International Journal of Engineering and Advanced Research Technology (IJEART)
ISSN: 2454-9290, Volume-2, Issue-3, March 2016

Acoustics Reduction in Marine Vessel Using Active Noise Cancellation System

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Abstract— **Noise from anthropogenic sources is considered as a world-wide problem for marine biosphere, and recent studies have shown a wide range of adverse effects in various species. Underwater noise from shipping is widely accepted as a vital and prevalent pollutant with the capability to impact marine ecosystems on a global scale. Recent researches have confirmed an alarming effect of shipping noise on aquatic life. It is clear from previous researches that the noise is proportional to the speed of ship and their size. The smaller ships had little effect on noise and the military ships were comparatively quiet but their technology is unrevealed. However, we have proposed a possible solution to reduce the noise from ships. The active noise cancelling principle could be effectively installed in large ships. A three dimensional wave cancellation technique has been developed to reduce the noise. The main idea is to actively cancel the noise and phase out in order to reduce the amplitude which will in turn reduce the effect of noise pollution on flora and fauna.**

***Index Terms*— Active noise cancellation, Hydrophone, Noise isolation, Phase shifter, Ship noise reduction.**

I. INTRODUCTION

The effect of noise pollution on marine ecosystem is more significant and serious than what was previously thought. Underwater noise was first posited as a potential threat to marine fauna, fairly recently, in case of long range communication between baleen whales (Payne and Webb, 1971). Initially the underwater noise research was focused mainly on military applications. Hydrophones have been used to listen for sounds produced by submarines from World War I, and radiated noise from ships was identified as a nuisance in signal processing of active sonar during World War II (Lemon, 2004). In the last few decade noise has as a source of disturbance to marine life become a field of study (Simmonds et al., 2014). Aglaia badino et all proposes that the difference between the effect of noise on marine ecosystem and the technological solutions to it are very long and insists on the need of a technology to prevent the effect of ship noise on ecosystem.

Shipping noise at close range has high frequency that actually mask the endangered Southern Resident killer whale calls known as 'echolocation clicks'. Commercial ships ply over the oceans on a daily basis as they move raw materials and consumables around the ports. Since the World War II the global commercial shipping has grown substantially which results in an increase in low frequency noise in the world's oceans. The noise produced by commercial shipping is the significant source of underwater noise at frequencies up to 200 Hz. Increasing noise levels in the oceans are of particular concern for marine mammals because they rely on sound to communicate, hunt, detect predators and find mates. Baleen whales are more sensitive to low-frequency underwater noise often associated with shipping, displaying both behavioral and physiological responses to ship noise. This is because they are low-frequency specialists with hearing thought to be most sensitive at frequency range of 10-1000 Hz. Less is known about the potential effects of shipping noise on toothed whales whose hearing sensitivities range from 150 Hz-160 kHz for mid-frequency cetaceans and 200 Hz-180 kHz for high frequency cetaceans.

TABLE 1.1

COMPARATIVE SCALE OF OCEAN NOISE AND THEIR NOISE LEVELS

TYPE OF NOISE	NOISE LEVELS
20 Kg TNT	279 dB re: 1μPa
Air gun arrays	230-255 dB re: 1μPa
53-C mid-range sonar	235+ dB re: 1μPa
Effective source level of LFA sonar	230+ dB re: 1μPa
Super tanker (340m)	190 dB re: 1μPa
Tanker (135m)	169 dB re: 1μPa
Fishing trawler	158 dB re: 1μPa
Maximum allowable exposure to LFA sonar for civilian divers	146 dB re: 1μPa
Avoidance behavior in 80% of migrating gray whales	136 dB re: 1μPa
Maximum Jet Ski noise	125 dB re: 1μPa
Avoidance behavior noticed in Bowhead whales	116 dB re: 1μPa

Shipping within this coastal area causes considerable underwater noise at both low- and high-frequencies, within the ranges (10 kHz-40 kHz) that killer whales use to communicate, hunt and navigate. This means that at close range shipping traffic may have the potential to mask the calls or echolocation clicks by killer whales.

The various methods which are currently adapted include passive noise reduction and reducing the generated noise by slowing down the ship in the areas of animal activities. The passive noise reducing techniques includes damping, silencing the exhaust gases from engine (Reflection and Absorption types), and sound absorption using materials like mineral wool.

II. SOURCES OF NOISE POLLUTANT IN MARINE VESSEL

The source of pollutant is classified into two major categories which happen to be primary and secondary noise sources. The primary noise source covers propeller cavitation noise (200dB), engine exhaust sound (135-142 dB) and ventilation noises (81-110 dB) from engine room ventilation, cargo ventilation, air conditioning system and galley ventilation. The secondary source covers reefers, cooling containers, pumps and winches (85-90dB).

Other than these, the noise arises from the surface of the vessel while it is maneuvering due to contact between the walls of the ship and the sea water, which is usually not considered as a significant source that possess greater threat to killer whales and dolphins. The overall noise produced due to vessel activity is given by

$$\mathbf{P_{Total}=P_{Background}+P_{Structure}+ P_{Fluid}+ P_{Propeller}}$$

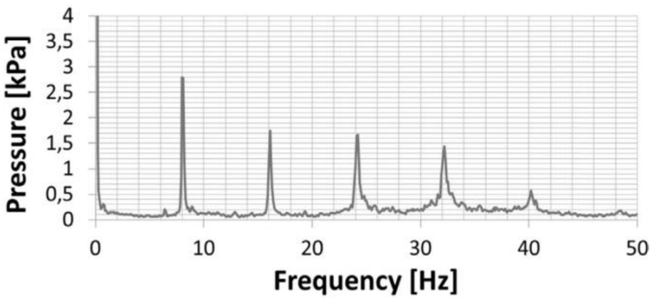

Fig 2.1 Pressure pulses at normal propeller operation.

III. DESCRIPTION OF THE SYSTEM

The principle used to reduce the noise is active noise cancellation system. Even though the passive system serves its purpose of reducing the noise, the effectiveness and the efficiency of the system is not up to requirement level that can possibly solve the problem of reducing the noise, so that the marine organisms are not affected. The active noise cancellation technique is a well-entrenched system that has been used in various forms for the noise reduction purposes. The most popular applications include noise cancellation headphones and noise cancellation mics in mobile devices. So we thought that we could implement the same principle in the marine vessel with slight modification in the hardware components which are used to accommodate them in large vessels. The technique serves dual purpose by actively reducing the noise level as well as providing camouflage effect to some extent. These vessels may be escaping the incoming sonar waves from other ships as the system will cancel out them before they are reflected back. Even when the cancellation is not that effective during particular rare scenarios, the wave will lose its amplitude so that it will be tough job for the predator vessels to interpret and decode them.

The technique involves superimposing the 180 degree phased out wave with that of the original noise wave. It utilizes special recording equipment's with software wave modification technology and specifically designed high intensity sound generators. Adding to this the hardware components are corrosion resistant.

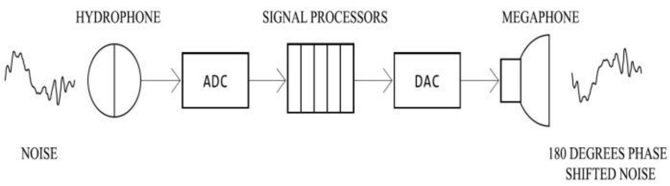

Fig 3.1 Block diagram of the system

Firstly, the noise waves are inscribed with help of the hydrophone which works with piezoelectric transducer. The sound which is in the form of acoustic pressure wave is converted to a sound of electromagnetic wave which is a direct analog form of an acoustic wave. These electrical signals have to be transformed from analog to digital signals. Then the signals are processed using Digital signal processor. In DSP the processing characteristics includes phase shifting of the original waves which are basically in the sine form by an angle of 180 degrees. Then the digital signals are reverted back to analog form and amplified using a high watt amplifier with high bridged output.

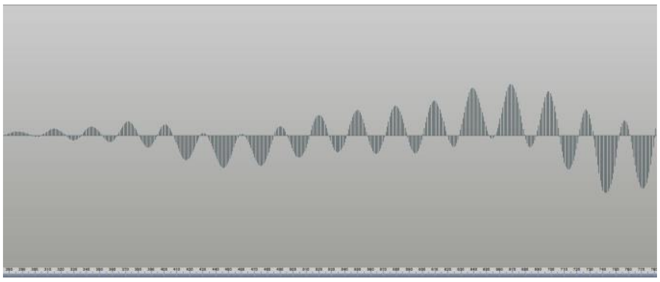

Fig 3.2 Sound waves produced at the surface of the vessel which is generated by the hydrophone.

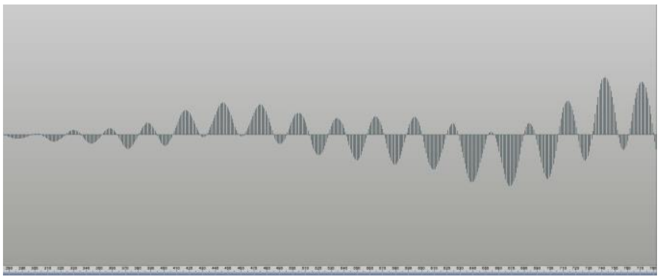

Fig3.2 Phase shifted sound waves coming out of megaphones.

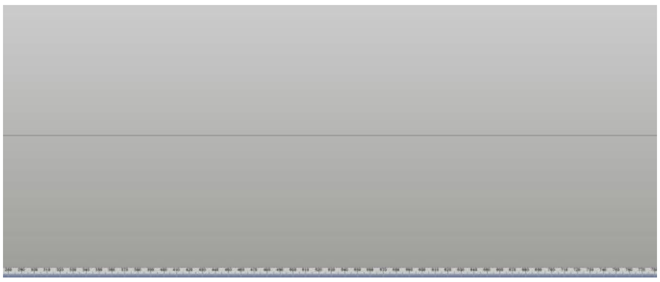

Fig 3.3 Resultant sound wave after coincidence of initial sound wave with phase shifted sound wave.

IV. CHARACTERISTICS OF THE COMPONENTS

A. Hydrophone

They are basically underwater microphones. They are com-posed of piezoelectric ceramic elements. Mostly these devices are without preamplifiers and are often reciprocal i.e. they can both transmit and receive sound. Preamplifiers are used as an integral part of a hydrophone to boost the piezoelectric ceramic signal. Hydrophone sensitivity is given in dB referenced to 1 Volt/μPa (dB re 1 V/μPa). A μPa is 1 μnewton/meter-squared. In some older literature sensitivity may be given in dB re 1μ bar.

Hydrophones are selected for underwater measurement system has the feature of being Omni directional for higher angle and has high sensitivity which is suitable for underwater acoustic recording that has a working frequency range of 20 Hz-50 kHz and working depth up to 25m below the plimsoll line.

B. Signal Processor

Signal processors form the core of the system. They have high precision in working so that they could accurately reproduce the sound. The delay period between the noises received by the hydrophone and reproduced in the megaphone after processing marks the effectiveness of the system, because extended time delay cannot be tolerated. Even slight delay in the time could result in lag in the sound produced and the cancelling efficiency is drastically reduced.

The signal processing system consists of a digital signal processor and a microprocessor coupled with suitable inter-faces. Specifically developed algorithms are encoded into the memory modules which process the noise signals and phase shift the signals. The dynamic range of the processor is 90dB to 200dB whose band is limited from 20 Hz-50 KHz.

C. Megaphone

The sound waves which are phase shifted are generated using the megaphones which are placed in the outer periphery of the vessel. The megaphones are of high magnitude to produce sound waves of enough amplitude in order to nullify the noise waves. The megaphones are of strong construction which allows it to operate beneath the sea at much greater pressure. It is equipped with a ceramic magnet inner construction which is encapsulated with polyamide copolymer, Acrylonitrile butadiene styrene (ABS). The frequency response range is 100 Hz-10 KHz.

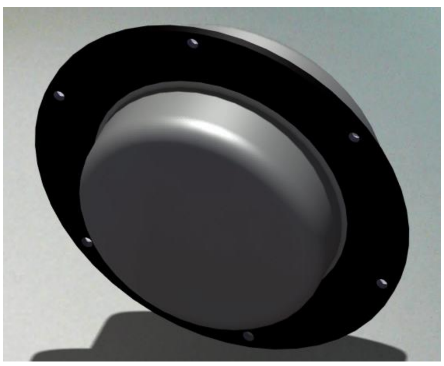

Fig 4.C.1 The above figure shows the megaphone without the wet-niche.

V. FIGURES AND TABLES

A. Schematic Figure of Marine Capsule

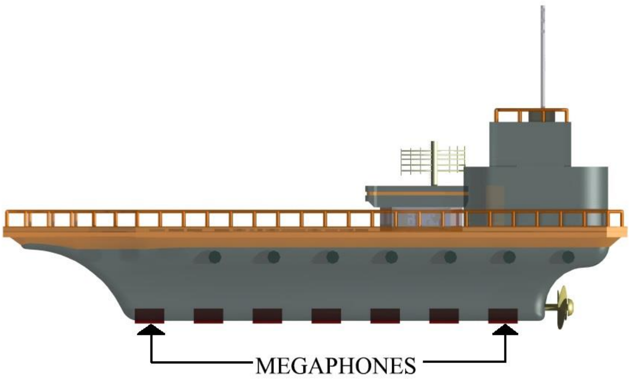

Fig 5.A.1 The above figure shows the marine vessel equipped with the system.

Fig 5.A.2 The megaphone integrated with hydrophone is shown.

B. Properties of High Impact Acrylonitrile Butadiene Styrene

PROPERTIES	**VALUE**
Density	1040 Kg/m^3
Youngs modulus	2.42e+9 pa
Poissons ratio	0.35
Bulk modulus	2.6889e+9 pa
Shear modulus	8.963e+8 pa
Tensile yield strength	4.44e+7 pa

VI. ANALYSIS OF MEGAPHONE INSTALLED IN THE SYSTEM

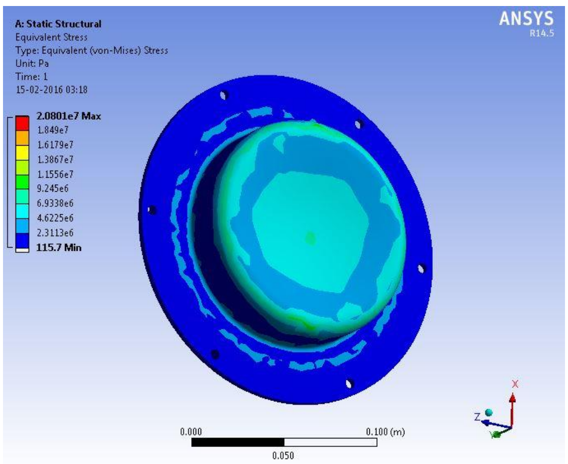

Fig 6.1 Analysis showing Equivalent (Von-Mises) Stress

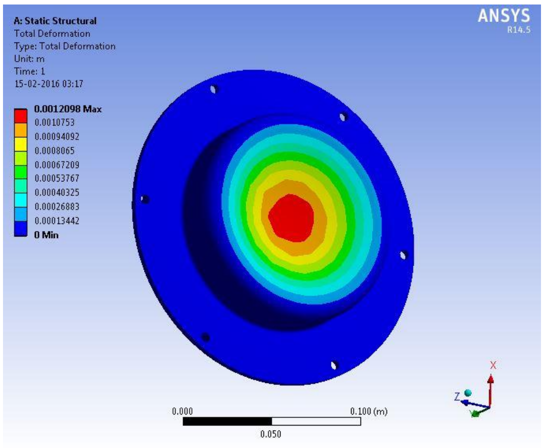

Fig 6.2 Analysis showing total deformation under stressed condition.

VII. CONCLUSION

In normal vessels the noise arising is around 111db which is equivalent to 173db in water. In normal passive noise reduction system, the amount of acoustics reduction is around 3-5db. But in the proposed system the reduction amount is around 20db when considered in a three dimensional space. The system is also ecofriendly as the materials and other components used will not be having any adverse impact on the marine environment.

The intervence of the anthropogenic noise with the marine life is greatly reduced and the ecosystem is reserved in its natural phase. The system does not require frequent human assistance. The system allows the ship to increase its speed as the noise produced is directly related to the speed. The components are analyzed with ambient sea boundary conditions.

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