Propulsion of Offshore Support Vessels
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Abstract
This paper describes how the design process works at MAN B&W Diesel when engineering propulsion packages. The company’s strategy is to further develop its role as a single source supplier of propulsion systems for offshore support vessels – like for numerous other marine propulsion segments, which have been continuously developed since 1904. The recent technological progress done in the offshore propulsion field is presented in this paper. Making optimal custom-designed propulsion solutions involves many parties such as owners, shipyards, consultants/ship designers and suppliers. The best solution for the customer requires close cooperation and coordination between all parties. With the application of CFD (Computational Fluid Dynamics) as a propulsion optimisation tool, MAN B&W Diesel has developed an improved propeller nozzle design for various applications. The most interesting results of the latest development supplemented by model test results will be presented.

Introduction
The development of the offshore propulsion business at MAN B&W Diesel dates back to the early 1970s, and has since then not only been focused on supplying complete propulsion systems but has also been concentrated on the associated know-how and technology. The demand for system engineering and package responsibility has grown in recent years. One reason is the reduced technical staff at most shipyards in combination with outsourcing of technical work to consultants and partners. A general and common experience is that the engineering of a propulsion package not only requires engine, gear, propeller and control expertise. A number of integration tools and skills are necessary as well. Not even the best engine specialist in cooperation with the best gear specialist, the best propeller specialist and the best control specialist are capable of engineering and attaining an overall optimisation of a genuine propulsion package without these integration tools and disciplines.

Propulsion plant engineering as well as single element engineering are vital for the creation of genuine complete propulsion packages which cover the ship-owners’ need for reliable ship propulsion.

MAN B&W Diesel takes responsibility in the entire plant life cycle by supplying and servicing propulsion systems and equipment.

The typical standard OSV (Offshore Supply Vessel), designed for maximum bollard pull, is a twin screw vessel with CP propellers operating in nozzles. To ensure that a certain bollard pull is attained, different approaches can be taken into use. Most of them are methods that directly lead to the required power to be installed and are based on thumb rule figures. Precise optimisation of an OSV for bollard pull, requires a more detailed analysis of parameters like engine power, propeller diameter, nozzle design and propeller hull interaction.

Limiting ourselves to twin screw vessels and their propulsion systems, the following describes a design procedure that will ensure an optimum solution with respect to attaining a certain bollard pull. As it is customary with most projects, this procedure is divided into a project stage where the main parameters are fixed and subsequently an order stage where attention is paid to the details.
The bollard pull de-

The example clearly reflects the influ-

The power for maintaining a vessel ser-

Order Stage

Further refinements

The previously described optimisation
deals with the project phase. However
a fully customised propulsion solution
requires that attention is paid to the de-
tails of not only the individual propulsion
components but also to the interaction
with hull, struts, nozzle supports, rudd-
ers, etc. Some of the more important
details are:

Aft ship design: The bollard pull de-


corresponding with full-scale measurements,
a new refined formulation has been made.
Input is now not only the engine power
but also the propeller diameter being
combined into the power density given by:

\[
P_d = \frac{P_v}{D_p^2}
\]

where \(P_v\) [kW] is the delivered power
at the propeller (engine power minus
transmission and shaft losses) and \(D_p\)
[m] is the propeller diameter.

Displaying the specific bollard pull as a
function of the power density gives a
universal coherence as shown in Fig. 1.

Converting from specific bollard pull to
an absolute bollard pull in kg is done
by multiplying with the delivered propell-
er power. As can be seen from Fig. 1,
the obtainable bollard pull depends on
the power density. To achieve the high-
est bollard pull for a vessel with a given
power, a low power density should be
chosen. As a consequence, the propel-
er diameter should be as big as the hull
can accommodate, and still secure a
full immersion of the propeller in ballast
draft. It is presumed that the propeller
speed is optimised for the given power
and propeller diameter.

Example

In order to obtain a bollard pull of 90
tons, several combinations of engine
power and propeller diameter exist.
The MAN B&W Diesel standard propul-
sion programme for the L27/38 engine
type can be used to illustrate a number
of possibilities for obtaining a 90 tons
bollard pull. Possible twin screw propeller
combinations with ducted propellers
are listed in the following table.

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Gearbox</th>
<th>Propeller Type</th>
<th>Bollard pull for a twin screw OSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>6L27/38</td>
<td>AMG288EV</td>
<td>AMG288EV</td>
<td>600 [kW]</td>
</tr>
<tr>
<td>7L27/38</td>
<td>AMG288EV</td>
<td>AMG288EV</td>
<td>600 [kW]</td>
</tr>
<tr>
<td>8L27/38</td>
<td>AMG288EV</td>
<td>AMG288EV</td>
<td>600 [kW]</td>
</tr>
<tr>
<td>9L27/38</td>
<td>AMG288EV</td>
<td>AMG288EV</td>
<td>600 [kW]</td>
</tr>
</tbody>
</table>

The power for maintaining a vessel ser-
vice speed of 12 knots as given in Fig.
3 again favours the lower power density
given by the 6L27/38 propulsion plant.
From both an initial investment and op-
erating cost point of view, the lowest
power density configuration is indeed
preferable.

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erating cost point of view, the lowest
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preferable.
B. Nozzle design: For years it has been common practice to design and optimise the propeller blades for each individual project, but using more or less standard nozzle types. Since the early 1970s, the 19A and 37 type nozzles have been applied universally for all sorts of purposes. The 19A originates from model tests carried out by MARIN (previously Wageninger) and is a simplified version of the 19 type nozzle in order to make it more production-friendly. The 37 type nozzle has, due to its more rounded trailing edge, a better astern performance though at the expense of its forward thrust. Recently, new nozzle types have appeared on the market claiming a higher performance based on a CFD shape optimisation. At MAN B&W Diesel a new nozzle type called Alpha High Thrust (AHT) (AHT) has been developed to increase the performance compared to earlier types. The AHT nozzle is not a standardised design but customised according to its application. As an example, an Anchor Handling Tug Supply (AHTS) vessel could be optimised for maximum bollard pull, whereas a purse seiner could be optimised for service speed. The two nozzle designs will differ significantly not only in its appearance, but also in performance when compared to a standard off-the-shelf nozzle design. The development of the AHT nozzle design will be described in a subsequent part of this paper.

Developing the AHT nozzle design series
The need for investigating more complex flow phenomena has led MAN B&W Diesel to introduce and implement CFD software. Among those areas which have benefited from this are nozzle designs and their interaction with the propellers. Viscous effects, that play an important role in this respect, are dealt with by using CFD as it relies on solving the full Navier-Stokes equations. By systematically designing various nozzle geometries and subsequently performing CFD calculations on each individual parameter, an optimised solution has been established. Calculations have been performed for various conditions including bollard pull, astern and ahead.

An iterative process was used in the development of the AHT nozzle series for an OSV type including the following steps:
1. Calculations based on several design proposals were used to determine whether a bollard pull improvement compared to the 19A nozzle was present. The AHT design was improved successively finally leading to an optimum solution for bollard pull.
2. After reaching an optimum design using the 2D model, a more detailed 3D model consisting of nozzle, propeller blades and hub is calculated in order to verify the bollard pull improvement from the 2D model calculation. If further improvement is needed, the ability to study flow details such as propeller tip circulation, flow separation and similar phenomena associated with viscous effects is an advantage when using CFD. Nozzle, propeller and hub are presented for the AHT type nozzle calculation.

An optimum geometry is characterised by a uniform pressure distribution at the nozzle inlet followed by an even conversion of the high velocity flow into thrust. A comparison between the 19A type nozzle and the AHT design shows improvement of both the relative pressure and the velocity distribution, see Fig. 4. The pictures on the left side show the 19A type nozzle while the AHT type is to the right.

The higher velocity at the leading edge of the AHT nozzle design results in a lower pressure which generates more forward thrust. It is also shown that the diffusion angle results in a larger pressure at the trailing edge. This pressure difference contributes to a larger bollard pull. The calculations for this particular case were performed in model scale. The influence going from model scale to full scale showed a tendency towards a better full scale performance.

Fig. 4: Pressure and velocity distribution – 19A left and AHT right

Other parameters which have been subjected to investigation are listed below:
1. L/D ratio: It is a fact that longer nozzles provide a better thrust at lower ship speed than shorter ones. Nozzles with smaller L/D ratios than the original L/D=0.5 were introduced for vessels where free sailing plays an important role in combination with a pull condition. Furthermore, smaller nozzles require less installation space which can be beneficial in connection with fitting to an existing vessel with limited space available. In bollard pull condition the CFD studies confirmed a better performance for the higher L/D nozzle types, which can be observed from Fig. 7.

It is obvious that especially in bollard pull condition the nozzle thrust is significantly higher for the longer...
nozzle type. In this case, the nozzle thrust increases about 8% giving a total thrust gain of around 6% for the combined propeller/nozzle system.

b. Outlet diffuser angle: In order to generate as much thrust as possible, a non-viscous solution would predict a very high exit angle. Taking viscous effects into account, a too high exit angle will lead to flow separation at the exit of the nozzle, reducing the thrust significantly. Consequently, these two factors have to be balanced in order to reach an optimum. This optimum is not universal for all types of nozzle applications and for that reason each individual project should include an analysis of the propeller and nozzle interaction in the operating modes. During the design process, several design proposals showed flow separation which required a lower outlet diffuser angle to be used.

c. Axial location of propeller in nozzle: For the nozzle types tested so far the optimum location of the propeller is found to be in the center of the nozzle.

At MAN B&W Diesel, CFD is introduced in order to perform relative studies of design proposals, aiming at capturing the same tendencies as experienced during tank test. Correctly applied, this method will ensure an optimum design before tank testing is initiated.

Example
The design procedure described above has been applied for an ocean-going tug boat having a bollard pull requirement of 210 tons. The vessel is designed with a propeller diameter as big as the draft of the vessel allows, thus leading to a relatively small clearance between the hull and the nozzle. Among several considered nozzle supports the chosen one was finally selected to be of the head box type. In order to avoid vibration, a relatively wide head box is needed to keep a sufficiently high natural frequency. The negative influence of the head box on the performance of the nozzle is however limited due to its location in the hull boundary layer. This is also confirmed by a relatively small thrust deduction in the order of 5-6%.

A thorough investigation of several propeller and nozzle combinations was carried out, supplemented by intensive CFD optimisation. As a basis, the 19A type nozzle and a corresponding propeller design were used for benchmarking. Based on various CFD optimisation studies, a customised AHT nozzle and propeller blade design finally emerged showing a nozzle thrust improvement in bollard pull condition of almost 8%. In order to make a comparison with subsequent model tank test results, all calculations were carried out in model scale. An example of propeller grid and a 3D propeller/nozzle system for the AHT nozzle is presented in Fig. 8. The cutting plane illustrates the velocity distribution, Fig. 9.

Concluding Remarks
To obtain an optimum propulsion solution for an OSV, the importance of paying attention to not only the individual components but also to their interaction has been demonstrated. It has been shown that bollard pull is not only a matter of engine power. Bollard pull depends particularly on the propeller and nozzle design and the environment in which they operate. The ability to analyse and optimise the design using CFD opens new possibilities to improve the performance of OSV vessels by analysing different alternative design proposals.

From an economical point of view, an optimised solution results in not only a lower initial cost of the propulsion plant but also contributes to a lower operating cost leading to the lowest overall life-cycle-cost.

Only a strong and genuine propulsion plant supplier is able to secure that optimum solutions are accomplished, which leads to the most favourable economical yield.

References


MARIN (2005), “Training Course on Ship Hydrodynamics”, Part I & II

