

Naval ship's susceptibility assessment by the probabilistic density function

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Abstract

The survivability of the naval ship is the capability of a warship to avoid or withstand a hostile environment. The survivability of the naval ship assessed by three categories (susceptibility, vulnerability and recoverability). The magnitude of susceptibility of a warship encountering with threat is dependent upon the attributes of detection equipment and weapon system. In this paper, as a part of a naval ship's survivability analysis, an assessment process model for the ship's susceptibility analysis technique is developed. Naval ship's survivability emphasizing the susceptibility is assessed by the probability of detection, and the probability of hit. Considering the radar cross section (RCS), the assessment procedure for the susceptibility is described. It's emphasizing the simplified calculation model based on the probability density function for probability of hit. Assuming the probability of hit given a both single-hit and multiple-hit, the susceptibility is assessed for a RCS and the hit probability for a rectangular target is applied for a given threat.

Keywords: Survivability; Vulnerability; RCS (Radar Cross Section); Probability of hit; Probability of detection

1. Introduction

When a naval ship in a modern combat environment is exposed to a threatening weapon and attacked, the combat system and hull structure suffer critical damage. The ability of a naval ship to withstand such threats encountered in a battle environment is defined as the survivability of the ship [1]. The survivability of the ship is evaluated by three types of stochastic indicators—susceptibility, vulnerability, and recoverability [1-3]. The most fundamental method for improving the survivability of the naval ship is to design the ship such that its susceptibility becomes close to zero. However, because it is difficult to attain zero susceptibility in reality, the realistic approach to improving the susceptibility involves considering various situations that may arise on being attacked [4]. The susceptibility of the naval ship refers to the probability of the ship being attacked by threatening weapons after being identified by an enemy's detection technology and equipment [4, 5]. Therefore, the signals generated by a naval ship, the devices for detecting and identifying these signals, and the defense and deception system employed against enemy's threatening weapons following detection need to be analyzed [6]. The susceptibility should be comprehensively evaluated by considering the shape of the naval

ship's radar reflection area, infrared signal characteristics, electromagnetic equipment performance, and radiation noises [7]. Many studies have reported on the aforementioned evaluation factors individually [8], and the analysis field can be divided into Radar Cross Section (RCS), Infrared (IR), Underwater Radiated Noise (URN), and Electro Magnetic Interference (EMI) according to the respective detection characteristics and equipment [6]. In the present study, as a part of a naval ship's survivability analysis, a theoretical process model for the ship's susceptibility analysis technique was developed. The applicability of this model was demonstrated through an example model and arbitrary attack situations.

2. Susceptibility analysis of naval ships

2.1 Susceptibility analysis theory

To analyze the susceptibility of a naval ship, the characteristics and performance of the equipment used for detecting enemy naval ships, and the possibility of being hit by threatening weapons must be analyzed. In this study, the susceptibility analysis process model was constituted as shown in Figure 1 based on the stochastic theory. The attacking probability (P_H) is based on the detection probability (P_D), which is the probability of identifying the friendly naval ship by the enemy detection equipment, and on the hit probability (P_{hit}), which is the probability that the friendly naval ship could be hit by the threatening weapon after being detected. The at-

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tion using examples based on the proposed theory. However, the detection characteristics, which are identified upon exposure of the naval ship in a battle environment, vary depending on the detection equipment; hence, the detection probability calculation must be formulated based on the S/N value for various detection characteristics such as infra-red and underwater radiated noise. In addition, the probability distribution, which is the core of the present susceptibility analysis procedure, is assumed as a normal distribution; in future, a probability distribution model with a quantitative base should be established.

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