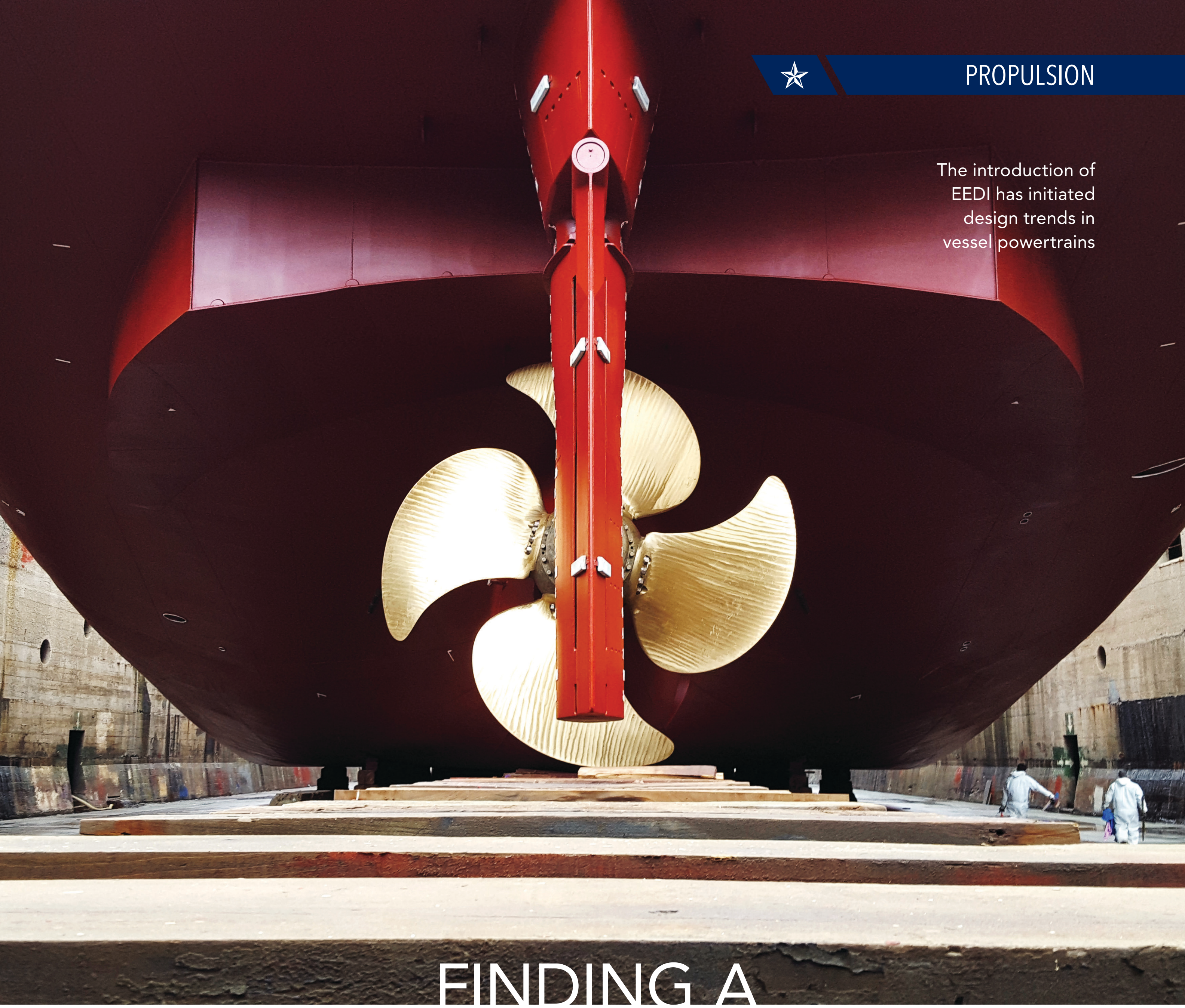

The introduction of EEDI has initiated design trends in vessel powertrains

FINDING A WORKAROUND

Calculating Barred Speed Range During Simulations & Sea Trials

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Maritime industry efforts to improve environmental performance have led to the production of next generation engines and propellers that can be too efficient for the designs of some powertrains, particularly those powering common commercial vessels such as bulkers, tankers and containerships.

The trend has reduced power and torque margins and increased the use of thinner and shorter shaft lines that are more vulnerable to external disturbances, such as the forces from heavy propellers or from operating in heavy weather.

Those margins are presently managed by regulating the time it takes for the powertrain to accelerate through what is known as the "Barred Speed Range" (BSR). An extended passage through the BSR can cause fatigue-related failure of the vessel's shaft line or problems maneuvering in heavy seas.

Research projects to address this issue are on-going at the **International Association of Classification Societies** (**IACS**) and at **CIMAC, the International Council on Combustion Engines**. For its part, **ABS** is helping to establish industry solutions at both forums.

In the interim, there is no official guidance to help prevent owners from having vessels delivered with this issue, but there is a work-around until the Rules are established.

EEDI Impacts Design of Vessel Powertrains

The introduction in 2013 of the **IMO's** Energy Efficiency Design Index (EEDI) initiated trends that have affected the design of vessel powertrains, including the adoption of larger diameter propellers, de-rated engines with lower revolutions per minute (RPM), shorter shaft lines and decreased space for engine rooms.

As a result, a growing number of ship operators are reporting unacceptable durations through the BSR while undergoing sea trials, leading to requests for estimates of shaft-line fatigue and BSR passage times at the plan-approval stage.

This poses a challenge for class societies, shipyards, and engine makers alike.

Traditionally, IACS members have approved the torsional-vibration characteristics of a powertrain according to an established Rule (IACS UR M68), which defines two "semi-empirical" limits stemming from a recognized approach to fatigue prevention and industry records.

In addition to applying IACS UR M68, most supplemental class Rules would include a qualitative clause such as "to be passed through as quickly as possible" to avoid accumulating potential fatigue cycles.

Before the EEDI era, the BSR passage was limited to a few seconds, and an insignificant number of torsional cycles. Post-EEDI, the small power margins (PM) attained by the new eco-efficient engines can result in the creation of an insufficient amount of torque to ensure a quick passage through the BSR.

Sorting Out BSR with Computational Simulations

The substantial increase in the time needed to pass through the BSR has vessel operators questioning the continued validity of the IACS UR M68, largely because it focuses on determining the upper and lower limits of the BSR, rather than exploring the potential effects of extended time durations.

To assess the effect of duration times, computational simulations that seek to predict the performance need to consider data such as shaft-line acceleration times throughout the operating range, including within the BSR. Simulations of this nature require data from the engine-control system, including speed governor functions and fuel indices to establish torque-versus-speed ratios.

Data is also required to define the dynamic torque capacity and engine's acceleration performance under load, which would necessarily include any torque-limiting function of the engine's control system, and the potential effects from turbochargers or additional details from the combustion process. Any simulation would also require data on vessel dynamics—including but not limited to the torque and thrust coefficients and the advance coefficient of the propeller.

"Predicting the impact of BSR transit times requires data and information that may not be available at the plan-approval stage."

An assumption regarding the propeller's "light running margin" (LRM) is required, as are the initial and final vessel speeds (in knots) and ship resistance (RS).

The volume and complexity of the data required is significant, if the calculations are to inform the plan-approval process and some assumptions will have to be made.

Over-Boosting the Torque Inside the BSR

Any acceleration challenges on operational ships traditionally have been resolved by changing engine parameters to increase the dynamic torque; propeller modifications often can achieve similar results. Increasing the engine torque in the BSR is achieved by increasing the index limiters, allowing more fuel to be injected, while ensuring that the EEDI value remains unaffected.

Experience from vessel sea trials appears to indicate that, by "over-boosting" the torque inside the BSR, the stress levels on the shaft line are slightly reduced during acceleration within the range. This is thought to be caused by the shorter time spent on the resonance—resulting in less time for vibration to build to maximum levels—and increased propeller damping due to its heavier curve during acceleration.

In terms of fatigue lifetime, there may be an optimum BSR transit time; any further reduction to that by "over-boosting the torque" has the potential to cause stress/torque amplitude responses that shorten the lifetime of powertrain components.

Quantifying the BSR transit time not only affects the fatigue life of the shaft line, but it can also affect the maneuverability of the vessel. The power margin varies depending on the propeller curve, such as during the scantling trial, design trial, ballast trial and Bollard Pull curve. A small PM or a small LRM indicates reduced acceleration capability and reduced maneuverability.

According to engine makers, a minimum value of at least 10% of PM at the upper limit of BSR using the Bollard Pull curve of the proposed propeller should be required to provide enough acceleration capability to pass through the BSR. They say that transit times should never exceed 30 seconds during sea trials.

If the 10% limit cannot be achieved, specialized fatigue calculations may be required to demonstrate acceptable powertrain fatigue lifetimes and maneuverability.

Conclusion

When a BSR transit time is unacceptably long, engine makers use software to intervene in the engine control system and increase torque by using Dynamic Limiter Functions (DLF). Measurements appear to indicate that this approach does not increase the vibratory stresses unless excessive power is used.

Predicting the impact of BSR transit times requires data and information that is usually not available at the plan-approval stage.

These "transient analysis" types of calculations also require engineering assumptions, which affect the accuracy and the sensitivity of fatigue lifetime estimations.

Accordingly, it may be more advantageous to use the power-margin approach to assess BSR transit times, rather than modify the IACS UR M68 methodology, as the main engine makers have proposed to IACS.

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