Anti-fouling Paints and Boat Bottom Maintenance

1.5 Why is Boat Bottom Fouling Such a Problem?

Heavy marine fouling can:

- Reduce speed
  - Increase fuel consumption
- The bigger the boat, the worse the effect

Biofouling can produce several negative effects, including:

- Increased surface roughness on hulls
- Increased frictional resistance (drag)
- Even without fouls, the hull can account for as much as 90% of drag
- Increased fuel consumption
- Decreased speed and range of speeds

Maximum "drag penalty" occurs when barnacle coverage is around 75%.

- If you reduce barnacle coverage to 5% you will cut the drag penalty by one third.
- HEIGHT of the largest barnacles has the dominant effect on drag.

NOTE: An estimated speed reduction of 10% by biofouls translates to a 40% increase in fuel consumption to counter added drag (resistance).

The effects of biofilms on frictional drag:

- Even low amounts of algal fouling leads to a significant increase in frictional drag.
- How much of an increase in drag depends strongly on:
  - Fouling type
  - Amount of fouling coverage

There are significant differences in frictional drag from antifouling and fouling release paints when these products are tested in conditions where there is a lot of movement and speed versus very little.

- There is very little frictional drag for fouling release products (those that contain no toxic products for the fouls but rely on a slippery surface to prevent fouling) when the boats are moving or attaining speed.
- In some cases, fouling release paint products had less frictional drag than copper-based antifouling paints

Effects of propeller roughness on vessel power can be very significant.

- Providing an antifouling coating to the propeller may lead to significant performance improvement because of a decrease in fouls and associated roughness.

Predicted change in total resistance at a speed of 15 knots, and again at 30 knots is as follows:

- Typical changes with applied antifouling coatings 1%, 3%
  - Deteriorated coating or light slime 9%, 7%
  - Heavy slime 18%, 12%
  - Small calcareous fouling (barnacles, tubeworms, etc.) or aquatic weeds 31%, 20%
  - medium calcareous fouling 47%, 30%
  - heavy calcareous fouling 76%, 47%

NOTE: Roughness from fouling can cause an average 20.4% increase in fuel consumption.

NOTE: Alternative boat bottom paints have the same inherent roughness as traditional antifouling paints, therefore there are no differential effects on accumulation of fouling.

There is cost savings if boats can be maintained at lower than typical fouling ratings without greatly increasing cleaning expenses or reducing the lifespan of boat bottom paint.

NOTE: Even modest improvements in hull fouling conditions can cover the cost of extra cleaning or inspection.

BIOLOGICAL FOULING colony types and extent depends on:

- local environment
- inorganic deposits
- organisms

INORGANIC FOULING: from non-living particles

- Caused by deposits from
- Corrosion
- Crystallization
- Suspended particles
- Oil
- Ice

Fouling affects vessels in several negative ways including:

- Engine stress
- Hull drag (resistance)
- Corrosion and bio-corrosion from acid producing bacteria
- Increased fuel consumption

Marine platforms are affected by fouls through:

- Increased structural load

- Increased Structural Stress
- Increased Structural Fatigue

On individual large ships, marine fouls are most often found on:

- Windlass of the stern and bow
- Propeller
- Bridge keel
- Sea chest
- Bow thrusters
- Anchor locker

Marine biofouling occurs on the following:

- Vessels
- Buoys
- Sonar devices
- Pontoons
- Off-shore structures (windmills)
- Oil installations
- Platforms
- Underwater cables
- Underwater acoustic instruments
- Seawater cooling systems
- Marinas and marina structures

Individual ship areas with the highest amount of fouling are areas with the best aeration such as:

- Vessel's water line
- Propeller
- Rudder blade

NOTE: Common fouls of these areas include Green and Brown Algae, Ulva and Ectocarpus, respectively, and common hard-shelled barnacles.

Biofouling morphology that affects the vessel and control of the fouling includes:

- Film thickness
- Film density
- Film structure
- Film composition
- Bioadhesive strength
- Weight of fouling organisms

A biofilm 1 mm thick can increase ship hull friction by 80%, which translates to a 15% loss in speed.

A 5% increase in biofouling can increase ship fuel consumption by 17% with a concomitant increase of 14% in greenhouse gases.

Biofouling can cause slippery structures and walkways.

Biofouling can cause extra weight loading and damage or sinking of fishing nets and buoys.

Biofilm: Five Stages of Colonization

- Initial attachment
- Irreversible attachment
- Initial growth
- Final growth
- Dispersion

Biofoul growth rates depend on:

- organism
- substrate
- flow velocity
- shear stress
- temperature

For example, tubeworms prefer settling on a biofilm, but bryozoans and barnacles do not need biofilms to settle on your hull.

Tenacity of biofouls depends on bioadhesion of the foul to a hard surface, which is in turn dependent on:

- organism type
- substrate
- biofilms, which the separating fluid between the substrate and the fouling organism

Inorganic Fouling

Inorganic fouling consists of non-living particles.

- May form in addition to or independently of biofouling
- Come from the following:
  - Corrosion
  - Crystallization
  - Suspended particles
  - Oil
  - Ice
- Salts from aqueous solution crystalize and deposit on surfaces
- Other from minerals in the water:
  - Mg
  - Ca
  - Ba

Types of inorganic fouling:

- particulate fouling
- freeze fouling
- gas stream fouling

Particulate fouling: suspended solid particles deposit onto heat-transfer surface

Freeze fouling: Cold region oil pipelines when waxy hydrocarbons contact cold pipe walls

Gas Stream fouling: mineral, organic, and inorganic particles deposit on:

- gas lines
- reactors
- combusting chambers
- heat exchangers

NOTE: Biofouling may initiate inorganic fouling especially where biocorrosion causes formation of corrosive particles:

- scale
- sludge

Surface Factors

Biofouling and inorganic fouling depend on surface factors such as:

- Wettability

- Microtexture
- Color
- Contours

Wettability Preferences for Hydrophobic (water repelling) Surfaces:

- Bryozoan larvae
- Mussel larvae

Preference for Microtextured Surfaces:

- Hydroids
- Bryozoans
- Ascidians

Preference for Light Colored Surfaces: LARVAE, including:

- Sponges
- Barnacles
- Ascidians
- Mollusks

Barnacles prefer convex contours.

Calcareous sponges prefer concave contours.

Hydrophobic surfaces typically have:

- low wettability
- low surface energy

Hydrophilic (water attracting) surfaces typically have:

- high wettability
- high surface energy

NOTE: Antifouling, superhydrophilic surfaces attract water to form an evenly distributed water layer.

- can confuse and disrupt microorganism settlement

In general, microorganisms prefer to colonize hydrophilic surfaces, BUT:

- Ulva linza algae prefers hydrophobic surfaces
- Balanus amphitrite barnacle prefers hydrophobic surfaces

Surface microtexture influences organisms such as hydroids, ascidians, and bryozoans.

- These seek shelter from strong currents and settle in:
  - grooves
  - cracks
  - pits
  - crevices

Microorganisms prefer to settle in areas slightly larger than themselves for the following reasons:

- maximum protection
- maximum surface area in contact with substrate

In general:

- Biofouling on superhydrophobic surfaces will wash off more easily (self-cleaning) when compared with hydrophilic surfaces
- Certain barnacle larvae are deterred by microtextured surfaces if the features are the same size or slightly smaller than the juveniles
- Biofouling will be the most difficult to control in ports because of:
  - lack of water movement
  - higher concentration of bacteria from:
    - pollution
    - stagnant water

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