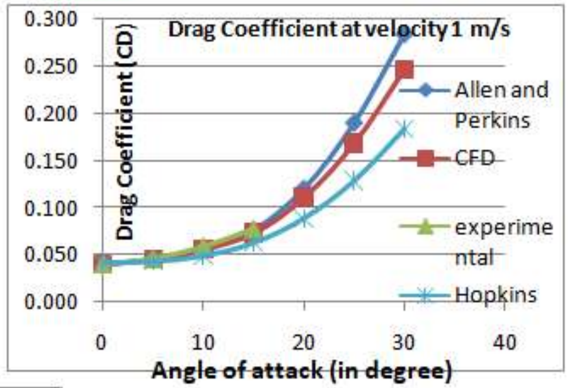


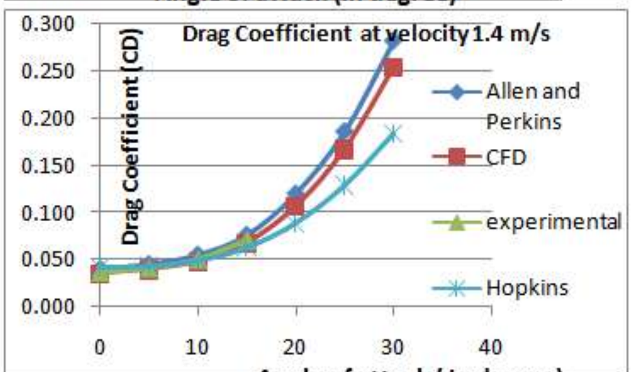


- Graphs showing Lift coefficients at velocities 0.4, 1.0 and 1.4 m/s
- **Predicted lift coefficients using semi-empirical method are in good agreement with experimental and CFD results up to 15° angle of attack**

Comparison of Drag Coefficient at .4, 1.0 and 1.4 m/s

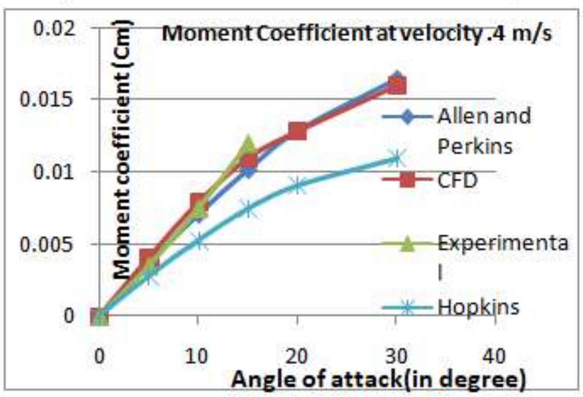


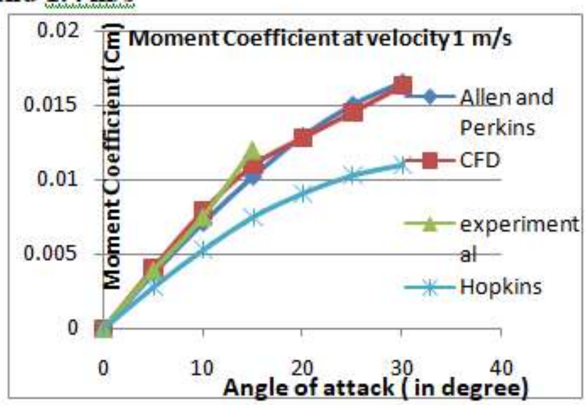


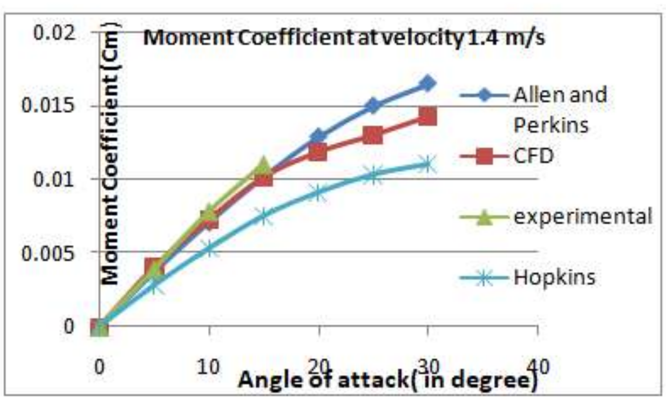


- Graphs show Drag coefficients at velocities 0.4, 1.0 and 1.4 m/s
- **Predicted drag coefficients using semi-empirical method are in good agreement with experimental and CFD results up to 15° angle of attack**

Comparison of Moment Coefficient at .4, 1.0 and 1.4 m/s







- Graphs show Moment coefficients at velocities 0.4, 1.0 and 1.4 m/s
- **Hopkins formulation underestimates the moment coefficient while Allen & Perkins formulation is in good agreement with CFD and experimental results up to 15° angle of attack**

Conclusion:-

In this paper, the main goal was to investigate the range of semi-empirical methods and their suitablechoices to provide satisfactory results compared to those obtained from experimental and CFD methods. It was noted that the experimental results are given up to 15-degree angles of attack only, so beyond that,wehave compared the predicted values of lift, drag, and moment coefficients using a semi-empirical method to those obtained from the computational methods. Therefore,wehave calculatedthe values of the lift, drag, and moment coefficients using CFD. Finally,wehave compared the obtained value of hydrodynamic coefficients, which arecalculated by a different form of semi-empirical method and computational method with the experimental values.

The CFD calculation has provided a very good prediction for the bare hull lift, drag, and moment coefficient with the experimental values at the different speeds. This makes the information given by the flow visualization and pressure distribution very useful to select the semi-empirical formulas for predicting those parameters based on the vehicle geometry.

It has been finally concluded that the combinations of Allen & Perkinssemi-empirical methodology with CFD can give good cost/benefit results. This type of information will certainly play a major role during the phase of vehicle design to meet desire open-loop performance requirements.

Reference:-

1. Munk, Max M. (1924). "The Aerodynamics Force on Airship Hull", NACA Rep. 184,
2. Allen, H. Julian (1949). "Pressure Distribution Measurement on the Hull and Fins ", NACA TN 2044 ,
3. Allen, H. Julian (1950). "Estimation of the Force and Moments Acting on Inclined Bodies of Revolution of Finess Ratio, NACA RM A9I26
4. Hopkins (1951). "A Semi-empirical Method For Calculating The Pitching Moment Of Bodies Of Revolution at High Angle of Attack.",
5. Nahon, M. (1996). “A Simplified Dynamics Model for Autonomous Underwater Vehicles, Autonomous Underwater Vehicle Technology”, AUV ’96, pp. 373-379.
6. Nahon, M. (2006). “A Simplified Dynamics Model for Autonomous Underwater Vehicles”, The Journal of Ocean Technology, Vol. 1, No. 1, 2006.
7. Prestero, T. (2001a). Verification of a Six-Degree of Freedom Simulation Model for the REMUS Autonomous Underwater Vehicle, M.Sc Paper, MIT & WHOI, September 2001.
8. Prestero, T. (2001b). “Development of a Six-Degree of Freedom Simulation Model for the REMUS Autonomous Underwater Vehicle”, OCEANS, Vol. 1 pp 361- 368.
9. Perrault, D. (2002). Autonomous Underwater Vehicles (AUV) Sensitivity of Motion Response to Geometric and Hydrodynamic Parameters and AUV Behaviors with Control Plane Faults, Doctoral Paper, Memorial University of Newfoundland, St. John’s, Newfoundland, Canada.
10. Evans, J. (2003). Dynamics Modeling and Performance Evaluation of and Underwater Vehicle, Master’s Paper, McGill University, Montreal, Quebec, Canada.
11. Evans, J., and Nahon, M. (2004). “Dynamic Modeling and Performance Evaluation of an Autonomous Underwater Vehicle”, Ocean Engineering, Vol. 31, pp. 1835 – 1858.
12. Hwang, Y. L. (2003). “Hydrodynamic Modeling of LMRS Unmanned Underwater Vehicle and Tow Tank Test Validation”, Proceedings of the Conference OCEANS ’03, Vol. 3, pp. 1425 – 1430, September, 2003.