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Risk Assessment and Measures to Improve Safety Management of Offshore Platforms in Marine Engineering Projects

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Abstract: Offshore engineering refers to the exploration and exploitation, rational utilization and proper protection of marine resources and is notably characterized by high risk and high investment. With the increase in human's deed and ability to use and develop the ocean resources, offshore operations are becoming more and more frequent. In the process of offshore oil and gas exploration and clean energy development and utilization, offshore platforms are indispensable means of equipment. Due to the problems of the technology, management and natural disasters, the offshore operation accidents emerge one after another. It is an important and hot topic to study the operation safety of offshore platform, find out the root cause of accidents, and take proper measures to prevent them. This paper mainly analyses and summarizes the risk factors affecting the safety management of offshore platforms based on the accident cases of offshore platforms over the years, and combines with the analysis results by means of expert questionnaire the risk matrix method to assess the level of each risk factor, determine the influencing factors with higher risk levels, and finally, based on the results of risk assessment, put forward corresponding safety management suggestions to promote the improvement of the effectiveness of maritime safety management.

Keywords: Safety Management, Offshore Platforms, Marine Engineering Projects, Offshore Accidents, Risk Factors

1. Introduction

Offshore engineering projects are a strategic and key industry for the country and offshore platforms are an important part of it, which plays an important role in the exploration and development of marine energy such as oil and gas and natural gas hydrate [1]. With the increase in the number of offshore projects and the construction of offshore platforms, how to ensure the safety management of offshore platforms has become a focus of attention [2].

According to domestic and international statistics on offshore accidents, accidents on offshore platforms often result in large economic and human losses. Among them, in 1988, the Piper Alpha conduit rack platform in the North Sea exploded due to a natural gas leak that met with an open fire, resulting in 167 deaths and direct economic losses of US$900 million [3]; in 2010, a fire and explosion at the BP Deepwater Horizon semi-submersible mobile offshore drilling unit (MODU), caused by a well blowout, killed 11 people and caused more than US$6.1 billion in damages [4]; in 2015, a fire on an oil rig in the Caspian Sea in Azerbaijan, caused by damage to a gas pipeline due to strong winds, severely damaged the platform and killed 32 people and injured many others [5]; in 2022, the offshore wind farm project construction platform "Fu Jing 001" sank

after its anchor chain broke while avoiding a typhoon. This resulted in the death of 25 people and huge economic losses. Therefore, it is necessary to analyze and study the risk factors affecting the safety management of offshore platforms and propose targeted safety management measures.

2. Analysis of Risk Factors Affecting the Safe Management of Offshore Platforms

Major accidents in the offshore industry usually have a low probability of occurrence, but the consequences can be catastrophic [6]. Accident statistics over the years show that the main types of accidents on offshore platforms are fires and explosions caused by uncontrolled well blowouts and oil and gas leaks [7], platform capsizing due to operational errors during piling, platform mechanical failures and improper emergency handling of personnel leading to grounding or even sinking, seawater corrosion and personnel fatigue as well as structural failures caused by excessive wind, wave and current loads caused by harsh environments.

2.1. Analysis of Risk Factors

(1) Environmental factors

The majority of offshore platforms operate in the deepest parts of the ocean in a harsh operating environment. In addition to facing the daily effects of offshore winds, waves, currents and tides as well as the corrosion of equipment by seawater, they also have to face extremely destructive natural disasters such as typhoons, sea ice, heavy rain and earthquakes. Adverse weather is not only a trigger for accidents on offshore platforms, but in many cases can facilitate the development of accidents, resulting in greater loss of life and property damage [7].

In recent decades, most of the offshore engineering operations are affected by bad weather and cannot operate normally. [8] Among them, in 1979, China's drilling vessel Bohai II was hit by a typhoon during towing operations and sank to the seabed, resulting in 72 deaths; in 2005, hurricanes in the Gulf of Mexico caused 15 offshore platform accidents, resulting in huge economic losses; in 2011, the Russian jack-up drilling platform Kra was hit by a storm during towing and the accident resulted in 53 people being declared missing or dead. These accidents have had a significant impact on the exploitation of offshore oil and gas and the use of wind energy.

(2) Equipment factors

In terms of production equipment, the main factors affecting the safety management of offshore platforms are the quality of the equipment, the maintenance and renewal of the equipment, the placement of the equipment and the incomplete configuration of the platform-related equipment.

The materials, manufacturing processes and technical parameters used in the construction of offshore platforms have a direct impact on the quality of the equipment and therefore on the safety of the platform. Production equipment and facilities also need to be maintained and updated regularly to ensure their proper functioning and use, otherwise breakdowns and problems may occur, which may lead to accidents. For example, in 2012, a rig at the Jurong shipyard in Singapore suddenly tilted due to the failure of a lifting mechanism, resulting in 89 injuries [9].

(3) Personnel factors

In the course of production operations, operational errors and irregularities, lack of safety awareness and health conditions of personnel can directly affect the safety management of the platform and may even lead directly to accidents.

According to a statistical analysis by the International Maritime Organization (IMO), 70 to 80 percent of accidents at sea are caused by human factors. [10] The human factor also accounts for a significant proportion of accidents on offshore platforms. Compared to physical unsafe conditions, human unsafe behavior is more difficult to manage and evaluate. The occurrence of accidents is often closely related to personnel. Human insecurity factors in most cases are the direct cause of the accident. [11]

(4) Management factors

Management error is a manager's decision or action deviating from the management objective in the process of implementing management behavior in the organization [12]. In the process of offshore platform operations, management errors are also one of the main causes of accidents, especially in the face of various unexpected situations, management errors can easily lead to more serious accidents. In 2020, China's wind power installation platform "Zhen Jiang" in the process of pile extraction operations, part of the ring beam pins could not be pulled out, and due to the crew's decision mistake and this led to an accident at sea where the deck of "Zhen Jiang" was submerged at high tide, causing a total economic loss of around 0.2 billion RMB.

Modern management concepts constantly emphasis the application of information technology, and offshore platforms also require the use of various information technology tools to enhance safety management. At the same time, the implementation of safety concepts and policies and the development of emergency response mechanisms also have a very important impact on the safety management of platforms.

2.2. Risk Factor Sorting

In summary, the causal factors of accidents on offshore platforms are analyzed from four aspects: personnel, equipment, environment and management, and elaborated with specific accident cases. It is found that the complexity of human factors, the uncertainty of environmental risks and managers' decision-making errors are still the main factors affecting the safety of offshore platforms. A summary of the risk factors affecting the safety management of offshore platforms is shown in Table 1.

Table 1. *Sorting out the risk factors affecting the safe management of offshore platforms.*

Risk Category	Risk factors
Environmental Risk B1	Excessive wind load C1
	Excessive wave load C2
	Excessive flow load C3
	Storm Tide C4
	Tsunami Earthquake C5
	Maritime traffic impact C6
Equipment risk B2	Quality of equipment C7
	Equipment renewal and maintenance issues C8
	Problems with the placement of equipment C9
	Incomplete configuration of platform-related equipment C10
Personnel risk B3	Inadequate staffing C11
	Personnel operation error C12
	Personnel irregularities operation C13
	Personnel are not familiar with the operation of the equipment (not competent) C14
	Inadequate safety awareness of personnel C15
	Health status of personnel issue C16
Managing risk B4	Conceptual and Policy Issues in Security Management C17
	Inadequate safety management system C18
	The quality of management staff C19
	Inadequate emergency response capacity C20

3. Risk Level Analysis

3.1. Constructing a Risk Matrix

The risk matrix is a structured method for identifying the importance of risks in safety management and is simple to operate and easy to use with a combination of qualitative and quantitative analysis. The risk level values are calculated using the formula

$$R=PC \tag{1}$$

In equation (1): R is the risk level value; P is the probability of risk occurrence; C is the severity of the consequences [13]. According to the relevant research results on offshore platform safety management and the current national standards, the probability of occurrence of the relevant risk factors and the severity of the consequences are determined as shown in Tables 2 and 3. The risk level values are calculated according to equation (1), where risk level values [1, 5] represent low risk, risk level values [6, 10] represent medium risk, risk level values [11, 15] represent higher risk, and risk level values [16, 25] represent high risk, as shown in Table 4.

Table 2. *Risk probability rating scale.*

Probability of risk occurrence	Probability interval	Quantification of scores	Qualitative notes
Extremely low	(0, 10%]	1	Almost never happens
Low	(10%, 30%]	2	Rarely happens
Moderate	(30%, 70%]	3	Occurs in some cases
High	(70%, 90%]	4	More often occurs
Extremely high	(90%, 100%]	5	It often happens

Table 3. *Risk consequence severity measure table.*

Severity of consequences	Quantification of scores	Qualitative notes
Very slight	1	Little to no effect on people, ships or the environment
Slight	2	Minor effects on people, ships and the environment
Moderate	3	Moderate impact on people, ships and the environment
Significant	4	Serious impact on people, ships and the environment
Catastrophic	5	Catastrophic effects on people, ships and the environment

Table 4. *Risk level values.*

Risk level R			Probability of risk occurrence P				
			Extremely low (0, 10%]	Low (10%, 30%]	Moderate (30%, 70%]	High (70%, 90%]	Extremely high (90%, 100%]
			1	2	3	4	5
Risk impact C	Very slight	1	1	2	3	4	5
	Slight	2	2	4	6	8	10
	Moderate	3	3	6	9	12	15
	Significant	4	4	8	12	16	20
	Catastrophic	5	5	10	15	20	25

3.2. Determining Risk Level Values

This paper uses the risk matrix method to analyze the risk factors in the safety management of offshore platforms, and selects several industry experts to score the risk factors summarized in the previous paper. Based on the principle of equal weighting of experts, the arithmetic mean score of experts is used to represent the average of the probability of occurrence of risk and the severity of consequences caused by the occurrence of risk, and its calculation formula is:

$$x = \frac{m_1+m_2+\cdots+m_n}{n} \tag{2}$$

where m represents the result of the expert scoring and n represents the number of experts.

The list of risk factors summarized in this paper was scored by a total of more than 50 experts in the relevant

fields, including master, safety managers and front-line staff. All of the experts who rated the risk factors had been working on offshore platforms for more than 10 years and had considerable experience in management and operations. The types of offshore platforms involved include drilling platforms, wind power installation platforms, offshore production platforms and other offshore platforms. In this paper, the scoring results collected from the experts were processed and summarized, and the scoring results of 12 experts were finally selected as the basis of this paper, and the results of the experts' scoring were calculated by equations (1) and (2), resulting in the calculation results shown in Table 5.

Table 5. *Results of expert score calculations.*

Risk factors	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Expert scoring average for probability of risk occurrence P	3.67	3.33	2.83	2.83	2.25	3.17	2.83	2.83	2.58	2.67
Severity of Consequences Expert Scoring Mean C	3.92	4.00	3.33	3.42	4.42	3.25	3.58	3.33	2.92	3.58
Risk level R=PC	14.39	13.32	9.42	9.68	9.95	10.30	10.13	9.42	7.53	9.56
Risk factors	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
Expert scoring average for probability of risk occurrence P	2.75	3.33	3.17	3.25	3.25	2.75	2.50	2.83	3.08	3.25
Severity of Consequences Expert Scoring Mean C	3.67	4.17	4.00	3.92	3.67	3.25	3.42	3.58	3.50	3.92
Risk level R=PC	10.09	13.89	12.68	12.74	11.93	8.94	8.55	10.13	10.78	12.74

Based on the calculation of the expert scores, the risk rating of each of the risk factors listed in this paper can be derived. Among them, factors C3-C6 under environmental risk, factors C7-C10 under equipment risk, factors C11 and C16 under personnel risk, and factors C17-C19 under management risk are in the medium risk category. Factors C1 and C2 under environmental risk, factors C12, C13, C14 and C15 under personnel risk and factor C20 under management risk are at a higher risk level and require further corresponding risk factor control measures and safety management recommendations.

4. Safety Management Recommendations

After classifying the risk level of each risk factor, the corresponding risk level of the risk factor is used as the basis to further propose corresponding safety management recommendations and form targeted safety management measures, so as to ensure the smooth implementation of marine engineering projects.

1. Environmental risks. Environmental factors are inherently uncontrollable and trying to prevent severe weather is itself impossible to achieve, but efforts can be made to mitigate its potential impact and subsequent damage. According to the results of the analysis, it can be seen that the environmental factors, such as wind and wave weather, have a greater impact on the safety of offshore platforms. Therefore, a perfect weather forecasting and monitoring system should be established to provide early warning and monitoring of the upcoming heavy wind and wave, cold wave and other bad weather, so that corresponding safety measures can be taken in time. For all possible natural disasters, perfect contingency plans are formulated and regular emergency drills are conducted to ensure that offshore operators take prompt and correct measures to deal with various risks. Prior to the arrival of severe weather, operational activities on the offshore platform need to be stopped in a timely manner to ensure the safety of all personnel and equipment, and wait for the weather to recover before carrying out operations.
2. Equipment risk. As can be seen from the results of the analysis in Section 3, the risk factors with higher risk levels in equipment risk are mainly "quality of equipment", "renewal and maintenance of equipment" and "incomplete configuration of platform-related equipment ". Therefore, for new offshore platforms, it is necessary to consider the wave, wind, seismic vibration load and other factors [14], increase its ability to resist wind and waves, and equipped with the latest technical equipment and devices; for offshore platforms that are already in production, regular maintenance and updating of relevant equipment should be carried out to ensure that the platforms can operate normally. At the same time, in addition to production equipment, other communication equipment, life-saving equipment and sanitary equipment on the offshore platforms should be fully equipped to deal with possible accidents.
3. Personnel risk. The most important part of the personnel factor is the personnel working on the platform. The analysis shows that the risk levels of factors C12, C13, C14 and C15 of the personnel risk are all high risks. In response to these risk factors, the following recommendations are made for the safety management of offshore platforms: (1) The process of personnel selection and training needs to be more stringent, to ensure that personnel meet the relevant qualifications and experience requirements. [15] (2) Establish effective safety publicity and education to develop safety awareness among employees, so that everyone clearly understands safety precautions and operating procedures. (3) Enhance monitoring and management of personnel behavior to ensure that violations can be detected and dealt with in a timely manner. (4) Check and review the safety status of personnel on a weekly basis to obtain more accurate safety data and forecasts. Attention should also be paid to the length of time

personnel work, rationalizing their working hours and avoiding fatigue.

4. Management risks. According to the assessment results of the risk level, the problems of management factors are mainly reflected in three aspects: imperfect safety management system, quality of management personnel and insufficient emergency response capability. To address these problems, in the daily management of offshore platforms: (1) A complete safety management system should be established and regularly updated and revised. (2) Define the safety responsibilities and management requirements of management personnel, establish a job responsibility system and a safety assessment system, and manage and operate strictly in accordance with the regulations. (3) Develop a sound emergency plan and exercise programme to improve emergency response capability and personnel's ability to cope.

5. Conclusion

This paper combines the accident cases of offshore platforms over the years, analyses and summarizes the risk factors affecting the safety management of offshore platforms, uses the risk matrix analysis method to assess the risk level of each risk factor, and explains the safety management measures that can be taken for the corresponding risks in the operation process according to the assessed results of the risk factors from four aspects: environment, equipment, personnel and management, it provides a certain theoretical reference for improving the safety management level of offshore platforms.

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