The Energy Efficiency Design Index (EEDI) for RoRo- Vessels

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Summary. Several RoRo- Ships which were known to be very fuel efficient were analyzed according to the proposed EEDI- concept. It was found that this EEDI actually results in a severe speed limit for those ships. It was further found that this type of ship can fulfil the EEDI only at physically impossible negative wave resistances for their desired design speed. This is due to the fact that the present EEDI violates commonly accepted physical principles of the powering of ships. It is strongly recommended to review the EEDI concept or to introduce a better speed dependency into the future baseline definition.

At the Institute of Ship Design and Ships Safety of Hamburg Technical University, the Energy Efficiency Design Index (EEDI) has been implemented into the existing ship design software. This allowed to use our design data database of about 60 recently build Ro-Ro and Ro-Pax vessels which included reliable model test data with respect to the hydrodynamic performance of the investigated ships. The proposed baseline of DNV has been used to simulate a required EEDI and its impact on ship design. At first, all ships were investigated with respect to the EEDI obtained and they were found to be roughly in line with the DNV investigations, see Fig. 2. It has to be remarked that the general scatter of the data is significant. It was further found that this large scatter does not represent the fuel efficiency of different ships, instead it represents only the deficit of the proposed EEDI concept. Therefore, some ships were investigated more in detail.

The calculation procedure was the following: For a given ship with a certain deadweight and speed, the required EEDI results in a maximum installable main engine power for propulsion purposes. This calculation is valid for the full scantling draft of the ship. On design draft, including sea and engine margin, this maximum allowed installable power by the EEDI results in a maximum speed the ship can achieve at design draft under design conditions. For all investigated RoRo ships it was found that this maximum allowable speed is drastically smaller compared to the speed the ship was designed for, so the present EEDI concept clearly results in a significant speed limit for RoRo ships.

It may be argued that these ship designs may be inefficient ones with respect to their fuel consumption, as their attained speed loss is that high. Therefore, we further investigated the possibility of improving the ships designs with respect to hydrodynamic performance. In a second step, we have postulated that a ship shall be operated at its desired design speed and must be optimised to meet the EEDI requirements. This results in a theoretical reduction of the ships resistance which is to be achieved by the optimisation. As the frictional resistance can hardly be influenced by the ship designer, especially for fuel efficient ships with small block coefficients, the only possibility for optimisation is the reduction of the wave resistance. Therefore, we have computed the necessary wave resistance which is to be obtained for the ship to fulfil the required EEDI. If that permissible wave resistance becomes zero, the ship must be operated as a submarine.

As an example, we have selected the ship which has the best hydrodynamic performance of our data base, which is represented by the smallest residual resistance coefficient CR. The results are shown in Fig. 1. The ship gets an attained index of 48.6, whereas the required index would amount to 29.0. On the other hand, the ship has an extremely low power demand at its design speed of 22.5 knots, indicated by an extremely low CR value of 0.8E-3 at design speed. The graphs in Fig. 2 show that the permissible speed occurs where both curves intersect, which is the case for Fn=0.21, corresponding to a ship speed of 18.3 knots. The ship was actually designed for a speed of 22.5 knots (Fn=0.255), and the graph shows that the required wave resistance to meet the EEDI requirements must actually be negative:

If this (already very efficient) ship shall be operated at its design speed of 22.50 knots, the wave resistance to fulfil the EEDI requirements must actually be negative, which means that the ship has to gain energy from the waves. This is clearly not possible due to fundamental physical laws of ship hydrodynamics.

The same trend was also found for all other ships of our database.

On the other hand, the graphs in Fig. 1 show the fact that if the speed of the ship is low enough (e.g. below Fn=0.2), the ship will fulfil the EEDI requirements even with a significantly increased wave resistance. This will definitively lead to the fact that – regardless of the actual limiting value of a possible base line – slower ships will according to the present EEDI concept become significantly more inefficient compared to existing ships. This will lead to waste of fuel and increased emissions.

The graphs in Fig. 1 clearly show that there is a fundamental different slope of the actual CR value of the ship and the required CR according to the EEDI concept. This is due to the fact that the actual proposal of the EEDI clearly disregards fundamental physical principles of the powering of ships. Because it is a well known principle that the required power of a ship depends on the speed to the power of approximately three, which is not reflected by EEDI or by the baseline definition. The latter must at least appropriately take the speed of a ship correctly into account.

This results in the following situation for RoRo- Vessels:

- All very fuel efficient hull forms we investigated fail to pass the EEDI close to their design speed.
- Beyond Fn=0.25 (abt. 22 knots for a 200m vessel), the required wave resistance to meet the EEDI requirements must become negative.
- The design of RoRo- ships beyond a Froude number of 0.22 (e.g. 18.9 knots for a ship of 200 m in length) will be impossible, as their wave resistance must be close to zero.
- If the selected speed of the ship is slow enough, the EEDI allows for totally inefficient ship designs.
- The EEDI is therefore clearly a speed limit, which favors inefficient ships at slow speeds.
- The above mentioned problems occur due to the fact that the present EEDI proposal as well as the general base line concept clearly violate well known fundamental physical principles of the powering of ships.

It is therefore the main conclusion of TUHH to replace the present EEDI concept by an alternative proposal which does take into account the influence of the ship speed on the fuel consumption according to the well known physical principles. This may be done by either modifying the principal formula of the EEDI or by introducing the relevant variables into a future baseline definition.

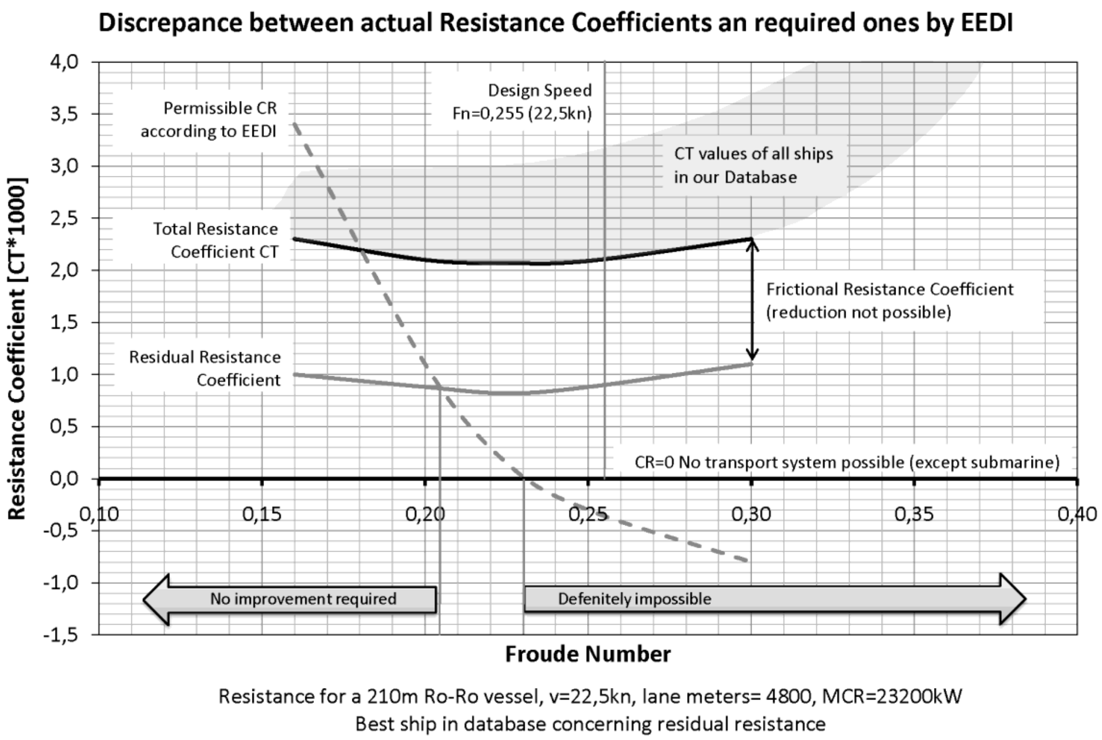

Figure 1. Impact of the EEDI on the most fuel efficient ship of our data base. If the ship shall operate at its design speed, the wave resistance must be negative to fulfill the EEDI requirement

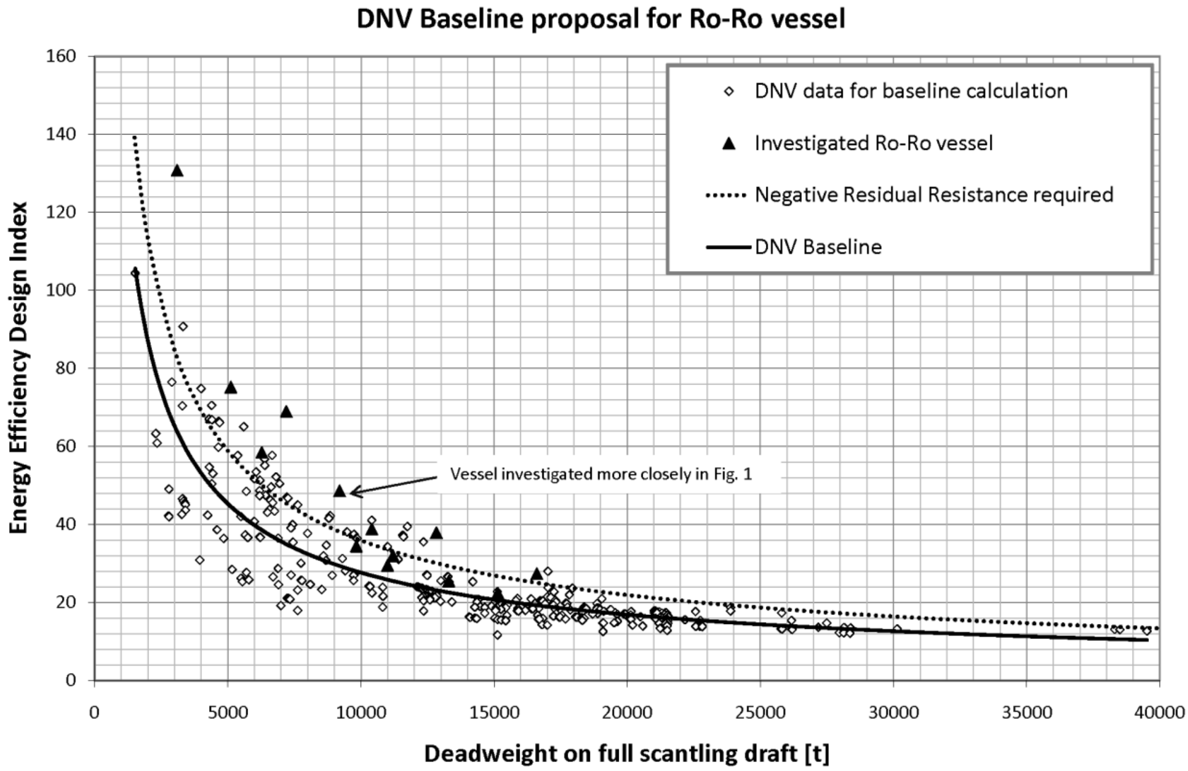

Figure 2. EEDI for all RoRo- ships investigated by TUHH compared to the DNV results and the baseline definition. The dotted line indicates an allowable wave resistance of zero, which means that these ships must operate below the surface to fulfill the EEDI

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