SIGNATURE MANGEMENT OF NAVAL PLATFORMS

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ABSTRACT:

This Paper provides an overview of signature management of naval platforms with special emphasis on structure borne noise control. It is now an established fact that signature management is most effective if it is incorporated as an integral part of platform's design. Requirement of signature management emanates from the need to assess threat perception of the platform from sensors sensing its emitted signatures and to build in adequate stealth during design to avert the threats. Emitted signatures are many but more important ones for naval platforms are Underwater Noise (***Acoustic***), Radar Cross Section (***RCS***), Infra Red (***IR***), Magnetic and Electric (***ELFE/UEP***) signatures.

Signature management primarily involves ***prediction, measurement and mitigation*** of emitted signatures. Computer modelling techniques have advanced to a level today that accurate prediction of signature is feasible which allows the designer to optimize signatures. Prediction provides a lot of insight into the nature and pattern of signature thereby providing the basis for the approach to be adopted for control. To validate the predictions as well as to understand the effectiveness of stealth designs, measurements of signatures are essential. Measurements of course needs more complex and elaborate set up in the form of ranges. This paper provides a broad coverage of prediction and measurement approaches being employed for various signatures of naval platforms.

Signature mitigation techniques are many and varied in nature depending on the specific signature being addressed. Both ***passive and active techniques*** are employed for signature control. Most of the techniques currently in practice are passive in nature as active control is more complex and still to be matured. In this paper, control techniques applicable for emitted signatures are discussed. Some emphasis is laid specially on ***structure borne noise control*** techniques such as Vibration isolation and Damping. Innovative techniques such as multi stage isolation and constrained layer damping have provided significant noise reduction from platforms. Structural modifications, detuners and acoustic tiles are some more approaches that are found to be effective in structure borne noise control. Another approach is adopting a material such as FRP composites with better inherent damping than metals for fabricating structures such as foundations, propellers, shafts and hulls.

While the competition in developments continues between sensors and its counter measures, it is inevitable for naval platform designer to adapt to the changing scenario to build in adequate stealth to survive the battle field. It is therefore important to realize that signature management has to keep pace with the modern detection technologies. The paper also brings out that while design and construction would make a platform stealthy, efficient life cycle management of the platform also plays a vital role in maintaining its effective role in the fleet.

Keywords: Signature Management, IR, RCS, Noise, Magnetic, Electric

1.   INTRODUCTION

Naval Stealth technology is an assimilation of a range of techniques for air, marine and land platforms that makes them less vulnerable to detection by adversary, thereby enhancing their survivability, and consequently, operational effectiveness. Today, it is well recognized that all warships are required to be designed for stealth. Stealth design enables the ship to ***avert threats*** from air or underwater while ***enhancing*** its own ***first strike capability***. Stealth design parameters include low observable signatures such as acoustic, radar, infrared, magnetic and electric among others. With advent of many advanced computation technologies one can predict each of these signatures during design and build in stealth features to manage these signatures within acceptable limits. . With an increased emphasis on warship stealth, there is a growing need to predict and measure signatures. The analysis of the predicted signature presents a way ahead to take appropriate mitigation measures during the design phase itself.

Signature management encompasses three aspects i.e., Prediction, Measurement and Control of emitted signatures of the platforms. While prediction can be done using analytical/computational techniques, measurements need elaborate field equipment to cater for large complex bodies such as ships. Control of various signatures poses different challenges. It is also pertinent to keep in mind that control of one signature should not be detrimental to other signature. Care should also be taken to ensure that integrated signature management of a platform does not affect its functional/performance requirements. In view of these factors, it is very important to emphasize that ***signature management must be considered from the design stage itself*** rather than implementing stealth as retrospective fitments on already designed and constructed platform. Thus the role of designer becomes critical in realising a stealth platform.

This paper delineates an overview of Signature Management as applicable to naval platforms. Though many types of signatures are emitted from a naval vessel, focus of study is driven by ***threat perception*** posed by detectability of various signatures. For example, a typical warship signatures include IR, RCS, Acoustic, Magnetic, Electric, Wake, LCS and Visual/Optical. However, considering present and near future scenarios, some of the signatures assume more significance than others. Accordingly, this paper discusses two of the above water signatures (Infra Red and Radar Cross Section) and three of the underwater signatures (Acoustic, Magnetic and Electric). Broad approach to manage each of these signatures is brought out. For each signature, prediction, measurement and mitigation approaches are discussed. Special emphasis is laid on 'Structureborne Noise Control'. It is brought out that present signature suppression methods are primarily passive in nature though some progress is seen in active control methods in recent times. In the end, need for integrated signature management approach at design stage of the platform and efficient life cycle management for effective role of the fleet is emphasized.

2.   THREAT PERCEPTION AND SIGNATURE MITIGATION APPROACH

This section discusses about signatures of prime importance to naval platforms. Importance of these signatures, their generation and broad mitigation approach are briefly brought out.

2.1 Infrared (IR)

Infrared (IR) light is electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 0.74 micrometers (µm) to 1000 µm. Infrared signature is one of the methods for the detection and attack of warships. Hence, it becomes imperative to suppress the IR radiation of naval platforms to make it less susceptible for detection and attack. The contrast of the colours in IR image is detected by seekers. The contrast has to be reduced i.e. the temperature of the object has to be brought to the reference temperature range to make the object undetectable. There are three major IR sources in a ship. These are exhaust plume, duct surfaces, hull and associated surfaces. IR radiation is particularly dominant in certain wavelength windows depending on atmospheric transmittance in case of exhausts and hulls. A Naval Ship should be specially designed in such a way that it is efficient in reducing the temperature and thus the IR signature of the ship. **IRSS devices and water mist** are two of the solutions which provide necessary protection for exhaust ducting of ships while **IR paints** can be effective for deck surfaces.

2.2 Radar Cross Section (RCS)

Radar Cross Section (RCS) is one of the stealth signatures by which a target can be identified/ classified at a longer range measures. RCS is a function of target shape, frequency of observation and aspect angle. For a ship like object, projected surfaces above the water level are important as the superstructure and equipment such as mast, antenna, turret gun etc become major sources of RCS. The designer of a stealth vessel therefore emphasizes on **shaping** of these projected surfaces for reduction of RCS. Material treatment is an option for the existing vessels where shaping is not possible and also an additional measure for new design ships. Approaches such as **Radar absorption** and **Radar transparency** are adopted using various materials. **Composites (FRP)** have become a viable and efficient material in recent times for such solutions. Radar Opaque and Optically Transparent **(ROOT)** materials are suitable for certain applications. Passive cancellation using resistive sheets over the scattering centres is another approach for RCS reduction. As most of these treatments are frequency and aspect angle dependent, their performance are to be evaluated over the frequency range and aspect angles of interest prior application onboard. In recent times, more advanced approaches such as FSS and active cancelation etc are being tried by researchers for RCS reduction.

2.3 Acoustics

It is well established fact that Underwater **Radiated Noise** is the most potential threat for a naval platform as noise can be detected by sonars / acoustic sensors at fairly long distances. Therefore, controlling acoustic signature emanating from naval platform is an active area of research. This noise is primarily contributed by **machinery** onboard the platform and the **Propeller** though flow contributes to some extent. Reduction of acoustic signature can be achieved by modification of the Source-Path-Receiving space environment. For retrofit measures, modification of the source is generally not feasible, more so for critical applications. In the Naval context, the receiving space is theoretically infinite and practically unmanageable, and therefore one has to address the **path of noise propagation**/transmission. Vibrations generated by machinery transmit through their foundations to the hull and thereon transmits as underwater radiated noise through interaction of hull with surrounding water. Propellers on the other hand can contribute to radiated noise in two ways. One is by structure borne transmission of vibration through its shafting to the hull and resulting radiated noise while the other is direct radiation of noise by interaction of propeller with surrounding water. Airborne noise onboard is also studied as a part of acoustic signature though it is not a very significant contributor to underwater noise. This is due to the fact that airborne noise suppression can improve habitability and thereby intelligibility of communications onboard. In view of the above, various methods for vibration and noise control are employed to mitigate acoustic signature to desired level. Passive methods such as **Isolation and Damping** are mostly applied as they are well established while active methods find limited applications due to complexity.

2.4 Magnetics & ELFE

One of the most effective weapons against naval vessels in littoral waters is multi-influential sea mines. In addition to being effective, sea mines are relatively inexpensive and represent an **asymmetric threat**. Sea mines use various underwater signatures emanated by ships and submarines such as acoustic, magnetic, electric and pressure for target detection and detonation. These signatures except electric are being exploited since a long time. Sensors developed for their measurement are durable and reliable; signatures are informative and stable and associated with decades of experience in this area. Also reduction techniques and countermeasures for these signatures have been developed and implemented. Compared to this, electric signature generated by ships and submarines is an emerging feature based on which they can be detected and identified even at long ranges. However, it has not been completely understood and exploited. Also development of high sensitivity and low noise underwater **electric and magnetic field** sensors provides an opportunity to detect very low level of signature. In this

background, it is highly critical to measure, analyze and quantify the electric and magnetic signatures of ships and submarines to find their source, strength, pattern and frequency content. Magnetic signature comprises of two major components, namely, ***Permanent and Induced magnetic*** fields. For reducing magnetic signature, two major approaches are adopted. One is Deperming and the other is Degaussing. While Deperming is used for permanent signature suppression, Degaussing is employed for reduction of induced signature and residual permanent signature. Electric signature can be generated as Static potential ***(UEP)*** or Alternating field ***(ELFE)***. Active Cathodic Protection ***(ACP)*** and Shaft Grounding ***(PSG and ASG)*** are effective for electric signature suppression.

3. DIFFERENT ASPECTS OF SIGNATURE MANAGEMENT

3.1 INFRARED (IR)

3.1.1 IR Signature Prediction: IR signatures of ships can be predicted with reasonable accuracy during design stage of a warship. The prediction process involves generation of ***CAD model and thermal solver***. Based on back ground, geometry and material inputs, heat transfer equations for different modes of heat transfer are solved to arrive at steady state temperatures of surfaces involved. Similarly, plume model of exhaust gas is solved taking into account relevant inputs. The prediction also includes engagement analysis by feeding proper threat perception parameters. IR signature of a ship can be computed taking into account the background in which it resides. For a seeker to locate and track a ship, the ship must appear different than its background. The appearance of the background depends on a number of factors including Solar radiation, Solar scatter by the atmosphere (dust, aerosols), Solar reflection/scatter from clouds, Solar reflection from sea surface, Solar interference (shadows) from clouds, Sky and path radiation. The thermal and IR signature of the ship in above mentioned background conditions can be computed using analytical/computational tools.

3.1.2 IR Signature Measurement: The measurement and analysis of infrared signature of ships have gained lot of importance in ship detection techniques and stealth technology development. With new advances in the missile technology, IR signature suppression has been a thrust area for all frontline navies. In making IR measurements, ***Infrared thermography cameras*** are used to capture IR images, when ship is moving with full/cruise speed. Usually, measurements are carried out in mid wave and long wave IR bandwidths. These recordings/images are analyzed with software to find parameters such as ***radiant intensity, contrast intensity and lock on range***. IR hotspots identified are vulnerable to guided threats and provide a clue on the area for focusing IR suppression treatment. Typical measured IR signature of a ship is depicted in Fig. 1.

Fig 1: Typical measured IR image of a ship

3.1.3 IR Signature Suppression: Infrared suppression onboard ships can be achieved by passive or active or hybrid (combination of both passive and active) methods. **Passive devices** employ approaches such as Eductor-Diffuser, Cheese Grater and DRES ball. However, selection of any of these devices depends upon various factors such as back pressure, weight and view angle protection apart from required IR signature suppression. Multi ring **Eductor-diffuser** type infrared suppression device, which works on the principle of ejector action combing with film cooling diffuser is considered most effective for shipboard applications. The objective of IRSS is to reduce or eliminate the exhaust duct and plume signatures for the desired range of view angles. It can be shown that for metal cooling this is possible by cooling the visible metal to near ambient conditions. However, because of the selective radiating characteristics of the plume it is not necessary to cool the plume to the same degree as the metal to get a similar reduction in plume signature. Infrared Signature Suppression is the systematic reduction of high radiance source (Engine exhaust) of ship. Eductor consists of convergent nozzle and mixing tube which cools the hot exhaust gas remarkably and then passed through diffuser. Multi ring diffuser is designed to keep the diffuser ring metal surfaces near to ambient temperature. Typical IRSS device is shown in Fig. 2.
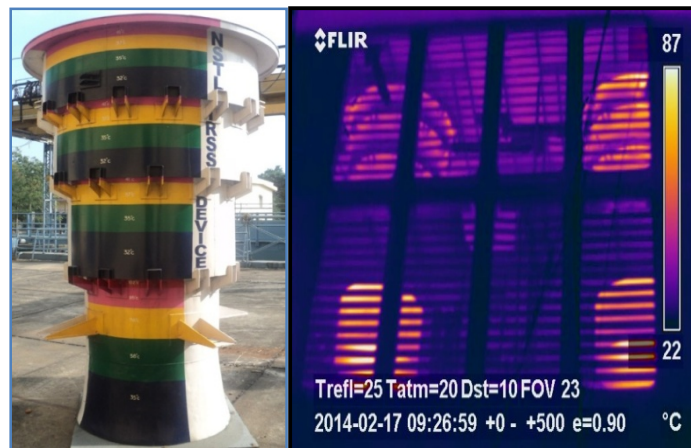

Fig 2: IR Signature Suppression Devices

The hot gas temperatures can be reduced by employing active method of injecting fine spray of water using **water mist** nozzles. Depending on the temperature reduction needed, flow rate, number of nozzles, droplet size etc will be determined for a water mist system. **Hybrid IRSS device** would combine both Passive device and water mist to achieve metal and plume temperature reduction.

3.2 RADAR CROSS SECTION (RCS)

3.2.1 RCS Prediction: RCS prediction provides simulation environment and concurrent design approach for EM design of naval targets for RCS application in wide frequency range. In general, prediction results are used to find the behaviour of a target for RCS signature more qualitative than quantitative. It gives first hand information about RCS pattern of the target so that the designer can concentrate in the zone where high RCS is observed. The software today provides sophisticated electromagnetic solution techniques like ***Physical Optics, Physical Theory of Diffraction, and Method of Moments*** etc. that can solve complex RCS computation problems. A representative RCS predicted pattern is shown in Fig. 3.
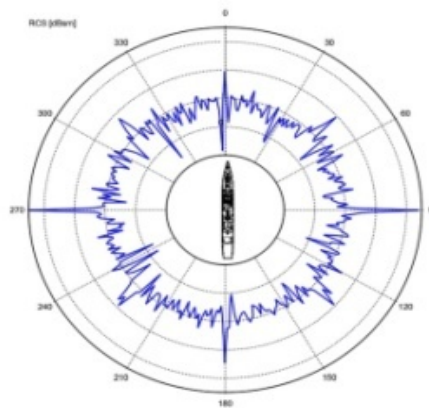
Fig.3: Typical RCS Predicted Pattern

3.2.2 RCS Measurement: Anechoic chambers and compact ranges are typically used to evaluate RCS characteristics for small objects or scaled down models. A typical anechoic chamber is shown in Fig. 4. RCS signature of platforms is measured using instrumented Radar. In case of ships, radar is configured to cater for wide frequency range, though sometimes only X-band radars are particularly used for specific analysis. The measurement and analysis of RCS is useful for identification of **pattern of RCS** and **hotspots** in real time sea scenario. Such Radars are also highly useful for evaluation of RF stealth products. The measurements are normally carried out by varying aspect angle in both azimuth and elevation. RCS measurements of targets are carried out at different grazing angles to simulate look angles of seekers.
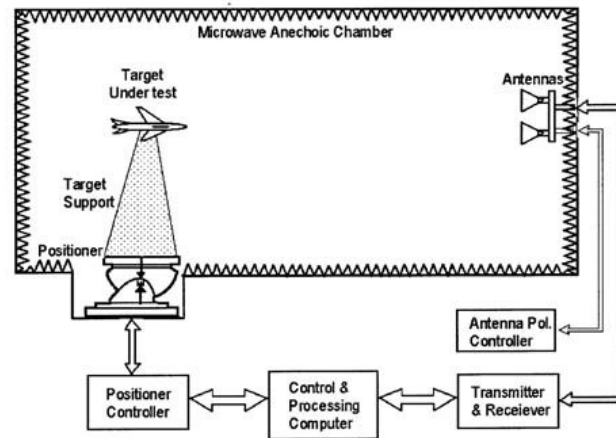
Fig 4: Anechoic Range set up

3.2.3 RCS Mitigation: RCS reduction is achieved mainly by *shaping* which plays major role for ships and aircrafts. Shaping is to orient the target surfaces and edges to deflect the scattered energy in different directions away from Radar. Shaping is achieved by either adopting circular surfaces in place of flat surfaces or by extending flat or singly curved surfaces so as to narrow down specular lobe. Another effective approach for RCS reduction is application of Radar Absorbing Materials *(RAM)* either in the form of paints or as sheets. As the name implies, the idea is to absorb the incident energy thereby minimising the reflected or scattered energy in the direction of Radar. Here the energy loss mechanism involves dielectric or magnetic properties of the material. Though most absorbers are designed to reduce specular reflection, specific designs can be evolved for non specular scattering also. Materials primarily used for such RAMs include carbon, magnetic materials and more recently composites. A composite superstructure is shown in Fig.5. Various innovative approaches such as Radar transparent structure, Net frames, Screens, Radar Opaque Optically transparent (ROOT) sheets etc are also realised for RCS mitigation.


**Fig.5: Composite Superstructure**

3.3 ACOUSTICS

3.3.1 Noise Prediction: As brought out earlier, radiated noise is contributed by different sources of the platform such as machinery, propeller and flow. Therefore, to predict noise radiated into the sea, one needs to estimate contribution of each of these sources. In view of the complexity involved for a large structure, either semi-empirical approach or advanced numerical tools are employed to estimate noise. An aspect that has greatly affected the noise control design is the availability of high-speed digital computers and the development of advanced numerical methods. ***Finite Element (FE) and Boundary Element Method (BE)*** methods have proved to be so powerful that their use in any major design and analysis has become a standard practice today. In addition to these, other methods like ***SEA (Statistical Energy Analysis)*** and certain data based empirical methods are also being resorted to in estimating the effectiveness of the ship design from the point of view of acoustical considerations. An example of noise prediction plot is shown in Fig.6.
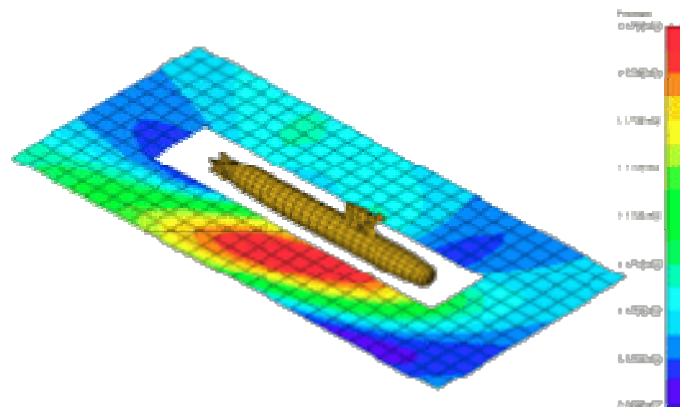
Fig.6 Noise Prediction Plot

3.3.2 Noise Measurement: Noise ranging is an aspect that needs to be considered for verification of noise predictions and noise control designs. Both ***portable and permanent ranges*** can be used for this purpose. Also, ranging is useful for regular monitoring of noise levels during the life cycle of the ship. If any abnormalities are observed in trend of noise, corrective measures can be taken up in time to try and bring back the noise within acceptable limits. Permanent range typically consists of an array of hydrophones positioned at specified locations on the sea bed and connected to data acquisition system at shore via a fibre optic cable. The ship is made to run over the array of hydrophones and noise picked up is transmitted to data acquisition system for analysis. In portable system, the hydrophone array is lowered from a specially designed buoy or another measuring platform. If the hydrophone is lowered from a platform, it is directly connected to a data acquisition system through a cable. If the hydrophone array is lowered from a buoy, the data is

fed through RF transmitter to data acquisition system positioned measuring platform. Analysed data shows whether the platform is within the safe noise limits or not. If the noise is not in acceptable limits, possible remedial measures are recommended. A schematic diagram of a noise measurement range is shown in Fig.7.
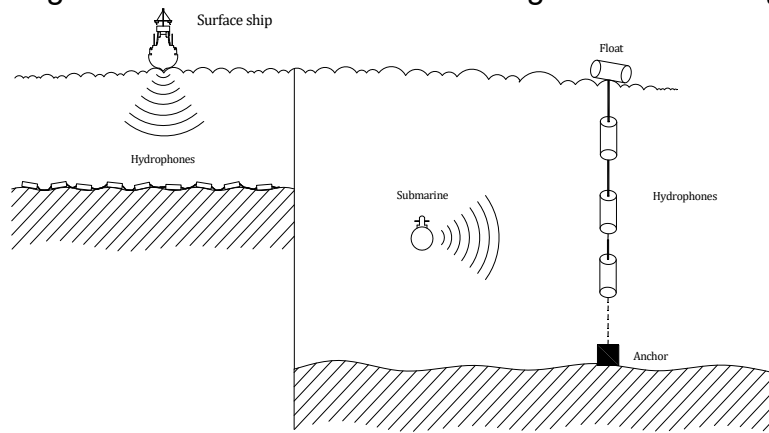
**Fig 7: Schematic diagram of noise ranging**

3.3.3 Noise Control: Noise control in any application is perceived as source-path-receiver concept. Thus noise control can be achieved in the following ways:

    i.   By reducing the fraction of the source mechanical power converted into vibratory power, (or)
        By selecting machinery with lower rated mechanical powers

    ii.   By isolating the source from the radiating surfaces, i.e. reducing vibration transmission (path treatment)
    iii.   By reducing radiation from surfaces that radiate sound

Reduction of noise at the source requires re-design of the mechanical system, which is practically not possible in many applications. Reducing radiation requires extensive application of anti-radiation treatments, which has its own practical limitations though not entirely infeasible. Isolating the source from the radiating surface is a more practicable approach and hence is normally resorted to. The techniques that are being employed to control acoustic signature can be broadly classified as two types, namely, *passive and active*. In passive systems, the emphasis is on impedance changes and damping measures whereas in active systems an adaptive cancelling field is generated to suppress the disturbing signal.

To reduce machinery vibration a simple *resilient mounting* is normally adopted. It involves placement of a flexible isolator (Typically Rubber Mounts) between the machine and its foundation. This approach is highly effective at frequencies larger than twice the natural frequency of isolated system. However, if severe specifications are to be met, *double stage isolation* is being employed which utilizes a resiliently mounted raft with machinery resiliently mounted upon it. Such two stage mounting

systems are employed where there is a requirement of higher structure borne noise attenuation than isolation obtained by conventional single stage isolation systems. Well-designed raft mounting systems can reduce vibration levels to almost double of that achievable with single stage isolation. The dynamic behaviour of the intermediate mass and mounts has a strong influence on the noise reduction performance of the whole mounting system. A two stage mounting system applied for a compressor is shown in Fig. 8. In addition, non-mount transmission paths such as piping are also required to be isolated using *elastomeric mounts*, *bellows* and other *flexible inserts*.
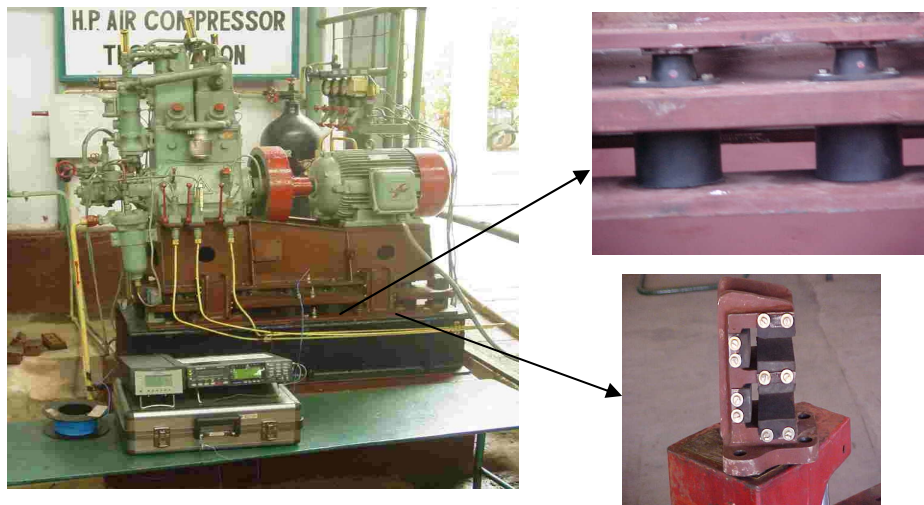
Fig.8: Two Stage Mounting System

Structure borne noise is also reduced by *surface damping treatments*. Two major types of such treatments are useful for shipboard applications. One is *Free Layer Damping (FLD)* while the other is *Constrained Layer Damping (CLD)*. Free layer damping involves application of visco-elastic layer of required thickness and modulus on the surface to be damped. This approach provides damping by extension of the visco elastic layer when subjected to vibrations. Constrained Layer Damping (CLD) involves application visco-elastic layer and a stiffer layer (metallic/FRP) on top. This approach provides damping by way of visco-elastic layer undergoing shear. Choice of type of damping treatment depends on several factors such as frequency range, extent of damping needed, space and weight constraints etc. Fig. 9 depicts typical applications of CLD and FLD respectively.

Fig.9: CLD and FLD Application

Propeller is a highly dominant source of noise, mainly due to cavitation. **Cavitation noise** is a high frequency broadband noise, which can be avoided only by delaying the onset of cavitation. Number of remedies such as using large diameter, higher number of blades, low rpm, high skew and selecting a blade profile for requisite load distribution are being used for minimizing cavitation.

Hull treatments for acoustic consideration are being given priority in all the stealth designs today. **Decoupling tiles** are provided to induce an impedance mismatch between hull and surrounding water to resist the passage of sound between hull and water. **Anechoic tiles** are designed to absorb or scatter incident sound energy from hostile sensors so that minimal sound is reflected off the hull. One of the techniques that is found suitable for flow noise reduction is **Ribcoat** technique. This involves fine coating of compliant polymer materials on the hull, which forms Riblets (fine micro grooves).

To reduce air-borne noise, **Barriers** adjacent to deck/bulkhead or shell plating can be used. **Enclosures** constitute the most frequently used measures to reduce airborne noise radiated by machines. Typical enclosure panels are multilayer composite treatments, consisting of an impervious, exterior layer and an interior layer of porous sound- absorbing material. The air borne noise radiated by the air handling systems can be reduced by providing **silencers** at the intake and at the exhaust. The silencing of gas turbine installations is basically a problem of attenuating the noise from the atmospheric inlet and the exhaust openings.

There are limits to what passive techniques can achieve. They are most effective at frequencies above 100 Hz and are not well suited to low frequency noise control. This is where Active control technique is found attractive. An application of active control is found in active magnetic bearing in which a magnetic field is used to support the rotating parts thus freeing them from mechanical contact, eliminating transmission path altogether. Magneto Rheological Mounting is an application of hybrid (Passive cum Active) control. Other applications onboard ships include cancellation of exhaust noise, duct-borne noise and air-borne noise.

Most of the acoustic measures are defined during the design and definition phases of the project. In some cases, a few measures may be taken additionally after preliminary design. In general, to build a quieter ship, varieties of technologies may have to be adopted. It may be pertinent to mention that propulsion machinery options, hull topology and perception of detection threat play major role in identifying needs of suitable noise control methods.
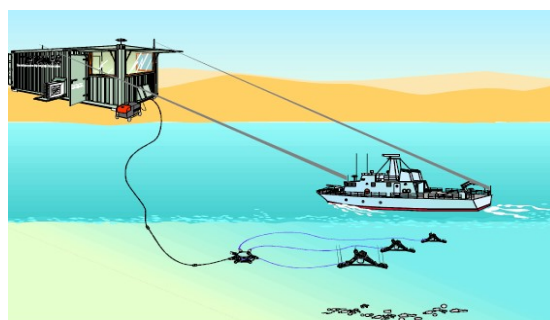

3.4 MAGNETICS

3.4.1 Magnetic Signature Prediction: In earlier days, mathematical models were limited to analytic formulations that were simple. These simple models were

relegated to predicting the general characteristics of a ship's magnetic field at distances somewhat greater than its beam. Advancements in mathematical *ferromagnetic modelling*, availability of computation power with the advent of latest computer technologies, faster numerical processing led to improvements in the fidelity of analytic models by allowing the inclusion of higher order terms in the evaluation of complex series formulations. As high-power computer workstations became readily available, the use of numerical models, based on Finite-element *(FEM)* or Boundary-element *(BEM)* methods, emerged as practical tools. Fig. 10 shows a screenshot of magnetic signature predicted.
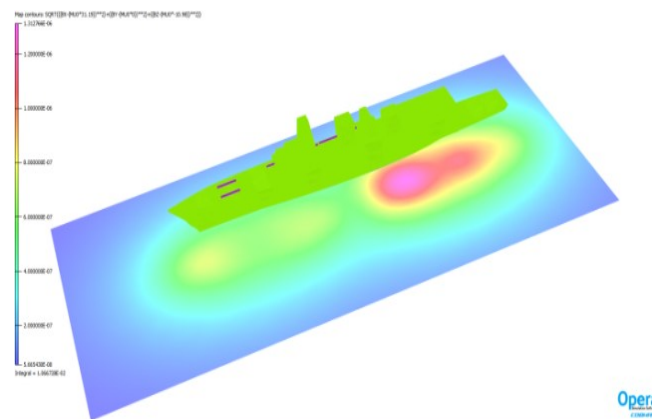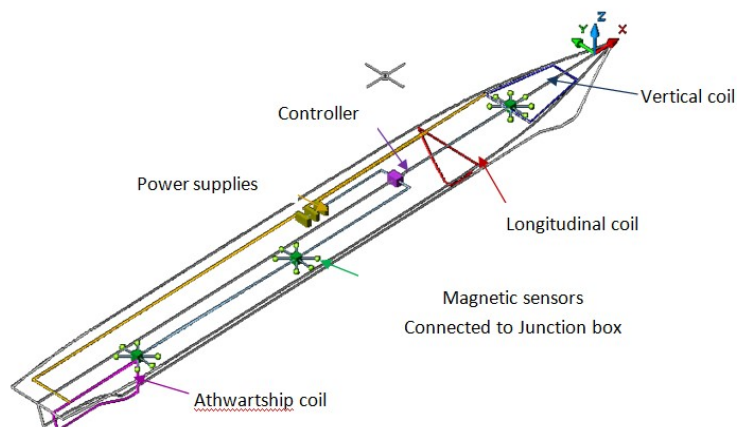

Fig. 10: Prediction of Magnetic Field

3.4.2 Magnetic Signature Measurement: Magnetic field strength is measured using a variety of different technologies. Vector sensing approach is more useful for naval applications. The induction coil and fluxgate *magnetometers* are the most widely used vector measuring instruments. The measurement setups are typically *Over Run Range or cage type static Measurement facility*. The overrun range comprises of underwater magnetic sensor array deployed offshore at certain depth. The naval vessel is made to run over the sensor array. The magnetic field measured by sensors is transmitted to a junction box. The data is multiplexed and transmitted to data acquisition system. At shore the data is converted back to desired format, de-multiplexed and stored in memory. Magnetic range schematic is shown in Fig. 11.

Fig.11: Magnetic Range Schematic

3.4.3 Magnetic Signature minimisation: There are two methodologies of compensating the magnetic signature of naval vessels. One is 'Active' and the other is 'Passive' compensation. In active method of compensation, a system such as *degaussing* system is actively pumping the currents through the vessel to compensate the magnetic fields in real time. Degaussing system is nothing but loops of coils inserted inside the ship. When energised with proper amount of coil, generates the same magnetic field as that of the vessel but in opposite direction. The effective magnetic field emanated by the vessel is minimal. The degaussing systems are mostly designed to compensate the complete induced magnetic field of the vessel and some part of the permanent fields. The more capable the degaussing simulating the magnetic signature of the vessel, the more stealthier the vessel would be. Fig. 12 displays a scheme of degaussing system. *Deperming* is a magnetic treatment method to reduce permanent longitudinal and athwart ship magnetisation and produce permanent vertical magnetisation which is equal and opposite of the induced vertical magnetic field for a specific geographic operating are. In Passive compensation, the magnetic signature of the vessel is compensated by providing magnetic treatment to the vessel/ subsystems from external sources. This procedure has to be undertaken at regular intervals to ensure minimal signature.

Fig.12: Degaussing System Schematic

3.5 ELFE (Extremely Low Frequency Electric field)

3.5.1 Electric Signature Prediction: Similar to magnetic signature prediction, electric signature prediction has gone through primitive modelling approach in earlier days to today's modern numerical tools. The modelling strategy has varied from simple *dipole type models* to detailed *boundary element models* of the vessel and its environment. For the dipole models users have had to choose the location and strength of the dipoles based upon experience, using range data or data from similar vessels. Whereas the boundary element model enables the user to define the actual geometry of the vessel, the electrochemical properties of the materials and the properties of the environment as data to the model and obtain predictions of the electric signatures. FEM and BEM numerical simulations use the detailed geometry of the ship's entire wetted part of the hull structure and its material properties for

prediction of electric signatures. Once these models are constructed, they can predict signature produced by the ship's corrosion currents, ICCP currents etc.

3.5.2 Electric Signature Measurement: To measure the Electric signature of the ship, the ship is required to run over Electric sensors installed underwater. The measurement approach is similar to the method described for magnetic measurements of *over run range*. A schematic is shown in Fig 13.

Fig. 13: ELFE Range Schematic

3.5.3 Electric Signature Mitigation: Electric signature of naval vessels is generated as static electric field, caused due to corrosion currents and alternating electric field caused due to non-corrosive currents flowing between hull and the propeller (dissimilar metals), active hull protection system (ICCP) current, ships power supply, equipment, etc. The flow of these currents cannot be completely eliminated and accordingly the electric field signature can only be managed and reduced but cannot be totally eliminated. Optimum design of Active Cathodic Protection *(ACP)* system is used for managing Static Electric field. Passive and Active Shaft grounding *(PSG and ASG)* techniques and filtering ACP power supply system are useful for managing alternating electric field. Fig.14 depicts a schematic of Active shaft grounding for minimising ELFE signature.
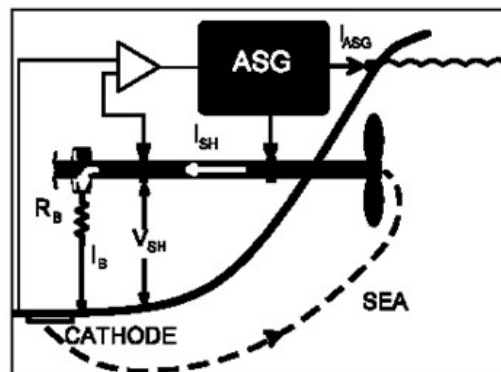
Fig.14: ASG Schematic

4. CONCLUSION

Signature Management of Naval platform is crucial not only to avert threat of detection by adversary but also its own performance in tactical warfare. In view of the ever increasing demand for stealthy naval platforms, it is very essential to master the technologies related to signature management. The requirements are multi fold and they include acquiring capability in prediction of platform's signatures, identifying possible major sources at early stages of design & construction, developing suitable control techniques and field measurement for vulnerability assessment. It is to be realised that integrated signature management without compromising on functional performance of the platform would yield desired result. Apart from signature suppression techniques, a number of countermeasures such as IR flares, Chaffs and acoustic decoys are deployed as a part of misleading the adversary to safeguard own platform. Some of the futuristic technologies such as electric propulsion, cloaking, holography, active cancellation, adaptive curtain, composite shafting and propellers etc., are expected to have big impact on stealth. While implementing newer technologies onboard platforms, it is important to watch out for ease of operation and maintenance because quality and reliability is crucial. In other words, Lifecycle management of systems is of utmost importance to ensure effective operation of the fleet.

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