

Trim Optimisation – Don't blind me with science!

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All standard references for ship energy efficiency, such as the IMO greenhouse gas (GHG) report or the the Oil Companies International Marine Forum (OCIMF) study for emission-mitigating measures, rank trim optimisation highly as a recommended measure.

Indeed, trim optimisation is easy to refit and generally gives short payback times, typically in the order of several months. But, customers are faced with an ever increasing array of vendors which use incomprehensible jargon. Should I take a “dynamic performance model based on advanced machine-learning technology” or rather the “RANSE with VoF”?

Simple advice: Don't be blinded by science; don't be impressed by a smoke screen of jargon. You don't need to programme the software; you just want to understand the basic principles and the pros and cons of the different approaches.

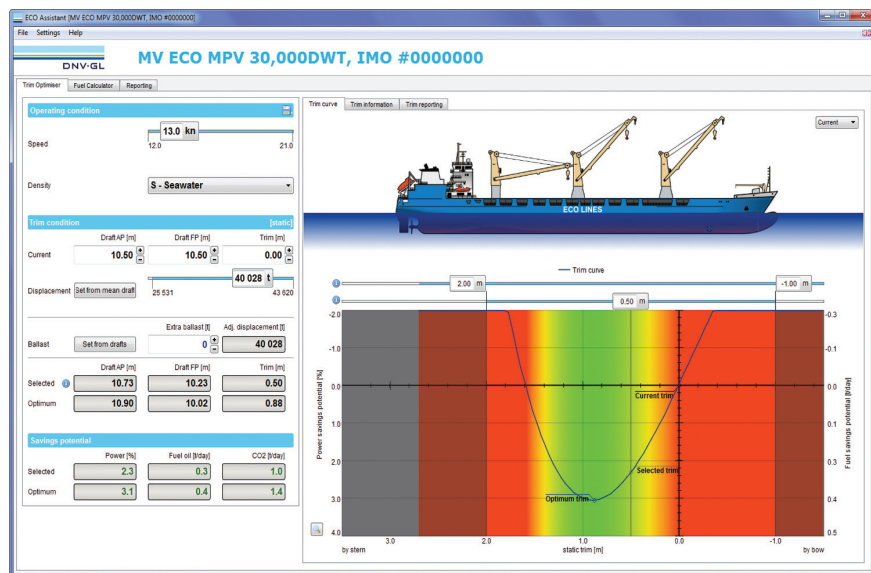
The following gives an introduction to available options, explains some of the jargon and discusses strengths and weaknesses of the different approaches.

A knowledge base is crucial

There are several commercial trim optimisation tools on the market. These vary in price, user friendliness, fundamental approach and performance. However, they all combine two key elements:

1. A ship specific database (often called the hydrodynamic “knowledge base”) for resistance or power as function of operational parameters
2. A user interface displaying the trim recommendation. Virtually all systems use an intuitive traffic-light scheme for good, acceptable and poor trim options.

Key operational parameters considered are speed, displacement (respectively draft) and in rare cases also water depth.



Screenshot of trim assistant software ECO-Assistant

Other factors, such as seaway, are seen as secondary for trim optimisation and therefore not considered. For certain cases, such as ferries or ships trading frequently in shallow waters (e.g. Baltic Sea), the inclusion of water depth as a parameter makes sense. For most other ships, water depth may be neglected. On very shallow water, aspects of safe manoeuvring overrule energy efficiency considerations.

The hydrodynamic knowledge base should be a dense matrix of speed, trim and draft values. Its range should cover all feasible operational combinations. Typically this requires 300-400 data sets (combinations of trim, draft and speed) for deep water, and 3-5 times as many if also shallow water variations are to be covered. The discrete data sets are connected by smooth interpolation (multi-dimensional response surface in jargon), allowing consistent interpolation for whatever operational conditions are specified by the user.

While each trim optimisation tool must have a hydrodynamic knowledge base, the chosen approach to generate this knowledge base decides costs and performance of a trim optimisation system.

First school, then work

There are two fundamentally different approaches to develop trim optimisation tools. The first group of systems is based on a “laboratory” hydrodynamic model which creates the knowledge base systematically and completely, before the trim optimisation software is used.

The system goes to school first and learns the knowledge base before being sent out to the real world. This school training may be through model tests or numerical simulations. As this approach does not require interfacing with onboard systems or sensors, it makes installations much more cost effective on most ships, especially for fleets of sister vessels. However, the

approach requires a geometry model of the hull, which may have to be re-engineered from available cross sections and main dimensions or from 3D scanning.

Model tests are in principle an option, but the creation of dense knowledge base involves much more time and cost than CFD (computational fluid dynamics). In addition, model tests suffer from scale effects (different wave breaking from full scale ship) and have thus also a slight accuracy handicap. Hence, some of the older trim optimisation systems were based on model tests, but today CFD-based approaches are now preferable.

Older CFD approaches used simpler flow models (using jargon such as potential flow, panel or Rankine singularity methods). These fail for breaking waves and have poor or no propeller models, leading to less accurate results. Better flow models give more accurate results and thus better trim recommendations and higher fuel savings.

Such high-fidelity simulations (using jargon such as full-scale RANSE simulations, viscous CFD, two-phase flow, Volume-of-Fluid (or VoF) method) may be more aptly called “numerical sea trials” than “numerical towing tank” tests, as they mimic the full-scale ship rather than the scaled-down model of a model basin. They are capable of modelling breaking waves accurately, which is essential in conditions where bulbous bows partially emerge or transom sterns partially immerse.

Learning on the job – Beware of incomplete training

The second group of trim optimisation systems is based on system identification of the actual ship. Typically some machine learning techniques are employed. This approach does not need any information about the ship hull geometry. However, it requires rather extensive sensor information. Ships must then be equipped with advanced data acquisition systems. These systems have to cope with changing ambient conditions (wind, waves, current, water

temperature, etc.), which affect the resistance of the ship.

Even if sophisticated correction methods are used, the uncertain nature of the ambient conditions introduces unavoidable scatter in the target data. Machine learning techniques perform in essence the task of putting a smooth “curve” through the scattered data. The more parameters are involved, the slower the computer learns. Therefore machine learning approaches work best for ships which feature fewer changes in operational and ambient parameters, such as ferries or cruise vessels.

While the first group (model test and CFD-based knowledge base) had the benefit of a proper school education, the second group has to learn on the job. Typically there is an apprentice period, though: Initial dedicated training periods vary draft, trim and speed, ideally during days where the ambient conditions do not contaminate the data sets too much. After that, it is life-long learning to fill missing patches in the knowledge base and to update existing knowledge. This continuous learning is called “dynamic” in trim optimisation jargon.

In a shipping fairy tale one captain was faced with a dilemma; the story goes like this: Once upon a time, there was a shipowner who was looking for the best trim optimisation for his vast empire of ships. He looked for suitable candidates and installed a CFD-based system and a machine-learning system on one of his ships. One fine day, the captain asked both systems for advice. The CFD-based system said: 1m down by the bow. The machine-learning system said: 1m down by the stern. Who should the captain trust?

It sounds like a fairy tale, but rumour has it that this happened more than once. But, the solution to the puzzle was that the comparison was made shortly after installation. The captain had never before driven the ship on that draft and at that speed other than with trim by stern. The machine learning system had, therefore, never “seen” that by trimming by bow the fuel consumption was lower and picked the best solution from its limited experience. Its knowledge base was patchy and thus its recommendation

not good. The CFD-based system had covered the whole knowledge base before installation and thus gave the right recommendation.

In all fairness, had the machine-learning system been trained on all possible conditions, it would have given the same recommendation. The vendor no doubt wrote this in his instructions. But, there is always the danger that we don't read the instructions.

Integrated or stand-alone?

Trim optimisation may come as part of larger advisory systems, e.g. coupled with stowage planning, voyage optimisation, or performance monitoring. Trim optimisation software in itself is good, but even better if combined properly with other functionality. The coupling to stowage planning is attractive as optimum trim should be achieved without extra ballast.

Similarly, automated recording functions are nice to have. The automated reporting serves a double purpose: as proof of energy efficient operation (for SEEMP documentation, national and port authorities, between charterers and shipowners, charterers and cargo owners, etc.) and as incentive for increased usage of the system.

Use with caution and exploit economies of scale

Trim optimisation is highly advisable for virtually all ship types. CFD-based trim optimisation is the most cost-effective trim optimisation option for fleets of sister vessels. Care should be taken that the CFD approach used is not based on out-dated potential flow methods.

The big advantage of CFD is that one can exploit the advantages of parallel computing. Dense knowledge bases can be typically generated in one or two weeks on high-performance computers with several thousand parallel processors. This is a unique advantage over model tests and system identification on real ships.

Machine-learning systems may give similarly good results, but must be trained properly, which requires more time and crew awareness. **NA**