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Identification of Design Drivers for Reducing Ship Radiated Underwater Noise and the Airborne Noise Levels on Tug's

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Abstract:
The most widespread and pervasive kind of anthropogenic energy is underwater sound. Shipping noise is a major contributor to the ambient noise levels of the oceans and a major source for adverse effects on marine mammals. Proper design considerations need to be studied on noise sources on ships to reduce airborne and underwater noise levels and improve safety.
There is a need to identify the various noise sources (propeller, machinery and flow around ship) on ship and check alternatives means to dampen each noise source propagations, so has to have considerable damping in overall airborne and underwater noise levels in the initial design stages.
Measurements of airborne noise have been carried out in various location of different propulsion type tugs in the channel of Visakhapatnam and a comparison of the results is tabulated. The measurements of the airborne noise levels on five tugs are noted during regular towing operation. The noise levels in the Engine room are well below the permissible limits but in other locations the noise levels are above the limits. The reason for the noise limits to be above the acceptable limits in upper deck regions being the position of the ventilation blower unit in the above deck and the windows in open condition during measurements. Also the average noise levels of Voith Schneider propulsion (VSP) and Schottel Rudder propulsion (SRP) is 103 dB. The vessel traffic noise levels at the entrance of the channel is around 69 dB.

1. Introduction

Standard ship operations produce noise at a range of frequencies. Low frequency sound waves experience little attenuation and will propagate over long ranges (100 Kms). As a results, noise from shipping activity dominates low frequency (<300 Hz) ambient noise levels throughout the ocean.

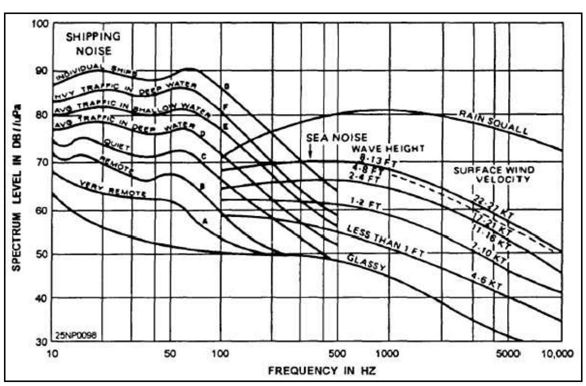

Figure 1: Ambient Noise levels (Ref. Journal of Mamma logy [3])

The elevated ocean noise levels from ships can interfere with the sound produced and / or used by marine organisms, especially marine mammals. Sound is an effective way to propagate energy through the ocean. Marine mammals relay on sound as a means of communication for finding food and mates, and for detecting predators. Increasing the background noise levels decrease communications ranges, and may potentially also modify behaviour and / or induce a stress response.

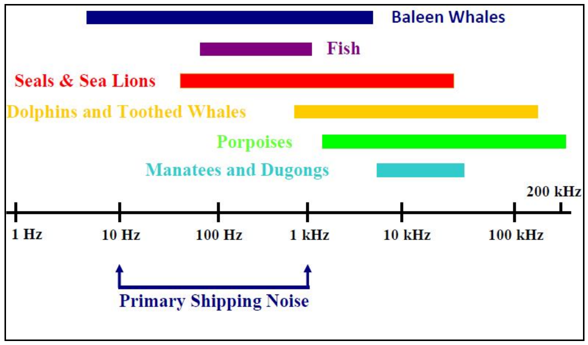

Figure 2: Frequency relationship between Marine animals sound and sound from shipping. (Ref. NOAA Fisheries [4])

The coastal regions with heavy shipping can have ambient noise background with noise level (~ 10 dB) high than wind- wave noise[1]. For a period in 2010 in Bay of Bengal the ambient noise level measured showed a Standard deviation of (~7.60 dB at 0.5 kHz and ~ 7.90db at 1.0 kHz) due to frequency of passage of a tropical cyclone, storm, changes in monsoon wind field and dominant coastal shipping activity[2].

The tugs are deployed for towing large ship into the channel of ports. The load onto the engine is generally <50% during normal operations and around 85-100% during towing operations in confined regions of the channel. Thus, the main engines being a major noise source on-board a tug. Based on the type of the propulsion system the positioning of the main engine and thruster is done. In general the cabins and other facilities are above main deck level. In these locations the airborne and structure noise propagation is high with minimum transmission loss.

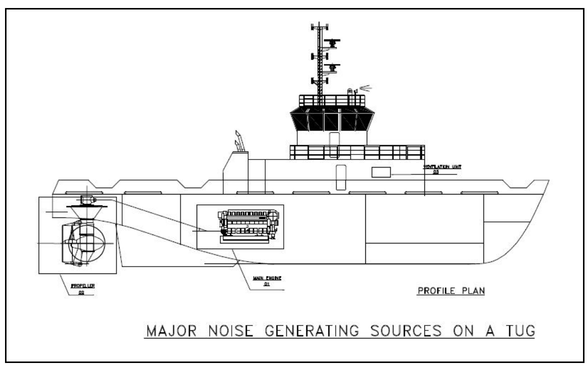

Figure 3: Major noise sources on a tug.

Proper acoustic insulation on deck head and floating floor in cabins shall be used to reduce the noise propagation to the above decks.

1.1. Definitions

The term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect. "Sounds" include both meaningful signals and "noise" which may have either no particular impact or may have a range of adverse effects. The term "noise" is only used where adverse effects are specifically described, or when referring to specific technical distinctions such as "masking noise" and "ambient noise." (Ref. Based on Southall et al. 2009 and Tasker et al. 2009[5])

Ambient noise level sometimes called background noise level, reference sound level, or room noise level is the background sound pressure level at a given location, normally specified as a reference level to study a new intrusive sound source.

The sound pressure level (SPL) is a measure of the effective pressure of a sound, averaged in time, and relative to a standard reference pressure. More specifically it is the root mean square (RMS) acoustic pressure expressed as a level, in decibels. The reference pressure in underwater acoustics is defined as 1 micro Pascal (symbol μ Pa), which is one millionth of a Pascal. The SPL values in water cannot be directly compared to those in water as a consequence of different reference pressures and the differences in impedance between water and air.

Sound exposure level (SEL) takes the different duration of sounds into account and it is a measure of the accumulated energy over a defined period (often 1 second). It also allows the comparison of sounds of different durations. The SEL is the integral of the squared acoustic pressure with respect to time, expressed as a level in decibels over defined period.

Power spectral density level: All organisms can only perceive a limited subset of sound frequencies, depending on their perception mechanisms. It is therefore necessary to describe how the power of sound relates to the frequency. Power spectral density level is expressed in dB re 1 $\mu Pa^2/Hz$ and represents the average sound pressure for each band of width 1 Hz.

Octave band level: When considering the impact on marine organisms, broader frequency bands are often chosen, with 1/3 octave bands most commonly used.

Sound mapping and Transmission losses of underwater sound is A- weighted sound level which greatly depend on the temperature of the water column and sediment properties. The transmission of underwater sound is mainly due to spherical spreading loss and absorption in water.

2. Design Drivers for Reducing the Noise On-Board Ship (Ref MEPC 60/18 IMO [6])

2.1. Propeller
Cavitation is a significant source of low frequency underwater noise from large vessels at high propeller loads. Blade tonal sounds, propeller depth and pitch setting are important in terms of long range propagation.
Certain design consideration with respect to hull-propeller interaction to improve the wake field around the propeller and reduce hull resistance.
Alternative propulsion devices effects on the underwater radiated noise with minimum disturbed flow on the propeller.
Propeller material, composite and reduce vibration with round edges on trailing and leading edges.

2.2. Machinery
Operating machinery at frequencies < 100 Hz at lower ship speeds propagate sound via hull due to vibration.
Reduction gears and medium speed diesel generators are other sources.
Equipment and propulsion must be fine tuned to achieve appropriate harmonics.
Resilient mounting, acoustic filters, damping to structure, active mounting systems, isolation and reduce electrical load are some measures to reduce the vibration and noise propagation due to machinery onboard ships.

2.3. Hull
Flow noise around the hull is generally minimal but increases significantly at low frequencies as the vessel speed increases.
Flow around appendages and appendage noise is of low intensity at frequency < 20 Hz. Underwater appendages could be streamlined and rudder (rudder bulb) and skeg designs optimized to improve flow of water and to reduce drag and noise.
Hull cleaning and silicon based coating will reduce hull resistance and propeller loading.
Rerouting of ships from zones of marine life passage shall be important consideration.

3. Measurement of Airborne Noise Levels on Tugs
During regular operation of the tugs of Visakhapatnam Port Trust, student of Indian Maritime University carried out noise measurements using Sound level meter (SLM) (make : Bruel & Kjaer, type 2250) as part of their academic exercise. The total equivalent continuous A-weighted sound pressure level L_{eq} is measured using the instrument.
Measurements on five tugs have been carried out, in which 3 no's are SRP and 2 no's are VSP systems. All the tugs hull and super structure is of similar standard design. The compartment arrangement and cabins layout are also similar.

Tugs	Propulsion type
A1	VSP
A2	VSP
B1	SRP
B2	SRP
B3	SRP

Table 1: Tugs on which the noise measurements are carried out

The measurements are taken on the following locations during the tug operation.
a) Main Engine
b) Thruster
c) ECR
d) Main deck hall
e) Ventilation room
f) Wheelhouse

The major source of noise being below main deck level, the noise propagation levels reduced as moving to the upper deck level.

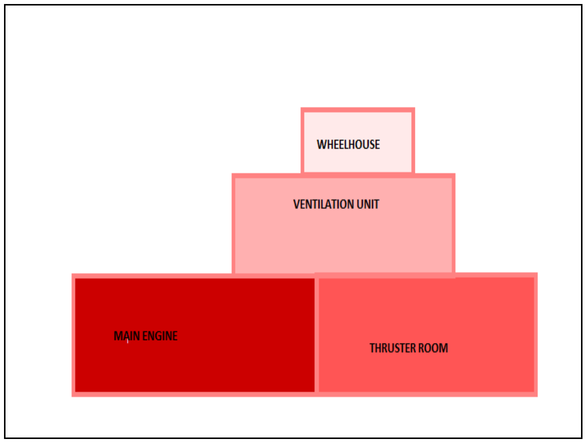

Figure 4: Indication of the noise propagation levels

3.1. Theoretical Prediction of Shipboard Airborne Noise Levels

With reference to the Technical and research bulletin No.3-37 of SNAME "Design guide for Shipboard Airborne Nosie Control[7]", prediction of airborne noise levels in the ship engine room is carried out. A systematic approach to predict noise levels requires three elements the source, the transmission path and the receiver. These calculations are based on the engine parameters like power, weight and size. The method also describes influence of more than one noise sources in the region.

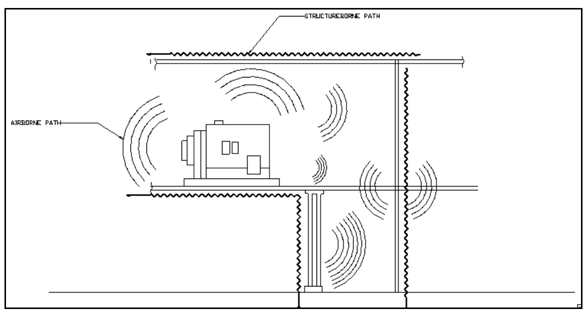

Figure 5: Airborne and structure borne noise propagation

3.2. Channel Noise Measurements

The airborne noise levels at the Visakhapatnam Channel entrance close to VTS station have been measured for a period of 3 hours (AN) during vessels movement with the channel. The measurement results are shown in table 6. The measurements are used to compare the noise levels during the vessels movement and idle condition. During the measurement the other external noise sources like wind, road traffic have some influence on the measurements. Generally, the vessel movement within the channel is done at very slow speed, the noise generated is mainly due to the tugs and the vessel exhaust.

4. Results

The sound pressure levels measured in the below main deck (machinery spaces) on the five tugs are as follows:

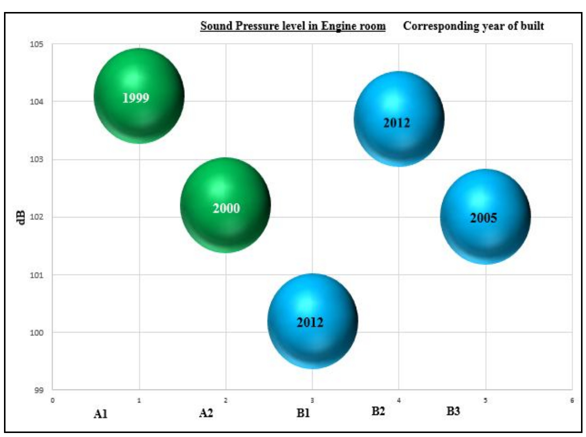

Figure 6: SPL in the Engine room

S.No	Name of Tug	MAIN ENGINE in db	THRUSTERS in db
1	A1	104.1	97.5
2	A2	102.2	97.7
3	B1	100.2	95.2
4	B2	103.7	103
5	B3	102	95.6
IMO LIMIT		110	110

Table 2: Sound pressure levels in Machinery spaces.

The sound pressure levels measured in the above main deck on the five tugs are as follows:

S.no	Name of Tug	Main deck hall in db	First super structure deck in db	Chief engineer cabin in db	Wheel house in db
1	A1	75.6	-	71	72
2	A2	79.5	78.7	75.8	84.3
3	B1	77.5	78.1	67.7	68.1
4	B2	75.7	87.6	-	69.9
5	B3	-	75.1	66.5	81.1
IMO LIMIT		65	85	60	65

Table 3: Sound Pressure levels in above main deck locations.

S. No	Name of Tug	MAIN ENGINE in db (Measured)	MAIN ENGINE in db (Predicted)
1	A1	104.1	101.53
2	A2	102.2	101.53
3	B1	100.2	100.74
4	B2	103.7	100.24
5	B3	102	100.24

Table 4: Comparison of Sound Pressure levels in Engine room.

S. No	Description	SPL (dB)
01	Visakhapatnam Channel Entrance (no traffic)	65.35
02	Visakhapatnam Channel Entrance (with traffic)	69.55

Table 5: Channel noise measurements comparison

5. Observations and Conclusions

From the measured values of the sound pressure levels the following observations are made.

a) The machinery spaces SPL dB (A) on all the tugs are well below the permissible limits as per IMO MSC 331(97), considering its applicability.
b) The above main deck cabins are having slightly higher SPL in Hall, cabins and wheelhouse then the acceptable limits, since the ventilation blower units is placed on the above deck and windows are also in open conditions during the measurements in cabins.
c) The average SPL of SRP and VSP systems in engine room is 103 dB, which is well below the acceptable limit.
d) The theoretical prediction and measured noise levels are quite close.
e) The sound pressure levels variation at the channel entrance is around 4 dB. This increase in SPL is not only due to the traffic but also the surrounding wind and other disturbances.
f) At most care must be taken at the design stage of the propeller, selection of machinery and hull form design giving consideration to the noise radiation from sources for improving the comfort and environmental aspects.

Considering the environment impact and comfort, at the design stage necessary precautions for ship radiated noise to be made by identifications of the sources and dampening to be done by providing proper acoustic insulation, floating floors, vibration isolators tiles and rubber mounting at all joints and by proper design layout.

The airborne and structure borne noise levels estimation at design shall be very helpful in understanding the comfort levels for good working environment. This can also be done by developing a database of measurement on vessels in different conditions for future prediction of similar type vessels.

The present measurement results on tugs give an indication of the trend on the sound pressure levels based on propulsion type, arrangement and increase in SPL over the years of the operation of the vessels.

The influence of shipping traffic in the channel effect the comfort levels of the surrounding domestic neighbourhood.
This study shall be very helpful in future predictions and design layout modifications on tug design and operation point of view.

6. Acknowledgment

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