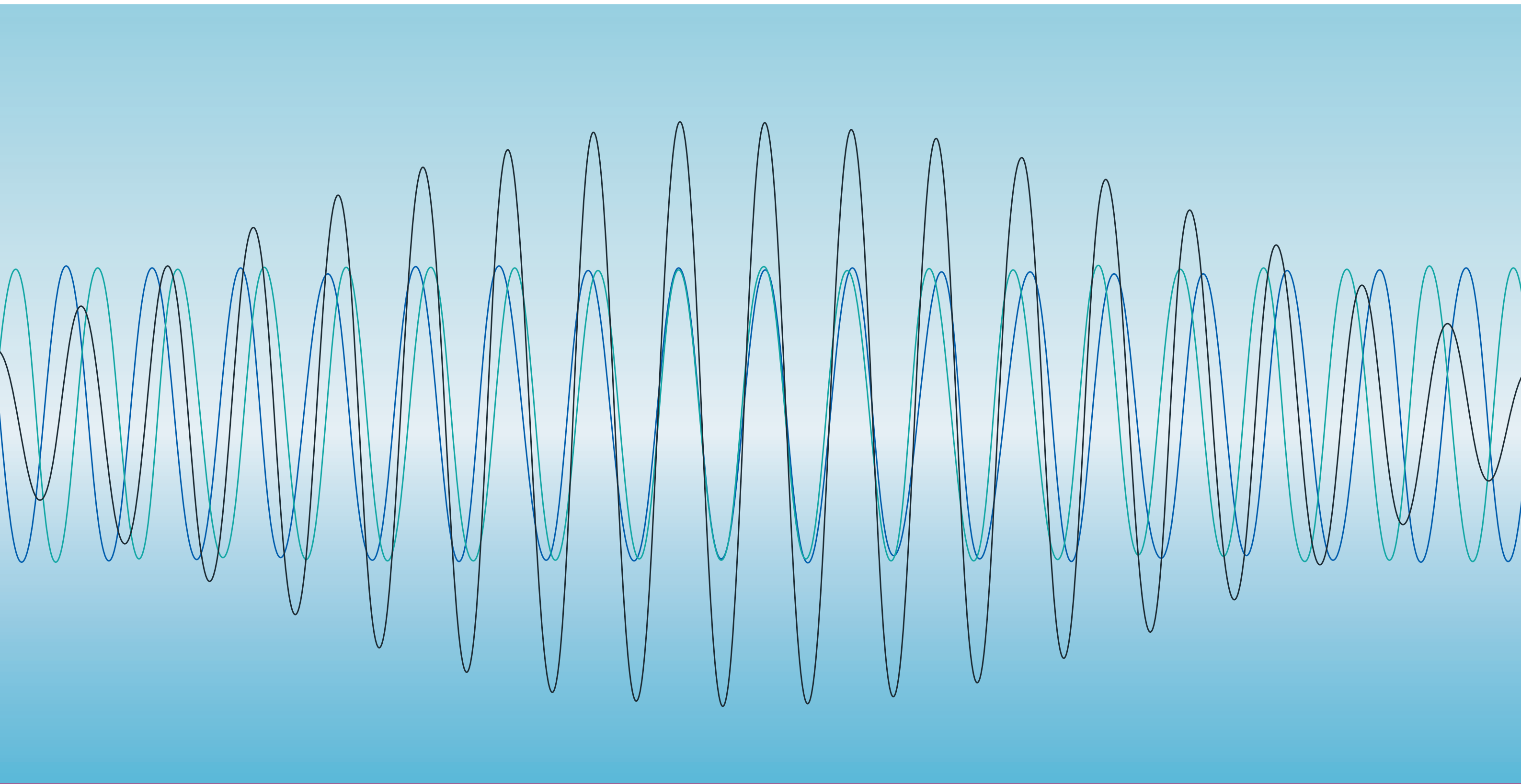
Everllence

Everllence B&W
two-stroke
marine engines



Enhanced vibration performance for twin propulsion vessels

Synchrophasing

Contents

Introduction, p. 5

Twin propulsion vibration control by synchrophasing, p. 6

- Reference list, p. 6
- Working principle, p. 6
- Non-synchronised shaftlines and vibration beating, p. 8
- Synchronisation by the synchrophasing system, p. 9
- Vibration measurements, p. 9
- Choosing the optimal synchrophase(s) and relative propeller position, p. 10
- Factors influencing shaft synchronisation performance, p. 10
- External disturbances, p. 11
- Vibration reduction, p. 11
- Requirements, ordering and commissioning, p. 11
- Retrofitting: synchrophasing potential, p. 11

Concluding remarks, p. 12

Synchrophasing Enhanced vibration performance for twin propulsion vessels

With the widespread adoption of twin propulsion designs, the Everllence synchrophasing system has become a well-established and highly effective solution for reducing vibrations in both vessel and engine structures. Originally introduced in 2018, synchrophasing has now been successfully implemented across a large fleet of vessels, demonstrating consistent vibration reductions in the range of 50–70%.

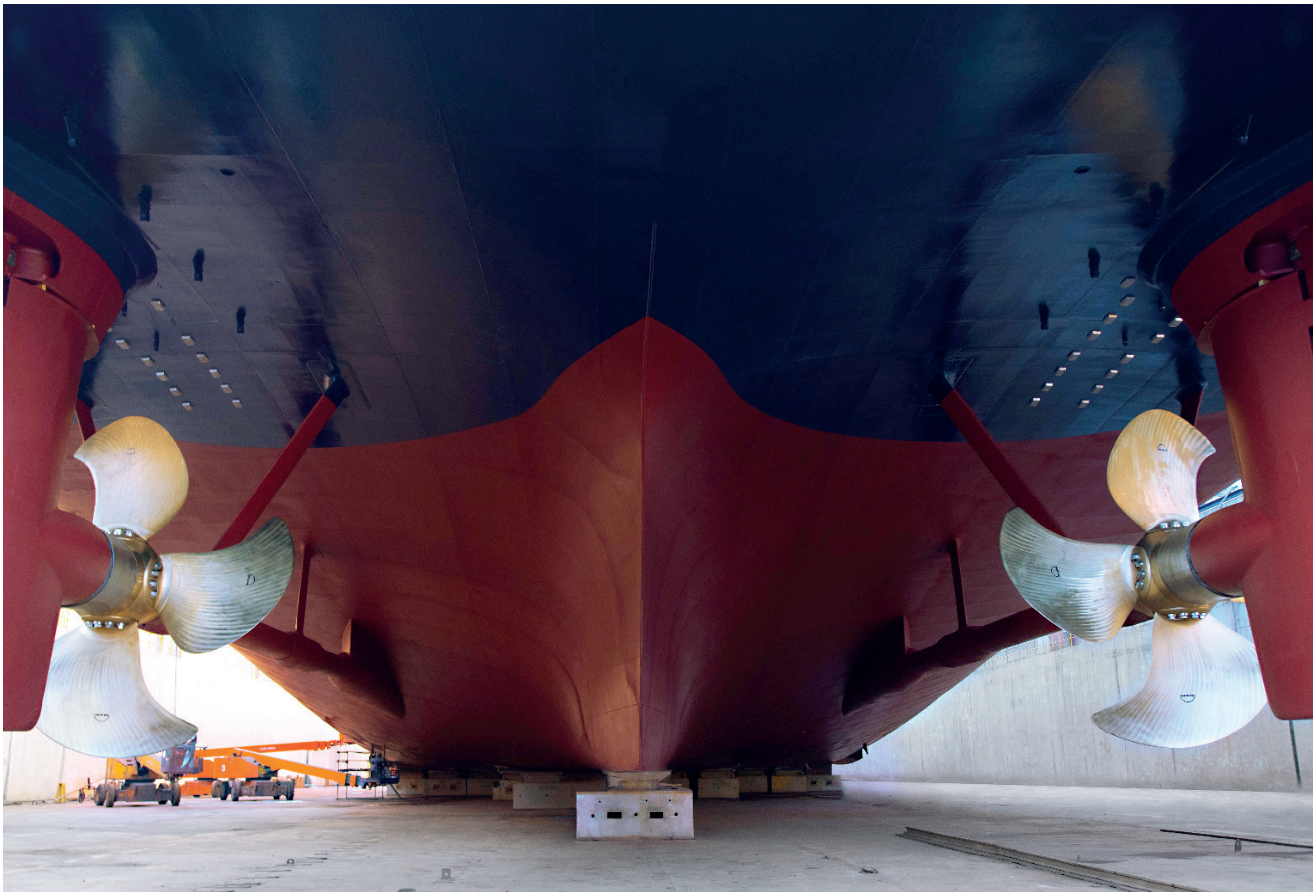


Fig. 1: Twin-propelled vessel

Introduction

Modern high-powered two-stroke engines continue to present challenges for hull designers and shipyards striving to meet increasingly stringent vibration limits outlined in current ISO standards. Synchrophasing has proven to be a reliable and robust solution to these challenges, and is a frequently selected feature for vessels equipped with twin Everllence B&W electronically controlled engines.

Extensive commissioning and operational experience have confirmed the system's effectiveness, with vibration reductions consistently observed across varying sea conditions and vessel dynamics.

By mitigating the combined excitation forces from port and starboard propulsion systems, synchrophasing not only lowers structural fatigue, but also eliminates the vibration beating phenomenon known to cause crew discomfort.

Twin propulsion vibration control by synchrophasing

Reference list

The system is fully developed and has been successfully commissioned on a wide range of newly built vessels equipped with twin Everllence B&W two-stroke marine engines.

Since its launch in 2018, the system has also been retro-fitted on numerous vessels already in service.

The various examples given in Table 1 illustrate the flexibility of system.

The synchrophasing system is highly flexible as it can control the excitation source of the most frequent types of structural vibrations encountered in merchant twin-propelled vessels:

- Propeller induced structural vibrations
- Vibrations due to shafting axial thrust forces
- Vibrations due to main engine forces and moments, primarily guide force moments and free external mass moments.

The sheer effectiveness and versatility of this system have eventually become apparent from the testing results, where many different excitation sources have been controlled and outbalanced by the system (see the last column in Table 1).

Working principle

The vibration reduction is achieved by synchronising the port and starboard shafts speeds, thereby out-balancing forces/moments from the starboard engine/propeller with the same forces/moments from the portside engine/propeller. Thereby, a specific type of excitation and the

Table 1: Selection of synchrophasing commissionings

Vessel type	Vessel size	Engine type	Vibration focus	Excitation source
LNG carrier	81605 DWT	2 x 7G70ME-C	Global deck house Longitidinal/Transverse directions	H-type: 7th order Propellor: 3rd order Propellor: 6th order
LNG carrier	81605 DWT	2 x 7G70ME-C	Global deck house Longitidinal/transverse directions	H-type: 7th order Propellor: 3rd order Propellor: 6th order
Shuttle tanker	123166 DWT	2 x 6S50ME-C	Local navigation deck Vertical floor vibration	H-type: 6th order
Shuttle tanker	123166 DWT	2 x 6S50ME-C	Local navigation deck Vertical floor vibration	H-type: 6th order
ConPax	19000 DWT	2 x 9S50ME-C	Local accomodation Cabin floor vertical vibration	X-type: 5th order X-type: 6th order Propellor: 5th order
LNG Q-Flex	109503 DWT	2 x 6S70ME-C	Global deck house Longitidinal direction	H-type: 6th order
LNG carrier	–	2 x 7G70ME-C	Local LNG pump tower Global navigation deck	H-type: 7th order Propellor: 6th order
LNG carrier	98064 DWT	2 x 5G70ME-C	Global navigaiton deck Longitudinal direction	L-type: 7th order L-type: 8th order M2V: 2nd order
LNG carrier	–	2 x 5G70ME-C	Global navigaiton deck Longitudinal direction	Propellor: 3rd order (1 x BPF)
LNG carrier	173400 m3	2 x 5G70ME-C	Global navigaiton deck Longitudinal direction	L-type 8th order L-type 7th order

way this excitation is transmitted into the hull structure can be minimised or changed, see Fig. 2 and Fig. 3.

The synchrophasing system will counteract the complex set of dynamic loads with the exact same level and in the same complex way by using the opposite engine (same symmetric force transmission path into the hull structure).

Basically, the opposite engine is transformed into a highly effective vibration compensator, thereby minimising most types of structural vibrations such as:

- Local engine frame vibration
- Vessel deck structures
- Accommodation areas/navigation deck
- Global hull girder bending modes.

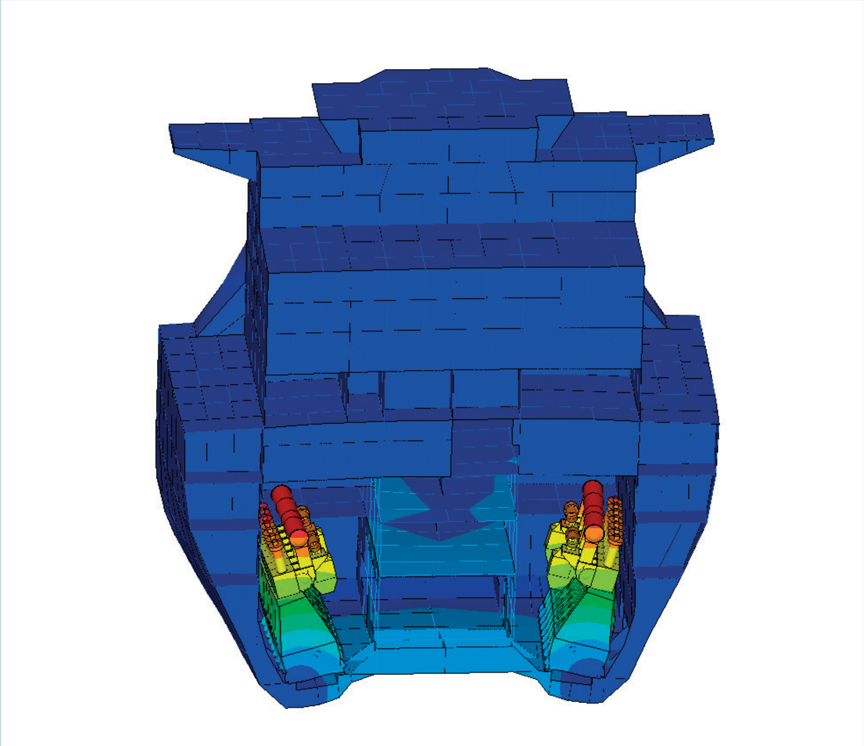


Fig. 2: Engine and hull vibration system on an LNG carrier subjected to main engines guide force moments.

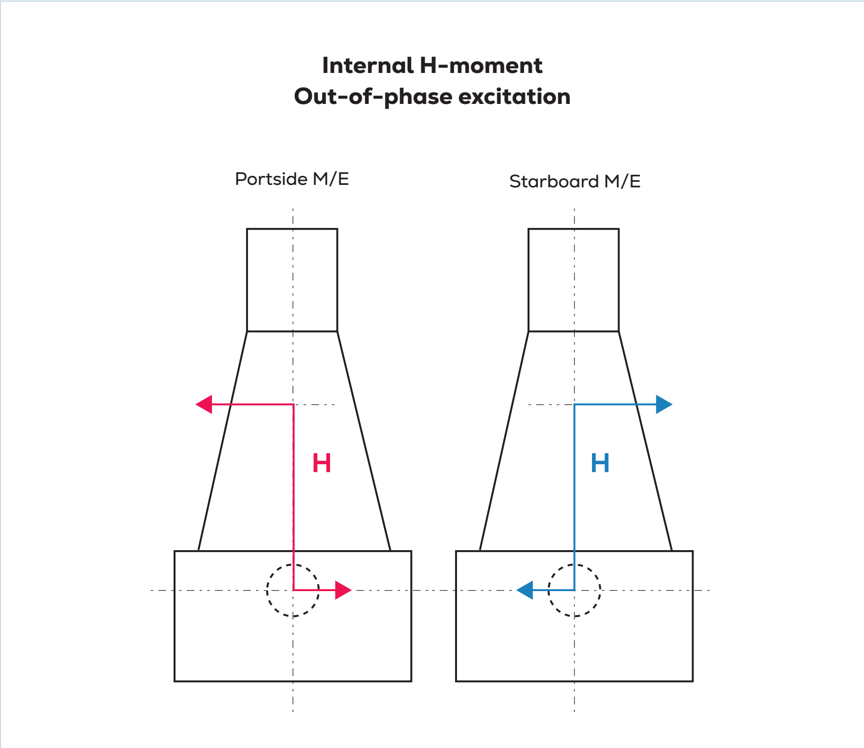


Fig. 3: Synchronised guide force moments (synchro phase = 0 deg.)

Non-synchronised shaftlines and vibration beating

Until recently, two-stroke twin-propelled merchant vessels had non-synchronised shafting systems. This means individually controlled port and starboard engine control systems (ECSs) and individual speed set points.

Ideally, the port and starboard speed set points are equal for the same telegraph handle position. However, in reality there is often a speed set point difference in the range 0.05-0.2 rpm. Today, this is considered to be an insignificant value, however, the impact on vibration beating is high, see Fig. 4.

The speed difference means that one propeller is running slightly faster than the opposite propeller and, thereby, continuously changes the relative propeller position - and hence also the vibration level.

In addition to speed set point differences, external disturbances from rudder, waves, wind and current will cause thrust and moment variations resulting in a completely random relative port and starboard propeller position that changes in time (for a definition of relative propeller position, see Fig. 5.

Due to one or both of these effects (set point difference + disturbance), vibration beating will always be present to some degree.

It could be said that the portside propeller is slowly "overtaking" the starboard side propeller (or vice versa) causing vibrations to increase and decrease with the rate of the speed difference.

The beating phenomena is also referred to as an interference pattern between the two engines where starboard and portside shaft speeds are slightly different (non-synchronised). For the non-synchronised shaft lines, the harmonic excitations from the two engines result in a constructive and destructive interference pattern, commonly known as "vibration beating."

The key objective of the synchrophasing system is therefore to keep the synchrophase at a constant and optimal value in order to reduce the vibration levels and to avoid vibration beating.

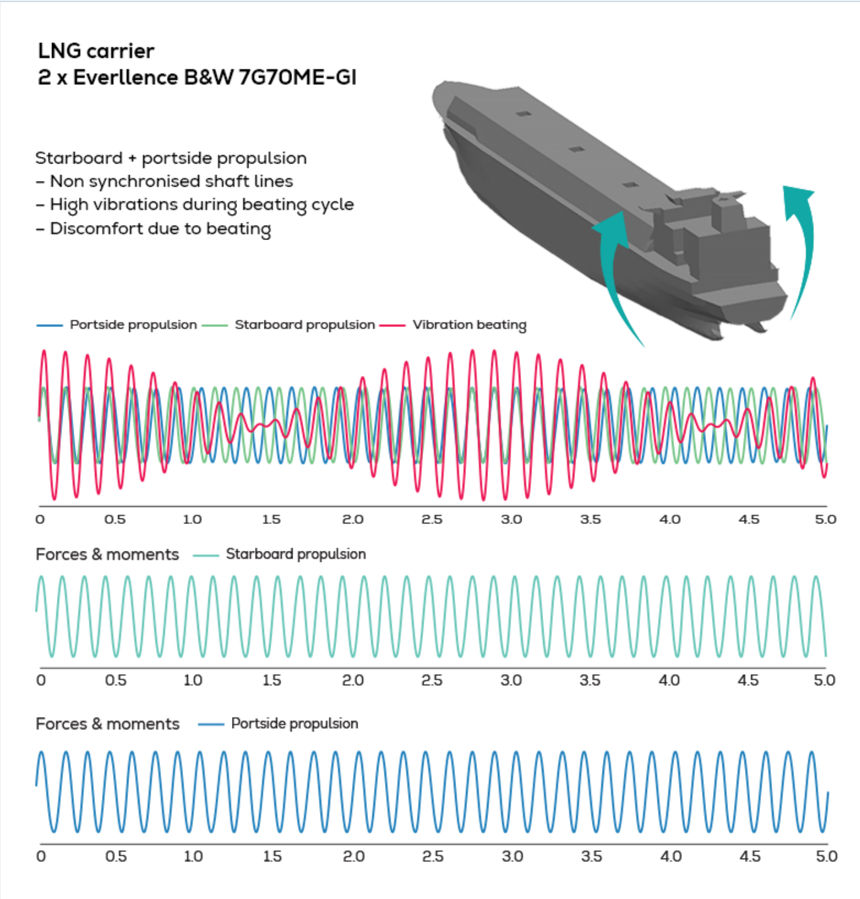


Fig. 4: Vibration beating in a non-synchronized twin propulsion system

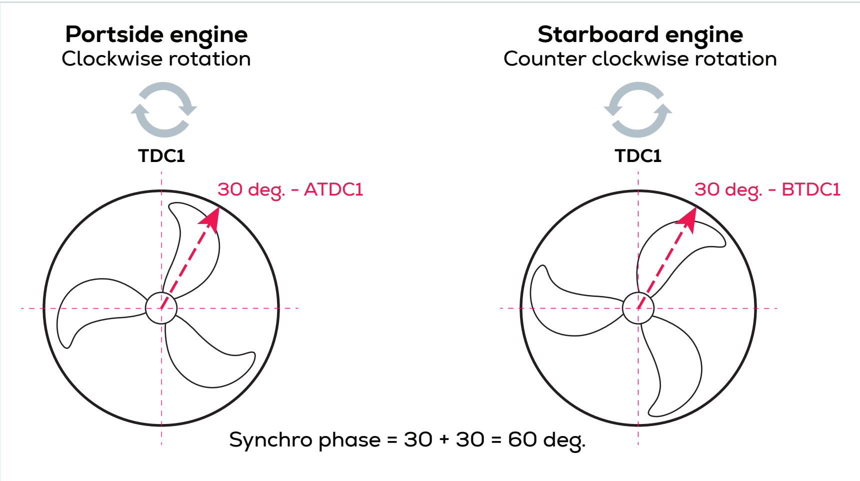


Fig. 5: Definition of synchrophase (example 60 deg.)

Synchronisation by the synchrophasing system

The system aims to achieve:

- Constant and equal engine speeds of port and starboard main engines in order to avoid beating type vibrations
- Constant and optimal synchro phase in order to reduce vibration levels

This means that not only will the system aim to achieve the same constant engine speed for the two engines, it will also keep a specific relative position (synchro phase) between the two shaft lines and propellers.

Vibration measurements

Fig. 6 and Fig. 7 show the measured beating vibrations as a function of time for 7G70ME-GI twin-engines on an LNG carrier and for 6S70ME-C twin-engines on an LNG QFlex, respectively. The measurements were taken during sea trials, before commissioning and before activiating the synchrophasing system.

Not only in this 7G70ME-GI case, but in fact for all the reference vessels listed in Table 1, it is common that pronounced beating phenomena are observed in vessel structures and accommodation areas for practically all sea conditions and engine speeds.

From the measurement plots, it is also clear that the vibration level is strongly dependant on the relative angular position of the propellers and shaft lines, the so-called synchro phase indicated as the black curve on Fig. 6.

Even though a rough estimate and selection of the optimal phase can be directly derived from such a simple time based plot, a more in-depth analysis of the frequency content is in general recommended for commissioning purposes. More advanced vibration analysis methods, such as FFT and/or Order Track method were used to select the optimal phase giving the lowest overall frequency-weighted vibration. The resulting vibration must be compared with the vibration limits stated in modern ISO standards.

LNG carrier with two Everllence B&W 7G70ME-GI engines

Port/starboard speed set point difference:	0.5 rpm
Dominant vibration:	7th order (firing frequency)
Beating frequency:	0.058 Hz
Time between beating cycles:	17 sec.

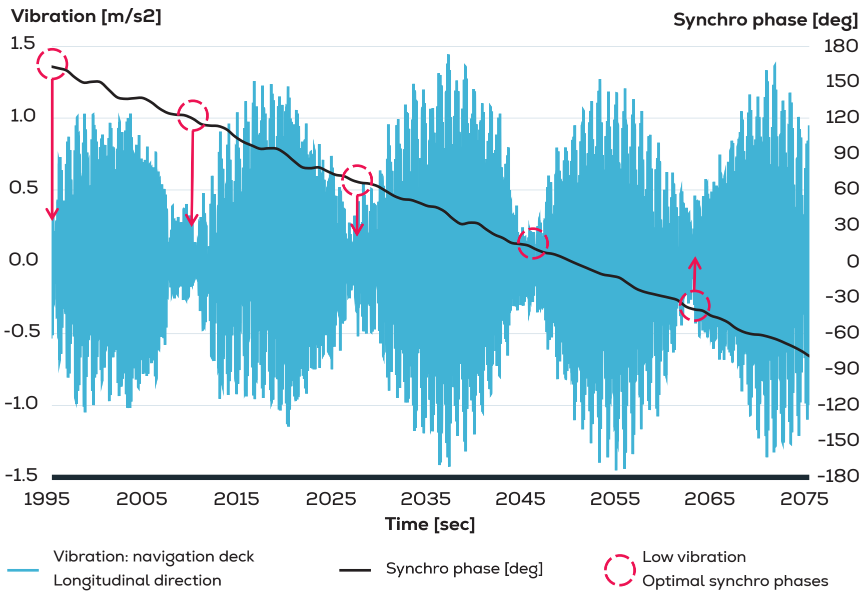


Fig. 6: Navigation deck – longitudinal direction (LNG carrier 2017)

LNG carrier with two Everllence B&W 6S70ME-C

Port/Starboard speed set point difference:	0.1 rpm
Dominant vibration:	6th order (firing frequency)
Beating frequency:	0.01 Hz
Time between beating cycles:	100 sec.

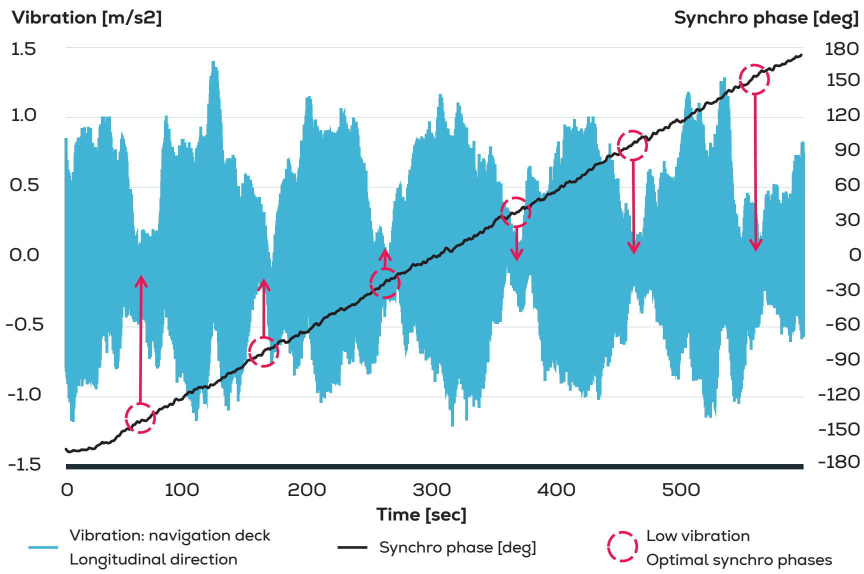


Fig. 7: Navigation deck – longitudinal direction (LNG Qflex 2006)

Choosing the optimal synchro phase(s) and relative propeller position

In general, the most optimal phase depends on the vibration characteristics of the specific and complex vibration system comprising hull, engine and propeller.

In addition, more than one vibration type can dominate the vessel vibration performance at the same or at different engine speeds for a given loading condition of the vessel.

Therefore, the selection of the optimal phase must be based on detailed commissioning vibration meas-urements taken in the full operational speed range of the main engines. The measurements should pref-erably cover both ballast and loaded conditions of vessel. It should be noted that the synchrophasing system must accommodate the potential situation of having six optimal synchro phases applied in each of their respective speed intervals (each optimal phase applied in a given speed range).

Fig. 8 shows the final synchrophasing commissioning result for the two 5G70ME-GI engines on an LNG carrier.

This result was obtained by using all six available synchronisation phases in their specific speed ranges, which was found by detailed vibration measurements during sea trial commissioning.

An optimisation example at 64 rpm is shown in Fig. 9.
The plot shows the overall vibration level as a function of the synchrophase. The plot also shows that to obtain the lowest longitudinal vibration of the navigation deck, the optimal synchro phase should be 36 degrees.

Factors influencing shaft synchronisation performance

The obtained vibration reduction is directly dependant on how well the system keeps the desired target synchronisation phase between the shaftlines.

The key parameter and a fundamental starting point for a good shaft synchronisation is the ability of the main engines' speed governors to obtain a stable an equal shaft speed of the two propulsion shaftlines.

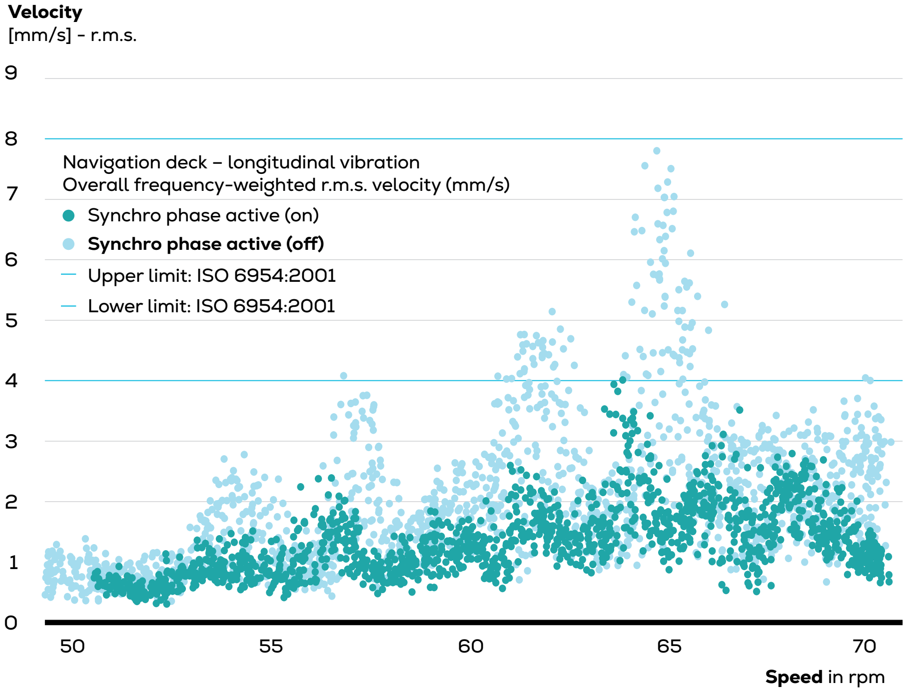


Fig. 8: Vibration reduction by synchrophasing for 5G70ME-GI engines on an LNG carrier

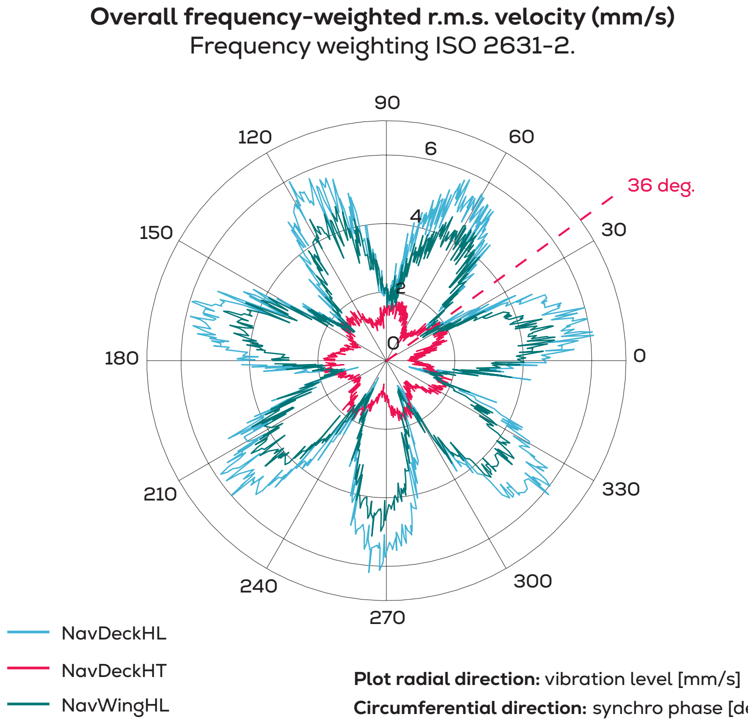


Fig. 9: 5G70ME-GI engine at 64 rpm, optimal phase = 36 deg.

External disturbances

The main engine's speed governor is challenged by external disturbances, primarily vessel roll and pitch (change of propeller wake field), where rolling has proved to be the most influential factor with respect to shaft synchronisation performance.

Vibration reduction

However, based on the many measurements, the average vibration reduction in normal sea conditions is in the range of 50–70%, when comparing the average vibration without synchrophasing (average vibration during a beating cycle) with the constant and low vibration achieved by synchronised shaftlines (active synchrophasing).

When comparing the maximum vibration level occurring during a beating cycle (no synchrophasing) with the synchronised vibration level (constant and low), the vibration reductions are in the range 70-90%.

Requirements, ordering and commissioning

The shipyard must specify synchrophasing in the EOD (extent of delivery) when ordering the engine.

The system requires:

- ECS software with synchrophasing functionality: For newbuildings, the synchrophasing software is optional and can be acquired as part of the design specification. For older electronically controlled engines (ME-C type), the ECS software can normally be upgraded to a newer version with synchrophasing functionality.

- Synchronisation cables: Engines must be cross-connected with synchronisation cables according to drawings and diagrams found in the engine design specifications. Cables and manpower is provided by the licensee or the shipyard depending on the EOD agreements.

- Vibration measurements: The optimal phases resulting in the lowest vibration levels are found by making vibration measurements during sea trial or in service. Either Everllence or the engine licensee can be ordered to perform the commissioning. The measurements are often performed in close cooperation with the shipyard vibration specialist or hull designer. The vibration measurements are normally not included in the EOD, thus the shipyard must order this additional service separately.

- Commissioning software: Everllence provides customised synchrophasing commissioning software free of charge to be used by the licensee's vibration specialist.

Retrofitting: synchrophasing potential

Everllence offers a pre-evaluation service to assess the benefits of retrofitting synchrophasing. Using vibration data loggers sent to the vessel and following a simple procedure provided by Everllence, the crew can take measurements during sea voyage in both loaded and ballast conditions. This proven method offers a reliable and cost-efficient way to evaluate the potential benefit of retrofitting synchrophasing.

Concluding remarks

In these times with ever increasing focus on higher performance parameters of our engine designs, we witness a correspondingly ever increasing dynamic excitation of the engine components. We are also in times of optimising our design which in effect means less steel for a given engine size. This in turn results in gradually reduced engine stiffness.

Combining increased dynamic excitation and reduced stiffness is virtually a dream scenario for a vibration specialist. It creates endless opportunities for mastering vibration challenges, which will continue to be one of our focus areas while developing our new engines over the time to come.

Everllence

Everllence
2450 Copenhagen SV, Denmark
P + 45 33 85 11 00
info@everllence.com
www.everllence.com