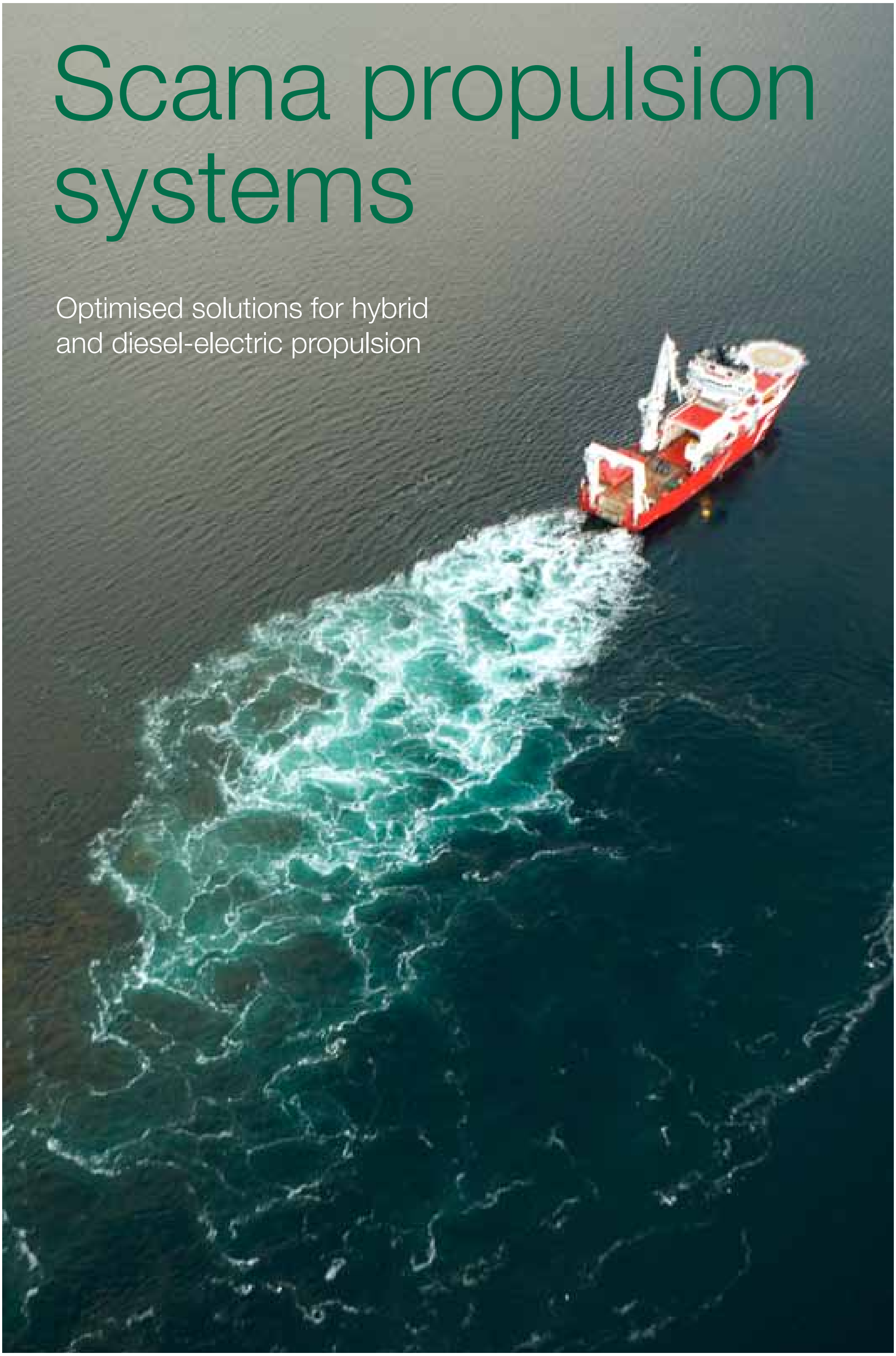
# Scana propulsion systems

Optimised solutions for hybrid and diesel-electric propulsion



**SVERRE TONHEIM, KENNETH SEKKINGSTAD - In order to build a vessel with optimal performance, good cooperation has to be in place between all stakeholders in the design and building process. Suppliers working with a shipyard interact with each other, and it is invaluable for the cluster of marine industries to be able to share experiences, discuss improvements and test new ideas beyond company and competition borders.**

*Generations* invited Scana Propulsion to contribute an article about the developments in gear box technologies applied in shaft line propulsion with CP or FP propellers. These solutions are used widely in the maritime industries. Recent years have seen increasing interest in the use of geared shaft line propulsion in hybrid diesel-mechanical and electrical propulsion. In such parallel hybrid designs, the ship gains the advantage of energy-efficient diesel-electric propulsion that is dimensioned for the lower transit and station keeping loads of the propellers, while the highest peak loads used for tugging and anchor handing, plowing, etc.etera are achieved with direct mechanical propulsion.

The electric propulsion part may also be used to add to the shaft torque to reach peak thrust demand. This solution is of particular interest to operators of anchor handling tug supply (AHTS) vessels where hybrid propulsion may form the optimal compromise between vessel performance, energy efficiency and CAPEX.

Scana Propulsion has for decades supplied gearboxes and CP propellers to the global shipbuilding industry. Thanks to its location in the middle of the Norwegian maritime cluster, the company, established in 1913, has interacted closely with Norwegian shipowners and designers in the fishing and offshore sectors. Offshore activity in the North Sea has led the way for sophisticated systems operating in harsh weather conditions.

Scana Propulsion has, through its engineering competence, played a major role in the development of today's sophisticated vessels, with tailor-made propulsion systems suited for any operation to meet customer, market and regulatory demands. Total propulsion efficiency forms the basis for the selection of system configuration for the particular vessel, whether the answer is diesel-mechanical, diesel-electric or hybrid propulsion. Scana Propulsion reduction gearboxes are an integral part of this system.

Over the course of the last decade, diesel-electric and parallel hybrid propulsion systems have become more visible on many types of ships. Such innovative propulsion is a blueprint for the future and may offer great advantages, both economically and environmentally.

The goal for using diesel-electric or hybrid propulsion instead of diesel-mechanical systems is to improve the efficiency and flexibility of the ship. In diesel-electric systems, the propeller is driven by one or several electric motors, while in parallel hybrid systems the propeller can be driven by a diesel engine, an electric motor or by both types of motor at the same time. However, electric or hybrid propulsion will not be the most economical solution for all types of ships and ship service profiles.

Ships with a uniform service profile will normally use a conventional diesel-mechanical propulsion system because of its simplicity, low investment cost and small transformation and transmission losses. However, there may be other reasons for using electric propulsion on such ships.

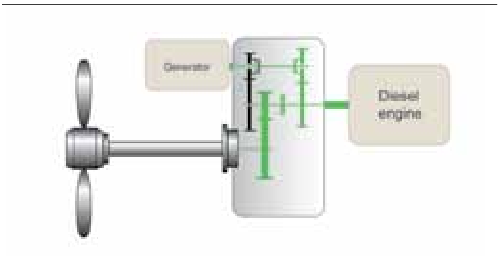
Ships with large variations in service conditions will gain advantages by using diesel-electric or hybrid solutions. The larger the variation in service conditions, ie, the ratio of peak power demand and actual power usage, the larger the potential benefit for energy efficiency and fuel saving.

## Propulsion efficiency - the basis for defining the optimum propulsion system

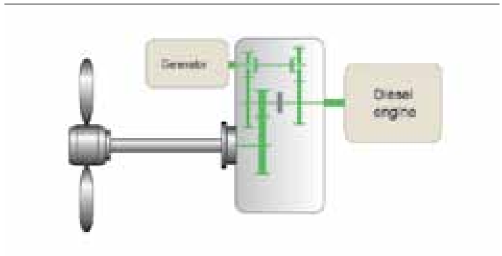
Total propulsion efficiency is a product of the efficiency in all parts of the propulsion train: main diesel engines, auxiliary diesel engines, generators, electric distribution systems and transformers, frequency converters, electric motors, reduction gearbox, shaft line, hull and propeller. The power consumption of the auxiliary systems should also be considered in overall energy efficiency.

**Title picture**
The 423 metric ton bollard pull vessel *Far Samson* with hybrid propulsion system

**1 The two-speed reduction gear run as a standard diesel-mechanical plant with a PTO**




**2 All main engine power is taken over the PTO shaft for optimum distribution between propeller and PTO/shaft generator**




All these factors will vary with the type of ship, equipment type and arrangement and with different ship service profiles. In order to make a correct comparison between diesel-mechanical and diesel-electric propulsion, each of these factors should be estimated for every service condition so that the total overall efficiency for the ship's particular service profile can be calculated accordingly.

As a simple comparison of running costs for a given ship/propeller arrangement, it can be assumed that the specific fuel consumption of the power sources and the propeller efficiency are the only influencing factors. The other efficiencies and propulsion factors are unchanged. The question then is whether the gain in propeller efficiency and in specific fuel consumption is big enough to compensate for additional losses caused by the energy transformation introduced by the electric system.

## Propeller efficiency

Propeller efficiency is defined as:

$$\eta_0 = \frac{T \cdot V_a}{P}$$

T = thrust, $V_a$ = speed of advance and P = power delivered to the propeller.

According to this definition, $\eta_0$ is zero when T or $V_a$ is zero. It is also clear that  is high when T and $V_a$ are high.

From this simple equation it can be seen that the propeller efficiency per definition is zero in a bollard pull condition, even if this is the condition of maximum propeller thrust. It is also seen that fast vessels have potential for high propeller efficiency. From this it is noted that propeller efficiency depends not only on propeller design, but more on its working condition.

Another simple but informative expression for propeller efficiency can be developed from the momentum theory:

$$\eta_0 = \frac{1}{1 + 0.5 \cdot \frac{U_a}{V_a}}$$

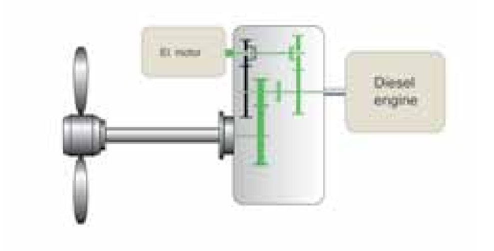
$V_a$ = the flow speed far upstream, $U_a$ = induced flow speed by the propeller action.

From this equation it can be seen that $\eta_0$ increases when $U_a$ decreases. To obtain a low induced speed $U_a$, the thrust per unit disc area must be low, meaning that for a given thrust the propeller disc area must be large.

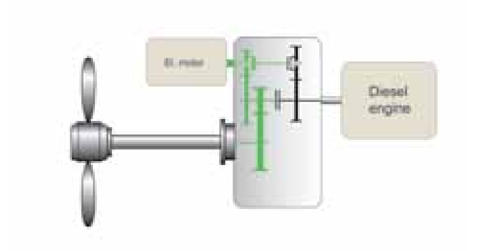
A certain momentum or propeller thrust can be created either by high velocity $U_a$ of a small mass, or by low velocity of a large mass. However, it should be noted that the alternative with the small acceleration and largest mass is the most efficient.

The conclusion is that the propeller diameter should be as large as possible with all consideration given to the necessary clearances to avoid vibration and noise. This is a general rule for all propellers, though there is an exception. Nozzle propellers at high ship speed will have a certain upper limit where a further increase in diameter will result in a reduction in thrust. In all propulsion conditions with high power and low ship speed, typical for tugs, trawlers and seismic vessels, the larger nozzle propeller will be superior. Accordingly, the first criterion for highest possible propeller thrust and efficiency is a large propeller.

3 Propulsion condition in boost mode to give the maximum power needed in heavy operations




4 Low propulsion power mode run by the electrical motor only and shutdown of the main engine




The second criterion is to establish the best possible working conditions for the propeller, through the optimum constellation between the primary design parameters – power, ship speed and wake, propeller diameter and propeller RPM. With a given engine and propeller speed, the optimum gear ratio is given. Further detailed optimisation of gear and propeller is carried out on the basis of these established optimum primary parameters.

## Selection of reduction gearbox in the total system configuration

Scana Propulsion has a wide configuration range from single-mode transmission to advanced systems customised for specialised vessels with a high number of operational modes. A wide range of power output (PTO) and power input (PTI) solutions are available for the optimisation of the gearbox system according to each customer's requirements. Stringent safety regulations and environmental concerns are addressed when designing a system for any type of ship to ensure cost efficiency and reliability. The right configuration may give the possibility to make extensive savings such as through reduced fuel consumption.

For vessels spending most of their operational time in low propulsion power conditions below 40 to 50 percent of the total available power there is significant potential for power saving if the zero pitch loss can be reduced or eliminated. There are a number of solutions on the market that reflect this, ranging from diesel-electric configurations, sliding frequency run shaft generators to different low-loss propulsion concepts. All these have advantages and limitations, and the operational profile of the vessel has to be considered in order to determine which solution fits a particular vessel.

## The advantages of two-speed reduction gearboxes

Scana Propulsion's solution is a two-speed reduction gear combined with diesel-electric features to create a flexible and redundant hybrid configuration. The Scana Propulsion two-speed reduction gear is a fully integrated solution to provide the option for two "steps" of different propeller speeds with the same input speed from the main engine, still allowing the integrated PTO shaft to run at the required speed.

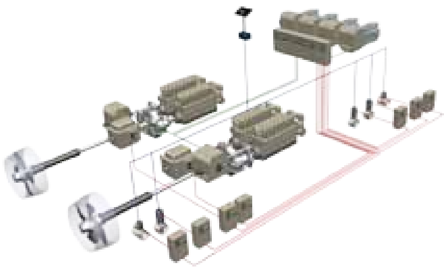
The most important feature is that the reduction gear can transfer all the main engine power over the PTO shaft. In medium-low propulsion power this enables the reduction gear to run a low step propeller RPM in combination with the rated speed PTO/shaft generator, reducing the zero pitch loss of the propulsion plant (Figure 2). It can also be combined with sliding frequency 50-60 Hz.

For high propulsion power the reduction gear can combine the main engine power with the input power of the shaft generator acting as a motor and creating a boost mode. The benefit of using a boost mode is that the size of the main engine can be reduced while maintaining the required maximum power needed for certain operations such as anchor handling or trawling (Figure 3).

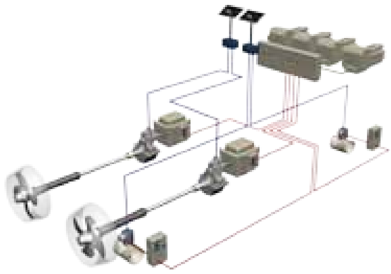
In a low propulsion power condition the propeller can be driven by the electrical motor (shaft generator in reverse power) at rated speed (50-60 Hz) with the reduced propeller RPM. The main engine can be shut down when running in this mode. Alternatively, the electrical motor can be driven with variable speed by a frequency converter (VFD), that gives additional fuel saving (Figure 4).

The above illustrations are principle sketches of the

5 **Hybrid propulsion system suitable for a 300 T+ AHTS**



6 **Diesel electric twin screw system suitable for a 120 T AHTS**



two-speed gearbox, which is available as single-in single-out and twin-in single-out versions. In an offshore vessel configuration where the twin-screw systems are most common, these systems offer a huge flexibility with numerous operational modes.

## Hybrid and diesel-electric propulsion systems for offshore vessels

Hybrid propulsion combines the better of two systems. It ensures optimum operational efficiency at both low and high power ranges through a combination of electric propulsion at variable RPM and diesel drive at fixed RPM.

On twin screw ships it is often desirable to use one of the main diesel engines as the power source for electric propulsion. This should be arranged in such a way as to ensure that both propellers are driven electrically. This can be arranged with a PTO and a generator in front of the main engine. The power is converted and distributed to each of the propellers via the PTI on the gearboxes. If it is not possible to position a PTO in the front of the diesel engine, the same function can be obtained by arranging a PTO on the main gearbox primary side.

## Diesel-electric propulsion

The arrangement can be similar to that described for hybrid system though the diesel engine is changed by an electric motor. There may be one, two or several electric motors coupled to the same main gearbox. These systems can be arranged for a combination of fixed and variable frequency on the different motors or with variable frequency on all. Such systems will have considerable flexibility and high efficiency in variable service conditions as the propeller has optimised working conditions in the entire power range.

Scana Propulsion gearboxes are available in vertical, horizontal and as twin-in, single-out versions with a wide range of PTO/PTI solutions and in single or two step power transmission.

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