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A mission-oriented risk assessment methodology for naval vessel fire caused by non-contact explosions using Bayesian Networks

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Abstract

In order to understand the fire damages on warship caused by non-contact explosion, a mission-oriented risk assessment methodology was developed in this paper. Firstly, an eight-step flow chart was proposed to analyze the fire effect on a warship, and the main factors, which determined the fire consequences, were summarized. Then based on the specialist marking methods and statistical data, the fire damage on warship could be calculated by using Bayesian Networks, which is a nice tool to assess the risk for complicated system. Finally, the methodology was applied a hypothetical ship with five compartments. The results show that fire intensity mainly depends on the fuel load and the fire damage depends on the function occupancy rate. Moreover, the result of sensitivity analysis indicates that fire damage could be effectively reduced by some ways, such as decrease leakage caused by shock, shorten the response time of fire detection and so on.

Keywords: Mission-oriented; Fire risk assessment; Bayesian networks; Naval vessel; Non-contact explosions

1. Introduction

In wartime naval vessels would be hit by contact explosion and non-contact explosion. Although non-contact explosion does not directly hit naval vessel, it can cause fire by shock wave. As one of the most serious disasters, the ship fire attracts many attentions.

As to commercial ship, International Maritime Organization (IMO) approved a structured and systematic methodology for assessing risk which was named Formal Safety Assessment (FSA) [1]. This method was initially used in IMO rule-making process, and then for ship fire risk assessment [2]. FSA provides a relatively standard assessment process which focuses on fire frequency reduction, but it is not intended to cover risk control options for consequence reduction.

However, warship emphasizes govern severity of a fire rather than probability of accidental ignition [3] and FSA is not proper for warship. Table 1 shows some fire risk assessment methods focusing on fire severity reduction for naval vessels. A Ship Fire Safety Engineering Method (SFSEM) was developed from Engineering Method for Building Fire Safety by U.S. Coast Guard Research and Development Center. SFSEM is a probabilistic-based structured and comprehensive fire risk analysis methodology which treats all types of surface ships as a fire safety system [4]. All relevant aspects of fire safety are considered, including the growth and spread of fire, the effectiveness of passive and active fire protection measures [5]. Moreover, NKF Engineering Associates developed a Fire Loading and Self-inflicted Fire Risk Analysis for a U.S. Navy Destroyer design. This method aimed at achieving a balanced ship design with respect to fire hazards, compartment value and fire protection [6]. The method was then improved by Materials Research laboratory of Australia, and the assessment results were demonstrated in an easily understood set of colored charts [3].

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Although two above methods focused on fire consequence (severity) rather than fire frequency (probability), the attentions were still paid on fires caused by self-inflicting in peacetime rather than by weapon attacks in wartime. In wartime, due to non-contact explosion attack, the fire ignition probability would greatly increase, the occurrences of fuel spills and hull crack would change combustion circumstance, and the damage of suppression system would reduce its efficiency. Compared to the condition in peace time, the wartime state would be more severe.

The purpose of this paper is to develop a Mission-oriented Risk Assessment methodology for naval vessel fire caused by Non-contact Explosions (MRANE). Firstly, an eight-step flow chart was given to introduce the evolution of fire and its effect on the ship. Secondly, the influence factors were figured out, and an index system was constructed in a hierarchy structure. Then based on Bayesian Networks, the fire damage on the warship could be calculated, and this method was used to study a case in the end.

Table 1. Application areas of different fire risk assessment methods

Fire cause	Methods focusing on fire frequency/probability reduction (merchant ship)	Methods focusing on fire consequence/severity reduction (naval vessel)
Internal cause (self-inflicting)	FSA	SFSEM/ Self-inflicted Fire Risk Analysis
External cause (weapon attacks)	—	MRANE (present work)

2. Methodology of risk assessment

2.1. Assessment flow

For naval vessels, the fire risk caused by non-contact explosion can be analyzed as following the flow chart shown in Fig. 1.

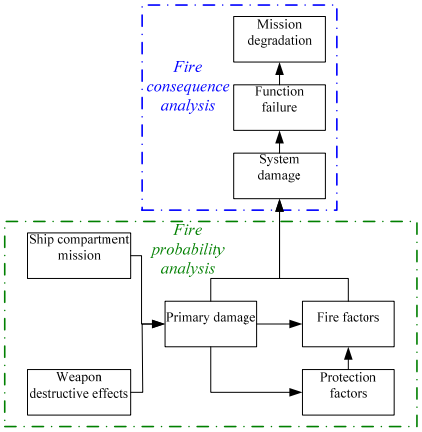

Fig. 1. Flow chart of MRANE.

Step 1: Ship compartment mission analysis

Assessment Goal:

The fire risk assessment goal is quite different for warship and merchant ships. For naval vessels, the goal of fire risk assessment is to evaluate the ship's residual ability to continue the assigned military mission after a fire caused by weapon attacks. So it can be called a mission-oriented assessment method. Among all of missions of naval vessels, the most important one is combat mission, which is concentrated in this paper.

Assessment scope:

Compartment is the basic unit of a ship. In this paper we tried to develop a method to assess the degradation of a compartment ability to perform combat mission after a fire caused by shock of non-contact explosions. Then the fire risk of each compartment in a ship could be evaluated, and the total fire risk of the ship could be obtained.

Assessment levels: