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NOISE LEVEL ANALYSIS ONBOARD A VESSEL X DURING SAILING AT SEA

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ABSTRACT

Naval vessels sacrifice some characteristics, like the comfort of the crews. This research will give compliance with the human factor standards in terms of noise onboard Vessel X. The research methodology developed in this study applies to all classes of ships through the available international standards. The study took full-scale noise onboard measurements for Vessel X in various compartments according to IMO compartments subdivision standards. Analysis for the most suitable international standards to be used in the measurement onboard is conducted first. Noise levels measurement is conducted in various spaces on all decks accessible to the crew to give a complete and adequate picture of the levels of noise onboard. The measured noise levels compare with current limits for working and living spaces using the international standards for noise (DNV, IMO, NIOSH, and DOSH). The measurement data analysed and identified the crucial spaces onboard regarding the crew's noise exposure and acoustic comfort while working onboard. Results show that this ship's noise level exceeds the standards set at the international level and is at risk of having an impact like motion sickness on the ship crew.

1.0 INTRODUCTION

Working as a seafarer is difficult since the platform is moving and sailing for lengthy periods, including few opportunities for engagement with the outside world. Furthermore, a seafarer's social life is also challenging since they live in two worlds: at sea, coping with living and working situations onboard, and with their relatives back home, as mentioned by Sekhon & Srivastava [1]. The Maritime Labour Convention (MLC) has changed the conditions that provide seafarers with decent lives and a broad perspective on seafarers' rights and fortification at work [2]. However, Wertheim et al. in [3] state that MLC does not cover seafarers serving warships and naval auxiliaries.

Vessel X is mainly designed and requires many performance capabilities as a naval vessel. Speed, endurance, weapons payload, ability to operate and survive in hostile environments, and reliability under combat conditions are essential for a naval vessel. Unfortunately, ship designs often compromise some parts to meet this requirement, and the need for crews is often disregarded. The crews work long hours and are typically subjected to repetitious working and living situations. Sekhon & Srivastava in [1] occasionally mentions that the situation turns tense and dangerous. As a result, MLC in [2] considers that most of the accident inquiries often include fatigue as a factor contributing to the occurrence of the accident. In addition, Zhao et al. [4] mention that fatigue has been linked to a lack of situational awareness and human mistakes, which can contribute to unintentional accidents. Unfortunately, Wertheim et al. in [3] declare that fatigue in the maritime domain has been under-researched more than in sectors of other transport.

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2.0 THE EFFECT OF NOISE ON SLEEP DISTURBANCE

Abidin et al. mention that ship motion is caused by fluid interaction with moving marine vehicles such as ships [5]. Fatigue is caused by a lack of noise, poor sleep quality, and insufficient rest time, as mentioned by Wertheim et al. in [3]. In addition, Endrina et al. in [6] specify that noise significantly affects sleep quality. Relevant organizations have advised mitigating and managing fatigue at sea during operations, as Andrei et al. mentioned in [7]. Some methods have been referred to in the design of the vessel, including minimizing noise, providing comfortable accommodations, and improving indoor climate, as mentioned by Abidin et al. in [5].

Voluntary standards and prescriptive guides are available and ready to apply for a new build vessel. Its focus is to enhance vessels' design by improving comfort and habitability for the crew. Using the design to control the environment will enhance the personnel's comfort level, give them the opportunity for better rest and sleep, and thus contribute to boosting their performance. For instance, two groups: noise and vibration (COMF-V notation) and indoor climate (COMF-C notation) (DNV 2009), are published by Det Norske Veritas (DNV) as an additional comfort class as mentioned by Ibrahim et al. in [8]. Three levels of comfort: highest (level 1), medium (level 2), and acceptable (level 3), distinguish the noise and vibration criteria. Noise criteria based on the standards on several separate places on the vessel shows in Table 1.

3.0 METHODOLOGY

An experiment was carried out onboard Vessel X from 18 until 24 July 2021. The vessel criteria were documented through vessels operating at sea measurements concerning noise. In addition, the data for the international standards collected through text mining and content analysis was conducted and used as the reference for measuring the level of application onboard, as mentioned by Ibrahim et al. in [8]. The noise was measured on the bridge, machinery control room, cabin, machinery room, and several other areas onboard (see Figure 6) using the Smart Sensor Sound Level Meter Logger (ST9604), as depicted in Figure 1. The sensor can measure the range of 30 to 130 dB using a resolution of 0.1 dB with an accuracy of 1.5 dB. Frequency weights were used.

Figure 1. Smart sensor sound level meter

The criterion adopted for the subdivision of the space is based on Rocca et al. in [9]:

i. The purpose of the cabin is public or private (cabin). Lower noise levels are required in private spaces.
ii. The expected noise level. Crew depends on the activity that is carried out. Expect to find different spaces that have different noise levels. For low (cabin), medium (bridge), and high levels (engine room).
iii. The time in one space spent by the crew. A higher level can be accepted if a crew spends in space only for a short time.

As regards the crew spaces in order from the most to the less demanding, in the comfort class (CCs), the following broad subdivision is used, referring to IMO in [8] such as accommodation spaces, navigation spaces, service spaces and workspaces.

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Table 1. A set for crew spaces

Space type	Definition	DNV (2009)	IMO (1981)	CCS (2016)	Measurement readings onboard	Differences with standards (highest)
Workspaces	Machinery spaces (continuously manned)	-	110 dB	85 dB	175.2 dB	+65.2 dB (59.3%)
	Machinery spaces (not continuously manned)	-	110 dB	85 dB	175.2 dB	+65.2 dB (59.3%)
	Machinery control rooms	75 dB	75 dB	85 dB	112.7 dB	+27.7 dB (132.5%)
	Workshops	-	-	85 Db	-	-
	Non-specified workspaces	-	-	70 dB	-	-
Navigation spaces	Navigating bridge and chartrooms	60 dB	-	70 dB	80.3 dB	+10.3 dB (14.7%)
	Listening post, including navigating bridge wings and windows	60 dB	-	70 dB	80.3 dB	+10.3 dB (14.7%)
	Radio rooms (with radio equipment operating but not producing audio signals)	60 dB	-	70 dB	80.3 dB	+10.3 dB (14.7%)
	Radar rooms	60 dB	-	70 dB	-	-
Accommodation spaces	Commanding Officer Cabin	60 dB	-	70 dB	73.9 dB	+3.9 dB (5.6%)
	Executive Officer Cabin	60 dB	-	70 dB	75.3 dB	+5.3 dB (7.6%)
	Navigating Officer Cabin	60 dB	-	70 dB	75.3 dB	+5.3 dB (7.6%)
	Senior Rates Accommodation	60 dB	-	70 dB	85.2 dB	+15.2 dB (21.7%)
	Junior Rates Accommodation	60 dB	-	70 dB	70.5 dB	+0.5 dB (0.72%)
Service spaces	Galleys, without food processing equipment, operating	60 dB	-	70 dB	73.9 dB	+3.9 dB (5.6%)
	Serveries and pantries	60 dB	-	70 dB	73.9 dB	+3.9 dB (5.6%)
	Spaces not specified	60 dB	-	70 dB	-	-

* The bold-underlined value is the highest value among the standards for Noise Vessel X during sailing at sea.

4.0 DATA EXPLORATION AND ANALYSIS

Based on the standards identified through the literature review, field measurements were carried out at Vessel X. Additionally, noise and motion measurements have been carried out at several locations on the ship that focus on accommodation spaces and workspaces that require crews to always be in the area.

4.1 NOISE MEASUREMENT

Smart Sensor Sound Level Meter measures the noise levels. The findings show that all the standard criteria were exceeded except for Junior Rate's Accommodation. Nevertheless, noise disturbances such as crashing noise, high, loud noise from machinery (Figure 3 and Figure 5), and noise from ventilation and air conditioning (HVAC) systems (Figure 4) show high readings above the standards set by DNV in [11], IMO in [10] and CCS in [12]. Table 2 summarises noise criteria compared to the measurement results. The comparison was made to the most significant reading to the sample ships, such as the standards set by the China Classification Society reserved for warships as mentioned by CCS in [12]. As a result, it shows a higher standard limit than the standards set by DNV in [11] and IMO in [10]. In contrast, the comparison

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of noise readings for machinery rooms was made against the standards issued by IMO in [10], as DNV set no specific standards in [11] and CCS in [12].

As presented in Table 2, the highest noise level was measured in the cabin at Vessel X while turning on the ventilation and air conditioning system while sailing at sea. The noise readings in this ship exceeded the standard limits set throughout the ship, with readings during measurement varying by area. The system is mandatorily turned-on during sailing to maintain the temperature and airflow in the ship compartment. Figure and Table Style for every description of a figure and table, respectively.

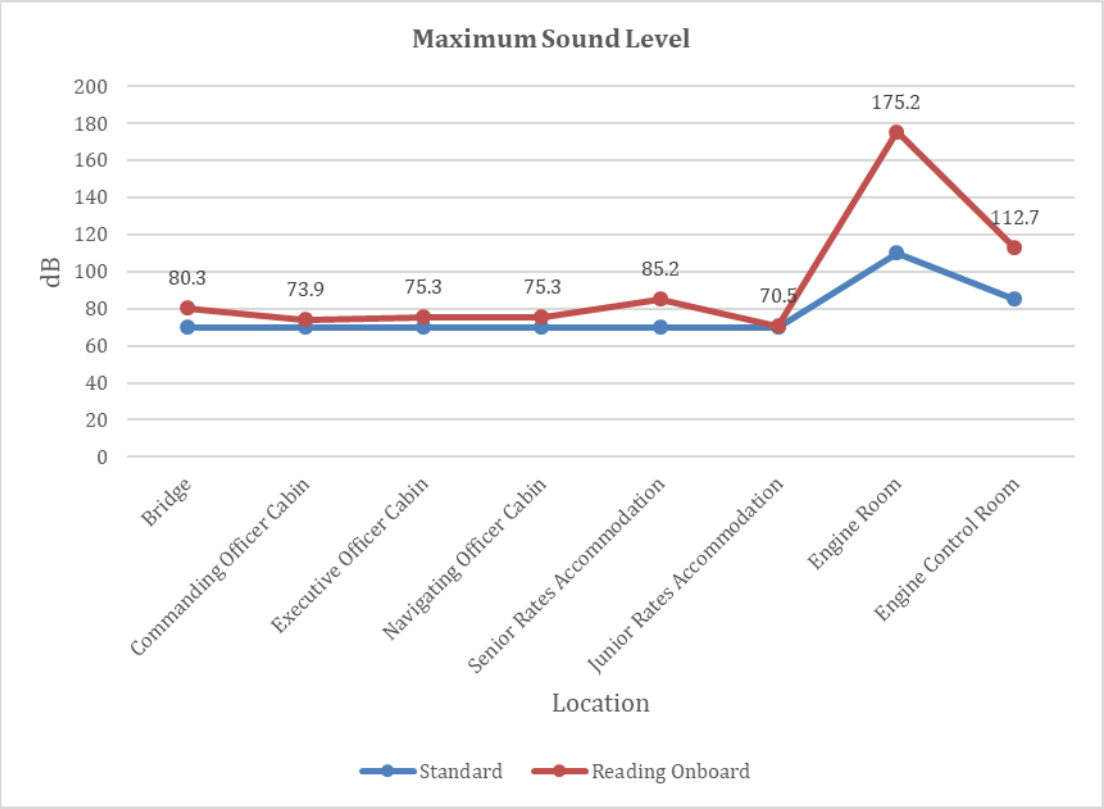

Figure 2. Graph of sound readings versus standards

4.2 Living Spaces

The accommodation area with the highest reading was Senior Rates Accommodation, with a reading of 85.2 dB, 21.7% higher than the standard. In examining the vessel's layout, this accommodation space is located at the very stern of the ship on Deck 02 (below the Main Deck), shown in Figure 6. Thus, this space is exposed to propeller vibration and noise from the Machinery Room near this accommodation.

In contrast, Junior Rates Accommodation recorded the lowest readings of 70.5 dB, 0.72% higher than the standard. Although the position of this accommodation space is at the bow, the sound from the slamming impact of seawater is not significant compared to other spaces. These findings also show that the noise factor from the ship's machinery and system substantially influences the vessel's space noise. The noise distribution from the machinery room can be seen in Figure 3, which shows that Senior Rates Accommodation is more affected by the noise from the Machinery Room than Junior Rates Accommodation.

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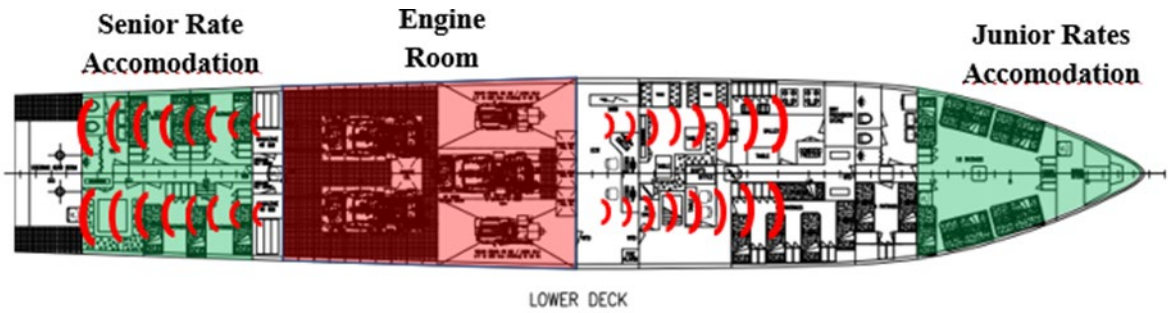

Figure 3. Sound distribution in Deck 02 (below the main deck)

For accommodation on Deck 01 (Main Deck), the noise readings of all accommodations also exceed the maximum noise standards set. This reading is because the accommodation on this deck has direct ducts with ventilation and air conditioning systems that emit noise when operated. Since this deck is above sea level, the sound effects from the shift and collision of ships with seawater are less significant. However, the conditions in the cabin were uncomfortable due to the noise produced by the system. Often these high-pitched sounds disturb their sleep. The noise distribution/ dissipation for Deck 01 (Main Deck) is shown in Figure 4.

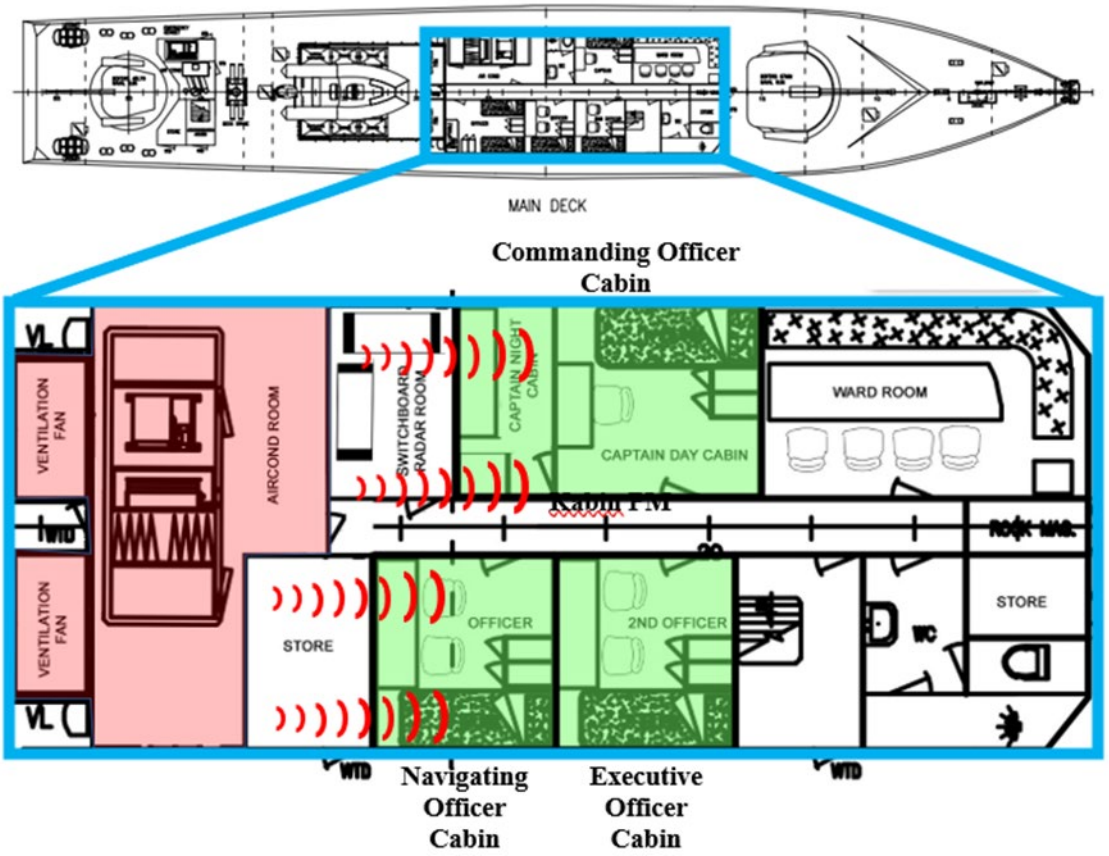

Figure 4. Sound distribution for Deck 01 (main deck)

4.3 Works And Navigation Spaces

The works and navigation spaces category, ranging from quiet environments, such as the Bridge, to extremely noisy locations, like engine rooms or machinery spaces, are analysed. Among all areas, the Engine Room (175.2 dB with 59.3%) recorded the highest reading, followed by the Engine Control Room (112.7 dB, 32.6%), higher than the maximum standard set. This situation indicates that the soundproof door in the Machinery Control Room can only filter 62.5 dB (35.7%) of noise from the Machinery Room out of a total of 175.2 dB. Therefore, noise from the Machinery Room is the main contributor that has caused the noise level to increase throughout the ship, as depicted in Figure 5.

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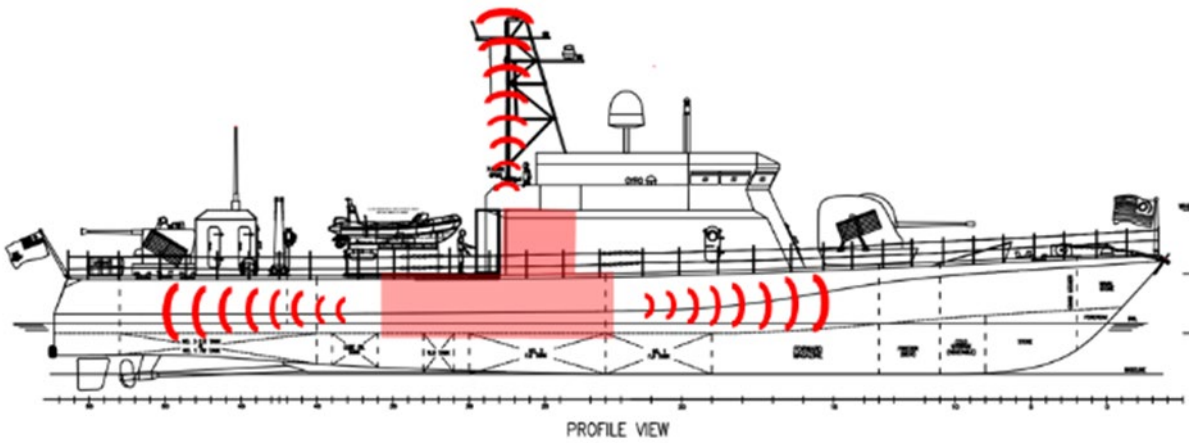

Figure 5. Sound source in Vessel X

Bridge also recorded a high reading of 80.3 dB, 14.7% higher than the set maximum standard. The high reading is also due to the ship's soundproofing system, which cannot correctly filter the noise from the Machinery Room and Air Conditioning System Room. In addition, the Bridge was also exposed to the noise produced by the ship's exhaust. These high readings on the Bridge affect the crew's comfort on duty and can affect their focus, thus threatening the ship's safety. The Bridge is a centre to ship operations and should be the most conducive area for the crew on duty. Based on past incidents, human error (HE) is one of the main contributing factors in more than 85% of maritime accidents. Most accidents at sea are caused by negligence, fatigue, and human error at Bridge, as mentioned by Shi et al. in [13].

5.0 Limitation Duration Of Exposure To Noise

Workers in any space with a noise reading exceeding 82 dB must wear hearing protection according to the standards issued by the Department of Occupational Safety & Health (DOSH) in Malaysia through Noise Exposure Regulation 2019 (2019 Industry Code of Practice for Management of Occupational Noise Exposure and Hearing Conservation). In the measurement at Vessel X, three areas have exceeded the limit, namely, the Machinery Room (175.2 dB), Machinery Control Room (112.7 dB), and Senior Rates Accommodation (85.2 dB). In contrast, other spaces have almost reached the limit of 70.5 dB to 80.3 dB.

The bridge is approaching this limit with a reading of 80.3 dB, which is hazardous because it is the primary location to control the ship. It also requires personnel to be there for a long time (4 hours for long watch and 2 hours for short watch), just like the Machinery Control Room. Accommodation should not be acceptable to have readings above 82 dB because the occupants cannot always wear ear protection. It is worse when it exceeds 85 dB, which can only be exposed for 8 minutes in that space (Table 2). Of course, it is not suitable as a space for Senior Rates Accommodation based on the standards issued by DOSH and Occupational Safety & Health (NIOSH) as published by NIOSH in [14].

This condition is highly unconducive to auditory emotional health and potentially results in other health complications. Standards for the time allowed to be exposed to noise in the workplace without using hearing protection as issued by the National Institute of NIOSH as follows:
Table 2 Standards of noise levels and allowable exposure times [14].

Table 2. Standards of noise levels and allowable exposure times [14]

NIOSH Standards	
Noise Level (dB)	Duration (Hours: minutes)
85	8:00
88	4:00
91	2:00
94	1:00
97	0:30
100	0:15

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6.0 CONCLUSIONS

In conclusion, the noise in Vessel X is more influenced by the noise produced by the machinery and systems on the ship. Noise from external factors such as sea and wind is less significant than the impact from the noise produced by machinery and systems onboard, as in Figure 4. The crew's comfort has been affected, and they are working under the pressure of noise on the ship. The available human factors criteria are unrealistic and cannot be applied by the crew of this ship. Based on this study, some of the existing human factor criteria should not be implemented on Vessel X operating in the waters of the South China Sea. The sound level in all three space categories, accommodation navigation services, and workspaces exceed the standards for naval vessels from 0.72% to 132.5%. According to NIOSH standards, some spaces are unsafe for humans to work in continuously. The primary source of noise pollution onboard Vessel X came from their engine room. Noise insulation between compartments onboard Vessel X can only filter out 35.7% of noise produced by engine room machinery. Such criteria must be reviewed and studied to suit the ship's functional role. It is acknowledged that the performance of the citizens on board Vessel X is not solely influenced by habitability or comfort onboard but also by several other factors such as duty schedule, alertness, season, and environmental conditions.

7.0 ACKNOWLEDGMENT

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