The predictions of resistance and propulsion for 4 types of ships

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ABSTRACT

In this paper the predictions of resistance and propulsion for 4 types of ships: container carrier, oil product tanker, ro-ro vessel and river-sea vessel included in the EUREKA „Baltecologicalship" project E!2772 are presented. All the above ships were designed by the SINUS Enterprise Ltd. The scope of the research covers: experimental measurement of ship resistance in calm water, determination of resistance increment in irregular waves and computational powering prediction for POD propulsors. The experiments were conducted in the Laboratory of the Department of Underwater Technology, Hydromechanics and Design of Ships, Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology.

Keywords : model tests, ship resistance in calm water, ship resistance in irregular waves, POD propulsors

INTRODUCTION

Trustworthy determination of the resistance characteristics of the designed ships through model experiments is necessary for confirmation of the hydrodynamic quality of design. Determination of the full scale resistance enables realistic prediction of the propulsive characteristics of ships, assessment of the delivered power and propulsive parameters. Minimization of the engine power and ensuring correct conditions for engine-propeller interaction is an important problem both from the economic (operational cost) and ecological (level of pollution) points of view. The above mentioned problems refer to the task "Resistance Model Experiments for 4 new types of ship", included in the EUREKA project E!2772. The Project covers the following ship types :

- Container carrier
- Oil product tanker
- Ro-ro vessel
- River – sea vessel.

All the above ships were designed by the SINUS Enterprise. The scope of the research covers :

- experimental measurement of ship resistance in calm water
- experimental determination of resistance increment in irregular waves
- analysis of the ship-induced wave system
- computational powering prediction for POD propulsors.

The experiments were conducted in the Laboratory of the Department of Underwater Technology, Hydromechanics and Design of Ships, Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology.

RESULTS OF EXPERIMENTS

The ship hull models for experiments were built in the model workshop on the basis of the theoretical hull lines supplied by SINUS. Resistance experiments were performed in the towing tank and visualisations of the flow on the hull were made in the circulating water channel. Ship models were tested for two displacements: design draught and scantlings draught. The resistance prediction for full scale was performed using three-dimensional extrapolation with form factor (1+k) calculated according to the ITTC-72 formula. The approximate computational powering prediction was based on experimentally determined resistance, on the propeller-hull interaction parameters determined by the Holtrop method, on the design POD propulsor data supplied by SINUS and on propeller design software based on lifting line/lifting surface theory. Prediction of ship resistance in irregular waves was done for the Baltic and North Sea wave spectrum. The results of all experiments and computations were the basis for assessment of the hydrodynamic quality of each ship design.

Container carrier – SINE 202

The basic parameters of the container ship SINE 202 are as follows :

➢ Length overall	138.10 m
➢ Length between perpendiculars	132.00 m
➢ Breadth	22.50 m
➢ Depth	11.20 m
➢ Design draught	7.60 m
➢ Scantlings draught	8.55 m

The hull geometry is presented in the form of body lines in Fig.1. The model of the container ship was manufactured to the scale 1: 84.5. The resistance characteristics obtained for design draught and scantlings draught, recalculated into full scale are shown in Fig.2. The calculated effective engine power curves for both draughts are presented in Fig.3.

On the basis of experimental results it may be concluded that the ship will reach the speed of 17.80 knots on trials at design draught, 17.20 knots in service at design draught and 16.25 knots in service at scantlings draught. Further increase of ship speed by 0.2÷0.3 knots may be possible by increasing the propeller diameter by about 10%.

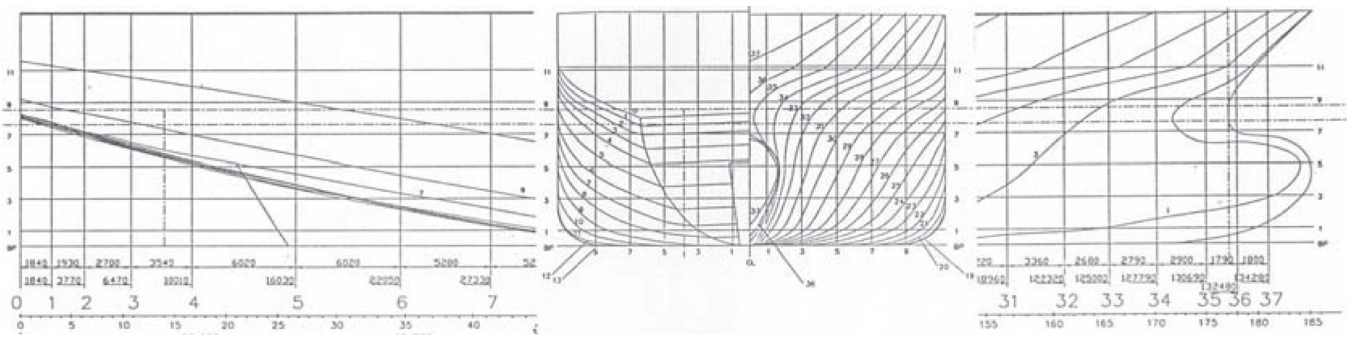

Fig. 1. *Body plan of the container carrier SINE 202*

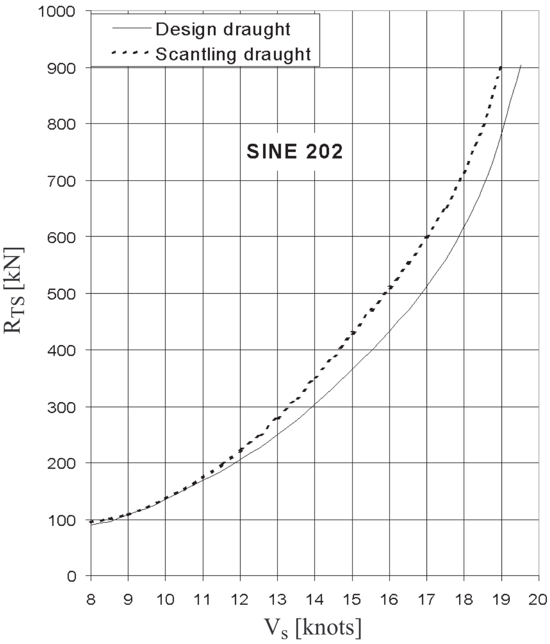

Fig. 2. *Total resistance of the container carrier SINE 202*

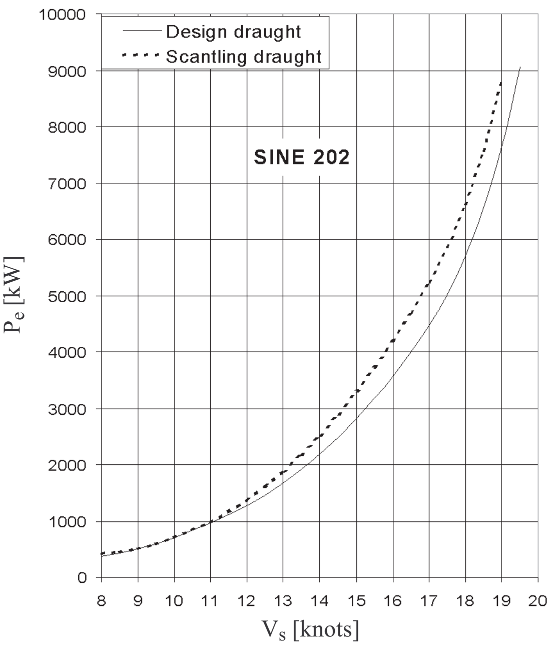

Fig. 3. *Effective engine power of the container carrier SINE 202*

It is assessed that the container ship SINE 202 has good sea-keeping quality. The increment of resistance in waves is relatively low both in the sense of long-term predictions (Fig.4) and in the sense of short-term predictions (Fig.5). It has been determined that the sea margin of 15%, applied in propulsive prediction, is correct for typical sea states in the Baltic and North Sea. Additionally, it has been determined that the resistance increment in waves is identical for the design and scantlings draught.

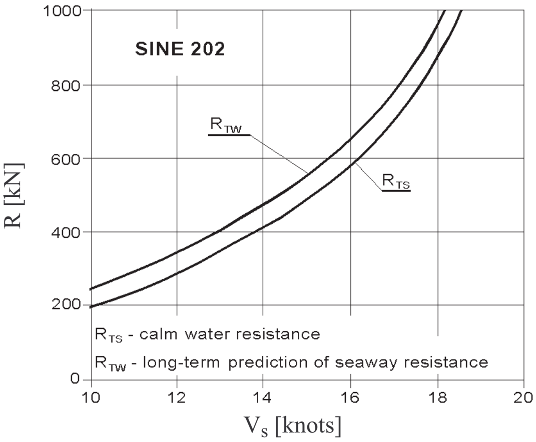

Fig. 4. *Resistance characteristics of the container carrier SINE 202*

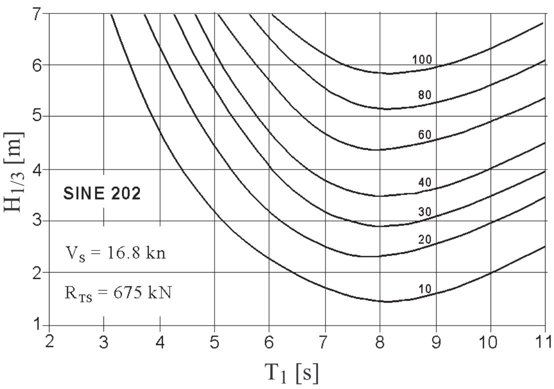

Fig. 5. *Relative added resistance* $\left(\frac{R_{AW}}{R_{TS}}[\%]\right)$ *contours in the* $T_1 - H_{1/3}$ *plane for SINE 202 ship. (set of the short–term predictions of the ship added resistance RAW)*

The detailed results of experiments and computational analyses are included in the report [1 , 2].

Oil product tanker - SINE 203

The basic parameters of the oil product tanker are as follows :

➢ Length overall	138.10 m
➢ Length between perpendiculars	132.00 m
➢ Breadth	22.50 m
➢ Depth	12.80 m
➢ Design draught	8.00 m
➢ Scantlings draught	8.70 m

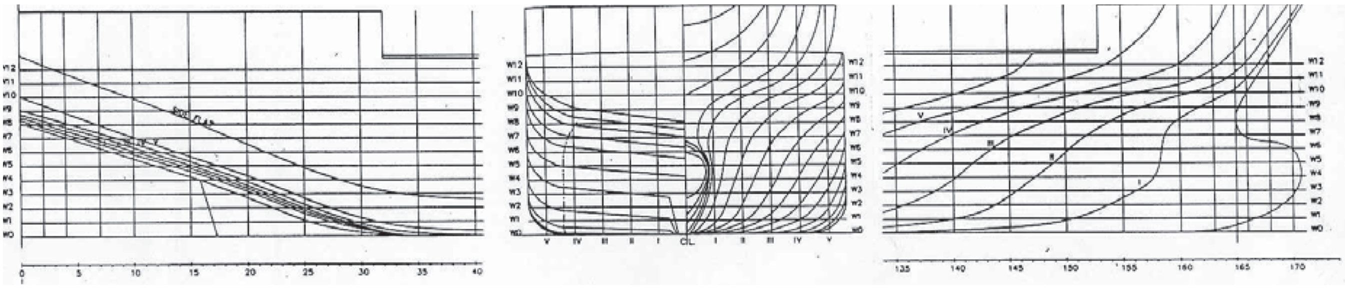

Fig. 6. *Body plan of the oil product tanker SINE 203*

The hull geometry is presented in the form of body lines in Fig.6. The ship model was manufactured to the scale 1 : 84.5. The resistance characteristics obtained experimentally for design and scantlings draughts respectively are shown in Fig.7. The calculated effective engine power curves for both draughts are presented in Fig.8.

On the basis of experimental results it may be concluded that the ship will reach the speed of 12.80 knots in trials condition, 12.25 knots in service condition at design draught and 12.05 knots in service at scantlings draught.

Model experiments of resistance in waves have shown that the SINE 203 model has a small increase of resistance in waves both in the sense of a long-term prediction Fig.9 and in the sense of a short-term prediction Fig.10 for sea states typical of the Baltic and North Sea.

The detailed results of experiments and computational analyses are included in the report [3].

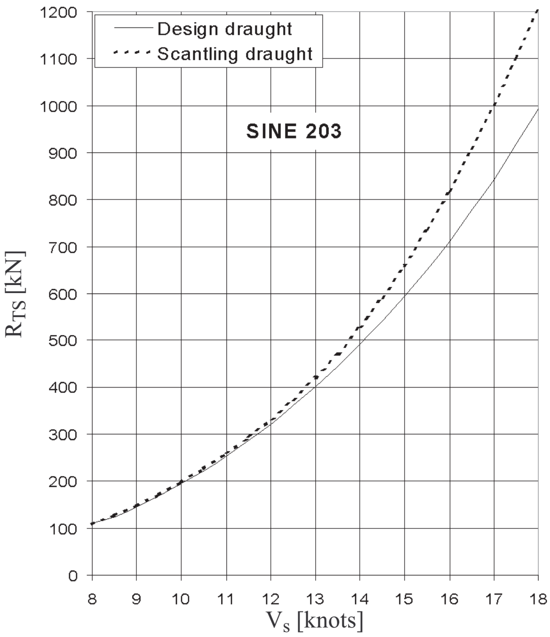

Fig. 7. *Total resistance of the oil product tanker SINE 203*

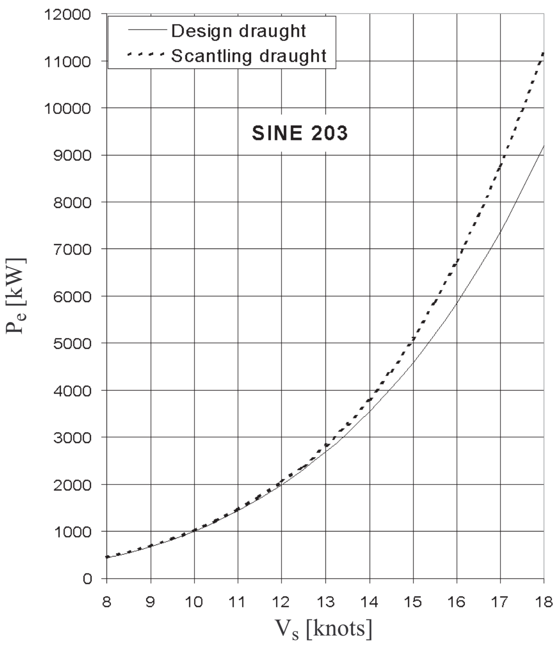

Fig. 8. *Effective engine power of the oil product tanker SINE 203*

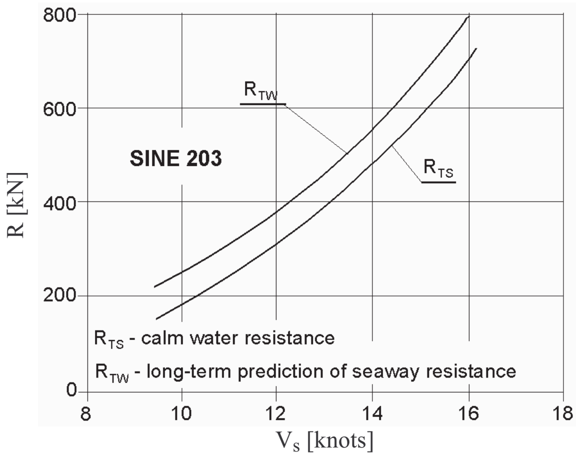

Fig. 9. *Resistance characteristics of the oil product tanker SINE 203*

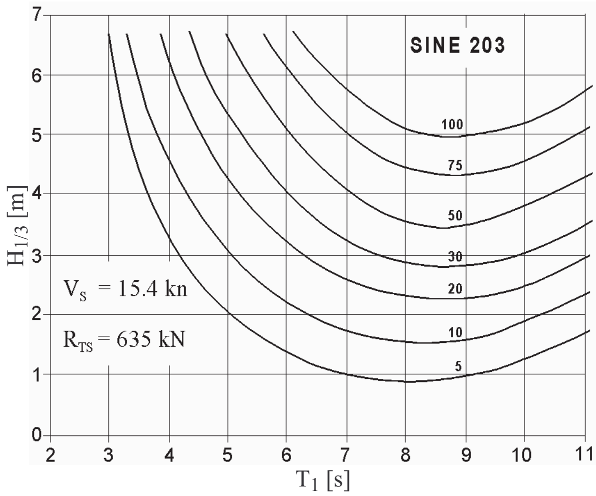

Fig. 10. *Relative added resistance* $\left(\frac{R_{AW}}{R_{TS}}[\%]\right)$ *contours in the* $T_1 - H_{1/3}$ *plane for SINE 203 vessel. (set of the short–term predictions of the ship added resistance* R_{AW}*)*

Ro-ro vessel - SINE 204

The basic parameters of the Ro-Ro vessel are as follows :

- Length overall 156.72 m
- Length between perpendiculars 147.75 m
- Breadth 24.80 m

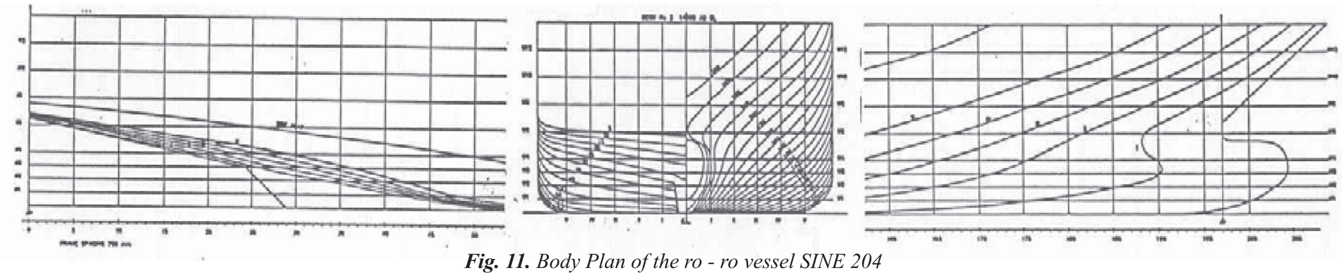

Fig. 11. Body Plan of the ro - ro vessel SINE 204

- Design draught 6.00 m
- Scantlings draught 6.50 m

The hull geometry is presented in the form of body lines in Fig.11. The ship model was manufactured to the scale 1:100. The resistance characteristics obtained experimentally for design and scantlings draught respectively are shown in Fig.12. The calculated effective engine power curves for both draughts are presented in Fig.13.

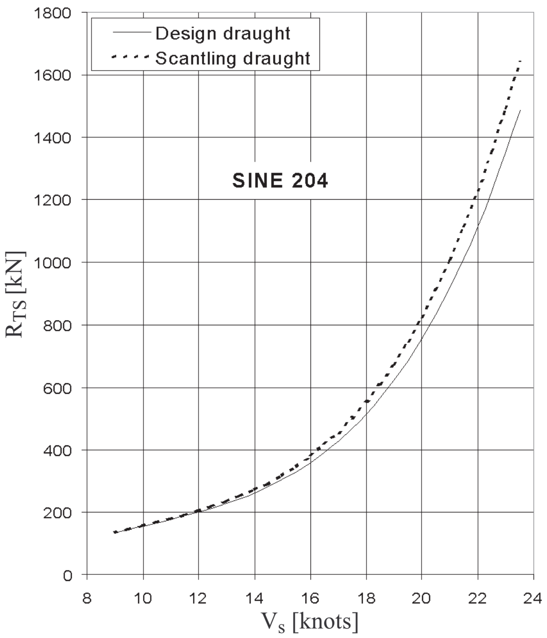

Fig. 12. Total resistance of the ro – ro vessel SINE 204

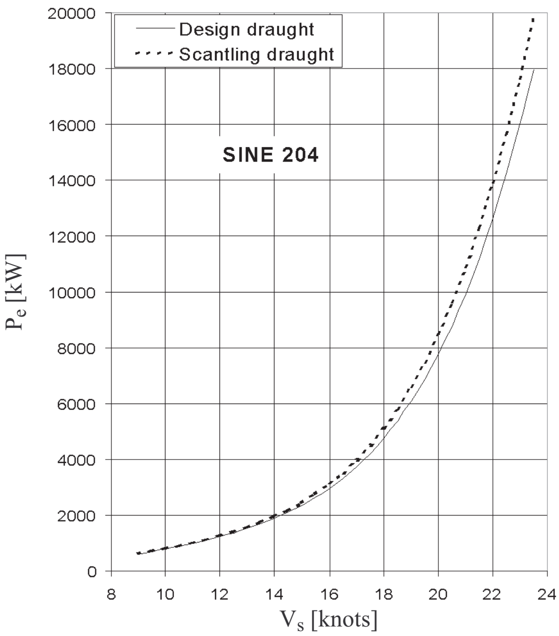

Fig. 13. Effective engine power of the ro - ro vessel SINE 204

On the basis of experimental results it may be concluded that the ship has favourable resistance characteristics. The planned value of delivered power is sufficient for attaining the planned design speed of 20.0 knots. A minor power deficit for scantlings draught with sea margin is meaningless from the practical point of view. The ship will reach the speed of 20.92 knots in trials condition, 20.45 knots in service condition at design draught and 19.90 knots in service at scantlings draught.

Model experiments of resistance in waves have shown that the resistance increment in waves is relatively low both in the sense of a long term prediction Fig.14 and in the sense of a short term prediction (Fig.15). It has been concluded that the sea margin of 15%, adopted in the propulsion analysis, is correct for sea states typical of the Baltic and North Sea.

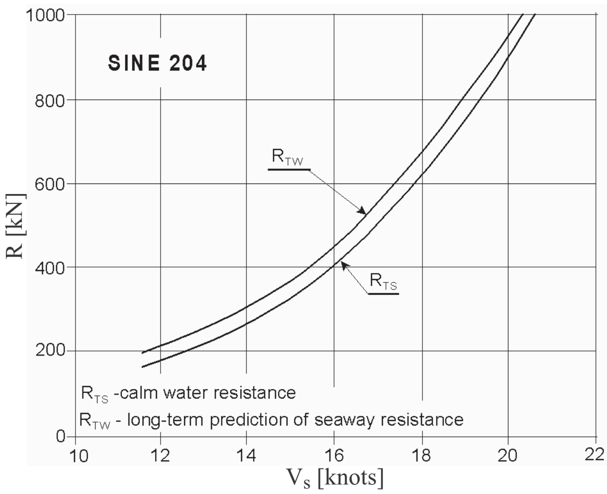

Fig. 14. Resistance characteristics of the ro - ro vessel SINE 204

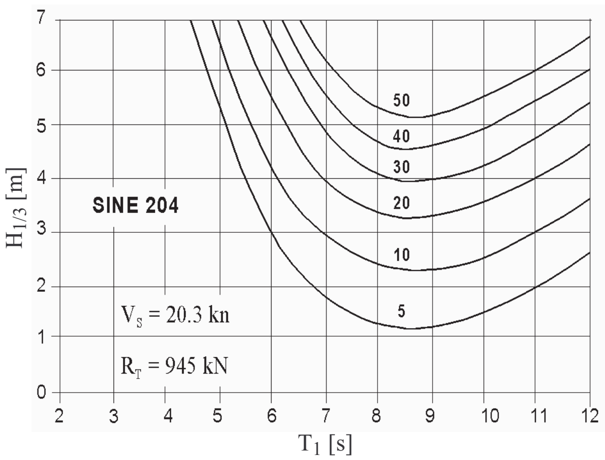

Fig.15. Relative added resistance $\left(\frac{R_{AW}}{R_{TS}}[\%]\right)$ *contours in the* $T_1 - H_{1/3}$ *plane for SINE 204 vessel. (set of the short–term predictions of the ship added resistance* R_{AW}*)*

The detailed results of experiments and computational analyses are included in the report [4].

River-sea vessel - SINE 205

The basic parameters of the River-sea vessel are as follows :

- Length overall 89.45 m
- Length between perpendiculars 87.47 m
- Breadth 11.40 m
- Depth 5.45 m
- Sea draught 4.40 m
- River draught 2.80 m

The hull geometry is presented in the form of body lines in Fig.16. The ship model was manufactured to the scale 1: 50. The resistance characteristics obtained experimentally for sea and river draughts respectively are shown in Fig.17. The calculated effective engine power curves for both draughts are presented in Fig.18.

On the basis of experimental results it may be concluded that the ship will reach the speed of 11.40 knots in trials condition at sea draught, 10.90 knots in service condition at sea draught and 12.00 knots in trials at river draught.

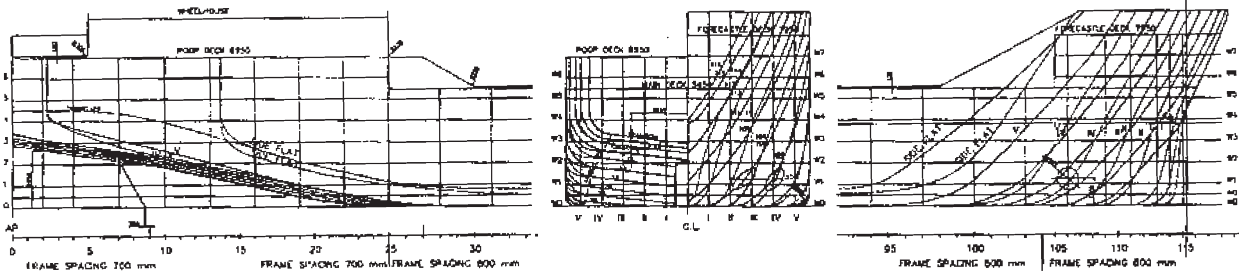

Fig. 16. Body plan of the river - sea vessel SINE 205

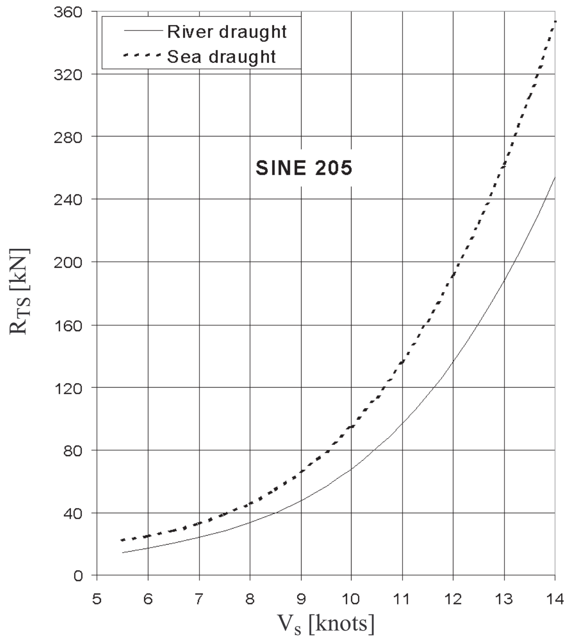

Fig. 17. *Total resistance of the river - sea vessel SINE 205*

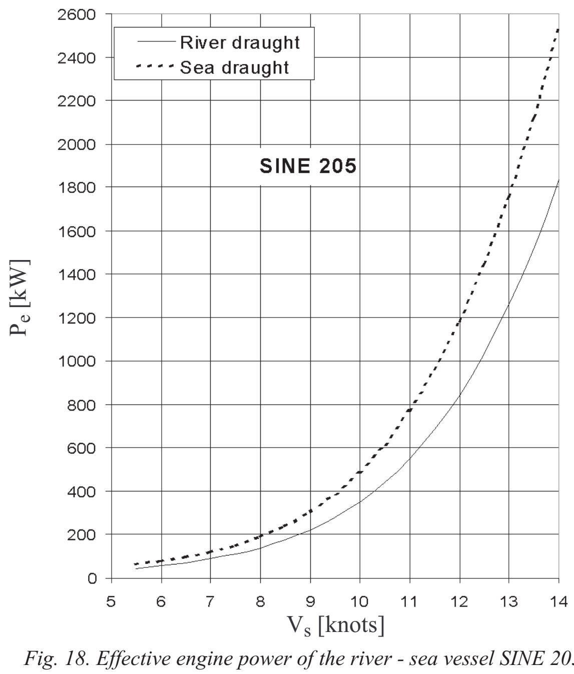

Fig. 18. Effective engine power of the river - sea vessel SINE 205

The detailed results of experiments and computational analyses are included in the report [5].

CONCLUSIONS

The above presented predictions of resistance and propulsion for 4 types of ship obtained through model experiments enable realistic prediction of the power and propulsive characteristics. In the cases where the performance required by the EUREKA project was not achieved, the directions for necessary modification were indicated. The positive results of experimental investigations demonstrate that the shape of the hull geometry and basic parameters were well selected and they create a possibility of ship design with favourable hydrodynamic characteristics.

NOMENCLATURE

$H_{1/3}$ - significant wave height [m]
P_e - effective engine power [kW]
R_{TS} - total resistance of ship [kN]
R_{TW} - long-term prediction of seaway resistance [kN]
T_1 - characteristic wave period [s]
v_S - ship speed [knots]

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