Chapter 3 - Trim optimisation, Hull and propeller condition

Mariners are used to know the best possible trim for their vessel using her sea worthiness as the main and only criterion. Often the best trim is one feet astern.

Shallow fairways may set as well criteria for her trim. Even keel loading in the port is quite common especially with the small ships operating from small harbours. Today a more important criterion is energy efficiency and if these two criteria result to the same time trim then it is excellent result.

Trim is normally defined as the difference between the aft draft and the forward draft. When the trim is positive, it means that the stern is more inside the water than forward. Accordingly, positive trim means trim to aft and negative values of trim means trim to forward. Optimum trim is the trim where the required propulsive power is minimal. Optimum trim is achieved via the proper planning and ship ballasting plan. When the ship is fully loaded, transferring the ballast water and extending fuel from one tank to another can be used to achieve the optimum trim. A ship’s resistances and trim are closely related to each other. Trim affects the hull’s wetted surface area and therefore increases or decreases forces that is slowing the ship.

The possible explanations for the relatively large dependencies of ship performance on the trim could be attributed to the following impacts of trim.

- Changes to wave resistance
- Changes to wetted surfaces and thereby the frictional resistance.
- Changes to form resistance due to transom submergence
- Changes to various propulsion coefficients including:
  - Resistance coefficients
  - Thrust deduction
  - Wake fraction
- Changes to propulsive efficiencies including:
  - Relative rotative efficiency.
  - Propeller efficiency

Using optimum trim, it can have 2% to 4% reduction on fuel consumption. However, this reduction can be higher or lower depending on the vessels type and operation draft. And when there are ways to save the environment and money all possible measures should be taken care of. When trim changes, the wetted surface of the hull and therefore the hull resistance will be affected. Therefore even 5 to 10 centimetres difference on trim can cause higher fuel consumption. However, it is difficult to measure the exact fuel saving levels due to trim while the vessel is underway because of all variables are never exactly the same. (Speed, draft, weather and sea impacts).

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There are different methods of determining the vessels optimum trim. The best results are obtained from self-propulsion tests using a scale model. In this method, not only the changes in hull resistance are investigated and the choice of propeller is examined but also the propulsion coefficients are normally measured. When these tests are made with different draft and speed the optimum trim, for different operating conditions, can be found.

Nowadays the accuracy has improved so much that, trim tables based on the use of Computational Fluid Dynamics (CFD) software tool calculations can be comparable to the results from the resistance model test. However, both resistance test and CFD methods tend to ignore the impact of the propeller: this may have significant impact on evaluations of vessels with light drafts. Normally when Trim is being calculated the tests are made at both forward and aft trims. Often forward trim is not even possible for the lighter drafts due to restriction in the propeller’s submergence.

The recent studies show that, currently on the great majority of cases, even keel (zero trim) is normal practice. This can be the optimum trim for large and slowly moving vessels, like bulkers and tankers. However, vessels like container ships and RoRo car carriers, with slimmer body and higher operating speed are more sensitive to trim and for that reason more care should be taken to optimise the trim.

Because of the recent energy efficiency regulation, more shipping companies have chosen to do trim optimisation calculations using the CFD software. The issue, however, is that all the calculations are based on analytical forecast. These calculations combined with feedback from the master on their judgement on trim tables and its impact on ship powering requirements, can give relatively accurate trim tables.

There are few problems that might affect the trim optimisation. When loading the vessel, the weight distribution should be determined to allow trim optimisation. Therefore, there needs to be good communication between ship and port. Also, transferring bunker and water on-board changes the vessels trim. This highlights the need of communication between deck department and engine department. Crew changeover is also one thing that can cause problems with trim optimisation, if there is lack of communication between the crews. The above barriers are possible to remove by understanding the subject and training of shipboard crew, but it also needs crew’s dedication to the best practice.

When talking about energy efficiency on ships, the trim isn’t the only factor that affects to ship’s propulsion fuel consumption. One almost as big thing to keep on mind is hull and propeller cleaning and maintaining.

As stated earlier, the vessels resistances due to the wetted surface areas are composed of frictional and wave making resistances. Frictional resistance is the main component that slows down the vessel. The frictional resistance is caused by the water flow along the hull. For that reason, the hull should be as smooth as possible so the water could flow fast and smoothly. Each 10\(\mu\)m to 30\(\mu\)m additional roughness causes the total hull resistance to increase by 1%, and as discussed earlier increasing resistance increases fuel consumption as well. Normally a new ship is delivered with hull roughness of 75\(\mu\)m and later when ship comes to dry-dock the hull roughness can be 250\(\mu\)m. Even with good maintenance, the hull roughness can increase 10 to 25\(\mu\)m per year, depending on the hull coating system.
Hull surface roughness can be divided into two categories, physical and biological. These two categories are normally divided into two subcategories micro roughness (less than 1mm) and macro roughness (more than 1mm). The physical micro-roughness is normally human made mistakes or mechanical failures like, mechanical damage, failure of the applied coating and even improper preparation of the surface and/or improper application of a new coating. Biological roughness (fouling) comes when some organic growth sticks on the hull of the vessel (slime, algae, barnacle etc.). Even micro level biological roughness has significant impact on resistance. Light slim covering the entire wetted surface can increase total resistance by 7 to 9 percent. Heavy slime increases resistance by 15 to 18 percent, and small barnacles and weed can push up to 20 to 30 percent increase in total resistance.

Biological fouling depends on many things such as:
- Initial roughness of the hull
- Quality of hull coating
- Robustness of the coating with respect to mechanical damage
- The areas of the hull where there is sunlight, along the sides of the hull and near the waterline.
- Temperature of water (colder water generally means less fouling)
- The salinity of the water (performance coating will be a function of salinity of water)
- Amount of algae in the water
- Ship speed and its operation profile (hull moving, speed, at berth, at anchor, layby, etc. or static)
- Hull maintenance

Surface roughness can increase during the operation due to damage on the coating as well as due to corrosion, all physical roughness on hull surface also attracts marine growth. Using antifouling paints is possible to reduce the growth of slime and other species. Antifouling paints last for 3-5 years, but its performance is reduced gradually over time. Therefore, hull need to be cleaned from time to time even when using antifouling paints. Cleaning can be done by divers or automatically. Keeping the coating in good condition reduces energy consumption. Cleaning the coating costs but savings from the decreased fuel consumption and extended time needed to renew the coating outweighs those costs. The renewing of the coating needs to be done in dry-dock and that is very expensive.

Minimising hull roughness can be done by using smoother surface finish, more appropriate paint, more appropriate maintenance of the hull and propeller, also avoiding excessive anchoring and port time reduces fouling. Care should also be taken to make sure the cleaning technologies used are appropriate to the coating, using wrong cleaning methods can damage the coating and every excessive roughness on the surface of coating make it easier to organic species to hold on the surface and therefore fouling increases faster.

Currently there are three different coating types in common usage and all of them have different resistance to fouling, different impact on hull roughness and have different cleaning intervals. These methods are:
· Controlled Depletion Polymer (CDP)

- Typical life before recoating is 3 years, but green slime or weeds can become a problem in less than two years. The average hull roughness increase is estimated at about 40 μm per year in surface profile, but this can vary greatly.

· Self-Polishing Copolymer (SPC)

- Five years of service for high quality systems can be achieved. Average hull roughness increase is estimated at about 20 μm per year.

· Foul-release Coating

- For slower vessels (less than 15 knots) this is a challenge for even the best coatings so some ‘soft’ cleaning is usually required to remove the micro fouling. If the vessel is stationary for some time, barnacles and other macro-size biota can become attached. The coating gains some of its effectiveness from its extremely smooth surface and this must be maintained for best performance. Roughness in a foul-release coating will reduce its ability to discourage adhesion and slime/ micro fouling can take hold. Mechanical damage, for example from tugs, is especially critical for these types of coatings requiring special care in operations as the damaged parts have no fouling protection. Average hull roughness increase is estimated at 5 μm per year.

When choosing hull coating things that needs to be observed:

1. Cost: The more effective the coating the more expensive it is
2. Speed of vessel: Ships using higher operating speeds need harder coating
3. Operating environment: Is the ship going to operate in a salt-water or fresh-water area.
4. Compatibility: Some coatings cannot be used on top of others due to chemical interactions
5. National regulations: Some of the coatings are banned in certain countries
6. Area of operation: Severity of fouling in the area the vessel is trading, some sea areas are much worse than others.

When searching for the best hull coating, the best opinions are coatings that provide smooth surface and can be reasonably, maintained in their smooth state, that prevents the fouling organism. High-quality coatings can save up to 4% in propulsion fuel consumption. Cleaning the hull and changing the hull coating to better working coating can save 10-12 percent on fuel consumption. However, removing the roughness and the application of prime, anti-corrrosive and advanced antifouling painting can cost about US $10/m², and on VLCC that makes about $300,000. Since the banning of TBT(Tributyltin), most antifouling coatings are self-polishing copper and tin based paints, but many countries have banned or planning to ban copper based products in certain areas. The “foul-release” coatings have so smooth surface that it is difficult to most organic growth to hold. New studies show that it is equally as effective as TBT-based products, but because of its relatively high price and its smooth surface is not lasting as long in higher operating speeds, it is not in wide use. If a ship is getting fouled up faster with one product, it is worth considering the change to another product. If fouling is becoming a very big problem, talking to other ship owners in the same
area and asking what product works for them, as they can give unbiased advice which one may not get from the original vendor.

Cleaning the coating is clearly always beneficial if it is done correctly and without harming the coating and therefore making the surface rougher. The savings on fuel consumption overweight the costs of hull cleaning so it is always recommended. When cleaning is done on regular intervals it is also often cost effective. The need of hull cleaning can be determined from performance indicators (like power versus speed) or with regular pre-cleaning inspections. Cleaning should be taken care of when the fouling is on micro level because removing macro level fouling is difficult without harming the original coating. Cleaning light slime can reduce fuel consumption 7-9 percent, heavy slime 15-18 percent and macro heavy fouling 20-30 percent. Cleaning the hull cost about US $1.5 to $2.5/m² in the far east. This could convert to US $50,000 for a full hull cleaning for VLCC.

It should be kept in mind that if a ship is operating on fresh water or brackish water the fouling is increased, also operating in warm water increases fouling. If a vessel is operating at fresh water for some time it should be considered to extend the cleaning intervals or changing to anti fouling paint specially designed for those areas.

Like the hull roughness, propellers also suffer decreased performance due to surface roughness. The absolute reduction in ship energy efficiency due to propeller roughness is less than those seen on hull roughness, but propeller roughness can increase propulsion fuel consumption up to 6 percent. Propellers suffer physical surface roughness created by corrosion, cavitation erosion and impingement attack. These damages can be cleaned and polished which will reduce the propellers frictional and rotational losses.

In the last 15 years, there have been created new coatings for propellers that can have even better surface properties than the polished propeller surface. Coatings can be damaged by cavitation erosion, but the force that caused the damage also prevents fouling so that damage doesn’t affect performance in any significant way. The propeller coating also gives protection against roughness caused by corrosion and fouling. Most damages to the propeller is caused by cavitation pitting which is caused by poor cathodic protection or by allowing the propeller to operate too close to the surface.

Cleaning and polishing the propeller can give 6 percent improvement on fuel consumption. Divers can clean a 5 blade 10m diameter propeller in about 3-4 hours and that costs about US $3,000 in Far East and about double of that in Europe.

When determining the need of hull and propeller cleaning, there are two ways to do so. First way is to use divers in port, who measures the roughness of hull and propeller and compare them to the baseline values. This method gives very accurate results and therefore it is easy for the ship owner to decide when the cleaning is needed. The second way is to compare the vessels performance indication and do calculations that way. However, it is very difficult to get accurate results with that way because all the variables (weather conditions, trim etc.)
are never the same, so determining what increase comes from what source is difficult. Doing performance monitoring for a long time and comparing these results to earlier performance gives a good overview of the condition of the hull and the propeller.