Recent Developments in Stealth Considerations for Surface Warship Design

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Abstract

The past two decades have seen a significant shift in design process to incorporate stealth features to make naval ships invisible to an array of modern electronic warfare systems such as sonar and radar, combining ways that lower a platform's emissions and those which eliminate reflected radiation, thus reducing detection range and threat vulnerability. Surface warships today face a most formidable threat posed by radar homing anti-ship cruise missiles, which home on to the target based on its various signatures like radar cross section, acoustic emissions, thermal signature, infrared signature, magnetic signature, extreme low frequency electromagnetic emissions, under water electric potential etc. Stealth technology is a combination of technologies that attempt to reduce the distances at which a vehicle can be detected, mainly reducing these signatures. In naval ships, the hull shape, the coating materials, equipment mounting, the type and amount of radiations that is emitted etc are key factors affecting stealth properties. Delayed detection by adversaries, reduced Lock-On range of weapons, enhanced performance of own sensors, enhanced effectiveness of hard-kill & soft-kill measures, reduced vulnerability leading to increased survivability etc can be achieved by incorporating stealth features of a warship. This paper explores the latest technologies that helps the designer to incorporate stealth in surface ships so that a warship with a much reduced radar cross section, acoustic emissions, thermal signature, infrared signature etc can be developed to better execute various naval missions.

Keywords- Radar Cross Section (RCS), Radar Absorbing Materials (RAM), Emissivity, Extremely Low Frequency Electric (ELFE), Active Shaft Grounding (ASG), Active Cathode Protection (ACP), Magnetic Anomaly Detection

I. INTRODUCTION

The idea of stealth is notable feat as the ability of the vessel to be undetectable from its enemy is substantial. In warship design, stealth technology has emerged as a major parameter, with the primary aim to make military platforms less visible to radar, infrared and sonar sensors. Reduced visibility implies the late detection as the element of surprise is an immense advantage in warfare. The advancement of engineering and signal processing in the modern era made it possible for stealth technology realization in vessels to deceive the enemy radar and other systems. Radar stealth can be achieved by passive cancellation, active cancellation, shaping and application of radar absorbing material to reduce radar cross section. The above water hull form is chosen naval architects with sloping surfaces to minimize radar cross section, by reducing levels of reflected radiation and at the same time, lowering the warships own emissions. Further advancements are also made to reduce the chances of detection such as reduced noise and infrared radiations. It is pertinent that incorporation of stealth features cannot guarantee safety and integrity of the vessel. The stealth of a vessel is depended upon the shape, material of coating, infrared radiation reduction, radar cross-section element and active stealth monitoring. In the 21st century, there is a rigorous increase in study on stealth technology. A country with such a technology will have a superior power compared to others. So it compels the era to introduce more stealth technology. India has gone a long way

in this field, with the commissioning on indigenous stealth frigates of the Shivalik, designed by the Navy and built by Mazagon Docks Ltd.

II. NEEDS OF A STEALTH WARSHIP

The advancement in missile technology, underwater machinery and so forth will be effective in warfare if it could not be used effectively. The vulnerability of the vessel can be reduced to a drastic extent by the implementation of stealth features. On approaching a target under stealth, a vessel could get closer than expected and thus detection by the antagonist is delayed, which in turn reduces their reaction time for taking counter measures. The improved performance of the mounted sensors when using at a closer proximity, can also contribute in modern day warfare. The chances of survival of the stealth vessel are much greater compared to conventional warships.

It is often mentioned in warship design circles that being invisible means invincible. The better disguised a vessel is the harder it is to detect. The element of surprise plays a key role in warfare. The attack capabilities are more deadly in up-close ranges. Moreover a stealth vessel has a lower chance of being actively targeted by enemy lock on missiles. Also, late detection can hamper the kill chain. The kill chain is the process structure of an attack. It is an end to end process and consists of six phases -find, fix, track, target, engage, access. Disrupting the kill chain increases the strategic advantages of a vessel.

The reaction time between the above processes increases for stealth warships. Various technological developments which are being used to keep warships from easy detection by enemies need regular updations. Defence sector capacity of nations is assessed based on the inventory, including ocean platforms. Moreover, stealth warships offer better safety to the personnel, thereby increasing their efficiency and effectiveness manifold in hostile situations. The possession of such warships in a country can make it less targeted by the enemies and could even end the war before it even begins. As stealth warships are hard in revealing its position to a vigilant enemy, further advancements can be done outside the battlefield while stealth warships hide beyond enemy lines. A fair attack strategy could be sorted out this while and targets can be annihilated with better precision and minimal attention towards the high priority vessels such as aircraft carriers.

III. SHIP SIGNATURE MANAGEMENT

It is imperative that ship designers are aware of the effects the design decisions on the various signature levels. Signature management analysis in warship design includes suppression tradeoff studies, detailed susceptibility analysis and cost benefit analysis. The various signatures of a warship are summarized in Figure 1

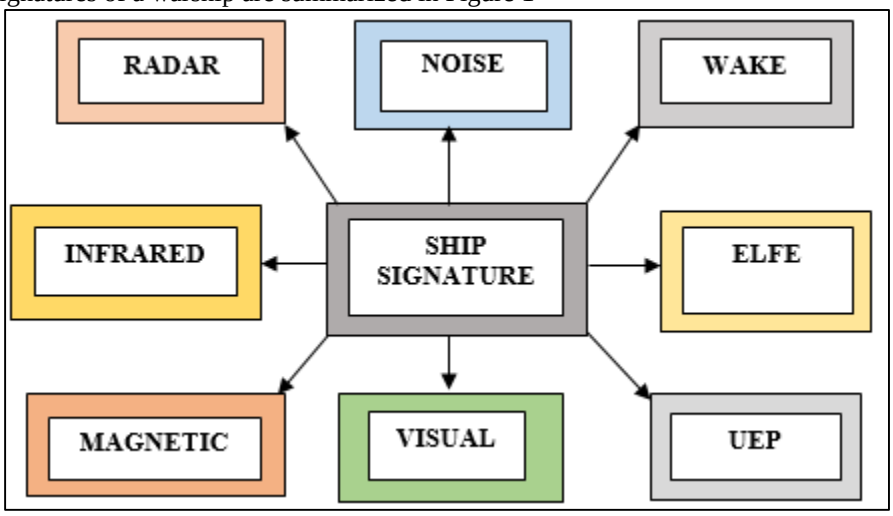

Fig. 1: Types of Warship Signatures

A. Radar Cross Section (RCS)

Radar Cross Section is the quantification of energy reflected from a vessel which gives away information to the enemy's detecting devices. The reflected energy is generally of contrasting energy level which helps to smoothly recognize the section of the vessel. To diminish the energy of the reflected wave, Radar Absorbent Materials (RAM) and optimization of vessel shape are generally used. The former method helps to eliminate most of the reflection by mopping up the radar energy from the enemy radar and confine it in a channel dematerializing the microwave energy into heat. Hull shaping aims to circumvent vertical, rounded surfaces, dihedrals and trihedral, cavities, crevices and sharp corners from vessel silhouette which will greatly demands the radar energy to disperse away from the combatant. A measure of RCS is expressed as σ. The below given is the relative magnitude of RCS in terms of dB_{sm} [9]

$$\sigma = 10 \log_{10} \left(\frac{\text{Measured RCS in m}^2}{\text{Reference value of 1 m}^2} \right) \qquad (1)$$

By diminishing the radar cross section the stealth property can be easily attained. As a thumb rule, if the detection range is deduced to half then the RCS should be 1/16 of the detection range.[9]

$$\sigma = \text{const} \times R^4 \qquad (2)$$

The supremacy of RAM is to reduce the electromagnetic interference (EMI) which affects the radar and communication receiver's performance. Use of plated mast and other topside structures as RCS reduction methods may substantially affect the stability and sea keeping stability of the vessel by ameliorating the tons of weight of the ships topside. At the same time the reduction of RCS is also a great disadvantage. Maneuvering of a stealth vessel in fogy condition will be treacherous, as well as sailing through an area were shipping with high commercial density will be insecure and risky. Comparing a conventional vessel to stealth vessel the RCS of conventional vessel is high.

B. Underwater Radiated Noise

Underwater radiated noise is an unwanted but an unavoidable property of a vessel. It severely influences the attribute of stealth vessel. The noise from auxiliary and main propulsion machineries, propellers, fluid flow though pipe lines and flow noise of ship can be radiated to a long range. It profess that, the speed of sound on water is 4.3 times more than the speed of sound in air, so it can reach an extensive stretch. Underwater radiated noise is generally expressed as Sound Pressure Level (SPL) with Decibel (dB) as its unit. Even though many formulations are available, a general expression for SPL is as follows:-[8]

$$\text{SPL} = 20 \log_{10} \left(\frac{\text{Measured Pressure in } \mu\text{Pa}}{\text{Reference Pressure 1 } \mu\text{Pa}} \right) \qquad (3)$$

Equation (3) is for the case under water radiated noise. For an airborne noise condition the SPL can be expressed as [8]

$$\text{SPL} = 20 \log_{10} \left(\frac{\text{Measured Pressure in } \mu\text{Pa}}{\text{Reference Pressure 20 } \mu\text{Pa}} \right) \qquad (4)$$

The resultant noise from the machinery vibration, propellers etc which will be disseminate to the enemy sonar should be amortized. So to reduce such unwanted noises, following aspects are considered by the designers.

- Selection of low noise and vibratory machineries
- Machinery foundation with sufficient stiffeners and damping strips which are visco-elastic
- Avoidance of reciprocating machineries use rotary auxiliary machineries
- Adoptable Design of system pipelines
- Use bow sonars
- Propeller design to minimize cavitation inception and noise

C. Wake

As the vessel move through the water, wakes will be generated. The water incompressible, and hence gets displaced and forms a wake. The wake proliferates outward until the energy is dispersed sufficiently. The bubbles formed due to wake are very important because these will be able to persevere behind the vessel up to kilo meters. The enemy radars can find the vessels easily with the aid of radars mounted on the satellites by detecting the wakes formed. As a countermeasure, transducers are used in vessels which emit acoustic waves of 1MHz. The role of the transducer is to convert the small bubbles of diameter 0.2mm formed due to wake into a large bubble by taking it to low pressure region. Large bubbles will not survive for long time as they are buoyant. But this method is not environmentally compatible. The radiation from transducers will steer to the death of marine life's and other organisms. So it is not a convenient method of stealth warships to reduce wake formation.

D. Electromagnetic Signature

Susceptibility of vessel fundamentally depends upon its detectability. Each and every vessel releases electromagnetic radiations which can be identified by the enemy and it can even distinguish the type of vessel, posing a dangerous situation. While designing a stealth vessel, it is important to reduce the release of electromagnetic signatures from the strong electric field that surrounds it.

Electromagnetic emissions from a vessel are mainly due to the presence of Active Cathode Protection (ACP) systems used for protection against corrosion. An electric current is passed from anodes located on the hull to the locations where there is inadequate protection against corrosion. A large electric field is formed around the vessel which will have periodic fluctuations. As such an Alternating Electric component also called Extremely Low Frequency Electric (ELFE) is formed.

In order to minimize these emissions a system known as Active Shaft Grounding (ASG) has been introduced. The system is capable of detecting the fluctuations in the electric field surrounding the vessel and with the help of a shunt resistance is able to maintain a constant current level. Thus we are able to achieve a significant reduction in the electromagnetic emissions given out by a vessel.

For the computer modeling of the EM signatures a number of algorithms are generated. Prognostication from the current level of active cathode protection system (ACP), will give the static electric component (SE) and alternating electric component (AE) can be envisage in assorted marine environment ranges.

E. Visual

Visual detection of a warship by the enemy has been a major problem since a long time. The solution to this problem is by using colours which cannot be distinguished by the human eye in different environment stages, and is termed as camouflage technique. This technique was introduced during First World War and is still in use. They are of several type like mist gray, light gray, medium gray, haze gray dazzle camouflage etc. This method help the vessel to be undetectable, also it reduce the vision of target as well as the direction to which the vessel is heading to.

F. Magnetic Signature

The major use of magnetic mines was introduced in Asia in 19th century by the Chinese. The first mine was gripped in to a wooden barrel and weighted in to the sea. Chinese first attack was on the Japan navy ships through this technique. It is estimated that as on date, more than 300 different types of mines are in existence. Generally mines are of different types such as contact mines, limpet mines, bottom contact mines, remotely controlled mines, influence mines, moored mines, bottom mines, unusual mines, anti-sweep mines etc. Contact mines are effective weapons because they are extremely low cost compare to other. When partially or fully immersed in sea, it releases the energy when the ship come contact. Contact mines can also be moored to the sea bed. The first remotely controlled mines used at the time of American civil war were controlled from shore. Drifting mines are placed near to the water surface it is also a kind of contact mine. Disposition of the mines vary based on the fighting strategy of each nation. Mines can be placed across the shipping routes where they wait for the enemy ships. All the sea going metal vessels are susceptible to threat from magnetic mines, unless the mines are detected by Magnetic Anomaly Detection and defused.

Efforts are made to reduce the magnetic distortions of a Stealth war ship, minimizing the chances of activation of the mines by its own magnetic field. Reverse magnetism method is normally used for this purpose, where the ship magnetism is reversed with respect to earth's magnetic field. This process is called Degaussing, and is achieved by an electromagnet that installed on to her hull. Degaussing coils are large diameter coils that carries large amount of electricity which produces the required electromagnetic field. When the ship is at war field, these electromagnetic fields safeguard the ship from mines. Degaussing coils are made of High Temperature Superconducting and super conducting ceramic cables are used to offset the magnetic behavior of the ship.

G. Infrared Signature

A ship emits heat from a number of sources such as engine, exhaust, weapons, reflecting radiation from the sun etc. As such a ships IR signature is vast and can be detected quite easily. The most significant contribution to IR signature is of course done by the main machinery of the ship such as the engine and electrical generators. The major threats arising from a large IR signature come in the form of heat seeking missiles.

Effectively reducing the IR signature of a ship can be done by controlling internal and surface emissions. In the case of the internal emissions the major cause is of course the engine room. This can be controlled and reduced significantly with the application of proper ventilation and by providing insulation to the external bulkheads. The next issue is the engine exhaust. This is done with the help of exhaust plumes in combination with cold air blowers/seawater injection system. This will allow the hot exhaust gases to cool and disperse quickly.

IR emissions from the surface of a ship can be reduced by three ways.

- Cooling heated surface with sea water
- Creating heavy mist of seawater around the ship
- By usage of special paints

The major disadvantage of seawater cooling would be the increased risk of corrosion. In the case of creation of seawater mist, the mist would reduce visibility and then of course there is also the risk of corrosion. As such the most effective method existing is to coat the surface of the ship with special paints of low emissivity.

IV. CONCLUSIONS

The incorporation of stealth technology onto a warship is to make it less visible to enemy detection systems such as RADAR, thermal, acoustic etc. As explained "less visible" implies late detection of the vessel and henceforth providing a huge advantage to the vessel in warfare and giving increased survivability. A warship can be detected in many ways as mentioned above and research is ongoing on new ways of detection. It is important to control or minimize the various emissions given out by a warship to misguide enemy detection systems. The various methods and systems which can be implemented to avoid detection have been discussed throughout this paper. The possibilities to persist by depleting the ability to detect are disputed in this topic and these will allow aggrandizement of ships signature.

Stealth features of a warship are achieved by reducing the signature effects, diminishing the platform susceptibility and enhancing the ability to survive is the principle aim of stealth. Obliterating corner reflectors, estrangement of super structures and Meta materials, use of low prospect of intercept and radar absorbent material will minimize the radar cross section. Under water radiations are also prime signatures which have to be foreshorten as possible. It can be superintended by rafts, sound insulations, resilient mounts, double mount, quiet propeller, flexible coupling and stream lined hull design. One of the surface quandaries is the infra-red emission. Practicing low emissivity paint and insulating equipment is an important aspect to reduce the infrared signature. Controlling and cooling the plume and heated stack parts can help to reduce it. The magnetic radiation from the vessels

can be decried by the mines installed by the combatant. To afford this stealth warship will perform reverse magnetism method which will obliterate the emitted magnetic radiation.

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