Journal of Electrotechnology, Electrical Engineering and Management (2024) **DOI: 10.23977/jeeem.2024.070308**
Clausius Scientific Press, Canada **ISSN 2560-6697 Vol. 7 Num. 3**

Feasibility Analysis of Submarine Debye Effect Magnetic Field Detection Based on Fluent

Weiyi Du[1]

[1]*Shenyang Ligong University, Shenyang, China*

Keywords: Debye effect magnetic field, magnetic anomaly detection, fluid simulation, Fluent

Abstract: High-salinity seawater contains a large number of sodium ions and chloride ions. These ions not only carry charges but also have different masses. The thrust generated by a submarine moving underwater will inevitably accelerate the ions and cause the centers of mass of positive and negative ions to separate, forming a polarization current. This, in turn, generates a special magnetic field known as the Debye Effect magnetic field. Can the Debye effect magnetic field be detected in relation to the movement speed of seawater ions? This paper establishes a simulation platform for submarine motion, and the results show that during the submarine's impact with the water flow, there will be fluctuations in seawater velocity. This indicates that it is feasible to detect the changes in the Debye effect magnetic field during submarine motion.

1. Introduction

Currently, submarine exploration mainly relies on sonar equipment, but in shallow sea areas, the interference from salinity, temperature, and other hydrological conditions, as well as fish schools and seabed topography, increases the sonar misjudgment rate. Moreover, the noise levels of submarines from neighboring countries are continuously decreasing , indicating that sonar detection is facing serious challenges, and there is an urgent need to develop and enhance non-acoustic detection technologies such as magnetic detection. Seawater with high salinity contains a large number of sodium ions and chloride ions. These ions carry different charges and have different inertias. The thrust generated by a submarine moving in the ocean will inevitably accelerate these ions and cause them to move. According to the principles of electromagnetism, the movement of charged ions will generate a special magnetic field, known as the Debye Effect magnetic field[1]. According to the principle of the Debye effect magnetic field, specialized Debye detectors can be developed for submarine detection. The Debye effect magnetic field is different from traditional magnetic anomaly detection fields; it is not an abnormal magnetic field caused by ferromagnetic materials on submarines, but rather an abnormal magnetic field generated by the movement of charged ions in seawater. Although the Debye magnetic field is relatively weak, it will not disappear simply because submarines do not use ferromagnetic materials or are periodically demagnetized[2].From this perspective, the Debye magnetic field generated by a submarine moving in seawater is "inherent" to the submarine, has nothing to do with whether the submarine itself is magnetic, and is only related to the speed of ion movement in the seawater. It will also accompany the submarine for a long time.

2. Materials and methods

2.1. Simulation Steps

Numerical simulation using CFD technology is roughly divided into several steps: geometric modeling, mesh generation, material property settings, boundary and initial condition settings, solver algorithm selection and iterative computation, display and output of computation results.Next, we will provide a detailed introduction one by one[3].

2.2. Geometric Model and Mesh Generation

Based on the data model from the literature, the basic model of SUBOFF is constructed, as shown in Figure 1 and this serves as the foundation for the research. The SUBOFF model is a standard model provided by the US DARPA research center, used to simulate the hydrodynamic and acoustic characteristics of submarines. This model is widely used in various academic journals, and many people have conducted experiments to provide corresponding data on it.

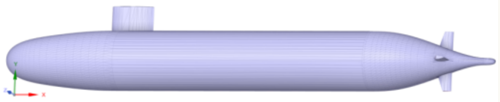

Figure 1: Suboff submarine model

In fact, due to the irregular dimensions of the SUBOFF model, many areas exhibit complex functions, including parabolic sections, which pose significant challenges for mesh generation. In fluid simulation, mesh generation includes two types: structured mesh and unstructured mesh. Roughly speaking, unstructured grids consist of triangles and tetrahedra, while structured grids only contain quadrilaterals or hexahedra. Mesh generation is quite critical for fluid mechanics simulation, as it can significantly affect the quality of the simulation results. In many fluid simulations, 90% of the workload is spent on mesh generation. Similar to the butterfly effect in turbulence, even minor differences in the mesh can lead to vastly different simulation results.

Structured grids can more easily achieve boundary fitting for regions, making them more suitable for fluid calculations in isotropic surfaces where surface stress is concentrated. Its main advantages are: 1. Fast mesh generation speed; 2. Good mesh generation quality (good orthogonality); 3. Simple data structure. Usually, spline interpolation or parameterization methods are used to fit spatial or surface models, resulting in smoother regions and making it easier to approach the actual model. The main disadvantage is that its applicability is relatively narrow, only suitable for regular-shaped figures.

Unstructured grids differ from structured grids in that they lift the structural constraints on nodes, allowing for better control over the distribution of elements and nodes. This makes them more suitable for handling boundaries and simulating intricate and complex shapes. The drawback of unstructured grids is that they are somewhat forced in handling viscous problems. If only triangular or tetrahedral grids are used in the surface layer, the number of grids becomes particularly large. Another drawback is that for fluid spaces of equal volume, the grid filling efficiency is not very ideal, so under the same flow field calculation conditions, the number of generated grids is much higher than that of structured grids.

Regarding the fluid problem to be addressed, it is hoped that the viscous force can be fully utilized, and that the number of grid points can be minimized as much as possible to reduce the computational load of numerical calculations. As shown in Figure 2, this is the grid structure design for the current simulation.

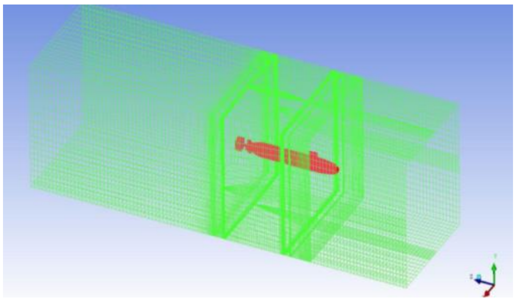

Figure 2: Grid partitioning

2.3. Boundary Conditions and Initial Conditions

The selection of boundary conditions in simulations is extremely important, and the solution to the differential equations will change with variations in the boundary conditions. If you want to obtain a unique solution for the physical equations (system of differential equations), you need to provide some parameter values at the boundaries of the computational domain, such as flux (magnetic flux, thermal flux) and motion states, etc. The boundary condition content includes: defining the positional information of the boundary conditions (such as solid walls, symmetry planes, inlets, etc.) and the important parameter information on the given boundary. In the simulation of this model, the following initial settings are often made: the submarine surface is set as a wall, the boundaries of the water area are set as flow inlet, pressure outlet, and symmetry boundary (with all variable normal gradients equal to zero). During the process of grid generation, there are also unstructured grids near the propeller, which have boundaries with the surrounding structured grids. These boundaries are handled using internal boundaries (Interface). Next, set the initial conditions, such as the inlet velocity. This simulation is similar to a wind tunnel experiment. In fact, the submarine is not given a forward speed; instead, it is fixed in place while the water flows to create the effect. In fact, the water speed around the submarine is definitely not uniform, but before the simulation, it is impossible to know how these speeds are distributed. Therefore, if we want to solve the final state, we need to simulate from the very beginning, which requires simulating the inlet speed starting from zero. Clearly, it doesn't matter how the submarine accelerates from zero speed to cruising speed; it only concerns the flow field information when it is traveling at a certain speed. This requires a method to quickly achieve the desired state, which is steady-state computation. The primary difference between steady-state (steady) and transient (transient) calculations lies mainly in the time component. In other words, are their calculations time-dependent? However, in real life, almost all physical phenomena are related to time. Thus, it can be understood as follows: steady state is an approximation as time approaches infinity. The mathematical difference lies in whether or not there is a time term. If the time term exists in the simulation, it is a transient calculation; otherwise, it is a steady-state calculation. In differential equations, steady-state calculations are also called stationary calculations, while transient calculations are also called non-stationary calculations. Fluid problems require analyzing the variation of flow velocity over time, which is an unsteady problem. First, use steady-state calculations to obtain a reasonable initial value for the unsteady-state solution, in order to accelerate the convergence speed of the unsteady-state solution and reduce the number of iterations required for the unsteady-state solution. Although theoretically, not every problem can reduce computational complexity using this method, it can generally be achieved in practice. So, the approach here is to first set a sailing speed, then use steady-state calculations to quickly determine the surrounding flow field, and then use that as the initial condition for subsequent unsteady-state calculations.

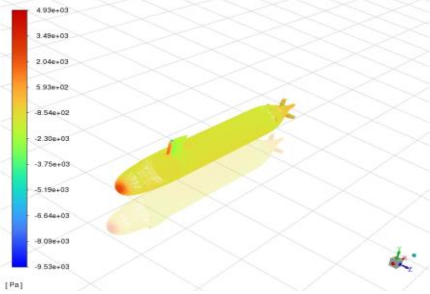

Figure 3: Pressure cloud chart

The figure 3 shows the distribution of pressure coefficients on the submarine's hull surface (only the submarine's surface is shown for better color differentiation). From the figure, it can be seen that at the bow, the front end of the conning tower, and the front end of the stern, the pressure coefficients are significantly higher than in other areas. This is because in these nearby regions, the water flow velocity field collides with the submarine's hull surface, causing a rapid decrease in the velocity of the nearby water flow

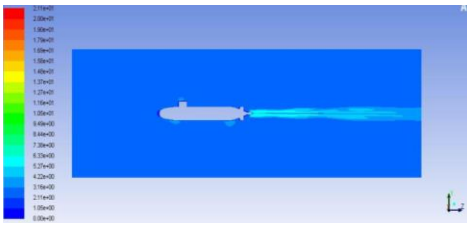

Figure 4: Speed Cloud Map

The simulation shows the submarine at rest, with the water flow washing over it. As shown in the figure 4, when the submarine is in motion, a drag zone appears at the front, causing the flow speed to decrease. The speed in the wake field is also lower than the forward speed, with an increase in speed on the sides, mainly due to the reduction in the cross-sectional area of the water flow being compressed. This increase in speed can easily cause the inertial force to exceed the viscous force.

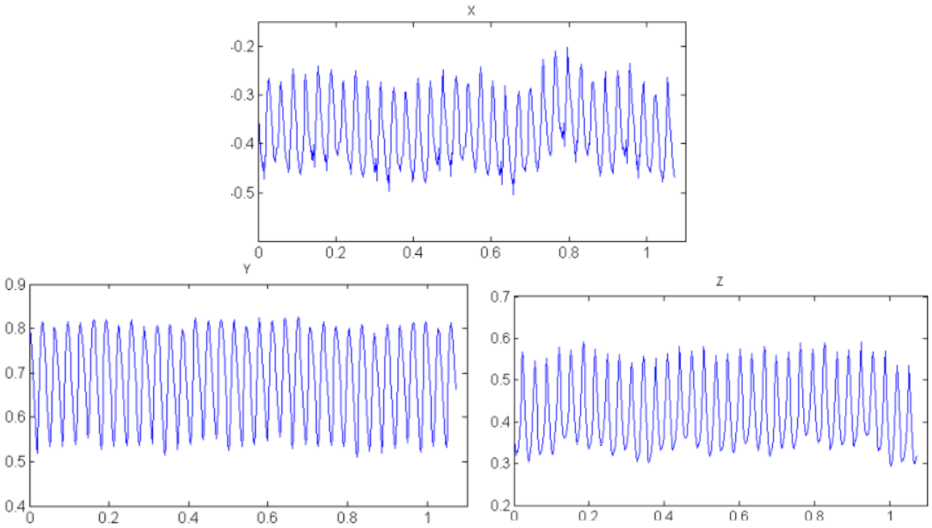

Figure 5: 0.2 meters above the centerline behind the command platform, changes in x, y, and z-axis speeds

As shown in Figure 5, the location is 0.2 meters above the centerline behind the command platform. You can clearly see the fluctuations in speed, which means that during the submarine's impact with the water flow, similar fluctuations will still occur. This is quite beneficial for the subsequent detection of the Debye magnetic field.

3. Conclusions

In response to the current challenges faced in submarine detection, and in situations where the reliability of traditional detection methods cannot be guaranteed, although the Debye magnetic field is relatively weak, it will not disappear because the submarine does not use ferromagnetic materials or is periodically demagnetized. Magnetic detection is indeed very important. Through research, this paper concludes that during the process of a submarine moving through seawater, there will be fluctuations in speed, indicating that detecting submarines through the Debye magnetic field is feasible.

References

[1] Debye P. A Method for the Determination of the Mass of Electrolytic Ions[J].Journal of Chemical Physics, 1933, 1(1):13-16.
[2] Cui Guoheng, Yu Dexin. The current status of non-acoustic anti-submarine technology and its countermeasures [J]. Firepower and Command Control, 2007, 32(12):10-13.
[3] Ji Bingbing, Chen Jinping. Detailed Explanation of ANSYS ICEM CFD Mesh Generation Techniques [M]. China Water Power Press, 2012.