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Research Article

LAUNCHING EXHAUST FIELD OF UNDERWATER MISSILE BY CONSIDERATION OF VAPORIZATION EFFECT

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ABSTRACT

In the present study, launching exhaust field of underwater missile was simulated and a suitable modeling of launching exhaust field was obtained by consideration the vaporization effect. The viscous non-stationary compressible phase flow theory was used through this study. In lower missile speed, the cavitation in a great depth case was ignored. The obtained results revealed that the launching exhaust field was significantly decreased with increasing injection. However, too much water injection resulted in exhaust difficult. Also, vaporization had a little influence on the underwater missile movement. Based on results, the gas injection at the nose missile was depended on the depth and missile velocity.

Keywords: *Launching Exhaust Field; Underwater Missile; Vaporization Effect; Gas Injection*

INTRODUCTION

Based on type of guidance system, propulsion system, launching and impact, trajectory, trim and control device, the missiles can be classified in five groups including Air-to-air missile (AAM), Air-to-surface missile (ASM), Surface-to-air missile (SAM), Surface-to-surface missile (SSM), and Underwater-to-underwater missile (UUM) (Dagan and Arad, 2014). Another classification method based on whether to use the carrier (Wang, 2010). One is the missile launch without carrier. Submarine ballistic missile launch without carrier. The other is underwater-launched missiles with carrier. The launch vehicle is equipped with missiles container. Using the Launch program can reduce the missile's design requirements, and can design the missile shape with the aerodynamic requirements (Zhao, 2006).

Underwater missiles with high velocity capabilities have been built in Russia, Ukraine, USA, Germany and etc. The gas injected at nose is used to reduce drag, while those injected through the nozzle is used to achieve system's propulsion. However, the main drawback of underwater missiles is the presence of a non-condensable phase in the liquid-vapor phase diagram (Petitpas et al.., 2011). In order to minimize the travel of the missile in the water, strengthen the missile motion control, and ensure the missile a good aerodynamic shape, the use of vertical hot launch with launch vehicle is necessary. Therefore, the numerical simulation of launching exhaust field of underwater missile is an inevitable (Saurel et al., 1999). Moreover, the numerical simulation of flows around underwater missile due to the interfaces separating fluids effects during underwater high speed motion is necessary. To overcome these problems, Saurel et al.., (2008) developed method to deal with phase transition and cavitation fronts. This model was able to deal with both condensable and non-condensable fluids. In other study, Petitpas et al., (2009) generalized the flow model to an arbitrary number of fluids and shown that efficient computations of flows around hypervelocity underwater vehicles was possible.

In the present work, modelling of launching exhaust field of underwater missile was designed based on viscous non-stationary compressible phase flow theory.

Modelling

By consideration the following conditions:
- Assumed that the gas burner full, without regard to the gas resurgence effect.
- The flow field is axisymmetric structure.
- Flow field of gas is only a single gas.
- Does not consider the effect of the thermal conductivity between the flow field and the launcher.
- Relax the pressure toward mechanical equilibrium.

- Reset the internal energies.

The pressure non-equilibrium model is given as follows:

$$\frac{\partial \alpha_k}{\partial t} + u.grad(\alpha_k) = \alpha_k \mu(\mathrm{p}_k - \mathrm{p}_*)$$

1

$$\frac{\partial \alpha_k \rho_k e_k}{\partial t} + div(\alpha_1 \rho_1 e_1 \, \mathrm{u}) + \alpha_1 p_1 div(\mathrm{u}) = -\alpha_k p_I \mu(\mathrm{p}_k - \mathrm{p}_*)$$

2

By combination of the internal energy equations with mass and momentum equations, the additional mixture energy equation is given as follows:

$$\frac{\partial \rho(\sum_k Y_k e_k + \frac{1}{2}\|u\|)^2}{\partial t} + div\left\{(\rho(\sum_k Y_k e_k + \frac{1}{2}\|u\|)^2) + \sum_k \alpha_k p_k)u\right\} = 0$$

3

The intermediate wave speed is estimated as follows:

$$S_M = \frac{(\rho \mathrm{u}^2 + \mathrm{p})_L - (\rho \mathrm{u}^2 + \mathrm{p})_R - S_L(\rho u)_L + S_R(\rho u)_R}{(\rho u)_L - (\rho u)_R - S_L \rho_L + S_R \rho_R}$$

4

From the wave speed the following variables are determined as follows:

$$(\alpha_k \rho_k)^*_R = (\alpha_k \rho_k)_R \frac{S_R - u_R}{S_R - u_M}$$

5

$$p^* = p_R + \rho_R u_R (\mathrm{u}_R - S_R) - \rho^*_R S_M (S_M - S_R)$$
$$\rho^*_R = \sum_k (\alpha_k \rho_k)^*_R$$

6

$$E^*_R = \frac{\rho_R E_R (u_R - \mathrm{S}_R) + \mathrm{p}_R u_R - p^* S_M}{\rho^*_L (\mathrm{S}_M - \mathrm{S}_L)}$$

7

In the relaxation step:

$$\frac{\partial \alpha_k}{\partial t} = \alpha_k \mu(\mathrm{p}_k - \mathrm{p}_*), \frac{\partial \alpha_k \rho_k}{\partial t} = 0,$$
$$\frac{\partial \alpha_k \rho_k e_k}{\partial t} = -\alpha_k p_I \mu(\mathrm{p}_k - \mathrm{p}_*), \frac{\partial \rho u}{\partial t} = 0, \frac{\partial \rho E}{\partial t} = 0$$

8

The influence of gas-liquid two-phase flow using the mixture model is displayed. Mixture model was characterized by two-phase coupling effects. Cavitation is the vaporization phenomenon of fluid flow under a certain pressure and temperature. High-temperature gas, the water is boiling occurs, to produce steam. Assumed internal and external pressures in equilibrium in the initial moment.

Under steady flow assumption, the mentioned equation is given as follows:

$$\int_V div(\rho u\times u+pI)dV=\int_s \rho u(u\bullet n)dS+\int_s pndS=0 \tag{9}$$

In the reset step:

$$p(\alpha_k,\rho_k,e)=\frac{\rho_e-\sum_k\left(\frac{\alpha_k\gamma_k p_{\infty k}}{\gamma_k-1}\right)+\alpha_k\rho_k q_k}{\sum_k\left(\frac{\alpha_k}{\gamma_k-1}\right)} \tag{10}$$

In this study, the flow model for diffuse interfaces presented in Kapila et al., (2001); and the Stiffened Gas equations of state presented in Métayer et al., (2004).

RESULTS AND DISCUSSION

Effect of Vaporization

The effect of vaporization on the speed of underwater missile is illustrated in Fig.1. As shown, without considering the vaporization of the missile, the speed is 31.2m /s, considering the vaporization of the missile speed was 32.1 m /s. The obtained results indicated that the vaporization had a little effect on the missile movement. The influence of water injection on the underwater missile speed was similar to the vaporization effect on the missile movement.

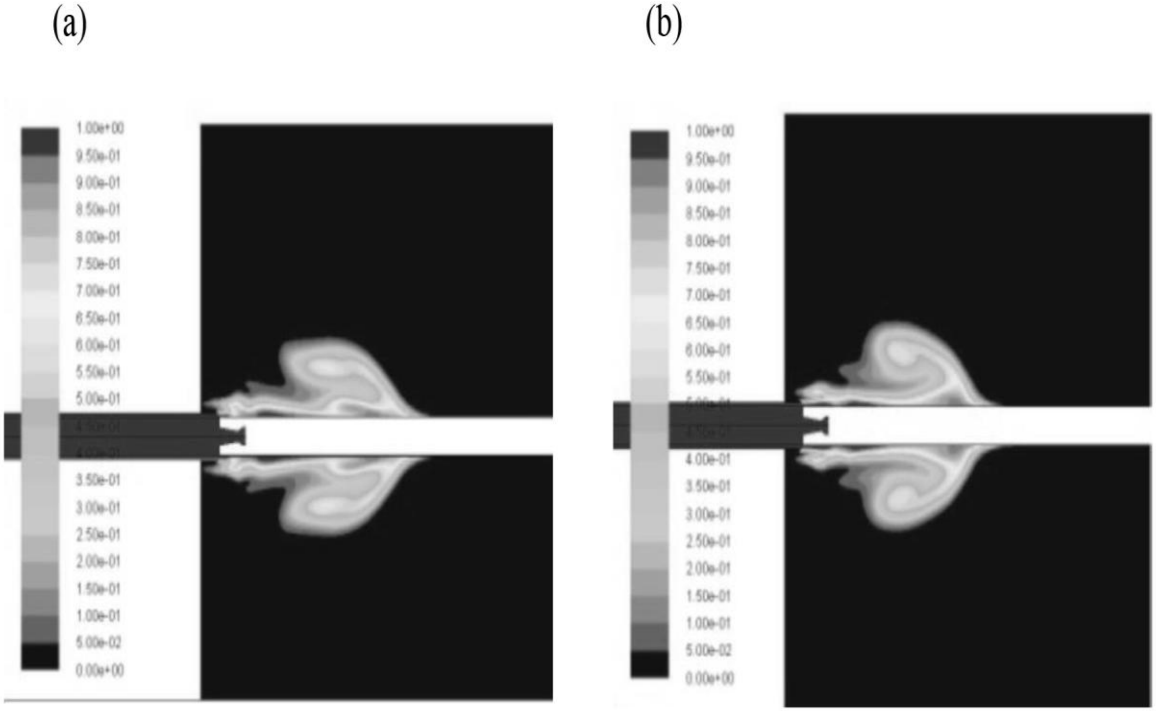

Figure 1: Gas fraction (a) without vaporization and (b) with vaporization

The Effect of Gas Injection on the Missile Movement

A model to treat high speed cavitation has been applied to 3D cavitation flows around underwater missile. The results are shown in Figure 2. The results proved that the gas injection at the nose of underwater missile was of fundamental importance depending on the depth and missile velocity.

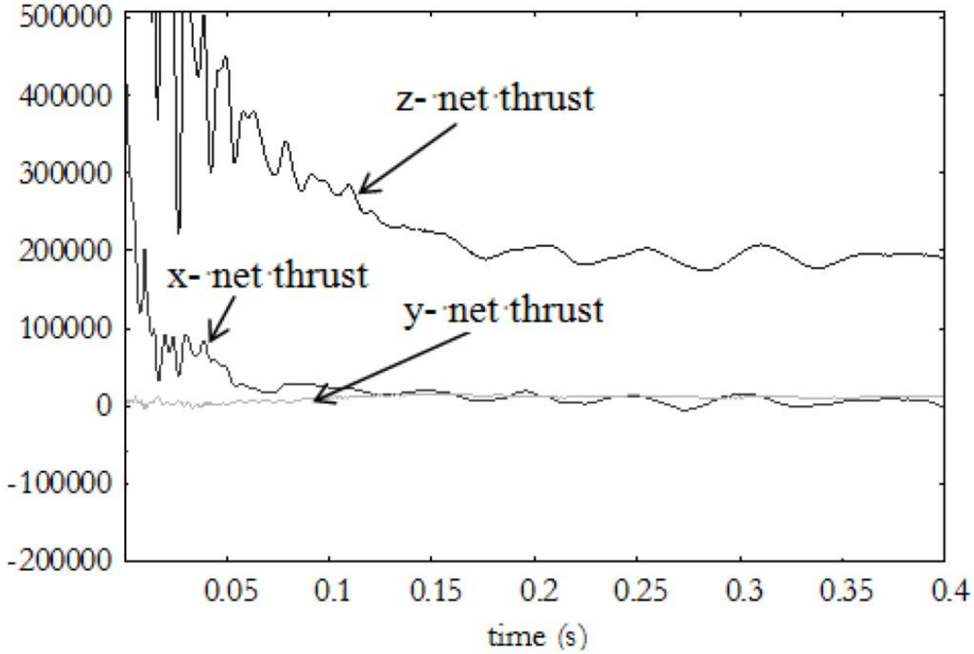

Figure 2: Missile moving at 40 m/s under 5 bar of external pressure with a tilted angle of 4°

Conclusion

Launching exhaust field of underwater missile was successfully simulated via viscous non-stationary compressible phase flow theory. Based on results, the cavitation was ignored in lower missile speed. Increases in injection resulted in decreasing launching exhaust field. The effect of vaporization on the speed of missile indicated that the missile movement was not significantly change in the presence of vaporization.

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