Modeling and Simulation of Torpedo Leading Angle Variety With Observation Errors

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Abstract. The straight-shooting is the torpedo's important shooting method and its leading angle is key factor. Based on the theory of the torpedo straight-shooting triangle, modeling and discussing the torpedo leading angle variety caused by the target observation errors in straight-shooting. And simulations under different instances are presented to show the leading angle Variety.

Introduction

Torpedo is the important r weapon in sea war and the most important weapon of the submarine. According to the homing method the torpedo can be classified such as the straight-running torpedo, the homing torpedo and the wired-guided torpedo. Even though the homing torpedo and the wired-guided torpedo are the main development direction of the submarine weapons, the straight-running torpedo's tactical significance can not be ignored. In some special conditions the straight-running torpedo or the straight-shooting method of the homing torpedo and the wired-guided torpedo are the more effective means on attacking targets.

In straight-shooting of the torpedo the leading angle is an important factor that influences the torpedo hit effect. In fact the target observation errors are the key factors that influence the straight-shooting torpedo's leading angle. In the paper in consideration of the target observation errors the model of the torpedo straight-shooting is establish and the effect of leading angle produced by the target observation errors are analyzed and simulated. The conclusion can provide reference on not only the straight-running torpedo's shooting but also the homing torpedo and the wired-guided torpedo's straight-running.

1 The Model of the Torpedo's Straight-shooting

For the sake of the main course and the key factors, the process of the torpedo straight-shooting is predigested. We assume that the target and the torpedo both has a currently movement without changing their speed and direction. The assument can be characterized the torpedo straight-shooting's process in despite of some inessential factor such as velocity of flow and so on. In Fig.1 shows the relatively situation of the target and the submarine when the torpedo is fired out of the submarine torpedo tube, M is the target's position and W is the torpedo's position when the torpedo is fired out of the submarine torpedo tube. In order to hit the target, torpedo must adopt an appropriate angle towards the target's motion direction. After a certain time , the target and the torpedo reach the point

C at the same moment which d enotes the torpedo hit the target. ΔWCM is called the torpedo shooting triangle, V_M and V_T are the speed of target and torpedo, S_M and S_T are the t the target's and the torpedo's running distance, D_S is the distance between the target and the torpedo when the torpedo is fired out of the tube as shown in Fig.1 .The angle j is called the torpedo leading angle，the angle l is the target shipboard angle and the angle q is the torpedo hit angle . According to the torpedo shooting triangle and the law of sines, the torpedo's straight-shooting's motion equations are as follows,

$$\frac{S_T}{V_T} = \frac{S_M}{V_M} .$$

(1)

$$\frac{S_M}{\sin j} = \frac{S_T}{\sin l} .$$

(2)

$$\sin j = \frac{S_M}{S_T} \cdot \sin l = \frac{V_M}{V_T} \cdot \sin l = m \cdot \sin l .$$

(3)

Where m is the velocity ratio of the target and the torpedo.
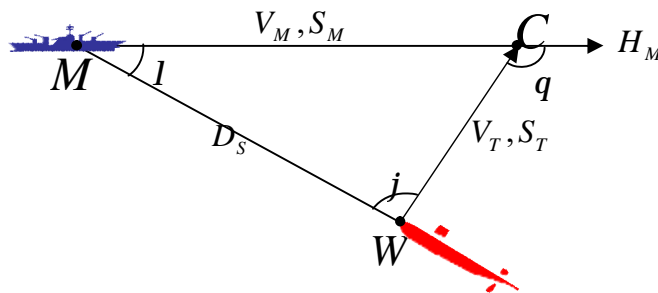

Fig.1 The Torpedo Shooting Triangle

2 The Modle of the Torpedo Leading Angle Variety with the Target Observation Errors

In the torpedo straight-shooting's process, the torpedo leading angle must be decided exactly according to the target motion elements such as the target's bearing and speed. The target motion elements are obtained by the submarine's observation. In actually the target motion elements obtained by observation have errors inescapability and bring some influence to the torpedo leading angle. As shown in Eq.3 the target's bearing and speed are the main factors that influence the torpedo leading angle. So we must analyse the errors of the target's bearing and speed and find out their influence to the torpedo leading angle. ΔV_M and Δl are the errors caused by the observation of the target's speed and the target's bearing, and Δj_V and Δj_B are the errors caused by the observation of the target's speed and the target's bearing.

2.1 the Torpedo Leading Angle with the Target's Speed Error

When observe the target's speed, the error ΔV_M ineluctability exits. In this section we analyse the torpedo leading angle caused only by the target's speed error. According to the geometrical analysis of the torpedo shooting triangle and the Eq.3, we can educe the relation equations as follows.

$$\sin(j \pm \Delta j_V) = \frac{V_M \pm \Delta V_M}{V_T} \cdot \sin l .$$

(4)

Let $\Delta m = \Delta V_M / V_T$, Eq.4 can be translated as follows,

$$\sin(j \pm \Delta j_V) = (m \pm \Delta m) \cdot \sin l .$$

(5)

According to the law of sines and Eq.5, we can educe that

$$\sin j \cdot \cos \Delta j_V \pm \cos j \cdot \sin \Delta j_V = (m \pm \Delta m) \cdot \sin l . \tag{6}$$

When value of the error Δj_V is little comparatively, and $\cos \Delta j_V \approx 1$.

$\mathbf{Q} \cos \Delta j_V \approx 1$ and $\sin j = m \cdot \sin l$,

$$\therefore \sin j \pm \cos j \cdot \sin \Delta j_V = (m + \Delta m) \cdot \sin l . \tag{7}$$

$$\therefore \sin \Delta j_V \cdot \cos j = \Delta m \cdot \sin l ,$$

$$\therefore \sin \Delta j_V = \frac{\sin l}{\cos j} \cdot \Delta m = \frac{\sin l}{\cos j} \cdot \frac{\Delta V_M}{V_T} . \tag{8}$$

$$\therefore \Delta j_V = \arcsin\left(\frac{\sin l}{\cos j} \cdot \frac{\Delta V_M}{V_T} \right). \tag{9}$$

Eq.9 shows that the torpedo leading angle's change Δj_V caused only by the target's speed error.

2.2 the Torpedo Leading Angle with the Target's Bearing Error

When observe the target's bearing, the error Δl ineluctability exits also. In this section we analyse the torpedo leading angle caused only by the target's bearing error. According to the geometrical analysis of the torpedo shooting triangle and the Eq.3, we can also educe the relation equations as follows.

$$\sin(j \pm \Delta j_B) = m \cdot \sin(l \pm \Delta l) . \tag{10}$$

According to the Eq.10 and the law of sines, Eq.10 can be translated as follows,

$$\sin j \cdot \cos \Delta j_B \pm \cos j \cdot \sin \Delta j_B = m \cdot (\sin l \cdot \cos \Delta l \pm \cos l \cdot \sin \Delta l). \tag{11}$$

When value of the error Δj_B and Δl are little comparatively, and $\cos \Delta j_B \approx 1, \cos \Delta l \approx 1$.

$\mathbf{Q} \cos \Delta j_B \approx 1$ and $\cos \Delta l \approx 1$,

$$\therefore \sin j \pm \cos j \cdot \sin \Delta j_B = m \cdot (\sin l \pm \cos l \cdot \sin \Delta l). \tag{12}$$

$\mathbf{Q} \sin j = m \cdot \sin l$,

$$\therefore \sin \Delta j_B = m \cdot \frac{\cos l}{\cos j} \cdot \sin \Delta l . \tag{13}$$

$$\therefore \Delta j_B = \arcsin\left(m \cdot \frac{\cos l}{\cos j} \cdot \sin \Delta l \right). \tag{14}$$

Eq.14 shows that the torpedo leading angle's change Δj_B caused only by the target's speed bearing.

3 Simulation

According to the Sec.2 we assume four representative cases to simulate the torpedo leading angle errors caused by the target observation errors to find out some disciplinarians. Case 1 and Case2 revel the torpedo leading angle variety mainly caused by the target's speed errors with different target speed and torpedo speed in Fig.2; Case 3 and Case4 revel the torpedo leading angle variety mainly caused by the target's bearing errors with different target speed and torpedo speed in Fig.3.
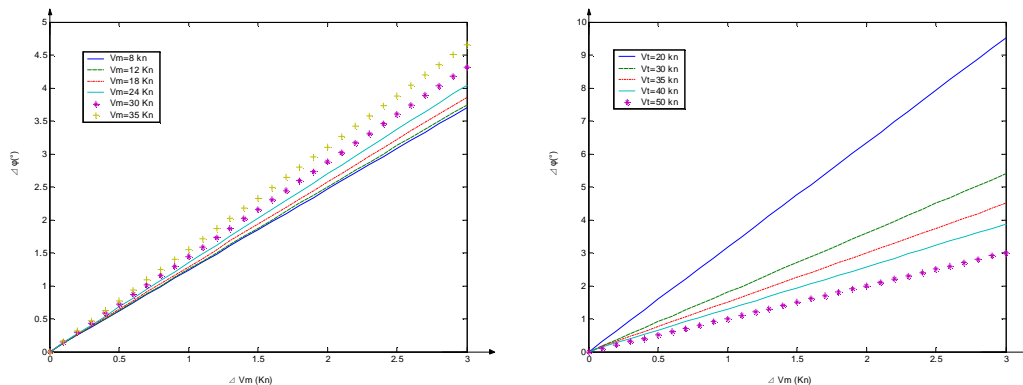

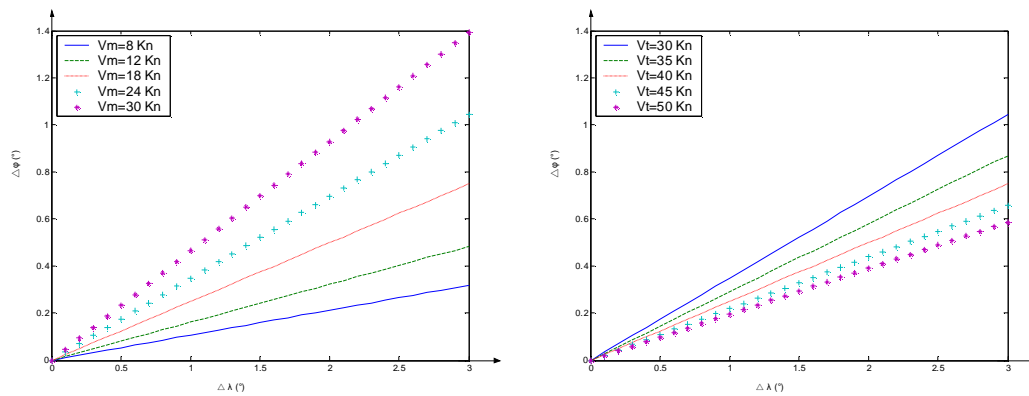Fig.2 the Torpedo Leading Angle Errors mainly caused by the Target's Speed Errors

Fig.3 the Torpedo Leading Angle Errors mainly caused by the Target's Bearing Errors

4 Conclusions

The modeling and simulation of torpedo leading angle error in straight-shooting with the target observation errors such as speed and bearing are given in this paper. Through four representative instances of the torpedo leading error are discussed. The torpedo leading angle variety caused by the target's speed errors and the target's bearing errors show that leading angle variety increases with the target's speed and decreases with the torpedo speed. Therefore increasing the torpedo's speed can decrease the leading angle variety. Further work will focus on the hit probability with the target observation errors.

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