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An Applied Case Study Flaws in Spanish National Noise Standard in Maritime Transport

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ABSTRACT

Noise can be considered as one of the strongest health problems for seafarers. In the present paper, we present the major flaws in standards related to maritime transport, which should be resolved, and the precarious state due to its anachronism or its suitability in application at the national level of Spain. Finally, based on a practical case study, we propose as work risk protection procedure for noise work risk prevention for improving the present national standards in accordance with IMO and ground standards and procedures. Results showed values higher than that recommended for standards. In particular, the higher noise levels were reached in between the main engines and the compressors room. At the same time, the lower illumination values were observed in these two zones, which eventually became the principal hazard of the engine room that must be prevented.

1. Introduction

Recent studies showed that noise can be considered as a fundamental parameter, with temperature, that affects the comfort conditions in a ship (Goujard, B. et al., 2005; Orosa and Oliveira, 2009). Furthermore, it is considered as one of the strongest healthy problems for seafarers (Tamura et al., 2002; Tamura et al., 1997). The present noise working law that exists in Spain is the Royal Decree 1316/1989 of 27 October. This decree consists of the indications for protection of workers from noise from the risks of its exposure during the working period. The problem appears when we try to employ it on board due to this article is not of application for maritime and aerospace transport crews.

In the abovementioned situation, only the general regulation (Gestal-Otero et al., 1999) for Occupational Safety and Health (NIOSH), which was passed in March 9, 1971, is applicable. Despite this, we can see that the Royal Decree presents faulty alternatives for the exceptions of its ambiences of application.

The work risk prevention standard in his article 3 states that "The Estate must put all its interest to develop a specific standard as soon as possible". In this sense, we must take the procedure employed to develop the Royal Decree 1316/1989 as reference. This standard establishes the limit admissible value (LAV) for noise contamination at work, and it is based on working periods of 8 hours per day and 40 hours per week. Therefore, it is not adequate to be applied on board and a scientific study, before the development of this standard, must be conducted to consider these specific conditions.

Another typical consideration that must be arranged in accordance with the on board conditions is the hear recuperation. In this sense, standards remember that a hear begins its recuperation from the noise exposition when it is not exposed to this, but we can find that maritime transport crews are always under the working noise during the sea line, which must be about 4, 5 or 6 months. Furthermore, in this particular study of noise on board, we must consider time periods. The first period must consider the working time, considering the noise levels during the entire working period of eight hours for full time working period. The second period must consider the 16 hours of full time working period when the seafarer is on board, but out of the working ambience.

In particular, these time periods present interest in some zones, such as engine room, to be investigated and applied to a corresponding legislation.

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The only Spanish standard that really considers on board conditions is the Decree March 9, 1971, which passes that the General Decree of Safety and Hygiene at Work (GDSHW) is of required compliance in noise ambiences, including ship crews.

In particular, in Title II, the "General conditions of working places and protection procedures" are shown in Chapter 1, Article 31 "Noise, vibrations and rapid changes". In this article, point 1 shows that the noise and vibrations will be avoided or reduced as much as possible in its origin source, trying to reduce its influence in nearer premises. Furthermore, point 8 indicates that the control of aggressive noise sources will not be limited to the isolation source. It must be adapted to the technical requirements to prevent reflection and resonance phenomena that could drastically affect the workers' health.

These conditions are of special interest for engine rooms where the engines are a significant noise source of the ship. Therefore, in its point 2, it is indicated that the hold systems of engines are noise, vibrations or rapid changes sources must be developed to reach the optimal static and dynamic equilibrium. Furthermore, in point 3, it is mentioned that engines will be adequately isolated, and at its point of location, only the maintenance staff will be allowed to work for a short period of time.

Finally, these conditions are translated to the ship design process in point 4, where the standard comments that it is forbidden to install engines or noisy devices near walls or columns. It must be distanced, how to min, 0.70 meters from dividing walls and one meter from outer walls.

In Spain, this is the only information about the noise control on board in merchant ships. As we can observe, there are a lot of good intentions; however, the permissible objective noise values dB (A) are not shown.

Once the need for a specific noise work risk prevention standard arises, it is the time to revise indicators of the principal international organizations such as the International Maritime Organization (IMO) and the International Labour Organization (ILO). The convention 148 of ILO about the "working ambience" (ILO, 1977) was passed by Spain 12/17/80 and in article 1.1, it is stated that it is of application to all the economical activities and, thereby, for merchant ships so.

From this convention, article 4 is notable; it states that the national standards must adopt procedures in the work place to prevent and limit the professional work risks due to air pollution and vibrations. Despite this, procedures to limit the professional work risks are not known thus far.

Another organization that presents objective values is the IMO; the objective values were presented in its Decision of Assembly 468 (XII), passed November 19, 1981, "Code on noise levels on board ships". In point 2, introduction, it is shown that the objective of this code is to advise to administration about the higher noise level and its limits of exposure. Furthermore, in point 5, it shows that this code is not developed to be directly added to the actual national legislation and is only the basis of future standards. Finally, this code give us some noise limit levels for different spaces that can be referred by the work risk prevention staff while developing the noise map on board. These values are showed below.

a) Working place dB (A)
   1. Engine room (with permanent staff): 90.
   2. Engine room (without permanent staff): 110.
   3. Control engine room: 75.
   4. Work room: 85.
   5. Unspecified working places: 90.
b) Government place dB (A)
   1. Bridge and defeat room: 65
   2. Listen position: 70
   3. Radio room: 60
   4. Radar room: 65
c) Service room dB (A)
   1. Kitchen (without equipment working): 75
d) Unoccupied habitual spaces: 90

As a work risk prevention indicator, this Decision of Assembly showed that it is necessary to protect the ears from 85 dB, and in the Spanish case belonging to European Community, the IMO indicates 90 dB (A).

Finally, as a result of this standard, future directives were developed. For example, a future directive passed by the decision Assemble October 29, 2001 in accordance with the Directive 89/391/CEE that not excludes the maritime sector. This future directive shows the Upper exposure limits and three values for prolonged expositions:

a) Exposition limit, 8 hours: 87 dB
b) Upper exposition limits, 8 hours: 85 dB
c) Lower exposition limits, 8 hours: 80 dB

This Decision Assembly considers that the adopted values represent an adequate equilibrium between health protection and workers safety and a not excessively higher cost for companies; therefore, member states must have an adaptation period for crews.

2. Objectives

In present study, we will analyse the main flaws in the standards related to maritime transport at the national level of Spain. After this, a practical case study on board will be carried out with the aim of proposing a sampling procedure for noise work risk prevention of national standards.

3. Materials and methods

3.1. The ship

In this study, the objective that is related to ship is a fast ferry between Spain and France that transport new cars. Hence, this ship is considered as one of the most silent ships that a crew member can find in its working life. In particular, as shown before, the engine room is the zone object of this study.

3.2. Sound and lux units

Decibel is the measurement unit used for calculating the intensity level of sound; it relates the power of the sound source to study with the power source whose sound is on the threshold of hearing by Eq.1. It is employed to calculate the sensation received by a listener from measurable physical units of a sound source.

$$L = 10 \cdot \log \frac{W_1}{W_0} \tag{1}$$

Where W_1 is the power to examine and W_0 is the reference value in Watts.

The sound waves lead to an increase in pressure in the air, which is another way of measuring the physical sound, which is in pressure units as shown in Eq.2.

$$L = 20 \cdot \log \frac{P_1}{P_0} \tag{2}$$

Where P_1 is the pressure of the sound study and P_0 is the reference value equal to Pa.

While speaking of an electronic device such as a recorder or a mixer, it is useful to talk about the dynamic range known as decibels Fs on "Full Scale". In these cases, the dynamic range of an audio signal matches the highest level of the signal and is referred to as the maximum level of 0 dB, above which the system is saturated, and the noise level is a negative value, e.g., 80 dB. After this modification, the signal is amplified by retaining the shape of the original signal, but by making it wider.

Sound spectrum software has been employed with the aim of analyzing the principal sound on board; that allows the definition of the spectrum on full scale. In our case study, the software, "spectrum analyzer" was employed since it is a free download from the web. Subsequently, sounds were analyzed and the results compared.

3.3. Sampling methods

Standard measures procedures were applied as defined by ISO 140-4, and the equipment was calibrated prior to the measurements with an accuracy of +0.3 dB for sound pressure levels and +0.2 dB for velocity levels.

Samples between enclosures of identical size were made preferably with diffusers in each of the enclosures (e.g., furniture, engines). The area of each diffuser was at least 1.0 m^2.

In accordance with previous studies, the noise sampling process on board must take some considerations:

1. Wind must no exceed de range 4 in Beafort scale, particularly if we are sampling outdoors.
2. Sea condition must be in calm.
3. Rain.
4. Water depth under the keel must not be lower than 3 times the ship draught.
5. Presence of high reflectance surfaces near the microphone.
6. Another sound sources must be considered, for example, noise from workers during their daily tasks.

On the other hand, the sampling position must consider the following:

1. Take various samplings near a sound source, for example, 6 samples per zone.
2. Sampling process will be done at a height between 1.2 and 1.6 meters over deck.
3. Sampling position must not be lower than 0.5 meters near the limits of the room.
4. The distance between two sampling points must not be less than 2 meters. At the same time, in high spaces without any equipment, the maximum distance between the sampling points must not exceed 7 meters. In particular, in the cargo deck, the maximum number of sampling times must not be greater than three.

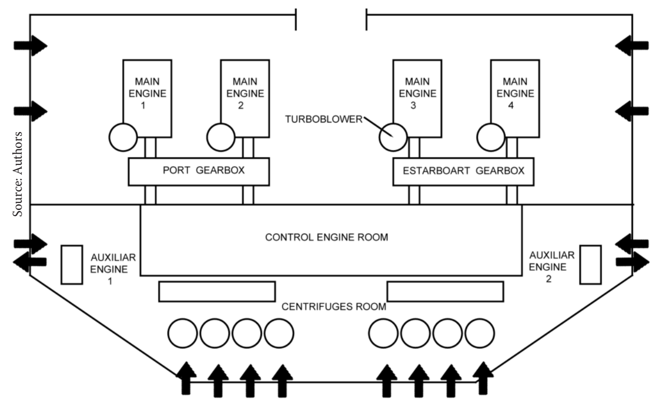

Figure 1: Engine and control engine room.

3.4. Effects of noise over health

Once the sampling process was defined, the noise effect must be analyzed. The comfort zone is located below 45 dB, and over 55 dB, the sound is perceived as nuisance. Over 85 dB, fatigue and dangerous situations are detected. The pre-capillaries undergo contraction and there is an increase in resistance to blood circulation, thus reducing the volume of blood that circulates. Finally, hypertension, digestive diseases, breathing, nervous problems, stress and insomnia can occur. Other consequences are the reduction to sensitivity to colors, reflex and concentration and, in some cases, the fatigue of ears bones can lead to momentary deafness.

The possible solutions to these problems are to stay away from the noise source and to rest. For example, a worker must recover from a noise exposure to 100 dB by resting for10 minutes; 36 hours of outer ear rest should be given if the exposure was for 90 minutes.

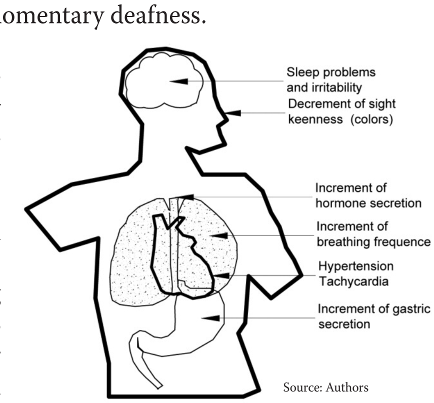

Figure 2: Symptoms that appear when the noise level is over 85 dB (A).

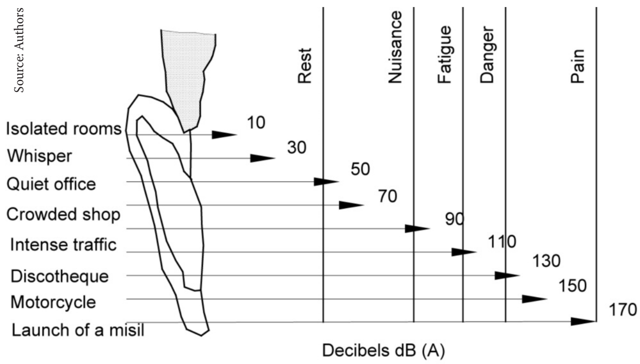

Figure 3: Examples of noise levels.

4. Results

Table 1 shows the noise and illumination levels in different zones of the engine room. Figure 4 shows the sound spectrums of different noises sampled in the engine room, such as noise from the main engine turbine, centrifuge and compressors rooms, and corridors between the main engines (MES).

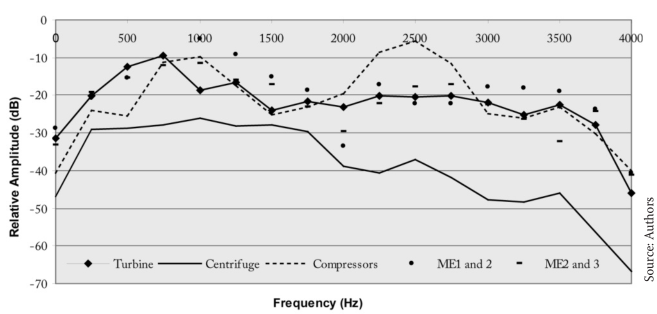

Figure 4: Sound spectra.

Table 1: Noise and illumination levels in different zones of the engine room.

Zone	Control engine room	Corridor ME1-ME2	Corridor ME2-ME3	Centrifuges room	Compressors room
Noise dB (A)	75-80	109.2	116	95	106-112
Illumination (lux)	10-118	2-5	20	10-90	2-100
IMO	75	90-110	90-110	90	90

Source: Authors

5. Discussion

In accordance with the indications in work risk standards, a noise map of the engine room was developed. In the control engine room, the sound sampled was of 75–80 dB when the main engines 1 and 2 are working with a strait of 60%. When the four main engines are working with a strait of 83%, the noise reached values of 80.5%. This value is higher than that showed by IMO for engine rooms with permanent staff, which is limited to 75 dB.

In corridors with a width of 1.5 meters between the engines 1 and 2 and the main engines 2 and 3, the noise level reached a range of 109.2 and 116 dB, respectively, with the four main engines working and a strait of 83%. If we observe the IMO indications, we can confirm that it exceeds clearly the limit value fixed of the engine room of 90 dB for permanent staff and the 110 dB for engine room without permanent staff. In particular, this value is high between the main engines.

In the compressors room, which is located under the control room, the sound reached a value of 106 to 112 dB during navigation without any compressor working. In the centrifuges room, the sound level was about 95 dB. Generally, in these two places, the compressors room and the centrifuges room, the noise level is higher than 90 dB fixed by the IMO.

In this same place, the lux value shows significant changes between different zones from 10 to 118 luxes. The maximum values were reached when sample near a reluctant screen and a near null value in corners and shadow zones.

The illumination was about 20 lux between main engines 2 and 3 and varied from 2 to 5 lux between the main engines 1 and 2. The temperature and relative humidity were about 35°C and 39.1°C and 33.5% and 30%, respectively, for main engines 1 and 2.

In the compressors room, the illumination value was from 2 to 100 lux. In particular, it is very interesting to note that in corners, where it is interesting to do some management task, the illumination values are significantly reduced. The temperature reached 34.5°C and the relative humidity reached 42.3 %during this sailing period.

In the centrifuges room, the illumination varies between 10 to 90 lux. Temperature reached between 32.7°C and 46.6°C and the relative humidity was 40.1% when the ventilation system was working.

Once we have analysed the principal sound levels in the main engine room, in accordance with more developed standards applied on ground, it is important to determine the relative amplitude for each frequency of each different sound that can be detected in the engine room. Figure 4 shows that the turbine of each main engine and compressors room present a higher relative amplitude for a lower frequency and that the centrifuge presents the opposite situation. Finally, the sound spectrum in the corridors between the main engines presents an intermediate value.

In general, from this map of the real sampled data, we can confirm that the values higher than that recommended for standards were reached. In particular, higher noise levels were reached between the main engines and the compressors room. At the same time, illumination values were lower in these two zones; in consequence are the principal hazards of the engine room.

Once it was showed that the principal zones of interest for prevention of work risk in the engine room, it is interesting to see the principal actuation way in ships in accordance with a revision of the royal decree 1316/89.

The first actuation step is carried out by the Shipbuilder. The Green Book of the European Commission, Brussels, 1996, recommends three basic methods for reducing noise exposure:

a) To reduce the noise at its source (engine), b) to limit the sound transmission by using barriers between the noise source and the affected staff, and c) to reduce the noise at the reception point through acoustic isolation. For example, the principal sounds heard in a real ship and its frequency spectrum were analysed. To determine these sound transmission barriers in an in-depth manner, the standards employed on ground should be considered. For example, ISO 140 specifies the methods for measuring the in situ properties of the airborne sound insulation of partitions between the two enclosures in a position for diffusing the sound field, and for determining the protection given to staff. In this standard, the effect of the frequency to define the perceived sound is considered. To consider the frequency, sampling methods give the values of acoustic insulation to airborne sound in terms of frequency and transform it into a single number which characterizes the acoustic qualities of an environment in accordance with ISO 717-1. Finally, results must be compared with the estimated values from the performance of elements EN 12354. As far as indoor noise is concerned, the standard covers both airborne and impact sound; but this was not analysed in this paper; therefore, future studies are required in this field.

The second actuation step with regard to the businessman. In accordance with the Work Risk Prevention Law, in its articles 14 and 15, the businessman must obtain hygienic samples of noise on board, try to delete and, if it is not possible, to evaluate and reduce its effects. The report from the prevention equipment about the noise must be send to health workers of Social Institute of Marine and Medical Prevention Services.

The third step is the prevention equipment. When this equipment develops its work risk evaluation in a shipping company, they must give a noise map to which crew is exposed to the ship owner, with the ship on port or sailing in different zones of the ship. This step was developed in this case study and helped in defining and characterizing different noise sources. What is more, results showed that only in the control engine room, the engineers could be without ear protections as the sound level is below 90 dB.

The last actuation step with regard to the health workers. The Social Marine Institute develops the health control to crew previous to sign. In particular, hearing medical control in accordance with the requirements of RD 1316/89 must be developed. This standard states the following:

a) Workers in environments that exceed 80 dB (A), medical examination once in 5 years, in accordance with the article 5.
b) Workers in environments that exceed 85 dB (A), medical examinations once in 3 years, in accordance with the article 6.
c) Workers in environments that exceed 90 dB (A), medical examinations each year in accordance with the article 7.

Therefore, we can conclude that a program for conservancy of hearing capacity of the crew is a work risk prevention measure that must be applied by health workers, especially by Public Health workers.

In general, we can conclude that all these steps were an adequate guide to develop this practical case study of formal safety assessment. Despite this, more studies that consider each ship characteristic must be conducted.

6. Conclusions

In present study, it were analyse the main flaws in the standards related to maritime transport at the national level of Spain. After this, a practical case study on board was carried out with the aim of proposing a sampling procedure for noise work risk prevention of national standards. As a general conclusion of this analysis, we can state the following:

1. Nowadays, there are no Spanish standards regarding the sound levels that are bearable by the crews of merchant ships.
2. There are reference values that can be employed at present for developing the standards.
3. From Spanish ratification in 1980 and the IMO convention, hardly any activities were carried out to limit the noise exposure to the staff on board. Therefore, a specific standard should be set with regard to the noise on board in accordance with the Work risk prevention on board and the IMO Assembly A.468 (XII). Furthermore, this new standard must consider the European Directive proposal, despite the fact that it only considers exposition periods of 8 hours. Finally, while this new standard is not developed, article 1 of the Royal Decree 1316/89 must be modified in its scope and show those parts that can/cannot be applied to merchant ships.
4. IMO recommendations were not considered for a program on the protection of the hearing capacity of the crew. In particular, the Social Marine Institute must obey considerations of IMO for developing this program for conserving the hearing capacity of the crew. Furthermore, this program cannot be developed to within the time of investigation on board by means of practical case studies and hence, more studies have to be conducted on formal safety assessment (Lois et al., 2004).
5. In accordance with the previous point, in the actual risk assessments, there is no noise map on sailing; hence, the equivalent values of 8 working hours and 24 hours of the day of each crew member are not known. It is a fundamental tool to prevent the noise problem during the ship design process taking as reference the Resolution A.468 (XII) of the IMO, in particular the Chapter 6.
6. This practical case study showed values higher than that recommended for standards. In particular, the highest noise levels were reached in the zones between the main engines and the compressors room. At the same time, these two zones had the lowest illumination values and hence were the principal work risk sources of the engine room. Finally, it is interesting to analyse the sound spectrum for differentiating various sound sources and to determine their actual effect on health. Mainly, the compressors room and the corridor between main engines are the zones with a higher sound level and higher relative amplitude for a lower frequency. Therefore, these are the principal hazards that must be prevented.
7. Solution to eliminate these work risk sources are based on the actual and future standards recommendations such as those for shipbuilders and health workers.

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