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IS A WED APPLICABLE FOR ALL SHIPS ?

ABSTRACT

As known that the wake equalizing duct (WED) is mostly used to improve the propulsive efficiency. The WED increases the inflow velocity at the propeller plane and reduces the non-uniformity of flow and separations. As the technology developing, the hull form of the ship becomes more efficient in terms of hydrodynamic and therefore a question arises whether or not WED is applicable for all type of modern ships. Within this context, a modern RO-RO ship is considered for application of a WED. A CFD tool is used to analyze the flow around the hull with and without WED. The results are discussed in detail.

1. INTRODUCTION

The wake equalizing duct is an aerofoil-type of vane and fitted in front of the upper propeller area. These are in the form of two half-ring as it can be seen in Figure 1. An important parameter for the effectiveness of the arrangement is the axis inclination of the half-ring ducts. After a WED application, the flow attachment to the hull would be better and the flow separation is reduced. The inflow of the propeller will be accelerated in the upper region where it is slow and in the lower region, where the speed of inflow is normally higher, it will be retarded [1].

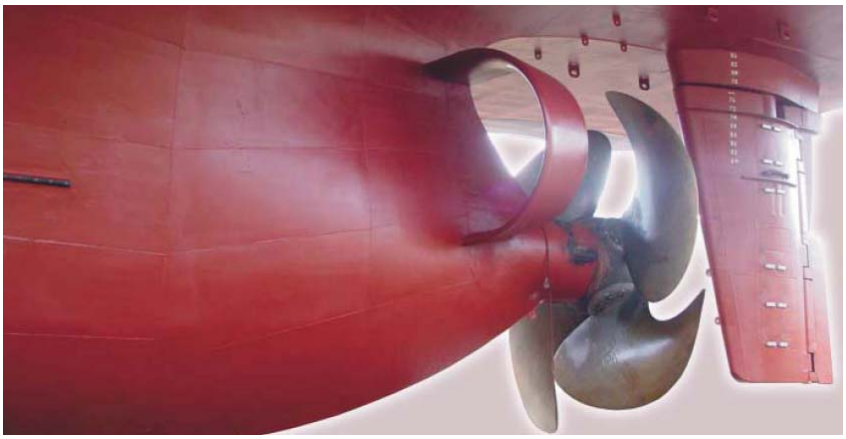


Figure 1. The wake equalizing duct [2]

The advantages of using a WED can be expressed as follows: [1,3]

1. Improvement of propeller efficiency owing to the more axial flow and more uniform velocity distribution over the disc area.
2. Reduction of flow separation at the after body.
3. Lift generation with a forward force component on the aerofoil section, in similar way of a Kort nozzle.
4. Uniform flow reduces propeller-excited vibrations.
5. Improvement of steering qualities from more straightened flow to the rudder.
6. No constructional changes and no modifications in propeller design are involved when the duct is fitted subsequently to an existing ship.
7. Offers possibility to integrate devices for ice protection to propeller.

The application of a WED for power saving is most evident for the speeds between 12 and 18 knots. Energy saving can reach to 14% with a proper WED design. The wake equalizing duct normally comes into consideration for moderate speed vessels whose block coefficient exceeds 0.6.

An improper WED design could lead to additional drag forces in a ship, which would bring about defects in hull efficiency. Computational Fluid Dynamics (CFD) is a useful tool analyzing the viscous flow around a ship. In this paper, a CFD technique is applied to analyze flow around the after body of a RO-RO ship with and without WED. A commercial CFD code Fluent version 6.2.16 [4] is used for these cases. The main particulars of the ship are shown in Table 1. and location of the WED at after body can be seen in Figure 2.

Table 1. Main particulars of the RO-RO ship

Waterline length, L_{WL}	138.9	m
Breadth, B	20	m
Draught, T	7	m
Displacement, Δ	14000	ton
Prismatic coefficient, Cp	0.6	
Block coefficient, C_B	0.5	

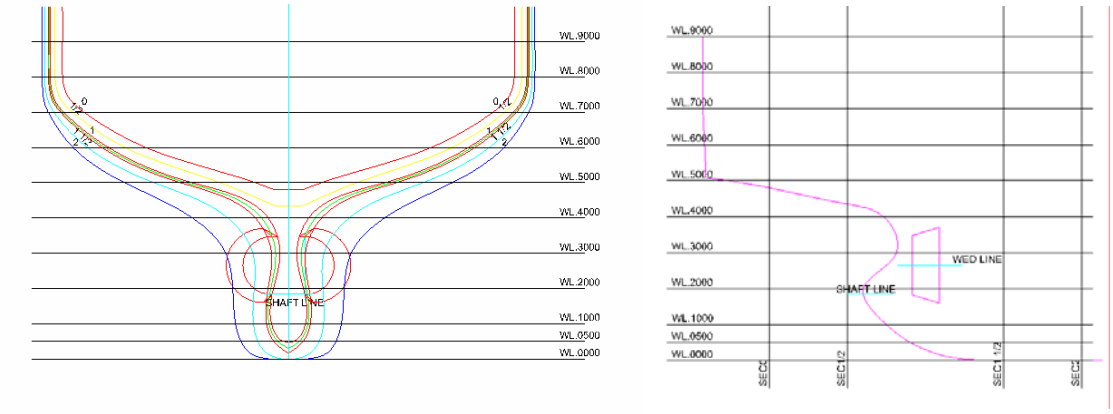


Figure 2. Location of the WED at the after body of the RO-RO Ship

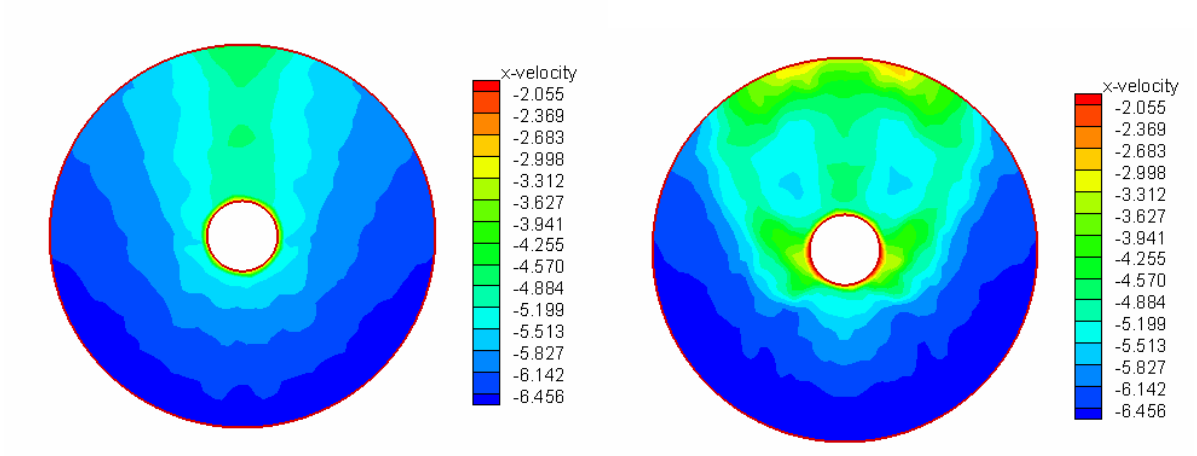
2. CFD ANALYSIS

The CFD analyses are carried out in two stages. In the first stage, the flow around the hull is analyzed with and without WED in the absence of propeller. The inflow velocity at the propeller plane is obtained for both cases, (Figure 3.). In the second stage, the propeller performance is analyzed using computed wake velocities, where the propeller geometry is given in Table 2.

Table 2. Propeller geometry

Wageningen B-4.60	
Propeller diameter, D	4.3 m.
Pitch ratio at 0.7R, P/D	0.9015

The benefit expected from a nozzle is improving of the inflow to the upper region of propeller. Thus the propulsion efficiency of propeller could be increased. As shown in Figures 3a and 3b, there is no significant increment in the velocities coming to the propeller blades, on the contrary the axial velocities at upper region of propeller disc is slightly reduced.



(a) (b)

Figure 3. Axial velocity distributions at propeller plane : (a) without nozzle and (b) with nozzle

In Table 3. propeller characteristics obtained from CFD analyes (with and without nozzle) are given.

Table 3. Propeller characteristics for both cases

	with WED	without WED
K_T	0.1730	0.1759
K_Q	0.02497	0.02508
η	0.603	0.641

For both cases, the viscous drag force of ship is almost constant, but the WED causes an additional drag force of 24.319 kN. As can be spotted from Table 3 that the propeller becomes less efficient with WED. It brings about approximately % 8.4 loss in terms of propulsive efficiency.

This result is supported by Jil-Pyo Ok' study [4] where extensive numerical investigations are carried about scale effect of WED for a tanker with C_B = 0.83. In his study, one of the significant conclusion is as follows; "Contrary to the expectations of Schneekluth and some other authors dealing with these ducts, the duct decreases the longitudinal flow velocity of the water flowing through it, while the water flowing outside of the duct is accelerated by a small amount. This numerical result can be understood also theoretically. Because the duct is fitted at a position where the infow velocity to the propeller is low (near the ship's centreline above the propeller axis), the duct does not act as a `wake-equalizing duct' as intended, but has just the opposite effect."

This concludes that the after body of the ship has a well-designed hydrodynamic form. There is no flow separation at the after body, the upper and lower regions of propeller operate in a good flow condition. It is clear that the use of a wake equalizing duct in the ship with such a after body form, where flow lines are not separated, could not bring about any additional benefit in the respect of stream lines.

3. CONCLUSIONS

Based on CFD analysis, following conclusions are obtained:

- When the stream lines in the direction of shaft axis are examined, it is observed that the inflow of propeller has a uniform character. Under this condition, a WED will not perform its main duty and in contrary it will disturb the proper stream lines and may also lead to vibrations.
- Since the nozzle could not increase the flow velocity at the propeller plane, it will not make any contribution to the propeller efficiency.

The overall conclusion is that a CFD analysis becomes more useful tool to help the designer at the application stage of WED.

References

[1.] H. Schneekluth "Ship Design for Efficiency and Economy", Butterworth & Co. Ltd., UK 1987, pp:72-79.

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[3.] H. Schneekluth "Wake Equalizing Duct", The Naval Architect 103, 1986, pp:147-150.

[4.] Fluent 6.2.16 User's Guide, Fluent Inc.

[5.] J.P. Ok "Numerical Investigation of Scale Effects of Schneekluth's Duct", PhD Thesis, Hamburg Technical University, Germany, 2004.