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QUALITATIVE METHOD FOR ANTIFOULING LONG LIFE PAINT FOR MARINE FACILITIES OR SYSTEM

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ABSTRACT

Ship Hull fouling reduces the fuel efficiency and speed of affected ships, increase in frequency of ship dry dockings, reduces propeller efficiency and accelerated corrosion rate. Antifouling paints are used to coat the underwater area of ships to prevent organisms such as algae and molluscs attaching themselves to the hull of the ship. As a result, antifouling paints which are alternatives to TBT systems such as controlled depletion systems (CDPs), tin-free self-polishing copolymers (tin-free SPCs) and foul release systems were developed in marine industry. However, most of these paints cannot last for long because misapplication. Paint is not a finished product until it has been applied and dried on an appropriate substrate at the designed performance film thickness. High performance paint systems are especially sensitive to misapplication and knowledge of the paint characteristics. Also recommended film thickness is vital to obtain optimum results to improve paints performance and reduce maintenance cost. Therefore, proper application is critical to the performance of the paint system. This paper presents the result of study made on the problems of fouling on ship hull structures and deduced a qualitative model for ship paints application in order to prolong the life span of antifouling paint.

Key words: antifouling, application, hull fouling, paint, qualitative

1. INTRODUCTION

Performance of ships depends on their speed and power generated. Likewise, economic and efficiency of ship operation is achieved at optimum speed, power and according to frequency of dry docking of ship. Hull fouling poses a lot of hindrances to design power and efficiency of ship. The fouling material can consist of either living organisms (biofouling) or a non-living substance (inorganic or organic).

Marine fouling is a perennial problem for vessels, ports and anything kept in the sea for a period of time. The sea is teeming with the tiny larvae of marine organisms that swim around until they find somewhere to settle and grow. Smooth surfaces are particularly attractive to many of these creatures, and are quickly encrusted. This slow down ships in seaways, block pipes and speed up corrosion. This study focuses on the problems of ship hull fouling which hull fouling reduces fuel efficiency and speed of affected ships, consequently increases their operating costs due to the increase in frequency of ship dry docking. It also reduces propeller efficiency [2,3] and accelerates corrosion [1].

The new IMO convention defines ‘antifouling systems’ as ‘a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organism’. Biocidal anti-fouling paints have been applied to the bottoms of ships for decades. The paints slowly leach into the water, killing anything attached to the ship hull, but leachates have been found to accumulate in harbors and the sea.

Among all the different solutions proposed throughout the history of navigation, tributyltin (TBT) paints have been one of the most effective deterrents to hull fouling organisms, but studies have linked TBT accumulations to deformations in oysters and sex changes in whelks. As a result, restrictions on the usage of TBT in vessels were imposed. The International Maritime Organization (IMO) adopted the Antifouling Systems (AFS) Convention in 2001. The Convention called for a global ban on the application of TBT-based antifouling paints by 1st January 2003 and the prohibition of the presence of such paints on the surface of vessels by 1st January 2008 (IMO, 2005). National bans on the use of the TBT paint will result in an increased hull fouling, unless environmentally friendly replacement paints are accepted by the shipping industry.

The paint industry has been urged to develop environmental friendly TBT-free products able to replace the TBT-based paint that yield the same economic benefits and cause less harmful effects on the environment. There are controlled depletion systems (CDPs) and tin-free self-polishing copolymers (tin-free SPCs). CDPs are upgrade of traditional soluble matrix technology by means of modern reinforcing resins. The reaction mechanisms are assumed to be equivalent to those of conventional resin-based AF paints. The tin-free SPCs are designed for the same reaction mechanisms with sea water as tributyltin self-polishing (TBT-SPC) paints.

Paint is not a finished product until it has been applied and dried on an appropriate substrate at the designed performance film thickness. When the paint is applied to the exterior layer to a ship hull, it is subject to a variety of parameters that can degrade the paint and reduce its useful life-span. These parameters need to be taken into consideration during ship paints application. Thus, ship paints application procedures are very important in order to enhance the performance or quality of antifouling paints. The parameters which need to be considered during application of the paints to the ship hull include surface preparation, paint application, paint materials, curing time, environmental conditions, locations, personal quality, inspections and others.

The performance of any paint coating depends on the correct and thorough preparation of the surface prior to coating. The most expensive and technologically advanced coating system will fail if the surface preparation is incorrect or incomplete. Additionally, methods of applying the paints are by brush, roller, conventional (air) spray, conventional (pressure pot) spray and airless spray. Although the application methods are very important, the application technique or skills of personnel also play a vital role. When applying marine paints, the most important factors to consider are the condition of the substrate, the surface temperature, and the atmospheric conditions at the time of painting. Appropriate ship paint materials can effectively prevent attachment or accumulation of fouling on the ship hull bottom. Furthermore, inspection by the coating inspector is necessary to make sure the coating is properly applied.

This study seeks to examine the related issues of antifouling (AF) paints, ship paints application and aims to deduce fouling prevention systems and enhance the performance of antifouling paints. This includes the study of biology of the fouling process, historical development of AF paints and also the proper way for ship paints application.

2. QUALITATATIVE APPROACH

The model design is for the ship paint application procedur produced through interview carried out with the ship yard personal in MMHE and M-Set. Data are collected from Painting and Blasting Department, reviewed about ship painting process and interview with the Classification Society and Paint Maker in order to get the further information. This is to make sure the procedure is compliance with the standard and IMO requirement. Data is analysed by considering the whole ship painting process and how the ship painting procedure is carried out according to the standard. And the analysis leads to deduce a qualitative model for ship paint application procedure [2].

3. RESULT AND DISCUSION

The model is produced with the intention of giving a guideline for all level of personnel on the standard of workmanship in the ship repair division; especially, the blasting and painting parts in order to satisfy ship owners and classification societies. This model indicates the elements accuracy to be kept in the process of blasting and painting repairs or modifications and the finished quality obtained.

The model is developed from several references, historical data and case study related to antifouling paints. The model can serve as a guideline of the standard of workmanship for painting process that mitigates fouling of ship's hull. . The quality of the end product relies on the whole ship paint application process. Thus, we must always keep in mind that "Quality is built in the process, not in the inspection" (See Figure 1)

From the existing ship paint application above, the gaps to improve the existing procedure is deduced. The improved ship paint application flow chart is showed in section 3.2. This flow chart can make the paint application becomes more efficient (See Figure 1).

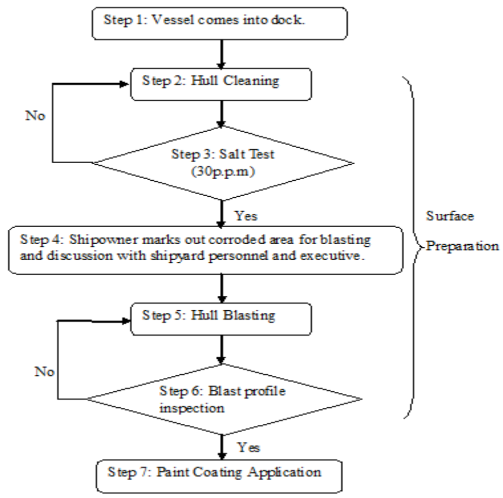

Figure 1. Existing flowchart for ship paint application

3.1. Improved flow chart for ship paint application

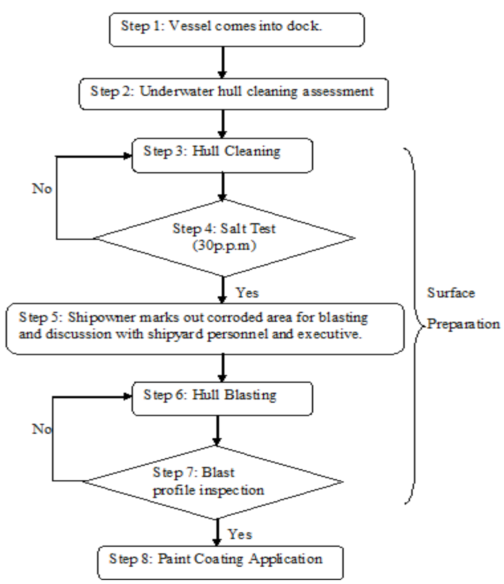

Figure 2. Improved flowchart for ship paint application

3.2. VESSEL COMES INTO DOCK

Since it is a class requirement, for each vessel needs to come into dock to undergo the bottom survey inspection of its underwater area every two and half years. Vessel will be put in the dry dock upon arrival in the shipyard. The vessel will be moored into the dock and when it had successfully sat on the keel blocks, the water in the dock will be pumped dry[4].

3.3. UNDERWATER HULL PRE-CLEANING ASSESSMENT

The step for the inspection process is to conduct an underwater assessment of the fouling growth that has occurred since the last inspection and evaluate the coating condition. This will be completed before any hull cleaning is performed. Normally, ship hull can be divided into 6 quadrants as showed in Figure 3. The six quadrants are: I - starboard forward, II - starboard aft, III - port aft, IV - port forward, V - starboard waterline, and VI - port waterline.

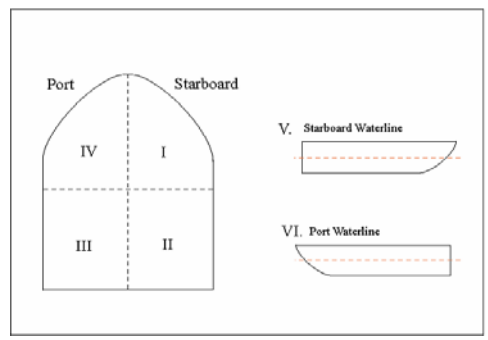

Figure 3: Hull quadrants (IRTA, 2009)

3.3.1. Fouling Assessment

Fouling growth on each boat hull will be evaluated on a 0 – 5 scale. 0 represents the optimal condition and 5 the worst condition. Table 1 determines the numeric ratings and provides a description of what type of fouling growth is associated with each rating. The paint maker's inspector will record the fouling rating for each quadrant and provide any additional observations or comments, such as noting the type of fouling present on the hull surface.

Table 1. Fouling rating scale

Rating	Fouling Growth
0	No silting, biofilm or fouling growth present.
1	Light silting or biofilm. Little to no discoloration; Paint surface still clearly visible beneath.
2	Heavy biofilm; Light to moderate silting as indicated by discoloration (a solid, discernible, physical layer); Painted surface may be slightly obscured.
3	Low to medium levels of fouling present; Dark algae impregnation; Hard growth may be present (tubeworms, barnacles, bryozoans, etc.); Painted surface definitely obscured.
4	Medium to high levels of fouling present; Hard growth present, such as tubeworms, barnacles, bryozoans, etc.; Macrofoulers may include mature forms that may be densely grouped; Paint surface no longer visible beneath fouling in areas.
5	High levels of fouling present; Lengthy, soft algae and hard, tube worms and possibly barnacles impregnating the coatings; Macrofoulers may be densely grouped; Coral** growth can be seen to extend out from the hull; Paint surface no longer visible beneath fouling.

*0 is best condition; 5 is worst condition; ** Coral is the local term used for limestone tubes of worms that grow on the coating's surface.

3.3.2. Coating condition assessment

Coating condition for the entire hull need to be evaluated based on Table 2 which identifies the rating scale of coating condition. The colour of undercoat also need to be recorded when the coating was applied to the ship hull. Ratings of 1-3 represent antifouling painted surface appearance associated with normal physical wear due to underwater cleaning action or hydrodynamic effects. Ratings 4 and 5 indicate either excessive cleaning actions or blistering due to internal failure of the paint system.

Table 2. Coating condition rating scale

Coating condition rating	Coating Description
1	Antifouling paint intact, new or slick finish. May have a mottled pattern of light and dark portions of the original paint colour.
2	Shine is gone or surface lightly etched. No physical failures.
3	Physical failure on up to 20% of hull. Coating may be missing from slightly curved or flat areas to expose underlying coating. Coating has visible swirl marks within the outermost layer, not extending into any underlying layers of paint.
4	Physical failure of coating on 20-50% of bottom. Coating missing from slightly curved or flat areas to expose underlying coating. Coating missing from intact blisters or blisters which have ruptured to expose underlying coating layer(s). Visible swirl marks expose dunderlying coating layer.
5	Physical failure of coating on over 50% of bottom. Coating missing from intact blisters or blisters which have ruptured to expose the underlying coating layer(s). Visible swirl marks exposed underlying coating layer.

3.4. SURFACE PREPARATION

Good surface preparation is one of the most important process of the entire coating procedures, as great percentage of coating failures are usually associated with poor surface preparation. All paint systems will fail prematurely if the surface preparation is not done according to standard procedures requirement. If contaminants such as loose rusts, oil, grease, dirt, salts, chemicals, dusts, etc. are not removed completely from the surface intended for coating, the paint adhesiveness as well as cohesiveness and its quality would be affected. Osmotic blistering would also occur resulting in premature failure of the coating in service. There is no paint system that would give optimum performance result over a poorly prepared steel surface.

3.4.1. Hull cleaning

There are various methods available for cleaning and preparing steel surfaces prior to painting. The choice and methods of surface preparation would depend on the location where the intended area of the vessel is required and the availability of equipment to be used. Hull cleaning includes hard scrap and fresh water washing. Hard scraping shall be carried out to remove slimes, weeds, shells, barnacles, etc. Besides that, approved detergents shall be used to remove any oil or grease present on the hull.

Hull cleaning standard by fresh water

Surface preparation by using fresh water can be divided into 4 levels. Table 3 is the levels or categories for fresh water surface preparation:

Table 3. Categories for fresh water surface preparation

Fresh Water Washing/Pressure	Cleaning Quality
Low Pressure Water Washing Pressure: Less than 68 bar (1000 psi)	It can remove surface salts, dust and loose surface debris.
High Pressure Water Washing Pressure: Between 68-680 bar (1000-10000psi)	For 68-204 bar (1000-3000 psi) It can remove salts, dirt, loose coatings and leached layer of antifouling coatings. For 204-680 bar (3000-10000psi) It can perform selective removal of coatings and intact coatings.
High Pressure Hydro-Blasting (Water-Jetting) Pressure: Between 680-1700 bar (10000-25000 psi)	It can remove all existing old paint or heavy rust. It scales to WJ 3 (Water jetting standards NACE 5/ SSPC-SP 12) to a uniform matt finish with at least two thirds of the surface being free of all visible residues (except mill scale) and the remaining one-third containing only randomly dispersed stains of previously existing rust, coatings and foreign matter.
Ultra High Pressure Hydro-Blasting (Water Jetting) Pressure: Above 1700 bar (25000 psi), but normally 2000-2800 bar (30000-40000psi)	It can remove all existing old paint or heavy rust. It scales to WJ 2 hydro jetting standard of uniform matt finish with at least 95% of the surface area being free of all previously existing visible residues and the 5% containing only randomly dispersed stains of rust, coating and foreign matter.

3.5. SALT TEST

The purpose of carrying out the salt test is to prevent coating failure due to effects of salt elements on the surface before coating. In order to prevent the defect, salt test is carried out to measure the level of salt and to make sure that salt content is at minimum level. Normally, salt test is carried out by using "Bresle kit sampler". Figure 4 showed the flow chart of salt test measurement by "Bresle kit sample".

i. Remove protective backing and foam centre from Bresle Patch and apply to the hull surface, press firmly around the perimeter of the patch to ensure a complete seal.

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ii. Syringe with 3 ml of deionised water is inserted into the patch through spongy foam perimeter and inject 1.5 ml of deionised water into patch and do not remove syringe, reposition needle and evacuate any air in the patch.

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iii. Once air has been removed, inject remaining 1.5 ml of water and removed the syringe from the patch. Surface of patch is then rubbed gently for 10 to 15 seconds to allow water to dissolve surface contaminants.

↓

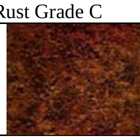
iv. Syringe is then inserted into the patch and extract the solution from patch. Salt content will be measured by salt-meter. Acceptable salt reading should not exceed 30 p.p.m.

Figure 4: Flow chart of salt test measurement by "Bresle kit sample".

3.6. CONDITION OF SHIP HULL (SIDE SHELL AREA) PRIOR TO GRIT BLASTING

Next, the Owner's representative will mark out the corroded area for blasting based on rust grade and shall discuss it with the Yard's Painting executive. There are four types of rust condition using Swedish Standard which listed in Table 4. When all parties had agreed on the total blast area and the blasting grade.

Table 4. Rust condition using Swedish Standard

 Rust Grade A	Steel surface largely covered with adhering mill scale with little, if any rust.
 Rust Grade B	Steel surface has begun to rust and from which mill scale has begun to flake.
 Rust Grade C	Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.
 Rust Grade D	Steel surface on which the mill scale has rusted away and on which pitting is visible under normal vision.

Shipyard shall draw up a work schedule based on the agreed areas and instruct the blasting contractor to proceed with the blasting works. The blasting time of inspection is usually divided into two sessions, once before noon and another late in the evening. This is to allow sufficient time for the blasters to produce a larger blast area so that when the paint is mixed and applied, there will not be much wastage for the coverage.

3.7. GRIT BLASTING

Grit blasting is the commonly used method for preparing a surface for the application of paint. When properly carried out, grit blasting can remove old paint, rust, salts, fouling, etc., and provides a good mechanical key (blast profile) for the new coating.

Copper grit is one of the blast media widely used for blasting in shipyard and is obtained as cooper slag waste from melting the copper metal at a very high temperature. It is a by-product and is often referred to as hard coarse-grained silicieous sandstone. This is the base for grit and can be found or prepared in different sizes for different types of blasting known as grit blasting. It usually comes in sizes ranging from 830cc (meshes) and 1030cc but most shipyard prefers the former over the latter because of its coarseness and larger size in order to achieve a higher blast profile on the steel substrate.

Besides that, it is important that the correct blast profile is achieved before the substrate is coated. Paint manufacturers should specify the blast profile for each coating, in terms of the pattern required for that paint. The instrument to measure the blast profile is called "Blast Profile gauge" and the reading is in micron. In general, thicker coatings will require a profile with a greater peak to trough measurement than a thin coating.

3.7.1. Blast cleaning standard

The most commonly referred standards are Steel Structure Painting Council (SSPC), National Association of Corrosion Engineers (NACE) and Swedish Standards or International Standards Organization (ISO) (1988). Each standard is divided into four standards of cleanliness, broadly described as; brush off, commercial, near white metal and white metal. Whilst each standard may be differ slightly in requirements and terminology. The Table 5 indicates the grades for steel surfaces using blast cleaning.

Table 5. Preparation grades for steel surfaces using blast cleaning

	Brush Off	**Commercial**	**Near-White Metal**	**White Metal**
SSPC	SP 7	SP 6	SP 10	SP 5
NACE	No. 4	No. 3	No. 2	No. 1
SWEDISH	Sa. 1	Sa. 2	Sa. 2½	Sa. 3

3.7.2. Blast profile

The correct blast profile is very important prior to painting. If the blast profile is produced too high, an inadequate coating coverage will result over any high and sharp peaks and this could lead to premature coating breakdown. However, grit blasting can also result in an insufficient surface profile and may simply re-distribute contamination over the steel surface trapping contaminants under the surface.

3.8. PAINT APPLICATION

The paint application is to provide a film which give protection or decoration of ship hull being painted. The success of any application and subsequent performance depends on some variables such as surface preparation, film thickness of the paint system, methods of application and conditions during application.

3.8.1. Film thickness measurement

The wet film thickness (WFT) of the coating is measured and can be converted to a dry film thickness (DFT) following the paint maker's guidelines for that product. The wet film thickness measurement can be determined by how much coating should be applied to reach the specified DFT. The dry film or wet film ratio is based on percentage of solids by volume of the coating being used. The basic formula to measure the WFT is:

$$WFT = \frac{DFT(\mu m) \times 100}{VolumeSolid(\%)}$$

3.8.2. Ship side coating thickness range

Different ship side area has different Dry Film Thickness (DFT). Table 6 shows coating condition thickness scale.

Table 6. Coating condition rating scale

Locations/Areas	Surface Preparation	DFT range, µm
Topside	1. High pressure fresh water wash (3000 – 5000 psi) 2. Grit blast Sa 2.0 or Sa 2.5	200 – 400 (epoxy)
Boot Top		150 – 300 (epoxy) 75 – 100 (tie coat) 150 – 200 (antifouling)
Vertical Side		200 – 300 (epoxy) 75 – 100 (tie coat) 250 – 300 (antifouling)
Flat Bottom		175 – 300 (epoxy) 75 – 100 (tie coat) 100 – 200 (antifouling)
Propeller		375 – 400
Rudder		500

3.8.3. Method of paint application

Airless spray is now almost a universal method for ship side paint application. This is by far the most important and efficient method for the application of heavy-duty marine coatings, which allows the rapid application of large volumes of paint as well as the application of high build coatings without thinning. Airless spray method can reduce the overspray and bounce back problems. Moreover, it follows that ships paints must be formulated and manufactured to be suitable for application by airless spraying.

Airless spray is a technique of spray application which does not rely on the mixing of paint with air to provide atomization. Atomization is achieved by forcing the paint through a special and precise constructed nozzle or 'tip' by hydraulic pressure. The choice of tip determines the film thickness applied per pass of the spray gun and should be selected in accordance with the coating manufacturer's guidelines. The speed of each pass and volume solids of the paint will influence film thickness. Airless spray equipment normally operates at fluid line pressure up to 5000 psi (352 kg/cm^2) and care should be taken periodically.

Modern products are most commonly applied by airless spray. One airless spray gun is capable of spraying between 50 and 80 litres of paint per hour, i.e. covering 150 – 400 m^2/hr at the required film thickness. Moreover, airless spray application produces less overspray than conventional air-assisted spraying, but there is some risk of painters inhaling spray droplets. Antifouling compositions offer special problems because of the poisons they contain, this applies both to the older copper poison types and more particularly to the organometallic poisons. Thus, suitable protective equipment must be used.

Commonly, painting must be inspected regularly to ensure that specifications regarding surface preparation, wet and dry film thickness, drying times, mixing of two-pack materials, overcoating intervals, quality of workmanship and others are met.

3.8.4. Condition during application

There are some factors which must be considered during paints application. The major factors are condition of substrate, temperature, relative humidity, weather conditions and condensation.

The proper ambient temperature for steel hull painting process should be 3°C above dew point. Most paints can tolerate high humidity but condensation must not form on the surface being painted. During the painting process for the ship hull, the relative humidity must be below 85%. Furthermore, paint should not be applied during fog, mist or raining. Generally, under these conditions, it is difficult to maintain the steel temperature above the dew point. Besides that, condensation is forbidden during hull painting process.

3.9. ANTIFOULING PAINTS FOR THE SHIP HULL AREA

Generally, there are two basic mechanisms employed in coatings to prevent fouling settlement which are toxic antifouling and foul release coating. Toxic antifouling means that prevention of fouling by a surface coating requires the maintenance, in the water in contact with the coating, of a concentration of toxin that is lethal to all of the target organisms. Meanwhile foul release coating has a surface with very low surface energy which reduces the efficiency of the attachment process dramatically, i.e. a "non-stick" surface is presented to the organism.

3.9.1. Typical ship paints properties

Ship paints properties are very important for us to understand because this is important on choosing the correct and proper types of ship paints.

3.9.2. Coating compatibility

Coating compatibility is important when the maintenance or repair work is carried out, to ensure that the repair coat will adhere to the original paint, otherwise failures will occur between the individual layers (inter-coat adhesion failure). Incompatibility between coating types, such as epoxy anticorrosive coatings with some types of antifouling paints, can be overcome by the use of a tie coat, which has good adhesion to both paint types and is therefore applied onto the anti-corrosive layer before the antifouling layer is applied. Thus, paint compatibility is a factor which must be taken into consideration.

3.9.3. Performance of antifouling paints determined by hull roughness

Ship's underwater hull is painted to protect the substrate and also prevent undue roughness. The most significant cause of hull roughness is fouling. Normally, paint fouling control technology can be characterized into 4 types: Controlled Depletion Polymer (CDP), TBT Free Self Polishing Copolymer (SPC), Hybrid TBT Free Self Polishing Technology and Foul Release Technology. Each type of paint fouling control technology has different Average Hull Roughness (AHR) value. Table 7 shows the AHR value for these 4 types of AF paints.

Table 7. Average Hull Roughness (AHR) value for antifouling paints

Types of paint fouling control technology	Average Hull Roughness (AHR)
Controlled Depletion Polymer (CDP)	40 microns/year
TBT Free Self Polishing Copolymer (SPC)	20 microns/year
Hybrid TBT Free Self Polishing Technology	30 microns/year
Foul Release Technology	5 microns/year

The paint fouling control which has smallest AHR value has lower percentage increase in power needed or fuel used. Thus, foul release technology can save more power and fuel used.

3.10. ANTIFOULING SYSTEMS REGULATIONS AND CONVENTION

Generally, antifouling system has their regulation to control the harmful antifouling systems on ships. This is very important for us to understand in order to enable the ship become compliant. In this research, I include Antifouling System (AFS) requirement and the Convention and Best Management Practices on marine pollution by removal of antifouling coatings from ships. From the AFS requirement, there is a prohibition on the application or re-application of organotin compounds which acts as biocides in antifouling systems. When existing vessels replaced the antifouling after 1 January 2003, they complied with this requirement or provided sealer to avoid a non-compliant antifouling to avoid leaching. All vessels after 1 January 2008 shall either not bear such compounds on their hulls or external parts or surfaces; or apply coating that forms a barrier (sealers) to such compounds such as leaching from the underlying non-compliant antifouling systems.

Furthermore, Convention and Best Management Practices is to prevent marine pollution by the removal of ship antifouling coatings. Thus, management for AFS waste collection is very important throughout the process. The adoption of management practices for the application and removal of antifouling systems can reduce the release of biocides into the natural environment. The aspects include choice of antifouling system, and collection, treatment, and disposal of spent coatings which have an impact on the release of biocides into the environment. If not managed properly, it may result in high concentrations of biocides in the marine sediments in areas close to where application and removal activities are conducted [1, 4].

3.11. Quality Assurance

Each model has their own standards in order to make sure the standard is controlled and complied with the rules and requirements. To ensure the model is controlled efficiently, quality assurance plays an important role. The purpose of a quality assurance system is to prevent problems from occurring, detect them when they do, identify the cause, remedy the cause and prevent recurrence. Quality Assurance mechanism in this model is to ensure that accuracy and precision throughout a procedure. The parties involved in this procedure include Yard's Painting executive, Shipowner's representative, suppliers, Paint Manufacturer and Surveyors. The responsibility of Yard's Painting executive is to use checklists and inspection records to ensure that the standards are followed. Besides that, they will conduct audit by QA department on a monthly basis. If sign of any incompliance is found, yard person such as Project Manager will issue Quality Assurance Note (QAN) or Non Conformance Report (NCR) towards suppliers. QAN is only for light or small incompliant, but NCR is for heavy incompliant.

Furthermore, Paint Manufacturer's inspector must have a widely experience and good judgement in order to make sure the paint job was completed as specified. They need to take concern on many aspects throughout the painting process. Adhesion test or "dolly test" which is commonly known among the paint inspectors, would have to be carried out when the external hull of the ship is being grit blasted and applied fresh coatings. This is to ensure the paint adhesion onto the substrate hull can withstand a pull-out pressure of not less than 300 psi. The higher the pressure of the "pull-out" test, the stronger the adhesion of the paint onto the steel substrate is. All parties must take concern on their responsibilities to ensure the quality obtained is in compliance. Every daily log, tests and inspections work must be recorded for future evaluations of the painting. There are no any by-pass steps that can be skipped. Throughout the process above, the quality of the paint is assured [2,5].

4. CONCLUSION

Fouling is unwanted accumulation material on solid surface. There is either living organism (biofouling) or non living substance. Antifouling paints are used to prevent the biofouling. There are two types of antifouling paints which are toxic and non-toxic alternatives to TBT systems. Nowadays, there is a trend to use the foul release technology which is also known as non-toxic alternatives to TBT systems such as silicon-type foul release AF paint. This product is expensive and requires longer working period to accomplish but the long term benefits can be seen from the smooth and faster speed of the vessel reaching its destination and it's cost effective saving which is believed to be about 40%. According to LNG Carrier Owners' Manual, foul release coatings are proving themselves to be the ideal solution for LNG hull and propeller fouling control. Not only can they keep hulls and propellers smooth and free of macro-fouling for extended service period of up to 60 months, but in addition, since they do not use biocides to control fouling, they can be an integral part of an LNG environmental management plan.

High performance paint systems are especially sensitive to misapplication and knowledge of the application characteristics and recommended film thickness is vital to obtain optimum results. For optimum service life, the surface must be completely free of all contaminants that might impair performance and should be treated as such to assure good and permanent adhesion of the paint system. The quality of surface preparation has a direct relation with the lifetime of a system. Nowadays, the paint application method commonly used airless spray. The degree of skill of the personnel can affect the performance of paints.

Throughout the whole ship painting process, it is necessary to inspect the work as it progresses if there is to be any reasonable assurance that a paint job was completed as specified. There are many failure cases due to poor workmanship occurred after the work has been completed and has been paid for. Beside that, quality assurance is part of quality management focusing on increasing the ability to fulfill requirements of the process. As a conclusion, the model results are complied with the standard requirements.

5. RECOMMENDATION

There are many aspects in this research which could be investigated in the future. Some suggestion and recommendations on future study are as follow:

i. The practical way to measure hull fouling is to use a professional diver to not only measure but to survey or inspect the general condition of the hull as a whole and record with video camera or CCTV. This is because hull fouling varies along the hull.
ii. There are many ship paints application methods discussed in this paper Therefore, it is suggested that investigation for each methods in much more details.
iii. The performance of AF paints can be determined by many factors. Thus, it is suggested that investigation for performance or quality of AF paints to be done in much more detail.

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