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Research on Prevention and Management of Seafarer Fatigue

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RESEARCH ON PREVENTION AND MANAGEMENT OF SEAFARER FATIGUE

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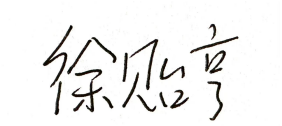
DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.



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Abstract

Title of Dissertation: **Research on Prevention and Management of Seafarer Fatigue**

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The phenomenon of seafarer fatigue has been acknowledged as a noteworthy element that contributes to maritime accidents. Despite the existence of protective measures such as the STCW Convention and the Maritime Labour Convention, ensuring compliance to regulations and enforcement remains an ongoing challenge in upholding the rights of seafarers to rest.

This dissertation reviews the existing limitations of the aforementioned regulations and puts forth recommendations for amending international conventions. Lists the dangers of fatigue for the human body. Analysis of the main causes of fatigue in seafarers. Proposal to exempt seafarers from the obligation to record work and rest hours. Introducing intelligent equipment to enhance the monitoring and management of seafarer fatigue. Explore the use of fatigue detection devices, and sleep monitoring devices on board ships, assessing their accuracy and applicability in the maritime industry.

Moreover, it is suggested that enhancing supervision through impartial third-party inspections, such as port state inspections and inspections conducted by major oil companies, could serve as an effective way to tackle the issue of seafarer fatigue. Proposals to establish a widely accepted set of criteria for determining fatigue levels and sleep. Introduce a fatigue clause into the ship's insurance contract.

Ultimately, the cultivation of a culture of awareness of fatigue and education. This includes emphasizing the significance of fatigue management within seafarer training and safety management systems. The implementation of comprehensive measures aimed at addressing seafarer fatigue is imperative to significantly enhance maritime safety.

KEYWORDS: Seafarer Fatigue, Maritime Safety, Fatigue Detection, Sleep Monitoring, Strengthening Supervision, Fatigue Awareness.

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LIST OF ABBREVIATIONS

AECS Average Eyelid Closing Speed

AIBN	Accident Investigation Board of Norway
AIS	Automatic Identification System
AMSA	Australian Maritime Safety Authority
DNV	Det Norske Veritas
EEG	Electroencephalography
FSC	Flag State Control
FSI	Focused inspection campaign
HRV	heart rate variability
ICS	International Chamber of Shipping
ILO	International Labor Organization
IMO	International Maritime Organization
ISM	International standard for the safe operation of ships and for pollution prevention
ISO	International Organization for Standardization
ITF	International Transport Workers' Federation
MAIB	Marine Accident Investigation Board
MLC	Maritime Labour Convention
NCBI	National Center for Biotechnology Information
NHTSA	National Highway Traffic Safety Administration
PERCLOS	Percentage of Eye Closure
PSC	Port State Control
PSCO	Port State Control Officer
PSG	Polysomnography
SMS	Safety Management System
STCW	International Convention on Standards of Training Certification and Watchkeeping for Seafarers
VDR	Voyage Data Recorder

VTS	Vessel Traffic Service
WHO	World Health Organization
WMU	World Maritime University

Chapter 1： Introduction

1.1 Background

Global trade is highly dependent on shipping, 90% of the freight volume in global trade needs to be transported by ships (IMO, 2009). Seafarers on these ships are key transportation workers, and their safety and well-being are essential for the healthy development of the shipping industry. Seafarer fatigue has been identified as one of the main causes of maritime accidents. The primary causes of seafarer fatigue are long working hours, harsh working condition, and mental stress. Seafarer fatigue poses a significant safety risk to the vessel, cargo, and environment. Seafarers have long suffered from fatigue.

The 24-hour operation of modern ships inevitably disrupts the circadian rhythms of seafarers, making them more susceptible to fatigue. Seafarers suffering from fatigue are no longer a secret in the maritime industry. For example, seafarer on container ships are often in a state of fatigue, and with their short time in port, fast loading and unloading, and frequent port calls, make them have no time to rest, let alone get enough sleep. In addition, a six-hour on-watch and six-hour off-watch regime is common in the shipping industry, leaving seafarers without adequate sleep.

Modern ship transportation tends to be more automated and intelligent, which also leads to fewer seafarers on board. With fewer seafarer on board, the amount of work on board increased at the same time, resulting in the seafarer continually having to

work overtime. So seafarer in the future are likely to be increasingly fatigued.

Seafarer fatigue impairs judgment, slows reaction times, and reduces the ability to concentrate, which can lead to accidents such as collisions, groundings, and oil spills. Seafarer fatigue can also cause a wide range of physical and psychological health problems, such as cardiovascular disease, diabetes, depression, anxiety, and sleep disorders.

Despite the fact that fatigue has a significant impact on seafarers and the maritime safety, the issue mostly remains unaddressed. Seafarers are a group that is vulnerable to social injustice and have few legal options to defend their rights. The main cause of seafarer fatigue is insufficient manning level on board ship (WMU,2020). The legislative predicament lies in the fact that the determination of the minimum safe manning level of ships is subject to the discretion of the flag state. The flag state will compromise with the shipowner to lower the manning level of the ship because of its interests, especially the flag of convenience state. In the fierce shipping market competition environment ship operators will endeavour to minimize the number of seafarers on ships in order to curtail operational expenses.

International Maritime Organization (IMO) and International Labor Organization (ILO) have made several attempts to establish an eight-hour working day for seafarers, the same as shore-based workers. However, these attempts have all ended in failure due to the fact that the flag state support by shipowners has consistently opposed these efforts.

This dissertation underscores the importance of investigating seafarer fatigue within the context of the maritime sector. Analyzes the causes and serious consequences of

seafarer fatigue and puts forward effective methods to try to solve the problem.

1.2 Meaning of research

To understand the root cause of seafarer fatigue and provide reference for the next step to propose solutions. The issue of seafarer fatigue poses a significant threat to the safety of the shipping industry. Seafarers are often subjected to extended work hours and inadequate rest, resulting in physical and psychological risks that compromise their performance and well-being. This study aims is to investigate the consequences of seafarer fatigue within the shipping industry. This will involve an examination of the physical and psychological risks associated with this phenomenon, as well as the susceptibility of seafarers to these hazards. Additionally, the potential threats to shipping safety and the infringement of seafarers' rights will be underscored.

The demanding work schedules and lack of rest experienced by seafarers contribute to chronic fatigue. This can result in increased physical and psychological risks, such as diminished vigilance, compromised judgement, and impaired cognitive abilities. Mental health concerns, including depression and anxiety, may also afflict seafarers, potentially resulting in enduring impacts on their holistic health. In certain instances, fatigue may result in maritime accidents and injuries.

The condition of fatigue has the potential to compromise the safe execution of responsibilities by seafarers, thereby increasing the likelihood of accidents and injuries occurring aboard vessels. A ship involved in a maritime accident can cause incalculable economic damage, loss of life, damage to the environment, lengthy legal disputes and damage to the reputation of the shipping company. Although seafarers

are known as key workers, in most cases their right to rest is seriously violated. Despite the existence of international conventions stipulating the minimum rest hours for seafarers, some shipowners are willing to violate the regulations and force seafarers to work long hours of overtime in order to pursue greater profits. This practice not only violates the basic right of seafarers to rest but is also detrimental to the healthy development of the shipping industry. Research on seafarer fatigue is essential to understand the underlying factors of seafarer fatigue and to develop effective measures to reduce its occurrence. Effectively reducing seafarer fatigue and avoiding seafarer fatigue on duty is a matter of maritime safety and the safety of seafarers, which can effectively contribute to the long and stable development of the maritime industry.

1.3 The internal relation between seafarers' fatigue and maritime accidents.

According to the IMO's 1995 review of maritime incidents that happened in the previous six months, the major cause of 16% of serious accidents and 33% of seafarer casualty accidents was seafarer fatigue. According to the 2006 IMO report, "fatigue" has been recognized as a significant contributing factor to accidents. The Exxon Valdez grounded on March 24, 1989, while sailing along Alaska's coast. The U.S. National Transportation Safety Board determined that the primary factor contributing to the accident was fatigue, the duty officer reportedly did not receive sufficient rest (Lutzhoft et al., 2007).

Based on a statistical analysis of maritime accidents, the main types of maritime accidents in a specific area of the Yangtze River from 2005 to 2010 were collisions, grounding, and self-sinks. These types of accidents accounted for 93.3 percent of the incidents, collision accidents constitute the majority (61.9%) of all accidents. In

addition, these accidents often occur at night and early in the morning, when the seafarer is more likely to be fatigued (Li et al., 2013).

In 1997, the German flag container ship "Cittas" ran aground in the English Channel, causing serious environmental pollution. An investigation into the accident found that the cause was a lack of adequate sleep by the officer on duty (Beyner, 2012). An inquiry into the MV Jambo accident off the coast of Scotland in 2003 found that fatigue among duty officers had led to reduced operational capability. The chief officer fell asleep while alone on the bridge, which ultimately led to a missed turn at a planned turning point (MAIB, 2004). The Antalya ran aground off the coast of Northern Ireland in 2008. An investigation found that the duty officer on duty fell asleep soon after taking over at midnight (MAIB, 2012). In 2008, the Panama flagged ship Crete Cement ran aground southeast of Aspond Island. The report of the accident investigation showed that fatigue was an essential factor leading to the accident (Maritime Accident Casebook, 2012). In 2010, the Chinese registered dry bulk carrier Shen Neng 1 ran aground in Douglas. An investigation into the accident revealed that the main cause of the accident was seafarer fatigue (Shen, 2012).

A Japanese study shows that the contribution rate of seafarer fatigue to ship grounding accidents and collision accidents is as high as 53% and 38%, respectively (DNV, 2012). According to a report released by the Marine Accident Investigation Branch (MAIB), seafarer fatigue was a factor in almost all accidents, and there was reason to believe the risk it posed was growing. Fatigue is a key factor in reducing avoid collision awareness, according to research carried out at Cardiff University (Smith, 2006). The seafarer fatigue factor accounted for 12% of the overall human factor, 15% of the critical human factor, 12% of the external human factor, and 14.1% of the internal human factor in ship collision accidents (Huang et al., 2006).

In 2004, the UK's MAIB reviewed data from 65 collisions and groundings investigated over the previous decade. The analysis showed that a third of the groundings took place at night with only one fatigued duty officer on duty. Two-thirds of all collisions occur due to a failure to maintain a proper lookout. The analysis led to one conclusion: fatigue among officers on duty was the main cause of most accidents, especially grounding incidents.

Muhammad and Ingrid (2015) conducted a study to compile 56 groundings and 98 collision/contact accidents from the MAIB in the UK (MAIB 2004). There were also 22 reports on maritime accidents from the Accident Investigation Board of Norway (AIBN). All of these accident investigation reports between 1999 and 2011 identified 33 fatigue-related accidents, including 16 collisions and 17 groundings. See Table 1 for more information.

Table 1

Fatigue-related maritime accidents

	Name of the vessel	Place of accident	Report	Year of the accident	Accident type
1	Pride of Canterbury	England	MAIB report nr 2/2009	2008	Grounding
2	Kivalina	Norway	AIBN report nr:9 205 885	2008	Grounding
3	Antari	Ireland	MAIB report nr 7/2009	2008	Grounding
4	Aqua -boy	Scotland	MAIB report nr 14/2007	2006	Grounding
5	Harvest Caroline	Scotland	MAIB report nr 13/2007	2006	Grounding
6	Kathrin	England	MAIB report nr 24/2006	2006	Grounding
7	Berit	Denmark	MAIB report nr 17/2006	2006	Grounding
8	Lerrix	Germany	MAIB report nr 14/2006	2005	Grounding
9	Jackie Moon	Scotland	MAIB report nr 5/2005	2004	Grounding
10	Jambo	Scotland	MAIB report nr 27/2003	2003	Grounding
11	Nedlloyd Mangellan	England	MAIB report nr 18/2002	2001	Grounding
12	Brothers	England	MAIB report nr 1/2007	2006	Grounding
13	Primrose	Scotland	MAIB report nr 13/2002	2001	Grounding
14	Resplendent	Shetland	MAIB report nr 10/2002	2001	Grounding
15	Lomur	Shetland	MAIB report nr 7/2002	2001	Grounding
16	Betty James	Scotland	MAIB report nr 34/2002	2000	Grounding
17	Choise	England	MAIB report nr 33/2002	2001	Grounding
1	Boxford	England	MAIB report nr 17/2011	2011	Collision
2	Skagern	England	MAIB report nr 6/2007	2006	Collision
3	Samskip Courier	England	MAIB report nr 6/2007	2006	Collision
4	Maritime Lady	Germany	MAIB report nr 2/2007	2005	Collision
5	Lykes Voyager	Hong Kong	MAIB report nr 4/2006	2005	Collision
6	Orade	England	MAIB report nr 23/2005	2005	Collision
7	Hyundai Dominion	China	MAIB report nr 17/2005	2004	Collision
8	Sky Hope	China	MAIB report nr 17/2005	2004	Collision
9	Dorthe Dalsoe	Sweden	MAIB report nr 10/2005	2004	Collision
10	Saint Jacques II	Germany	MAIB report nr 5/2002	2002	Collision
15	Celtic King	Wales	MAIB report nr 2/2001	2001	Collision
11	Atlantic Marmaid	Germany	MAIB report nr 12/2002	2001	Collision
12	Highland Pioneer	England	MAIB report nr 15/2001	2001	Collision
13	De Bounty	Wales	MAIB report nr 2/2001	2000	Collision
14	Bruce Stone	England	MAIB report nr 31/2001	2000	Collision
16	Dole America	England	MAIB report nr 32/2000	1999	Collision

Note. From Marine Accident Investigation Branch. Website:www.maib.gov.uk

AIBN: Accident Investigation Board Norway. Website: www.aibn.no

1.4 The current state of seafarer fatigue

The World Maritime University (WMU) has conducted a research on the record of seafarers' work and rest hours. The study collected a wide range of opinions from seafarers, port state control (PSC) officers, ship owners, and others by conducting 71

interviews with 81 participants. The analysis showed that undermanned ships were the root of seafarers' fatigue and falsified work and rest hours records. The special operation of the ship, the loading and unloading during the port, and the various inspections of the ship will make the already tired seafarer even more tired. In interviews, participants heavily criticized existing rules on seafarers' hours of work and rest. The convention's requirement that seafarers record their hours of work and rest proved to be pointless paperwork in an effort to prevent fatigue among seafarers. Seafarers who were asked to record their hours of work and rest were more fatigued than those who were not.

The research found a "culture of adjustment" onboard ships. The shipping company forced seafarers to amend their hours of work and rest records to meet the convention's requirements. Most companies do not pay attention to awareness of seafarer fatigue and ignore feedback from seafarers. Surveys and audits by flag states are reluctant to verify the authenticity of seafarers' work and rest hours records. With limited time and human resources, it is difficult for PSC inspectors to detect irregularities in the recording of work and rest hours. While all stakeholders are aware of the widespread practice of falsifying records of seafarer's work and rest hours, there is currently no solution to address such a problem (WMU, 2020).

Zhao et al. (2020), who conducted a study of 880 questionnaires and 60 interviews among seafarers and managers of Chinese and European shipping companies, found that seafarers from Chinese shipping companies were more fatigued. Wadsworth et al. (2006) conducted a survey of more than 1,800 professional seafarers, of whom 25 percent reported feeling tired or falling asleep at work.

One in four on-duty officers admits to dozing off during the watch, according to a

Cardiff University survey. Seafarers on short routes with frequent port calls are more fatigued than those on longer routes. Seafarers working on the Mini-bulkers were more fatigued than those working on other ships due to frequent port calls, short port stay times, frequent changes of cargo, six-hour on and six-hour off watch regimes, and lengthy pilotage (Smith, 2006). See Table 2 and Table 3.

Table 2

Perceived fatigue and symptoms of fatigue reported by the mini-bulker crew and the crews of the other ships

	MINI-BULKER	OTHER SHIPS
PFRS Fatigue	44.2 (5.6)	24.5 (10.8)
Symptoms of fatigue	3.96 (0.87)	2.63 (0.68)

Note. Source: Smith, A., Allen, P., and Wadsworth, E. (2006). Seafarer fatigue: The Cardiff research programme. Cardiff, UK: Centre for Occupational and Health Psychology, Cardiff University. (Scores are the means. s.d.s in parentheses. High scores = greater fatigue)

Table 3

Performance scores for the mini-bulker crew and the crews of the other ships

	MINI-BULKER				OTHER SHIPS			
	Day 1		Day 7		Day 1		Day 7	
	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work
Simple RT (msec)	385 (70	361 (54)	426 (51)	411 (55)	336 (61)	331 (98)	339 (132)	335 (114)
Lapses of attention (categoric search task)	18.7 (6.7)	12.3 (7.4)	20.2 (6.5)	14.3 (5.3)	5.5 (22.1)	4.6 (15.3)	3.9 (22.6)	2.7 (15.9)

Note. Source: Smith, A., Allen, P., and Wadsworth, E. (2006). Seafarer fatigue: The Cardiff research programme. Cardiff, UK: Centre for Occupational and Health Psychology, Cardiff University. (Scores are the means; s.d.s in parentheses. msec=millisecond. RT=reaction times. High scores = poor performance)

Gander (2005) conducted a study of seafarers' fatigue on inter-island ferries in New Zealand and found that 61% of seafarers were affected by fatigue while on duty. In the past six months, 26 % of ferries had incidents or accidents related to seafarer fatigue, the analysis showed. Seafarers' fatigue has become as common in the shipping industry as the falsification of seafarers' work and rest hours records.

According to research published in recent years by the British Maritime Accident Investigation Branch into the safety of bridge lookouts, there has been a rise in the number of bridge lookouts dozing off on container liners, bulk carriers, oil tankers and liquefied natural gas ships in the UK's ocean, offshore and coastal routes. The reason for this is that seafarers do not get enough sleep for extended periods, or even

get sick from overwork, so they cannot stay awake on duty. Every indication is that the fatigue of the seafarer on duty during the voyage is getting worse. The above research did not include seafarers who were reluctant to admit or deliberately hide their experiences of fatigue due to "can do culture" or fear of ridicule or other reasons. Some seafarers were also reluctant to reveal their true thoughts about fatigue during the survey. These surveys of seafarer fatigue may only be the tip of the iceberg.

1.5 Research Methodology

1.5.1 Literature research

Literature research, also known as literature review, is the critical and systematic analysis of existing literature or academic research on a particular topic. It involves gathering, analyzing, and synthesizing information from a variety of academic sources, such as journal articles, books, conference papers, and other relevant materials. The primary purpose of literature research is to identify and evaluate the current state of knowledge on a particular topic, to identify research gaps, and to make recommendations for future research.

1.5.2 Case Study Method

Case study method refers to the research method of investigation and in-depth analysis of individual cases, which is used to solve relevant problems. Case study is aimed at "individual" research. In the process of research, there are more or less differences between the individual and the whole, which will show particularity. Case studies require more in-depth study content because basic facts and past events

pertaining to particular cases must be tracked. In this instance, the research data will be increasingly thorough as time goes on and the case is studied in greater and greater detail. In the analysis stage, it is important to perform a comprehensive study of the documents, information, data, and other materials that have been acquired, summarize them and compare the link between various influencing elements. Based on the study of these data, draw a conclusion.

1.5.3 Comparative research method

Comparative research is a method for learning about and evaluating how similar or different two things or persons are. It allows for the comparison of different research subjects in order to gain insight into the nature of the problem. The comparative research method is an empirical research method because it not only allows two or more research subjects to be compared, but also allows empirical data to be used to validate research findings. Comparative analysis allows researchers to observe trends and connections that may not be obvious when looking at individual examples in isolation.

Chapter 2 Discussion

2.1 The definition of seafarer fatigue

IMO define “fatigue” is a condition of physical or psychological debilitation that arises due to various factors such as lack of sleep, prolonged periods of wakefulness, work and rest schedules that are not synchronized with the body's natural circadian rhythms, and physical, psychological, or emotional stress that can hinder the ability to maintain vigilance and carry out safety-related tasks while operating a vessel (IMO, 2019).

Fatigue is a complex physiological phenomenon, which is caused by overwork and mental exertion. Fatigue can cause cognitive impairment, poor concentration, slow response, and muscle relaxation (Yang, 2017). Fatigue is associated with a wide range of symptoms, including but not limited to anxiety, impaired short-term memory, diminished reflexes, decreased productivity, reduced motivation, lowered vigilance, reduce work performance, heightened work errors, and difficulty concentrating or delaying action in stressful circumstances.

2.2 Classification of fatigue

Fatigue can be categorized into two distinct types: acute and chronic, depending on when it appears. Acute fatigue is commonly experienced shortly after engaging in

work-related activities and can be mitigated through adequate daily rest. Chronic fatigue syndrome is a medical condition that manifests gradually over a prolonged period of time and often requires extended periods of rest or even a vacation to recover.

Another category divides fatigue into general fatigue and excessive fatigue, based on the level of exhaustion. The aforementioned phenomenon pertains to the customary physiological response of the human body to a specific workload. The latter type of fatigue exceeds the standard limits of the human organism and does not usually dissipate completely during rest. The occurrence of residual fatigue during the initiation of a fresh work cycle presents a noteworthy hazard to occupational safety. Even though fatigue is characterized by high incidence and prevalence of diseases, it is still ignored from the perspective of clinical practice and research (Shen et al., 2006).

The phenomenon of fatigue can be classified into three distinct types depending on the root cause: physiological fatigue, mental fatigue, and pathological fatigue. The state of physical fatigue is a result of the demands placed on the body through manual labour. Mental exhaustion, excessive cognitive demands, and high emotions all lead to mental fatigue. Pathological fatigue is a type of fatigue that emerges due to an underlying medical ailment. The boundaries between the various types of fatigue mentioned above are not distinctly defined due to the possibility of ongoing accumulation and interdependence. As the accumulation of fatigue continues, the process of fatigue may involve a transition from one stage to another.

2.3 The effect of fatigue on physical health

Fatigue will seriously affect the physical health of the human body, fatigue will make people's strength and endurance decline, thus affecting the seafarers to carry out duty effectively. Accidents and injuries are higher in high-risk industries, such as construction, mining, and transportation (Wickens et al., 2015). Seafaring is one such high-risk industry.

2.3.1 The effect of fatigue on the human nervous system

Fatigue can damage the nervous system by reducing blood supply to the brain, resulting in a lack of oxygen. This phenomenon is called "brain fatigue" and is accompanied by headaches, dizziness, memory loss, and inability to concentrate. These symptoms can interfere with sleep quality and can lead to problems such as insomnia, daydreaming and night terrors. When this goes on for a while, it can trigger a vicious cycle. This claim is supported by numerous scientific studies and tests in the fields of cognitive neuroscience and neurophysiology. Sleep deprivation may have deleterious effects on cognitive processes, including working memory and attention, which are controlled by the brain's prefrontal cortex (Lim et al., 2008). In addition, studies have shown that lack of sleep may negatively affect the motor system. Fatigued people make more mistakes and have slower reaction times when performing motor tasks (Thomas et al., 2000). Fatigue increases impulsivity and risky behaviour, research suggests that decision-making may also be affected (Killgore et al., 2006; Harrison et al., 2000).

2.3.2 The effect of fatigue on the human immune system

Fatigue can adversely affect the normal functioning of the immune system and lead to a decrease in immune function. A large increase in disease susceptibility occurs as

a result of impaired immune function, which reduces the body's capacity to fight off illnesses, weakens the body's natural defence against disease, and opening the way for disease to invade. Besedovsky et al. (2012) found that a continuous, protracted loss of sleep might negatively affect the immune system, making a person more susceptible to infections and other health problems. Even just one night of sleep deprivation can lead to a 70 percent decrease in the vital component of natural killer cells, such immune deficiency that increases the risk of various cancers, including bowel, prostate, and breast cancer (Walker, 2019). Chronic fatigue may lead to a weakened immune system, increasing a person's vulnerability to a number of illnesses like cancer, diabetes, and heart disease (Vgontzas et al., 2004).

2.3.3 The effect of fatigue on the human digestive system

Long-term fatigue in seafarers can result in gastrointestinal blood stasis, weakened peristalsis, and poor performance because it affects the neurological and cardiovascular systems. Reduced hunger, cause gastrointestinal discomfort, decreased appetite, irritability, and nausea are some of the symptoms. Ali et al. (2013) claim that their research shows a connection between sleep deprivation and gastrointestinal diseases and offers proof that this connection is a cause of intestinal disorders.

2.3.4 The effect of fatigue on the human circulatory system

Mullington et al. (2009) conducted a study to look into the effects of sleep deprivation on cardiovascular disease. Studies have shown that lack of sleep on the circulatory system of the body is mainly reflected in the rapid heartbeat, high blood pressure, thereby increasing the risk of heart disease. Lack of sleep can have adverse

effects on the cardiovascular system and increase the risk of heart disease (Walker, 2019). The state of fatigue can result in various physiological alterations in the cardiovascular system, such as diminished activity, sluggish blood flow, and stagnation of blood. Individuals who consistently experience a nightly sleep duration of 5 hours or less should be considered a population at increased risk for cardiovascular morbidity and mortality (Cappuccio et al., 2011).

2.3.5 The effect of fatigue on the human reproductive system

Studies have suggested possible associations between chronic fatigue or stress and effects on the reproductive system in humans. Chronic fatigue and stress can lead to premature ovarian failure in women, negatively affecting fertility (Pal & Santoro, 2002). Research has demonstrated that psychological stress, such as chronic fatigue, may have an impact on semen quality and, consequently, male fertility (Fenster et al., 1997). Sleep disturbances resulting in fatigue can heighten the likelihood of depression and potentially impact reproductive health in an indirect manner (Kalmbach et al., 2017).

Chronic fatigue may result in an atypical operation of the reproductive system. In males, the majority of symptoms include spermatorrhea, impotence, premature ejaculation, and loss of libido. The manifestation of symptoms such as waist soreness, soft legs, dizziness, tinnitus, insomnia, dreaminess, and memory decline may co-occur. In the case of female individuals, prevalent symptoms include irregular menstrual cycles (such as early or delayed onset, prolonged duration, excessive or insufficient bleeding, etc.), diminished sexual desire, and if left untreated, the possibility of infertility or sterility. Chronic sleep deprivation can lead to smaller testicles in men and testosterone levels similar to those of someone 10 years older, as

well as negative effects on women's reproductive health (Walker, 2019).

2.3.6 The effect of fatigue on the human sensory system

Fatigue is a complex phenomenon that affects various physiological systems in the human body, resulting in impaired functioning. The nervous and endocrine systems are particularly susceptible to alterations, which can subsequently lead to sensory abnormalities. Regarding abnormalities in the visual organs, primary symptoms include ocular discomfort, dryness, decreased acuity, photophobia, and asthenopia, among others. In the realm of auditory organ irregularities, the primary symptoms are typically exhibited as tinnitus and hearing impairment, leading to challenges with both auditory and visual perception. In the event that the officer of the watch experiences fatigue during their assigned duty, the initial response and sensation may manifest as ocular discomfort, followed by the emergence of symptoms such as ocular inflammation, accompanied by yawning, sluggish eyelid closure, and nodding of the head. Yoo et al. (2007) suggest that fatigue leads to reduced activity in the thalamus, an important part of the brain responsible for processing sensory information and controlling arousal.

2.4 The effect of fatigue on Mental Health

Fatigue is a prevalent phenomenon that can cause a considerable influence on an individual's mental well-being. Dinges et al. (1997) conducted a study in which 48 participants in good health were asked to sleep only 4-5 hours per night for one week. The participants were assessed daily on their sleepiness, emotional status and cognitive ability. The study showed that prolonged sleep deprivation led to a gradual increase in sleepiness and fatigue over the week, accompanied by a decrease in

positive emotions and an increase in negative emotions. The results of the study showed a significant decrease in cognitive function, which was reflected in the subjects' slower reaction times.

In general, the research underscores the adverse effects of long-time lack of sleep on psychological well-being, such as heightened exhaustion, unfavourable effect, and cognitive dysfunction. The aforementioned discoveries hold a impact on individuals who may experience persistent sleep insufficiency as well as on public health regulations concerning sleep and psychological well-being.

Moreover, fatigue can cause a substantial influence on cognitive performance, encompassing memory, attention, and concentration. Fatigue may have a negative effect on cognitive function and cause slower reaction times, decreased accuracy, and difficulties with complex tasks. These cognitive effects can cause a substantial influence on an individual's mental well-being, resulting in reduced productivity in academic or occupational settings as well as a diminished standard of living (Belenky et al., 2003; Thomas et al., 2017).

The impact of fatigue on mental health is substantial and diverse, impacting various aspects such as brain functionality, emotional state, behavior, and cognition. The aforementioned effects carry significant implications for the prevention and treatment of mental health disorders, underscoring the criticality of incorporating fatigue management as a fundamental component of a holistic mental healthcare strategy. Extensive documentation exists regarding the persistent and incapacitating impact of fatigue on human mental health. Fatigue can have a significant impact on mental health, leading to negative effects such as mood disturbances, cognitive impairment, and decreased quality of life.

2.5 Key Factors Contributing to Seafarer Fatigue

2.5.1 Long Working Hours

The workload of seafarers constitutes a notable contributor to their levels of fatigue. The non-stop operation mode of the ship itself determines that seafarers need to be on duty 24 hours a day. In addition, sailing across time zones will inevitably lead to irregular working and rest hours for seafarers, and they need to be on night duty for a long time and take turns on duty. Such a working mode will disturb the biological clock and disrupt the sleep-wake cycle. When the circadian rhythm is disrupted, it can lead to sleep deprivation and chronic fatigue (Akerstedt, 1995). It is difficult to change the existing ship operation mode due to, economic pressure, and resistance from shipowners who may prefer to maintain the current situations (Smith et al., 2006). Maritime workers often participate in prolonged and unforeseeable work schedules. Allen et al. (2008) conduct a research shows that a significant percentage of seafarers, specifically 45%, engage in work for more than 85 hours per week, which exceeds the typical workweek duration in other professions. Additionally, the study found that 37% of seafarers experience less than 6 hours of sleep per night.

The ILO and the IMO have tried several times to introduce an eight-hour working day in shipping, but all have failed because of opposition from flag states supported by shipowners. It took several rounds of negotiation and compromise to reach the current maximum 14-hour working day (Baumler, 2020). Even though international conventions permit seafarers to engage in labour for a maximum of 14 hours per day, a threshold that surpasses the typical 8 hour workday for onshore personnel, it is very often for seafarers to exceed this limit. The IMO has established regulations

regarding working hours; however, these may not always be implemented in practical situations. As a result, the seafarer have to accept work shifts that could last for multiple weeks without sufficient time for rest.

With the rapid development of science and technology, a diverse range of state of the art instruments and equipment have been applied on ships, thereby altering the daily work routine of seafarers. One opinion suggests that seafarers have experienced a reduction in physically demanding tasks while the efficiency of ship operations has concurrently accelerated. However, the prevalence of advanced technology has led to a significant rise in cognitive labour, resulting in increasingly weighty mental work. The proliferation of paperwork and associated administrative tasks contributes to the already onerous workload of seafarers. The magnitude of the seafarer's workload varies intermittently. As the vessel's manning levels decrease, there are few substitutes for every seafarer's job, resulting in the actual workload on board exceeding the capacity of the seafarers on board. The customary schedule for duty officers involves alternating four-hour work with eight-hour rest, followed by a repetition of the same pattern. Nonetheless, this particular system has the potential to result in insufficient sleep, specifically in terms of deep sleep, thereby inducing fatigue and impeding the seafarer's ability to recuperate from fatigue.

The most tiring time for seafarers is when the ship is in port, especially on short-sea voyages, which has the potential to disturb typical sleep and work routines, resulting in fatigue (Ahsberg, Kecklund, Åkerstedt, & Gamberale, 2000). The implementation of a 6-hour on and 6-hour off watch system during a ship's stay in port is a significant contributor to seafarer fatigue. The deck crew is engaged in the tasks of loading and unloading cargo as well as performing ballast operations. The engine department ought to utilize the available time to perform maintenance tasks that are

not feasible to undertake while the vessel is at sea. Ships now face more and more inspections of all kinds. Furthermore, the vessel must also engage in the processes of bunkering, purchasing provision and receiving spare parts, among other tasks. These activities can result in prolonged periods of overwork, leading to severe fatigue among the seafarers. Ships operating at an accelerated pace has resulted in increasing the workload of seafarers. In addition to their regular duties, seafarers often encounter additional work during their stay in port, these can make seafarers more fatigued. A study was conducted by Lutzhoft et al. (2010) to investigate the status of work and rest on 13 ships. The study involved two groups of 15 participants each, with one group performing a 6-on, 6-off watch regime and the other group performing a 4-on, 8-off watch regime. The investigation employed a range of objective and subjective measures, including EEG (electroencephalography) to monitor electrical brain activity, actigraphy to track physical movement, diaries to record self-reported data, and reaction time tests to assess the impact of shift work on fatigue and sleep. The findings indicated that seafarers who adhered to a 6-on, 6-off shift schedule experienced greater fatigue during nighttime hours and exhibited a more rapid deterioration in their level of fatigue compared to their counterparts who followed a 4-on, 8-off work pattern.

It is worth noting that seafarers are required to perform several jobs while working on board. Seafarers are required to possess a diverse skill set encompassing various responsibilities such as navigation, maintenance, loading, unloading, and cargo hold cleaning. Compared to work on land, the workload of seafarers is enormous and the responsibilities are daunting, which leads to seafarers generally being more fatigued than workers ashore.

2.5.2 Mental stress

The harsh conditions at sea and the small living space of seafarers during their work on board often put them in a state of nervousness. The stress and anxieties experienced by the seafarer are a significant contributing factor to their overall fatigue. Concerns about ship safety, interpersonal tensions and being away from family and friends are the main causes of stress in seafarers' minds.

Brooks and Greenberg's study is a systematic review whose goal was to find the most recent literature on variables that affect the mental health and well-being of seafarers (Brooks & Greenberg, 2022). The study revealed that seafarers encounter diverse stressors that can have detrimental effects on their psychological well-being. When exposed to intense psychological stress, the body begins to release cortisol, a hormone that promotes physiological responses to confront or escape stressors. Over time, long-term exposure to cortisol can lead to exhaustion and burnout syndrome, which can adversely affect the mental health of seafarers. All kinds of pressure in the special maritime working environment and the psychological influence of navigation will lead to seafarer fatigue.

2.5.3 Working environment

The working environment of seafarers is one of the main causes of seafarers' fatigue. The closed and small living quarters limit the movement of seafarers and are even nicknamed the "prison at sea." Ship's rolling, yawing, and pitching often keep seafarers awake, even through the night. Seafarers worked overtime almost every day, and dangerous working conditions make them more prone to fatigue. Ships often travel across time zones, so seafarers need to constantly adjust their body clocks to the new time zone, making them more prone to fatigue. The life of a seafarer on a

ship is monotonous, tedious, and lack of entertainment. Seafarers work and live on ships and spend most of time there. Seafarers have no days off or holidays during their time on the ship, which leaves them no time to relax. Separation from family and friends will cause homesickness for seafarers, which can cause anxiety and stress and interfere with sleep, and lack of sleep can lead to fatigue.

The high temperature, loudly noise and bad smell of oil in the engine room are all important factors affecting seafarers' sleep. High temperatures increase the metabolic demands of the human body. In order to cool down, the body automatically increases the secretion of sweat and blood flow. This process consumes more energy and leads to increased fatigue. During the voyage, the vibration caused by the running of the ship's engine and other machines will lead to the sleep interruption of seafarer and affect their sleep quality (Jepen et al., 2015).

The study conducted by Cui et al. (2022) explore the correlation between marine engine noise and seafarer sleep quality. Study shows that noise is considered a significant contributor to seafarer fatigue. During the voyage and berthing times, data was gathered from a 28-day onboard experiment as well as a questionnaire survey. The research indicates that seafarers express a desire to extend their sleep duration as a means of mitigating the negative effects of loudly engine noise, which can lead to high levels of anxiety and irritability. This tendency towards long rest manifests itself in increased time spent in bed and overall sleep time. The increase in volume and frequency of main engine noise will increase the waking time during sleep, and the time to sleep will also increase correspondingly, resulting in decreased sleep efficiency. There was a significant correlation between the noise energy of the engine and the sleep parameters of the seafarers.

Rapid seasonal changes, such as sailing from low latitudes to high latitudes, sometimes seafarers have to experience the change of four seasons in just a few days. Drastic changes in the weather will make it difficult for seafarers to adapt to them, affecting sleep which will lead to fatigue.

Chapter 3 Analyse the major issues with addressing seafarer fatigue.

3.1 Legislation on the working hours of seafarers

The following international instruments regulate Seafarer fatigue-related requirements.

Maritime Labour Convention (MLC) 2006
Regulation 2.3 Hours of Work and Rest
Regulation 2.4 Entitlement to leave
Regulation 2.7 Manning levels
Regulation 3.1 Accommodation and recreational facilities
Regulation 3.2 Food and Catering

International Convention on Standards of Training Certification and Watchkeeping for Seafarers (STCW)
Regulation VIII/1 (Fitness for duty)
Regulation VIII/2 (Watchkeeping arrangements and principles observed)

International Safety Management (ISM) Code
Section 1.4 - Safety management system requirements.

Principles of minimum safe manning (resolution A.1047(27))

Fatigue factors in manning and safety (resolution A.772(18))
Guidelines on Fatigue (MSC.1/Circ. 1598)

According to the aforementioned international instrument, seafarers may be required to work 14 hours a day, but, in practice, it seems like14 hours a day has become the minimum requirement for seafarers. This is much higher than the standard of 8 hours for work, 8 hours for sleep, and 8 hours for entertainment established by the International Labour Organization (ILO) in 1919.

The idea of an 8-hour workday has a long history and is the result of various social and political movements. One of the most famous advocates for the 8-hour workday was the American labor activist and socialist, Eugene V. Debs. He campaigned for the reduction of the working day to eight hours during the late 19th and early 20th centuries. Debs argued that working more than eight hours a day was detrimental to workers' health and personal lives and that an 8-hour workday would increase productivity and benefit both workers and employers.

Over the years, the ILO has repeatedly proposed to implement a maximum eight-hour working day system in the shipping industry. However, the proposal failed when the flag states supported by shipowners opposed it. It has been proved that the existing rules of work and rest hours are not based on scientific research but by shipowners' requirements. The right to determine the manning level of the ship belongs to the Flag State. The international maritime convention's entry into force takes two conditions, one is the minimum number of countries, and the other is the minimum tonnage. For their interests, some countries with significant tonnage willfully abuse their power and prevent the 8-hour working system from taking effect in the maritime field, regardless of seafarers' human rights (Raphael, 2020).

It sounds ironic that seafarers are required to work longer hours than workers on shore, even though they have a heavier workload, harsher working conditions, and greater psychological stress.

3.2 Regulatory challenges

Compliance with and enforcement of current regulations remain a critical issue. The Maritime Labour Convention (MLC 2006) stipulates rest hours for seafarers, but the reality is that these regulations are often violated due to various factors, including operational demands and insufficient manning level (Houtman, 2005).

Due to the unique way of ship operation, particularly the ocean-going ships sail in the different territorial seas and high seas. It is difficult to supervise, verify, and oversee ships effectively. According to interviews with ship owners, they claim that they often feel overwhelmed. The problem of crew fatigue is not all caused by the workload on the ship, and the crew's time outside of work is no longer under their control. seafarers may be tired from playing computer games, scrolling through phones, watching TV series, or doing other things in their cabins.

Ship safety supervision means such as Port State Control (PSC), flag state Control (FSC), major oil company inspection, and so on, these supervision can only be carried out during the ship in port. There is very limited safety supervision of ships while ships are at sea. As a result, the inspection of the seafarers' work and rest hours records can only focus on the paperwork. Usually, the seafarer's work and rest hours are recorded using computer software, then printed out and signed for confirmation. The software comes with a violation alert function that makes it easy to modify

records. Moreover, during port state inspection, the seafarer's work and rest hours records are not a priority item for inspection. Due to time constraints, they cannot or don't want to verify the authenticity of the records. Even when inspectors question, seafarers would just lie for various reasons to avoid further trouble. This is mainly because seafarers fear ship companies more than they fear inspectors.

It is written in the STCW convention that the master of the ship has the right to deviate from regulation in special circumstances. Therefore even when the inspector found some violation in work and rest hour records, it can explain by this "special circumstance" (WMU, 2020).

Inspectors don't have the knowledge, ability, or equipment to identify fatigue levels. When inspectors find noncompliance records, those violations usually occur in the past, making it difficult to obtain evidence. Even if there is evidence, it's hard for inspectors to use that evidence to take further steps. A review of port state inspection reports found that few ships were detained or punished for falsifying seafarers' work and rest hours records. Port State Control Officers (PSCO) are also under a lot of pressure when carry out inspections, multiple work tasks should be complete within limited time.

3.3 Insufficient Manning Level

Shipping companies mostly operate ships with the minimum manning level in order to reduce operational costs. This can lead to increased workloads and longer working hours for seafarers, which can lead to fatigue (Alderton et al., 2004). Flags of convenience became popular from the 1950s onwards, and such registrations allow shipowners can employ fewer seafarers due to the less stringent labour regulations

and oversight in these registries. This practice creates an economic effect named “bad money drives out good money” that has led other shipowners also to reduce their manning level in order to remain competitive. As a result, there is now a widespread trend of under-staffing vessels, which has become a major challenge in addressing seafarer fatigue. Despite efforts to standardize the manning level on a global scale, for instance, the International Labour Organization's Convention No. 180, there is a lack of universal implementation and enforcement of such regulations (ILO, 1996). Consequently, shipping enterprises frequently running the ship with the minimum manning level that are permitted by the respective flag states.

With the development of science and technology, such as automation and computerization, have increased ship efficiency and reduced the need for seafarers (BIMCO/ICS, 2016). However, while technology has replaced some manual tasks, the remaining seafarer still has to manage, oversee, and maintain these equipment, often leading to increased workload and stress (Hetherington, Flin, & Mearns, 2006).

Starting in the 1980s, the global maritime industry underwent significant changes due to globalization and increased competition (Lamb, 2019). Faced with a brutal competitive environment, shipowners are more likely to reduce the manning levels of their vessels in the pursuit of greater profit, which is also a major source of fatigue among seafarers. (Alderton et al., 2004). In addition, with fewer seafarers on board, the ability to carry out proper maintenance and repairs is reduced, leading to more breakdowns and longer working hours for the remaining crew.

The issue of insufficient manning level has become particularly acute in the context of increasing automation on ships. While automation can reduce the workload for some seafarers, it also means that fewer people on board are are able to respond to

emergencies or carry out repairs manually.

It has been proved that the flag state has not taken into account the IMO Resolution A.1047(27) for establishing minimum safe manning of ships. In the increasingly cruel and fierce competition in the shipping industry, the flag state will compromise with the shipowner in the manning level of ships for the sake of interests. Ship registration has changed from a public registration service to a money-making tool for some flag States. Shipowners are unscrupulously reducing the manning level of ships lead the workload on the ship more than the seafarers could handle (WMU, 2020). Hence, it is not easy to increase the manning of ships from a legislative point of view in order to reduce the workload of seafarers.

3.4 Lack of Awareness and Training

There is often a lack of awareness about the dangers of fatigue among seafarers and shipping companies. Fatigue is a complicated phenomenon that arises from a variety of underlying factors and has numerous consequences. Various factors, including long work hours, poor sleep quality, severe stress, and health issues. Seafarers and shipping companies may have an incomplete understanding of the variables that contribute to fatigue. Shipping companies and seafarers often think that fatigue is something that can be overcome through willpower, and are not fully aware of the harm and serious consequences of fatigue (Lützhöft, Dahlgren, Kircher, Thorslund, & Gillberg, 2010). The potential impact of fatigue on safety and performance is often underestimated by seafarers and maritime organization. Some seafarers may consider their experience of fatigue a badge of honor. Seafarer fatigue management and related guidelines are not integrated into seafarer education systems. Seafarers' training did not content the basic knowledge of fatigue, the hazards of fatigue,

fatigue management, ways to reduce fatigue, sleep knowledge, time management, stress management, and so on (Cartenuto et al., 2012). Some shipping companies see long working hours and fatigue as part of the job and part of the corporate culture. Such an atmosphere is not conducive to seafarers' true expression of their fatigue conditions, nor is it conducive to managers taking effective measures to deal with fatigue (Sampson & Thomas, 2003).

3.5 Lack of uniform criteria for determining fatigue level

One of the primary challenges in studying fatigue is the absence of a universally accepted definition of fatigue, which poses difficulties in accurately assessing its effects on the performance and overall health of the seafarer. In contrast to other health issue that have distinct biological indicators, fatigue is a subjective phenomenon that depends on a wide range of physical, psychological, and environmental factors. Stakeholders such as shipowners, seafarers, flag States, ship insurers and port states disagree on criteria for the definition and assessment of fatigue.Inconsistencies in reporting and addressing fatigue may arise across various ships and companies, as well as different regions and countries. Moreover, researchers cannot conduct data analysis and research on seafarers' fatigue. This hinders the development of preventive measures and research on seafarers' fatigue, which indirectly affects shipping safety

3.6 lack of uniform criteria for determining sleep

The sleep process is a complex physiological phenomenon, and there is still no consensus on the precise parameters that define adequate sleep. The definition of sleep will vary depending on the emphasis. Some definitions of sleep may emphasize

the amount of sleep, some the quality of sleep, and some the restorative effects of sleep. The absence of a universally accepted definition of sleep poses a significant obstacle to the quantification and comparison of sleep across diverse groups or populations (Buysse, 2014).

Various techniques are employed for evaluating sleep, including self-reported measures (sleep diaries), actigraphy (wearable devices that monitor movement), and polysomnography (a comprehensive diagnostic tool that captures brain waves, blood oxygen levels, heart rate, respiration, and ocular and leg movements during sleep). Each method has its strengths and weaknesses and may not be suitable for all situations or populations. Lack of a standardized measurement method can lead to inconsistencies and difficulties in accurately assessing sleep (Morgenthaler et al., 2007).

Individuals' perceptions of their sleep quality and quantity can vary widely and may not necessarily align with objective measures of sleep. For example, a person may report feeling well-rested after only six hours of sleep, while another may feel fatigued despite getting eight hours. This subjectivity can add another layer of complexity when trying to establish uniform criteria for determining sleep (Watson et al., 2015).

There is considerable variation in sleep needs and habits among individuals, influenced by factors such as age, health status, and lifestyle. Establishing uniform standards while balancing these individual differences is a major challenge (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004)."

3.7 The mistrust between the seafarer and ship company

The mistrust between seafarers and shipping companies contributes to the challenge of addressing seafarer fatigue. The physical and psychological distance between ship and shore, along with the unbalanced power in shipping companies, create a chronic atmosphere of mistrust between seafarers and shore-based management, hindering open cooperation. The blame/punishment-centered bureaucracy and the lack of appreciation for authentic information that may compromise commercial advantage lead to pushing the problem back to the ship. The culture of adjustments to work/rest hours records is also triggered by chronic mistrust between shore and ships and job insecurity.

Ship companies always ignore feedback from their ships regarding seafarer fatigue due to their lack of belief in seafarers. For example, when a ship reports seafarer fatigue to the company, the manager often considers it as a fuss and laziness on the part of the seafarer. Consequently, the company blames the seafarer for being incompetent to do the job. This cycle of blame and disbelief leads to seafarers eventually accepting the reality and not complaining anymore. A long history of mistrust has left shipping companies with little understanding of, let alone empathy for, the actual workload of seafarers.

Chapter 4: Recommendations and Best Practices

4.1 Exemption of seafarers from recording work and rest hours

The falsification of seafarers' work and rest hours records has become a widespread issue in the shipping industry, showing no signs of improvement. As a result, it is suggested that seafarers be exempt from record their work and rest hours. Given that seafarers are mainly forced by shipowners to falsify their work and rest hours records, this makes the records meaningless and recording the work and rest hours itself is a workload for the seafarer, Every month, the seafarers must take times to fill in the work and rest table, print it out and sign it, and submit it to the captain or chief engineer for signature confirmation. If any record is found that does not conform to the regulations, then they have to amend it, and then printed again and submitted to the captain or chief engineer for signature confirmation. Finally, the paper version must be kept for inspection (WMU, 2020). The international convention should be amended to eliminate this burdensome and ultimately meaningless paperwork. Rather than having seafarers allocate time to record their work and rest hours, this time could be better spent on actual rest.

Cao and Wu (2019) carry out three questionnaires in the seafarer training class, and it was found that only 31% of the seafarer were able to truthfully record the work rest hours and 69% of the seafarer falsely reported the work and rest hours. Allen et al.

(2006) carried out a survey and found that seafarers who kept records of their work and rest hours were more tired and in poorer health than those who did not and turns out that only about a third (37.3%) of participants record their work and rest hours accurately. Based on a survey only 31% of the participants claim that they always follow the work and rest hours recording requirements (Simkuva et al., 2016). Ironically, the original intention behind requiring seafarers to record their work and rest hours was to protect their right to rest; however, this rule has only exacerbated their fatigue. In practice, the inspectors, the shipowners, the seafarers, they all know that the work and rest hours records were, for the most part, falsified, but as the convention requires the records to be kept, this is the kind of formalism that everybody knew, but which continued to torture fatigued seafarers. The recording of seafarers' working and rest hours shall be automatically recorded by automatic equipment.

4.2 Apply sleep monitoring equipment on board ships.

Although There is currently no single, uniform international standard for determining sleep. However, there are widely accepted guidelines and techniques exist for measuring and assessing sleep in both clinical and research settings.

At present, the generally accepted standard of sleep monitoring in the medical field is polysomnography (PSG). Yu et al. (2004) proposed to use the mattress type low-load sleep detector. The mattress type sleep monitoring system only requires the subjects to lie on the mattress to sleep. Compared with the traditional sleep monitoring method (PSG), this method does not require electrodes, wires and pre-processing by medical personnel, and the monitoring process has almost no special requirements.

Sensors in the mattress convert human micro-movements into electrical signals that separate heartbeats, body movements and breathing signals. Can objectively record the process, assess sleep quality, and can automatically analyze the results. The analysis of sleep is based on measurements of heart rate, breathing, body movements, and so on. The heart rate slows down and breathing becomes even, which is one of the system's criteria for determining sleep. Breathing events do not occur when a person is awake, so if the system detects a breathing event, it will determine that the subject is asleep. The sleep measured in this way is more natural, more reliable and more convincing. Continuous sleep monitoring can be achieved, greatly reducing the cost of sleep monitoring.

Yang et al. (2004) developed a mattress based natural sleep monitoring technology, which integrates sensors, signal processing, and information mining technology, and successfully realizes sleep monitoring without the use of electrodes, and devices, without affecting the natural sleep process. Measures of sleep monitoring include total sleep time, deep sleep time, number of awakenings and average sleep heart rate. There are already inexpensive, accurate sleep monitoring devices on the market, such as smart bracelets, smart watches, smart mattresses and smart lamps. For example, Finnish company Emfit has developed a con-tactless sleep monitor that records a person's heart rate, breathing and physical activity throughout the night to identify factors that affect sleep and improve it (See figure 1). It is also the world's first contactless sleep monitor equipped with heart rate variability (HRV).

Figure 1

Emfit QS sleep monitor from Emfit firm

Note. Source: https://health.esdlife.com/shop/hk/product/em_emqs

A Shenzhen company has developed RestOn, a smart sleep monitoring devices based on a stress band that can be placed under a sheet to monitor physiological parameters such as heart rate, breathing rate, turning over and sleep cycle. The device is only two millimeters thick, a single charge will last a month, lightweight, non-contact, and can realize non-inductive monitoring sleep. An APP paired with the device will automatically analyze the data to form a sleep report, allowing participants to easily understand their sleep status. The device has the function of helping people sleep, and its working principle comes from the U.S. National Center for Biotechnology Information (NCBI) research report (see figure 2).

Figure 2

RestOn smart sleep monitoring devices

Note. source: http://webapi.test.sleepace.net/m.cn/product/reston.html

One of the most common ways to assess sleep is through actigraphy, which is a non-invasive method of measuring physical activity and rest. Actigraphy involves wearing a device, usually a wristwatch-like instrument, that measures and records movement during sleep (see figure 3). The subject's time and quality of sleep can be determined from the data collected.

Figure 3

Major smartwatch with sleep monitoring function on the market

*Note. s*ource:https://consumer.huawei.com/cn/wearables/talkband-b7/

https://www.apple.com/apple-watch-series-8/

https://www.mi.com/shop/buy/detail?product_id=18350

In some military medical and health support, sleep monitoring mattresses are placed on dormitory beds as routine equipment for daily use. Medical and sanitary personnel note the quality of the individual's sleep the night before so as to provide a reference for the military training and mission arrangements of the day. Natural sleep monitoring technology is already used in clinical and medical surveillance and is expected to be used on ships soon as the technology develops.

The application of the seafarers' sleep monitoring equipment on the ship should be able to record the seafarers' sleep duration and quality in real time, analyze the sleep data, and automatically save it in the cloud for the convenience of inspectors. Inspectors will be able to access sleep records from the cloud platform before boarding the ship. When a seafarer sleeps less than 8 hours in 24 hours, an alarm is issued, and the alarm information will send to the relevant authorities. The seafarer will also be temporarily banned from ship safety duty until they get enough sleep.

Sleep monitoring equipment on board, coupled with the establishment of a compulsory eight-hour sleep regime, can be more effective in protecting seafarers' sleep.

Moreover, fatigue is not always exclusively caused by work, scrolling through social media, watching TV shows, and other entertainment activities can interfere with sleep. Adequate sleep is crucial for recovery from fatigue. In order to ensure the navigation safety of the ship, seafarers shall have adequate sleep before take over the watch. IMO could mandate a minimum of eight hours of sleep per day for seafarers, as this is the scientifically established requirement for adults.

The IMO should encourage shipowners to equip their ships with fully automated sleep monitoring equipment, such as smart bracelets, mattresses, and pillows. These devices should be capable of automatically recording seafarers' sleep time in real-time, the recorded data cannot be changed, and saved in the cloud for easy checking by flag state inspectors, PSC inspectors, and major oil companies inspectors. The sleep monitoring device has an alarm function. If the device detects that the seafarer on duty is not getting enough sleep, for example, less than eight hours, it will alarm the captain and send the alarm information to the relevant authorities. To better urge seafarer to take a good sleep. Such sleep monitoring equipment can be tried on some ships first, collecting data and, if feasible, then rolling it out on a large scale. In terms of seafarers' work and rest hours records, Blockchain technology can be introduced to ensure secure and decentralized ledger, which can be guaranteed against tampering.

4.3 Apply fatigue detection devices on board ships.

Although there is no single uniform criterion for determining fatigue level. However, there is a multi-modal approach that combines subjective and objective measures can provide a comprehensive assessment of fatigue level. At present, a variety of fatigue detection equipment has appeared on the market, designed to monitor and assess fatigue levels in different settings. These devices typically use physiological and behavioral indicators to assess fatigue, relying on various technologies and sensors. The following are the main fatigue detection devices on the market.

Fatigue detection technology has been applied to air transport, railway transport, road transport and other fields for many years and achieved promising results. For example, a technology company called Subai in Hangzhou, Zhejiang province has developed a fatigue warning device that can accurately identify fatigue and sound alarm. With the aid of low power infrared light, it can also accurately identify fatigue at night, and has passed the laboratory photo-biological safety test. The advanced algorithm ensures high fatigue identification accuracy. The equipment is small and easy to install and can be used in a variety of places. According to the product's 800 user feedback it works well and can effectively prevent dozing off.

Figure 4

Safety driving assistant fatigue detection equipment

*Note. s*ource : https://www.china.cn/qtqicheanquanyongp/5036223738.html

RIDY, an American company, has developed a device to help alert drivers when they are tired or distracted. The device is a smart camera mounted on a car's dashboard, windshield, or rear-view mirror. The device has infrared night vision and can capture the driver's facial features, such as blink rate and yawn. Analyze the visual information, and if the RIDY device determines that the driver is fatigued or distracted, it will issue a warning.

Figure 5

RIDY Smart Camera

Note. source :https://www.digitaltrends.com/cool-tech/ridy-smart-camera-indiegogo/

Japan's Mount Fuji University, in collaboration with companies, has developed a device that tests saliva to determine a person's fatigue level. The principle is that when a person is tired, the amount of the special hormone glucocorticoid increases in the blood, triggering the release of alpha-amylase in the saliva. The device measures levels of the enzyme to determine fatigue levels, which can be measured in just 10 minutes (Zhao, 2011).

A technology company in Wenzhou has developed a fatigue detection software that allows users to constantly check their fatigue levels, make detailed analysis reports, and provide targeted and feasible suggestions to help them improve their mental and physical health. This APP is designed to monitor fatigue for shift workers (currently airplane pilots and air traffic controllers). The software, which can be installed on mobile phones, allows seafarers to quickly check for fatigue before each shift to ensure they are not fatigued. The application calculates the fatigue degree quantitatively through the user's main physical signs data. After long-term sample collection, it dynamically implements health data monitoring and analysis, and provides feasible health management suggestions for individuals regularly.

In 1996, the United States National Highway Traffic Safety Administration (NHTSA) developed a set of auto driver fatigue alarm system, the system is mainly composed of induction equipment, alarm, monitoring algorithm and so on, it aims to reduce traffic accidents caused by driver fatigue (Knipling et al., 1996). A professor of psychophysiology from the University of Virginia, named Dr. Walt Wierwille, has came up with a way to measure fatigue using Percentage of Eye Closure (PERCLOS). Currently, PERCLOS method has been recognized as the most effective, on-board, real-time fatigue driving detection method (Wierwille, 1994). In April 1999, the federal highway administration technical forum published titled "Ocular Measures of Driver Alertness", first proposed the PERCLOS as a feasible way to predict motorists driving fatigue. They believe that using eyes to measure fatigue is very appropriate and effective method.

Upon conducting an inquiry into the correlation between fatigue and various eye features, including pupil-based, blink-based, and saccade-based measurements, and

evaluating the hardware options currently available in the market. Analysis indicates that an eye-tracking system utilizing camera technology and a combination of multiple eye features holds potential as a viable solution for developing a fatigue detection system that can minimize the disturbance to the subject in the transportation industry (Hu & Lodewijks, 2020).

Adopt face image recognition, visual algorithms and deep learning algorithms were used to analyze the faces of the subjects, monitor their eye state, blink, yawn and additional fatigue features to determine if they are in a fatigued state is a practical and effective method (Hu, 2021). The fatigue detection algorithm is based on the percentage of eyelid closing time, which determines fatigue based on the proportion of the total time in which the eyelid is closed above a certain threshold.

A large number of experimental comparative studies have confirmed that among facial features, the percentage of eye closing time can monitor the fatigue state of the subjects most effectively. The design also classifies fatigue into primary fatigue and severe fatigue. When the system detects that the subject is in a state of fatigue, it will send out sound and light alarm, and send the alarm information to the monitoring center. The machine vision algorithm is used to determine the fatigue state of the subject, which is characterized by low cost, high real-time performance, small size, and easy installation. The equipment can effectively detect the fatigue state of the subject, and has certain convenience and practicability to provide guarantee for safe navigation.

Hu and Huang (2021) adopted the fatigue detection method based on facial feature analysis to optimize the face region positioning method to the light changes and improve the anti-interference. The fatigue features extracted can effectively reflect

the fatigue state of the subject, with an average recognition accuracy of 92.2%. When people are tired, the opening and closing time of their eyes will be extended greatly with the deepening of fatigue. Therefore, the maximum duration of normal eye closure of the subject under normal awake state can be counted as the threshold. When the maximum duration of normal eye closure of the subject within a certain period is detected to be greater than the threshold, it can be considered as fatigue state, otherwise, it is an awake state. When a person is tired, the blink frequency will decrease significantly, and the statistical data of the slowest blink frequency in the waking state can be determined as the threshold value. When the blink frequency of the subject is less than the threshold value, it can be determined that the subject is in the fatigue state, otherwise, it is in the awake state. The yawns were measured by the mouth frontal aspect ratio, and combined with the duration (typically more than four seconds). An efficient and reliable fatigue detection system combines multiple fatigue characteristics parameters.

Bal et al. (2015) conducted two lactate tests on an oil tanker and concluded that when Ships were in port seafarers were more tired than during sailing, proposed an objective way to measure fatigue which is the lactate test. Lactate is produced by anaerobic metabolism. It is recognized as the paramount indicator of physiological parameter. The breakdown of glucose in an anaerobic medium will produce lactate. When lactate stores up in the blood and muscles, it makes the subject feel fatigue and metabolic acidosis by reducing PH value (Sahlin, 1992). Usually the threshold of lactate is 2 mmol/L (Tanaka et al., 1983). After the body begins to function, anaerobic metabolic activity will be intensified and accompanied by lactate rise. The time and intensity of human activity determine the level of lactate growth. Lactate builds up further at high intensity work, and this also drops in PH value leads to further fatigue (Günay et al., 2006).

Liu et al. (2013) did a study on the relationship between visual features and fatigue. Use the method of combining interviews with real ship experiments. The study concludes that when the seafarer is tired, it is difficult to see the stimuli nearby, the gaze time will be prolonged, and the proportion of gaze time in the total time will be increased. The distribution of the viewpoint position of the seafarer can reflect the concentration degree of the seafarer in a certain area. Under fatigue conditions, the distribution range of the viewpoint of the seafarer will become smaller, and the frequency of the line of sight beat will be significantly reduced, and the stop times of the viewpoint in the observation area will also become less. The change in pupil size mainly refers to the change in pupil diameter. Under the condition that the external light remains basically constant, the pupil diameter will gradually decrease as the seafarer becomes tired or loses interest in the objects within the gaze range. The eye movement of the seafarer can be recorded by an eye tracker, camera and other equipment, and visual response data such as viewpoint location distribution, pupil size and visual distance can be clearly reflected. Combined with these visual characteristics, it can determine whether the crew is in a state of fatigue.

Li (2005) proposed a comprehensive application of six characteristics to detect fatigue for example, PERCLOS, average eyelid closing speed (AECS), nod frequency, and yawn frequency. Experimental results show that this algorithm is effective in fatigue detection.

Seafarers are the most critical factor to ensure the safe navigation of ships. In the past, the safety supervision of ships was more reflected in the supervision of machinery and equipment, but the fatigue management of seafarers was little or no. But it turns out that our management of seafarers is not accurate enough, especially in terms of

preventing fatigue. It is necessary to apply fatigue detection equipment to the ship. Fatigue detection equipment can be installed at seafarers' workplaces such as the bridge, the engine control room, the ballast water operations room, and the gangway to prevent seafarer fatigue on duty. Some ships already have a number of surveillance cameras on board which, make a slight improvements with intelligent algorithms, can be used for fatigue detection. The seafarer fatigue detection equipment, when applied to the ship, should be able to record the fatigue state of the seafarer during the watch in real time. With current communication technology, it is possible to monitor seafarers' fatigue remotely. When seafarer fatigue occurs, the equipment will sound an alarm and automatically send the alarm information to the relevant authorities.

4.4 Amend IMO procedures for PSC

It is proposed that amend procedures for PSC (Resolution A. 1155(32)), by incorporating criteria for determining seafarer fatigue level. PSCO should receive training in fatigue detection and be equipped with portable fatigue detection devices, enabling them to perform random fatigue detection of seafarers on board during inspections. Based on their professional judgment, the inspectors will determine what level of fatigue can meet the criteria for the detention of a ship based on data extracted from sleep monitoring and fatigue detection equipment. Make the detection of seafarers' fatigue as a mandatory inspection item. Clear guidelines and criteria for fatigue-related detentions should be established, developing a set of internationally recognized benchmarks such as specific thresholds for work hours, sleep deprivation, or consecutive days without adequate sleep. This approach will provide inspectors with a definitive framework for determining when a ship should be detained due to seafarer fatigue. For instance, a ship may be detained for 8 hours or until all seafarers

have achieved 8 hours of sleep in the previous 24 hours, whichever is longer, when more than 25% of the seafarers have slept less than 8 hours within 24 hours or when over 25% are determined to be severely fatigued by fatigue detection equipment. The IMO may first issue a guideline to encourage competent port states to take the lead in trial implementation, so as to accumulate experience and data and lay a foundation for subsequent popularization.

From May 1, 2022 to June 17, 2022, the Australian Maritime Safety Authority(AMSA) conducted an Focused inspection campaign (FIC) of seafarers' Hours of Work and Rest. A total of 281 ships were inspected and 27 ships were detained, including two due to Hours of Work and Rest deficiency (see Table 4).

Table 4

Hours of Work and Rest FIC Results

Question	Yes	Yes%	No	No%	N/A	N/A%
Is a table of shipboard working arrangements posted for seafarers accessible?	281	99%	0	0%	1	1%
Does the table of shipboard working arrangements ensure that the first watch at the commencement of the voyage and subsequent relieving watches are sufficiently rested and otherwise fit for duty?	278	98%	2	1%	2	1%
Do records of the daily hours of work or rest show compliance with the actual hours of work and rest hours, including the requirements for rest breaks?	253	90%	26	9%	3	1%
Do any seafarers have periods of shipboard employment exceeding 11 months?	13	5%	267	94%	2	1%
Has adequate compensatory rest been given to seafarers who have had their rest disturbed by callouts to work? (e.g. such as when a machinery space is unattended)	218	77%	3	1%	61	22%
Has the master suspended the schedule of hours of work or hours of rest, with in the last 3 months, and required any seafarer to perform any hours of work necessary until the normal situation has been restored?	11	4%	200	71%	71	25%
Have musters, firefighting and lifeboat drills, and drills prescribed by national laws and regulations and by international instruments, been conducted in a manner that minimizes the disturbance of rest periods and does not induce fatigue?	279	98%	1	1%	2	1%
Where non-compliance with the work and rest hours has been recorded, has the Safety Management System corrective action process (ISMC 9) been used to rectify non-conformance by determining the cause and preventing recurrence?	22	8%	15	5%	245	87%

*Note.*Source:https://www.amsa.gov.au/focused-inspection-campaign-hours-work-and-rest-outcomes-report

International cooperation should be fostered by working with IMO and other port state authorities to share best practices, coordinate efforts, and harmonize regulations concerning seafarer fatigue management.

To further deter non-compliance, penalties for shipowners who repeatedly violate seafarers' work and rest hours regulations should be increased. Implementing higher fines and other sanctions will encourage compliance these regulations and help prevent violations. By incorporating these measures, the maritime industry can more

effectively detect and address seafarer fatigue, ensuring a safer and healthier working environment for all seafarers.

4.5 Establish a widely accepted set of criteria for determining fatigue levels and sleep.

IMO and ILO could work with other international organizations such as The International Organization for Standardization (ISO), The World Health Organization (WHO), The International Transport Workers' Federation (ITF), The International Chamber of Shipping (ICS), to initiate and establish a set of widely accepted criteria for determining fatigue and sleep. Establishing such a standard is a complex and lengthy project, requiring scientific research cooperation, massive literature review and data collection, numerous experiments, and repeated verification. As well as a team in constitute of sleep medicine specialists, psychologists, occupational health professionals, data analysts, and so on. The difficulty lies in establishing the key index of fatigue and the measure of fatigue initial recognition. Then it's pilot testing and large-scale testing, data analysis and results.

Fatigue has been objectively measured by a variety of measures, such as PERCLOS, HRV, lactic acid measurements, slower reaction times, and so on. The equipment for detection fatigue has been non-contact, which can realize real-time fatigue detection without affecting the work and life of the subject, and can cope with some extreme working environment, such as waterproof, dust proof, long endurance and so on.

Establishing a widely accepted set of criteria for determining fatigue levels and sleep,

though, is a huge systematic project that requires a lot of money and human resources. But in the long run, such standards could improve the overall safety, productivity and benefits of the shipping industry. Overall, the advantages far outweigh the disadvantages.

Apply these standards to ship safety supervision, so that inspectors from the port states, flag states, and major oil companies, have a basis for enforcing the law. This would provide a theoretical basis for the subsequent application of fatigue and sleep monitoring equipment on board ships. After the establishment of such a standard, a follow-up survey is needed to test its effectiveness, and then make corresponding adjustments according to the actual application situation. This is a great and difficult task that requires the concerted efforts of all stakeholders.

4.6 Introduce a fatigue clause into the ship's insurance contract

The physical condition of seafarers is closely related to the safety of ships. Therefore, it is proposed to define seafarer's fatigue as ship unseaworthy in ship insurance contract. When it comes to the seaworthiness of ships, people think more about whether the ship' s hull is in good condition and whether the equipment is in good operation, but few people pay attention to the spiritual condition of seafarers. Even if the equipment of a ship is state-of-the-art, the safety of the ship is greatly endangered if the seafarers are in a state of fatigue.

The shipowner should be ultimately responsible for the safety of the ship, rather than the Captain who is in charge in the traditional time. In order to ensure that shipowners strictly observe the regulations on seafarers' work and rest hours, it is proposed to define maritime accidents caused by seafarers' fatigue as negligence and

willful misconduct. The burden of proof is on the shipowners. The ship insurance company may refuse to pay for losses caused by seafarers' fatigue.

With the support of seafarer's fatigue detection and sleep monitoring equipment, it can accurately record the hours of work and rest of seafarers. and the fatigue level of seafarer on duty. To ensure adequate rest for seafarers, prevent seafarer fatigue on duty. Different from the traditional navigation, the shipowner has more actual control over the ship than the Captain. Shipowners have the responsibility and obligation to ensure adequate rest for seafarers so as not to make them fatigued on duty. The inclusion of fatigue clause in marine insurance contract can improve the attention of relevant stakeholders to fatigue, which is beneficial to the enhancement of maritime safety. It is obvious that seafarers' fatigue will affect the safe navigation of ships, and such consequences can be reasonably foreseen by shipowners. Therefore, it is proposed to define the phenomenon of seafarers' fatigue on watch as shipowners' failure to carry out due diligence. The insurer may hold that the shipowner failed in his duty of due diligence on the basis of seafarer fatigue and may reject the shipowner's insurance claim.

4.7 Promote a culture of fatigue awareness and education

Promoting a culture of fatigue awareness and education is an excellent approach to addressing the issue of seafarer fatigue. Shipowners, shipping company managers all have this subconscious that it's a seafarer's job to put up with fatigue. Seafarers generally underestimate the harm of fatigue. Even though their are already severely fatigued, they are unaware that and they still keep watch in a fatigued state to put the ship in danger.

It is proposal that incorporate a module on fatigue awareness and management in the seafarer training curriculum. This module should cover topics like the causes and symptoms of fatigue, its impact on human performance, and strategies for managing fatigue. The training should be mandatory for all seafarers, regardless of their rank or role on the ship. Such training should also be carried out within the shipping company, so that the management personnel of the ship can have basic knowledge of fatigue and be fully aware of the harm of fatigue.

Provide fatigue related training for inspectors, so that inspectors have the knowledge of fatigue and can use fatigue detection equipment, so as to facilitate the inspection of seafarer fatigue conditions. IMO should launch some fatigue education activities, which can be carried out through seminars, short videos, online education, e-learning and other forms to fully mobilize the enthusiasm of learning.

Each ship should have a fatigue management plan that outlines the steps to be taken when a seafarer is identified as being at risk of fatigue. This plan should be communicated to all seafarers and regularly reviewed and updated. Incorporate fatigue management into the ship's Safety Management System (SMS). This will ensure that fatigue is recognized as a significant safety risk and that procedures are in place to manage it. Shipping insurance companies can try to reduce premiums, cash rebate and other measures to encourage shipowners to strictly abide by the regulations on seafarers' work and rest hours, effectively reduce seafarers' fatigue phenomenon and attach importance to seafarers' fatigue management. Some countries are at the forefront of the world in protecting the rights and interests of seafarers. The IMO should encourage them to introduce an eight-hour working day on their ships first, by way of domestic legislation, so as to create a favorable atmosphere to prevent seafarers' fatigue. To set an good example for other countries

in preventing fatigue among seafarers.

Chapter 5 Conclusion and Future Directions

5.1 Conclusion

Seafarer fatigue is a common problem in the maritime industry, which seriously affects the safety of ships and the physical and mental health of seafarers. The seafarers are experiencing an unprecedented dilemma of fatigue. The seafarers have been suffering from fatigue for a long time and it shows no sign of getting better. A large number of studies and accident investigation reports show that seafarer fatigue is one of the important factors causing maritime accidents. Scientific research has proved that fatigue will have a variety of adverse effects on people's health, which is not conducive to the healthy and stable development of the shipping industry.

The fact shows that it is difficult to implement the eight-hour working day system in the shipping industry. Due to the fierce competition in the shipping market, it is not desirable for shipowners to increase the manning level of ships. The harsh working environment at sea itself makes seafarers more prone to fatigue. Long hours of overtime work, away from family and friends, and 24-hour ship operation mode make seafarers suffer from endless fatigue and increase the risk of accidents and injuries.

This dissertation analyzes the main challenges in addressing the problem of seafarers'

fatigue. It is proposes that emphasis should be placed on the point of view of safety supervision. Strengthen the supervision of seafarers' fatigue from the perspective of protecting seafarers' basic human rights and occupational health. So far, only enforcement through port state controls and inspections of major oil companies has proven to be a tangible deterrent to shipowner breaches. So as to force shipowners to take effective measures to prevent seafarers' fatigue.

The unique operational nature of ships, navigation in the seas and visiting diverse ports add a layer of complexity to effective monitoring. The rapid development of science and technology has made it easy and feasible to monitor seafarers' fatigue and sleep remotely. Bring the dilemma of seafarer fatigue to the public. Maybe a breakthrough to solve the problem of seafarer fatigue.

The introduction of innovative fatigue detection and sleep monitoring technologies offers a promising solution to seafarer fatigue. These devices can provide automatic, continuous, and real-time assessments of a seafarer's sleep and fatigue levels, addressing the issue of falsified work and rest hours records and reducing the burden of manual recording on seafarers.

This not only encourages seafarers to take good sleep, thereby reducing the risk of fatigue-related accidents but also provides shipowners with a clear understanding of the seafarer's workload. Such data can serve as a reliable reference when considering increase the manning level of the ships and ensure seafarer have adequate rest. Moreover, advancements in technology have made these devices increasingly affordable, making it feasible for shipowners to install these devices on board ship.

To solve the problem of seafarer fatigue can not only stay in the level of instrument

monitoring and data recording. A comprehensive approach is required that promotes a culture of fatigue awareness, incorporates fatigue management into the Safety Management Systems (SMS), and encourages international cooperation and knowledge sharing. To address seafarer fatigue by working together with all stakeholders in the shipping industry.

5.2 Future Directions

Going forward, active collaboration with other international organizations will be critical to establishing universally agreed standards for fatigue and sleep. Establish a mandatory rest system for seafarers to get at least eight hours of sleep a day. To solve the problem of seafarer fatigue, it is important to distinguish between the definitions of rest and sleep. Rest should not simply be equated with sleep. Activities such as eating, laundry, or coffee breaks, while counted towards rest hours, sleep time should not include time spent on the above activities. Hence, sleep time should explicitly refer to the period a seafarer spends in bed asleep.

This refined definition of sleep will help the application of sleep monitoring equipment and fatigue detection equipment in the maritime industry. These devices can offer objective, accurate, and real-time data on seafarers' sleep patterns and fatigue levels, facilitating the effective enforcement of the proposed sleep regulations.

The government, industry and workers should attach great importance to fatigue management and prevention of fatigue related accidents. Research on fatigue and accidents should be accelerated to collect data and provide solutions for preventing fatigue related accidents in the next step (Dinges, 1995). In the future, the data

recorded by these fatigue detection and sleep monitoring devices will be connected to the ship' s Voyage Data Recorder (VDR) for real-time storage. This would provide invaluable insights into the role of fatigue in maritime accident investigations, contributing significantly to understanding and preventing such incidents.

Moreover, to facilitate ship safety supervision, the data recorded by these fatigue detection and sleep monitoring equipment should be connected to the ship's Automatic Identification System (AIS), which can broadcast the recorded data in real time. Facilitate inspection by relevant authorities. Imagine a ship's seafarers are tired due to frequent port calls, and the seafarers on duty have not had a good sleep for several days in a row. Because their ship is equipped with sleep monitoring equipment, their sleep time is automatically sent to the supervision department through the AIS system. The VTS (Vessel Traffic Service) refuses the ship to enter the port on the grounds of seafarer fatigue, and orders it to stop the ship immediately and rest until the fatigue is eliminated. Another scenario is that a ship in port is equipped with a fatigue monitoring device that automatically sends information about seafarers' fatigue status to the regulatory authorities, who will deny the ship permission to departure on the grounds of seafarers' fatigue until the tiredness subside.

Such arrangement can effectively prevent seafarers from being fatigued on duty, protect seafarers' human right, right to rest, and the data can be used as evidence in marine accident investigations. Aim to fundamentally improve maritime navigation safety, and ensure the healthy and stable development of the shipping industry.

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