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Comparative study of the noise levels: impact of renovation

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Abstract. Health effects from different noise exposures have been studied by many researchers. According to the frequency of the noise, the complaints induced differ. Some studies have shown that low frequency noise may have serious health effects from annoyance to sleeping disturbances. Using a sound analyser with 1/3 octave band sound spectrum analysis capability, measurements were conducted on a scientific research vessel. Measurements were carried out in cabins, mess hall and engine room. The results were then compared to the Estonian and International Maritime Organization's recommendations on noise as well as results from a previous study on the same vessel (previous study was conducted before the renovations to modernise both the engine and the cabins was conducted). The renovations did not have the desired effect on the overall noise levels of the vessel as a working environment; the noise values obtained after the renovations do not agree with the normative values during sailing. The situation has improved in several cabins on the vessel but the improvement is rather insignificant.

Key words: Noise, noise reduction, frequency analysis, vessel, occupational hazards.

INTRODUCTION

Health effects from noise exposure are well known – loss of hearing, sleep disturbances (Tamura et al., 1997; Alves-Pereira & Castelo Branco, 2007) and annoyance. Tamura et al. (1997) have suggested that exposure to ship noise of 65 dB(A) can have unfavourable effects on night sleep. Consequently noise measurements, risk assessment and both compliance to national norms as well as reduction of noise is important. The noise exposure of crewmembers on board of older vessels is a subject that still needs attention. Goujard et al. (2005) did a survey where respondents had to rank different comfort criteria that are relevant to sailing on board of a vessel. The results showed that 39% of respondents considered the importance of acoustics significant and 44% found improvements necessary. Borelli et al. (2015) have done a profound literature overview on the subject. Their results show that there are not too many articles on the topic of health and safety of the workers on vessels. Therefore, to contribute to the field, more research is necessary on the topic to obtain more data in order to give scientific solutions to an engineering problem.

On the other hand, a unique EU project on the topic of exposure to vibration and noise in maritime domain was SILENV (2012a). During the project new noise exposure values were recommended. For example the new cabin noise limit was suggested to be less than 50 dB(A). Estonian legislation for the limit of cabin's noise is 60 dB(A), whereas the limit for mess hall is 65 dB(A). Agreement with latter values has to be guaranteed to the crew at all times, regardless of whether the ship is sailing or anchored (EG, 2007).

The vessel under investigation is registered in Estonia; therefore it has to comply with Estonian norms. The value of 60 dB(A) is also given in The International Maritime Organization's (IMO) Resolution A.468(XII), which covers noise control issues on commercial ships. As the studied ship that was previously a fishing ship and was redesigned to serve as a research vessel, the IMO values are suitable for recommendation purposes.

Working environment noise norms do not have any specific exposure limits according to octave band spectrum. Nevertheless, research (Tamura et al., 1997) has shown that typically the frequencies of a diesel engine ship lay in the range of 100 to 1,000 Hz, which is below the threshold of the most sensitive range of perception – which is 1,000 to 4,000 Hz, as Salvendy (2012) suggests. Evaluation of acoustics should also include spectral composition as the effectiveness of personal protective equipment (PPE) at different frequencies varies. The octave band analysis helps to predict the attenuation of PPE (Salvendy, 2012) and thus select adequate PPE.

To understand the current study more thoroughly an overview of the investigated vessel is required. The vessel was built in 1974 as a fishing ship. In the year 2009 the ship was repurposed as a research vessel and therefore parts of it were renovated – the hold, galley and the main deck. Also, its engine had few minor fixes but the auxiliary device (the diesel generator) was not modernized. During 2015 additional renovations were carried out in the cabins to lower the noise. For soundproofing and insulation purposes several materials were used. Panels of 5 cm thick compressed wool were attached to the walls of cabins. Then 5 cm of soft wool was added, which was then covered with additional thin wall panels (which were made from compressed wool covered with foil). The ceilings were covered with 5 cm thick compressed wool and metal ceiling panels that, unfortunately, produce additional noise during sailing. The vessel's floors were also insulated with 5 cm of compressed wool.

The purpose of the study: (1) analyse whether the noise values have reduced after the renovations; (2) analyse whether the renovations have influenced the spectrum of the noise; (3) ascertain whether the materials that were used during the renovations were suitable; (4) to contribute to the research field in order to complement the overall amount of scientific data on the topic.

MATERIALS AND METHODS

The data was collected during three working regimes: (1) while vessel's auxiliary device (48 kW diesel generator) worked, (2) anchored while the engine still worked, (3) and during sailing. TES 1358 sound analyser with sound spectrum analysis capability in 1/3 octave bands was used for measurements (class I device): (1) the equivalent sound pressure level; (2) the peak sound pressure level; (3) the sound frequency spectrum. The analyser was held at a 1.55 m height from the floor (measured with a measuring tape), in the centre of a cabin or 10 cm from a working machine (in case of vessels engine, in the engine room). The centre of the rooms was selected to generalize the obtained noise values in the cabins. A measurement with both an A and a C frequency weighting was recorded during the period of 30…60 seconds at each location. The exposure levels were normalized to a nominal 8 h working day. All the results were compared to Estonian and International legislations.

Statistics were done with Excel, 2010. All measuring results have standard deviation of 1.0 to 1.5 dB and measurement uncertainty of 2.2 to 2.6 dB.

RESULTS AND DISCUSSION

Analysis of noise levels before (2013) and after (2015) renovations show that during sailing norms are exceeded (see Table 1) in both datasets. In some parts of the vessel the overall noise levels have aggravated – e.g. in the engine room. Both in the mess hall and in the cabin next to the engine room (Cabin E) the noise levels of being anchored regime increased after the renovations. Do note, noise spectrum of auxiliary device in cabin E is not available due to device error during measurements.

Table 1. Comparison of noise levels before and after renovations. Noise measurements were done in three occasions: (1) while only vessel's auxiliary device (diesel generator) worked, (2) when vessel was anchored while the engine still worked, (3) and during sailing. Cabin C – the chief officer's room; Cabin E – cabin next to the engine room

Measuring place		Noise level L_{EX} 8h dB(A)		Noise level L_{EX} 8h dB(C)		Norms dB(A)	Reference to norms
		2013	**2015**	**2013**	**2015**		
Mess hall	diesel generator	42.0	50.0	58.1	69.5	65	EG, 2014
	anchored	65.3	67.8	86.9	87.1		
	sailing	70.9	69.9	93.3	99.0		
Cabin E	diesel generator	52.8	48.7	74.2	71.1	60	EG, 2007
	anchored	72.1	74.2	86.5	97.5		
	sailing	81.0	79.4	97.0	98.5		
Engine room	diesel generator	-	-	-	-	85; 110	EG, 2014; IMO, 1981
	anchored	99.8	101.4	116.1	111.1		
	sailing	101.4	104.0	109.8	111.4		
Cabin C	diesel generator	-	44.7	-	71.7	60	EG, 2007
	anchored	73.5	68.5	89.9	102.3		
	sailing	-	75.2	-	100.5		

In the chief officer's room (Cabin C) the noise levels have gone down by 5.0 dB(A) and 13.4 dB(C) while the vessel is anchored. Unfortunately other comparative results considering the Cabin C from the year 2013 are not available, as the measurements were not conducted during a) sailing and b) while only the auxiliary device was working.

Comparing the results of lower frequency ranges before and after renovations, dB(C) has increased in most of the measuring places.

The noise frequency analysis in the research from theyear 2013 showed that most of the peaks, meaning the maximum sound pressure level values of the graphs, of different measuring conditions and measured areas appeared in range of 50 to 1,250 Hz while sailing (Reinhold et al., 2014). Two years later the range was a bit narrower – 63 to 1,000 Hz (see Table 2).

Table 2. Comparison of peak sound pressure level (dB(A)) before and after renovations and the peak frequencies in concurrence with the occurring peak values (Hz) in engine room and Cabin E (the cabin next to the engine room)

Measuring place		Peak sound pressure level dB(A)		Peak frequencies in concurrence with the occurring peak values, Hz	
		2013	**2015**	**2013**	**2015**
Cabin E	Diesel generator	46.6	56.3	100	100
	Anchored	65.8	67.9	250	100
	Sailing	73.5	72.9	400	160
Engine room	Anchored	84.1	84.8	315	1,000
	Sailing	87.6	87.5	1,250	630

In the engine room the peak frequency of 1,250 Hz has shifted to 630 Hz, while sailing (Fig. 1). In cabin E peaks have shifted from 400 Hz to 160 Hz (Figs 2, 3). The overall change of the noise frequency is not significant.

Goujard et al. (2005) analysed their questionnaire and found that 31% considered the cabins of ships to be acoustically uncomfortable and in need of improvement. The SILENV research (2012a) suggests a new stringent cabin norm of 50 dB(A). That value is very hard to maintain, as Borelli et al. (2015) have shown by indicating that just by using ventilation the cabin's noise levels exceed 50 dB(A).

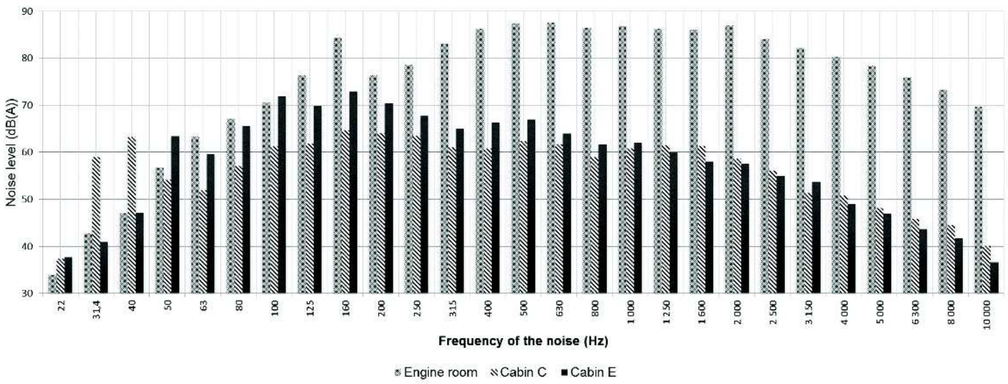

Figure 1. Ship, while sailing, noise frequency analysis 2015. Cabin C – the chief officer's room; Cabin E – cabin next to the engine room and both are situated in the stern.

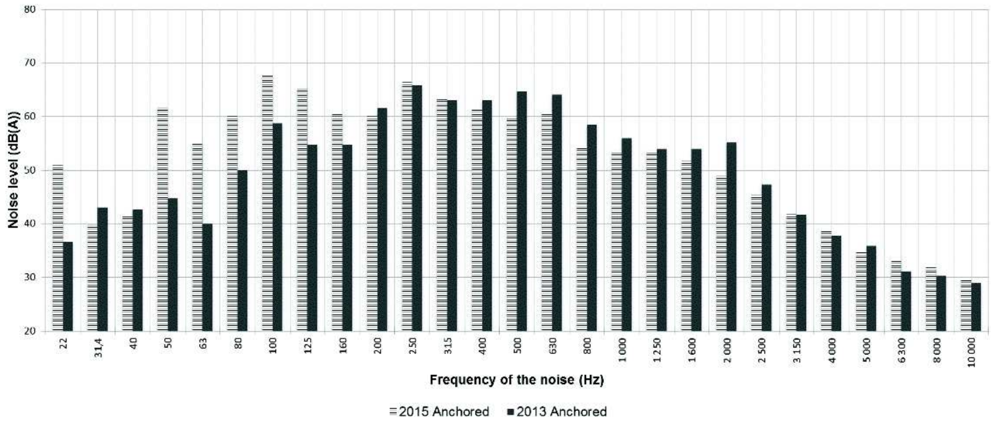

Figure 2. Noise frequency comparison of the results of measurements in Cabin E (in the stern, next to the engine room) in when the ship was anchored.

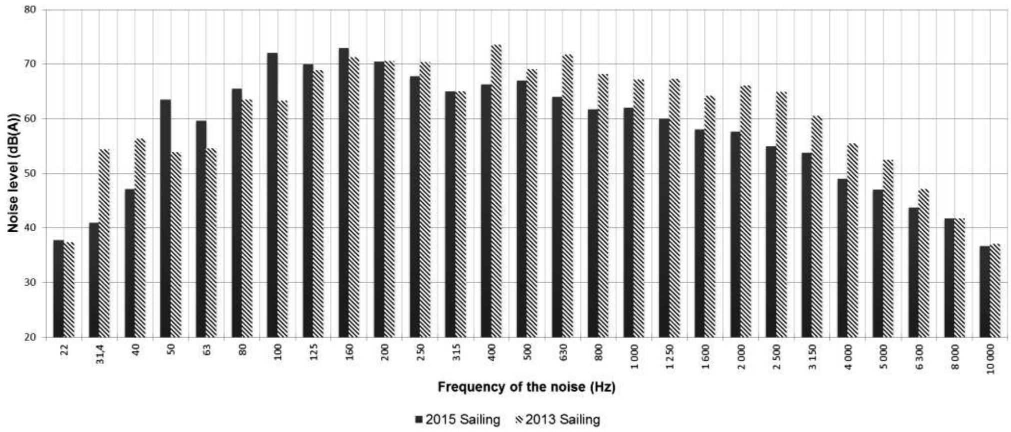

Figure 3. Noise frequency comparison of the results of measurements in Cabin E (in the stern, next to the engine room) while sailing.

Now, regarding the effectiveness of the renovations, it must be considered, that the main objective of the renovations was to lower the noise in cabins. In lower cabins the noise travels mainly through walls and floors. The floating room concept (SILENV, 2012b) was used during the renovations, but unfortunately desired effect was not obtained. Presumably the problem lies in a stiff connection between the ship's structure and either the cabin's inner wall, floor or ceiling. Although there is no information considering the direction of the fibre of wool that was used during the renovations, the SILENV (2012b) suggests orienting the mineral wool fibre in horizontal direction instead of vertical, to achieve an additional 7dB noise reduction. Another deficiency to explore is the possibility that the wool used had insufficient density for the environment and noise in question. By increasing the density of mineral wool by 100 kg m^{-3} up to 9 dB noise reduction can be achieved. To improve the cabins' (C and E) acoustic environment where the ceiling panels were creating additional noise, the metal ceiling panels ought to be replaced with more suitable material or reattached using some additional sealant to reduce the vibration induced noise.

Tamura et al. (1997) have suggested that exposure to ship noise of 65 dB(A) during sleep can have unfavourable effects on the quality of night sleep. Fortunately, during the night when only the generator works, the cabin's noise remains below 50 dB(A) and therefore no disturbing effects on the crews' sleep should occur.

CONCLUSIONS

Although the main purpose of the latest renovation was to reduce the noise levels in cabins, the best result obtained was 5 dB(A), while anchored. Even though cabin noise norms are exceeded during sailing, the 60 dB(A) norm is not surpassed during the night while only the diesel generator works. The renovations did not influence remarkably neither the noise frequency spectra nor the noise levels measured in the A weighting scale. Comparing the results of low frequency ranges before and after renovations, dB(C) values have mostly increased.

Probably the results would have improved more if the floating room concept was used correctly and mineral wool that was used on the walls as insulation was denser. To reduce the noise from metal ceiling panels, the panels ought to be replaced with more suitable material or reattached using some additional sealant to reduce the vibration induced noise.

Our research indicates that on the vessel the normative values of Estonian legislation were not achieved everywhere and at all occasions, which makes reaching the SILENV values even more impossible. Therefore further research, both from the scientific aspect as well as from the development of the suitable engineering solutions, is needed on the topic, to improve the conditions of workers on the vessels.

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