Journal of Engineering Mechanics and Machinery (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/jemm.2025.100108
ISSN 2371-9133 Vol. 10 Num. 1

Risk Analysis and Control of Towing Operations for Triple-purpose Work Vessels

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Keywords: Three Purpose Workboat; Towing Operation; Risk Analysis

Abstract: With the rapid development of marine resources development and marine engineering construction, the three-use workship (AHTS), as the core equipment to support marine engineering operations, plays an indispensable role in towing operations, which have a complex operating environment and high technical difficulty. This article analyzes the risks that three types of workboats may face during towing operations. The main risk factors include but are not limited to adverse weather conditions, equipment malfunctions, operational errors, and communication barriers. To effectively reduce these risks, it is recommended to take the following control measures: improve the management system; regulate the operation behaviour; increase the capital investment, optimise the level of hardware and equipment; strengthen the daily management, improve the quality of maintenance and repair; strengthen the training, improve the comprehensive quality of the crew; strengthen the education, establish a sound safety system. Through the above measures, the safety and efficiency of towing operations can be significantly improved.

1. Introduction

With the rapid development of marine resource development and offshore engineering construction, the Three Purpose Working Ship (AHTS), as the core equipment supporting marine engineering operations, plays an indispensable role in towing operations. It is widely used in scenarios such as offshore facility relocation, drilling platform towing, and transportation of large structures, with complex operating environments and high technical difficulty. However, towing operations involve multiple factors such as ship maneuvering, marine meteorology, equipment reliability, and personnel coordination. Any negligence in any link can lead to serious accidents, causing casualties, property damage, and even environmental pollution. In recent years, despite the continuous progress of ship technology and safety management systems, towing operations still face significant risks due to frequent extreme weather, variable operating sea environments, aging equipment, and human operational errors. Therefore, analyzing the potential risk factors in the towing operation of three purpose workboats and formulating scientific risk control strategies is of great significance for ensuring the safety of offshore operations and improving the industry's risk management level[1].

2. Characteristics of Three Purpose Workboats

The working characteristics of the three purpose workboat determine that it must have a special structural design to meet the requirements. Therefore, according to relevant regulations and operational needs, the characteristics of the three purpose workboat, especially the maneuvering characteristics, must meet the requirements of flexibility and stability. Due to the unpredictable changes in sea conditions, meteorology, and hydrology, the requirements for auxiliary objects in operations are also diverse. The maneuverability of a ship is not only related to whether it can successfully complete the required tasks, but also to the safety of the ship, platform, and personnel. The maneuverability and effectiveness of a three purpose workboat depend on many factors, including objective factors and supervisory factors. Objective factors include both internal and external factors. Internal factors mainly refer to the performance of the vessel and equipment itself, such as vehicles, rudders, anchors, cables, side thrusters, vessel shape, loading conditions, etc; External factors include meteorological and hydrological conditions[2], including wind, waves, surges, currents, visibility, etc. The determining factor for the maneuverability of a specific ship is the supervisory factor, namely the human factor, mainly referring to the captain's operational skills, psychological qualities, experience level, etc. Specifically, three purpose workboats generally have the following characteristics:

(1) The hull structure adopts a long bow ship design, with a spacious and flat deck, making it easy to load cargo such as drill pipes and bulk cement. The hull structure is sturdy, equipped with fenders and a double-layer bottom design to enhance anti sinking and stability. In terms of specialized equipment, the towing system is equipped with a high-power towing cable machine with a tensile force of up to 2000kN, and is also equipped with a tail drum and towing cable guide to ensure towing and anchoring efficiency. Deck machinery includes shark pliers, winches, and rope storage winches, some of which support remote control operation to improve safety. In addition, material handling systems such as bulk conveying systems and mud systems can achieve efficient material transportation.

(2) Low center of gravity, good stability, and small turning radius. Due to the variable pitch and lateral thrust of the three purpose workboats, their turning radius is relatively small.

(3) High horsepower. The power of the main engine is generally above 4500KW (6500HP), for dual vehicles. The main engine is usually a medium low speed model, and the propeller is controlled by variable pitch control (CPP).

(4) Dual rudder, equipped with separate/joint control system, usually equipped with a diffuser.

(5) The lateral thrust is generally greater than 5T, but it only becomes effective when the ship speed is below 3KT.

(6) The bridge is divided into front and rear driving, and can be operated independently in front and back, with a wide field of view, allowing for intuitive observation of the ship's dynamics and operations.

3. The emergence of navigation risks for three types of workboats

Navigation risk refers to all accidents caused by human factors, natural factors, or objective factors during the navigation, berthing, or anchoring of a ship at sea, resulting in damage to the ship or casualties of personnel. As a type of guard ship, the three purpose workboat mainly focuses on offshore oil engineering in offshore operations, and often relies on offshore oil platforms for patrol. Through observation and statistics, this article found that the common safety accidents near offshore oil platforms are mainly manifested as overtaking, poor visibility, sailing in rough seas, improper stowage, and fires caused by aging ship equipment. The towing operation of the three purpose workboat is shown in Figure 1:

Figure 1. Realistic picture of towing at sea

3.1 Grab over

At present, the number of crew members on China's three purpose workboats varies from 6 to 20 people depending on the size of the vessel. Through visits and conversations, it was found that although some crew members successfully passed the "Regulations on the Administration of Seafarer Training in the People's Republic of China" exam, they did not follow the navigation regulations in actual operation and lacked safety awareness. According to the "2022 China Seafarer Development Report" released by the Ministry of Transport, as of the end of 2022, there were over 1.716 million registered seafarers in China, including 808000 seafarers on ships, ranking among the top in the world. However, the overall professional and technical level, as well as comprehensive quality, of seafarers on Chinese ships varies greatly. For example, during the visit to several multi-purpose workboats, it was found that some crew members were still unable to meet the needs of national strategy and shipping development. For example, in terms of compliance with collision avoidance rules, this survey found that several crew members had resorted to overtaking the bow of other ships or forcibly crossing them in order to complete their tasks as soon as possible. And this kind of reckless overtaking behavior that ignores safety management greatly increases the risk and hidden dangers of the three use workboat [3-4].

3.2 Poor visibility

The adverse weather conditions, such as fog, haze, blizzards, sandstorms, etc., have reduced the visibility of the cockpit. At this time, some crew members engage in empirical behavior, thinking that they are familiar with the surrounding water conditions, but have not yet judged the dynamics of the surrounding ships, and have not followed collision avoidance rules. And this phenomenon will be detrimental to the safe navigation of three purpose workboats. This article only presents data based on the three types of workboat accidents that have occurred in Zhoushan in the past five years.

In recent years, there have been consecutive accidents and dangerous situations in the waters of Zhoushan, such as the sinking of three purpose workboats, cable breakage, and drifting out. The main reason for this is that Zhoushan is easily affected by typhoons, dense fog, thunderstorms, cold waves, and strong winds. Adverse weather conditions have a significant impact on offshore production operations, thereby exacerbating the risk of accidents and dangerous situations involving three purpose workboats. According to statistics, foggy and hazy weather is a high-risk period for ship collision accidents, which is more than five times higher than weather with good visibility. Therefore, as personnel working on multi-purpose workboats, it is necessary to strengthen safety awareness and avoid excessive empirical and reckless behavior, which may lead to risks in drilling operations[5].

3.3 Sailing in Storms and Waves

According to the Technical Regulations for Statutory Inspection of Domestic Ships, the wind resistance level of tugboats (also known as multi-purpose workboats) in Chinese ports is generally 6-7 levels. However, according to observations, the actual wind resistance level of some multi-purpose operation ships in China has not met the technical requirements, resulting in some multi-purpose operation ships finding it difficult to navigate in strong winds and waves during transportation, auxiliary operations, rescue, and other processes.

4. Avoid the risk of towing resistance

4.1 Management aspects

4.1.1 Improve management system

Without rules, there can be no square. If we want to improve the safety management level of the operation of the three purpose workboat, we must improve the management system. Based on the laws and regulations of our country, combined with the navigation area and types of work of the three purpose workboats, corresponding regulations and norms are formulated to provide standards for the operation of the three purpose workboats.

4.1.2 Standardize operational behavior

This study deeply analyzes the operation environment and operation content of the three-purpose operation vessel, and puts forward relevant safety management requirements and objectives. According to the difficulty and characteristics of the operation of the three-purpose operation ship, this study realizes the analysis of key problems, reforms and innovates related fields, chooses to standardize the operation behavior, and improves the efficiency and quality of safety management.

The operational behavior of safety management not only involves pre prevention and control, but also requires strict attention to the safety site. Offshore operations are the most important link in the entire safety management system. We should strengthen the supervision and monitoring of offshore operations, so that they are always in a dynamic management process[6].

4.2 Objective aspects

4.2.1 Increase capital investment and optimize hardware equipment level

With the development of science and technology in our country, more advanced equipment is being produced. In order to improve the safety management level of multi-purpose workboats, it is

necessary to ensure the quality of hardware equipment and the support of managers. By increasing total investment, optimizing hardware equipment level, updating and upgrading some hardware equipment, and improving the hardware strength level of multi-purpose workboats, basic conditions are provided for offshore operations.

4.2.2 Strengthen daily management and enhance the quality of maintenance and repair

This study strengthens the daily management of the three purpose work vessels, transfers the safety spot check work to the safety prevention work, focuses on the difficult operation process, difficult operation equipment and difficult management staff, improves the daily management level and does a good job in safety prevention. Regarding the maintenance and upkeep of hardware devices, it is important to keep records of their usage. Personnel who require the use of hardware devices must undergo additional training and pass assessments before they can use them, in order to avoid damage caused by human error. A dedicated maintenance department can be established, hiring relevant technical personnel to be responsible for the repair and maintenance of hardware equipment[7], extending the service life of hardware equipment, improving the efficiency of hardware equipment use, and laying a foundation for the operation of the three purpose workboat. The equipment maintenance requirements are shown in Table 1:

Table 1. Equipment Maintenance Requirements

Maintain category	Maintain the project	Maintain content	Maintenance Cycle
Dragging and anchoring system	1. Cable towing machine and winch	-Check the tension of the towing machine (22000kN) and the wear of the tail drum-Runluo winch bearings and transmission components	weekly
	2. Shark claws and guides	-Check the effectiveness of the quick release device-remove rust, apply anti rust lubricant	monthly
	3. Misalignment cabin and anchor machine	-Clean the cold mud in the anchor chain compartment-check the wear of the anchor brake pads and the sealing of the hydraulic system	every quarter
Power and propulsion system	4. Main propulsion diesel engine	-Check the crankcase oil level and cooling water circulation-replace the oil filter and fuel filter	monthly
	5. Dynamic Positioning System (DP)	-Testing DP system positioning accuracy and sensor calibration-checking hydraulic oil pipe sealing	every quarter
	6. Side push device	-Clean the spiral winding material-check the aging of bearing lubrication and sealing bacteria	semiyearly
Material supply equipment	7. Bulk material conveying system	-Check for leaks in the pneumatic transmission pipeline-clean up cement/drilling fluid residue	monthly
	8. Liquid cargo pumps and pipelines	-Test pump pressure and valve switch flexibility-replace aging sealing gasket	every quarter
Fire and rescue equipment	9. Fixed CO2 fire extinguishing system	-Leak Detection of Sound Pressure Gauge and Pipeline-Annual Gas Cylinder Weighing Inspection	Monthly/Annual Inspection
	10. Lifeboats and boat engines	-Start the boat engine and run it for 23 minutes every week-check the sealing of the lifeline and air bottle	Weekly/Monthly Inspection
	11. Life rafts and release devices	-Validity of Sound Detection Hydrostatic Pressure Release Device-Annual Inspection of Raft Water Tightness	Quarterly/Annual Inspection
Deck and hull structure	12. Deck anti-corrosion treatment	-Local rust removal and application of epoxy paint-inspect and publicize the wear of fender materials	every quarter
	13. Watertight doors and hatch covers	-Test the flexibility of opening and closing watertight doors-replace aging rubber seals	monthly
Pollution prevention equipment	14. Oil water separator	-15ppm alarm device function test-clean separator filter element and pipeline	monthly

4.3 Subjective aspects

4.3.1 Strengthen training and improve the overall quality of crew members

The main body of safety management is the crew, and the overall quality of the crew is closely related to the level of safety management. It is important to pay attention to the factors of the crew, strengthen their training, and establish rules for holding certificates to fundamentally improve their professional skills. In order to enhance the safety awareness of crew members, shipping companies need to strengthen safety education and training for crew members, using case studies and other forms of methods to strengthen their safety awareness. Emergency drills should be held regularly to train the crew's emergency ability.

4.3.2 Strengthen education and establish a sound safety system

It is not enough to only have a decentralized management and supervision system, but also to link up the relevant systems, establish and improve the safety system, and enhance the safety awareness of employees. In addition to relevant management systems, the safety system should also include talent incentive systems, linking the performance assessment of crew members with incentive systems and implementing practical and effective incentive measures.

5. Summary

Based on the above analysis, the risks of towing operations with three types of workboats mainly focus on cable breakage, collision grounding, and adverse weather conditions. To effectively control risks, it is necessary to strengthen the selection and inspection of towing cables, enhance the operational skills of crew members, accurately assess hydrological and meteorological conditions, and develop comprehensive emergency plans to ensure the safe and smooth progress of towing operations.

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