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Analysis of emergency evacuation in an offshore platform using evacuation simulation modeling

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HIGHLIGHTS

- Two evacuation scenarios in a semi-submersible drilling platform were simulated.
- Four parameters were employed to evaluate the evacuation efficiency.
- The casualties were analyzed based on the total evacuation time.

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ABSTRACT

The evacuation routes which are selected by crew will affect their evacuation efficiency when an offshore platform under emergency conditions. To quantify the influence of evacuation route selection on crew evacuation efficiency, two scenarios are considered: Scenario1 is that crew independently select the evacuation routes to evacuate to the assembling point, Scenario 2 is that crew evacuate to the assembling point in accordance with the prescribed evacuation routes. The evacuation efficiency of these two evacuation scenarios is analyzed and discussed from the aspect of evacuation time, waiting time index (WTI), optimal performance statistic (OPS), mean non-flow statistic (MNS) and casualty, respectively. It is found that the evacuation time of crew in Scenario 1 reaches 255.09 s, but Scenario 2 is 32.84 s shorter. By analyzing the WTI of each evacuation exit in these two evacuation scenarios, a large number of people in Scenario 1 are congested at the exit 1, which is the main reason for the increase of evacuation time of Scenario 1. Moreover, the comparison of the OPS and MNS of these two evacuation scenarios indicates that crew in Scenario 1 have not made full use of evacuation exit resources and make it impossible for crew to reach the assembling points timely. Furthermore, in Scenario 1, there are ten crew unable to reach the primary assembling point in time. Scenario 2, however, suffers no casualties.

1. Introduction

As main production facilities in the exploration of oil & gas, the offshore platforms are prone to accidents with a high probability for harsh working environment. Once a serious accident occurs, offshore platforms may be seriously destroyed and even collapsed. In July 1988, the most typical and the world's worst offshore accidents occurred on Piper Alpha in the North Sea [1,2]. 167 crew numbers lost their lives because they were not able to successfully evacuate from the

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installation [3]. Another recent example is the Deepwater Horizon accident, which occurred on the night of the April 20th 2010. In this accident, however, no casualties were reported as result of the efficient evacuation operation and 115 members on board were evacuated [4]. As shown in the above examples, when a major emergency occurs on an offshore platform, the timely and efficient evacuation could avoid or reduce the casualties.

Many previous studies have been conducted to study maritime evacuation. There are mainly two ways for this study. The first one is Full-scale evacuation exercise under an actual accident condition, which is the most reliable way to investigate crew evacuation behaviors and there are already several published reports on full-scale ship evacuations. However, it is a time consuming and labor intensive process, and cannot be implemented anytime and anywhere. The other way is to use modeling and simulation tools. Modeling and simulation tools provide an effective way to simulate evacuation process at sea. Considerable interest has been paid on the development of simulation tools, and many computer simulation software packages have been developed [5]. As reported in [6,7], around 20 such models and tools are available. A not necessary completely list of such software tools includes maritimeEXODUS [8], EVI [9], AENEAS [10,11], IMEX [12], BYPASS [13], FDS+EVAC [14,15]. These simulation tools have been used a lot in the maritime fields evacuation [16]. A maritime evacuation model, IMEX (intelligent model for extrication simulation), for modeling passenger ship evacuation was developed by Korea Research Institute of Ship and Ocean Engineering (KRISO) and it is closely coupled with a damage survivability assessment module and considers the effect of human factors on evacuation process [6]. An evacuation model called maritimeEXODUS, which was developed by the Fire Safe Engineering Group (FSEG) of the University of Greenwich, is suitable to simulate evacuations from complex maritime environments, and has been used in large passenger ships and naval warships fields [17]. Wang et al. introduced an agent-based microscopic evacuation simulation model-CityFlow-M to simulate a passenger ship evacuation case. The simulation results predicted from CityFlow-M were compared with experimental data to illustrate the CityFlow-M is eligible to simulate the assembling process in the passenger ship [16]. Ginnis et al. developed a multi-user Virtual Reality (VR) system called "Virtual Environment for Life On Ships" (VELOS) to assess passenger and crew activities on a ship for both normal and hectic conditions of operations, three evacuation cases for a ro-ro passenger ship were taken to illustrate the VELOS evacuation functionality [18]. Kim et al. used EVI to simulate one FPSO evacuation case, the simulation results were checked via evacuation drills to verify the accuracy of the computer simulation [19].

Compared with the research of ship evacuation, little attention has been paid to the offshore platform evacuation. Offshore platforms are not only main structures for marine petroleum and natural gas exploitation, but the platforms of production and life on the sea. Unlike the ships or common buildings, offshore platforms, which work in harsh environment, have narrow working space, concentrating operating equipment, and are far away from land. These factors may increase the difficulty of offshore platforms evacuation and reduce its evacuation efficiency when emergency conditions occur. Therefore, it is very helpful to improve the evacuation efficiency by setting up the corresponding evacuation plan in advance. In some ship evacuation studies, the evacuation efficiency of evacuation scenarios is quantitatively analyzed from the aspect of the evacuation time, egress rate, human behavior or ship listing and motion et al. [8,12,20,21]. However, few relevant studies on the efficiency of safe evacuation on the offshore platforms have been carried out in detail. Therefore, in this paper, we try to introduce several mathematical concepts, namely the total evacuation time, waiting time index, optimal performance statistic, mean non-flow statistic, to quantitatively analyze the evacuation efficiency of a semi-submersible drilling platform under different evacuation scenarios. BuildingExodus [22], one of evacuation models, is selected to study the evacuation patterns. The evacuation time, waiting time, exits efficiency and casualties are analyzed and discussed based on the numerical simulation results.

This paper is organized as follows. The proposed methods to assess evacuation efficiency are described in Section 2. The evacuation simulation model and evacuation parameters are introduced in Section 3. Numerical simulation results and discussion are given in Section 4. Conclusions are presented in Section 5.

2. Analysis criteria for evacuation efficiency

EER, short for "evacuation, escape, rescue", is the entire process that crew on an offshore platform have to move from a major accident event to an ultimate place of safety. The terms "evacuation", "escape", "rescue" are defined as follows [4,23,24]. Evacuation is the process of crew move away from their location at the time of the alarm to a temporary safe refuge (TSR) or assembling point. Escape refers to the movement of crew from the assembling point to a location (such as a safe offshore location or vessel) outside the hazard zone when the installation is no longer safe. Rescue is the process by which both escapees and man overboard casualties are subsequently retrieved to a safety place where medical assistance is available. Due to the constraint of evacuation software function, this paper only focused on the crew evacuation behaviors during evacuation process. The evacuation efficiency is evaluated by evacuation time, waiting time and exit efficiency, respectively. The following sub-section describes these three parameters in detail.

2.1. Evacuation time

The evacuation time (T_{evac}) can be divided into Response time (T_R) and Travel time (T_{TRA}) [25]. Response time is intended to reflect the total time spend in pre-evacuation movement activities begins with the sound of the alarm ends when the crew have accepted the situation and begins to move towards a TSR or assembling point. Travel time is defined as the time it takes for all crew on board to move from their initial location to the TSR or assembling point [26,27]. The evacuation time