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MV ESTONIA ACCIDENT INVESTIGATION

FORCES ACTING ON THE BOW VISOR DUE TO STATIONARY FLOW

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Abstract

A Non-Linear free-surface panel method code was used to compute the flow around the hull of MV ESTONIA. The aim of this study was to evaluate the steady hydrodynamic forces acting on the bow visor, caused by a stationary axial fluid velocity, on the bow part of the hull. The hydrodynamic force on the bow visor was computed at different drafts and speeds. The studied cases correspond to situations where the ship is forced to a given position and advancing at constant speed without any vertical motion.

Five different draughts were computed. The design draught of 5.50 meters with even keel and four draughts where the trim was -0.9 degrees. The submergence of the bow was 5.5, 7, 9, 11 and 13 meters. The flow velocities corresponds to the full-scale speeds of 10.0, 15.0 and 20.0 knots.

The steady vertical hydrodynamic lift seems to vary almost linearly with the visor submergence whereas the velocity seems to have an large effect on the forces. In the steady state situation the bow wave grows to an impressive height. A large bow wave increases both buoyancy and hydrodynamic forces significant. To what extent this bow wave grows in real sea-way has a large effect on the total force.

CONTENT

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1. INTRODUCTION

A Non-Linear free-surface panel method code was used to compute the flow around the hull of MS ESTONIA. The aim of this study was to evaluate the steady hydrodynamic forces acting on the bow visor, caused by a stationary axial fluid velocity. The hydrodynamic force on an approximation of the bow visor was computed at different drafts and speeds.

2. THE COMPUTATIONS

The non-linear panel method code SHIPFLOW was used in these computations. The panel number of the model varied from 2600 to 3300, depending on draft and speed. The number of panels representing the visor varied between 50 to 450 panels depending on the draft. The geometry of hull-visor junction was simplified accordion to the figure in Appendix I and constant pressure over each panel was used. By integrating this pressure force over the visor surface, the total steady hydrodynamic force acting on the visor was determined. In the non-linear computations the integration is carried out over the total vetted surface of the visor, including the par wetted by the bow wave. To estimate the effect of the bow wave on the visor loads finally some computations using a linear theory was made. In this computation the undisturbed water-surface is taken as the symmetry plane and no effect of the bow wave is taken into account.

Five different draughts were computed. The design draught of 5.50 meters with even keel and four draughts where the trim was -0.9 degrees. The submergence of the bow was 5.5, 7, 9, 11 and 13 meters. The flow velocities correspond to the full-scale speeds of 10, 15.0 and 20 knots.

The studied cases correspond to situations where the ship is forced to a given position and advancing at constant speed without any vertical motion. The theory used in these computations does not model the breaking of waves (breaking bow wave) neither time dependent effects. For these reasons, the results, especially the numerical values of the forces, should be used with care.

3. RESULTS

The pressure force on the bow visor and it's horizontal (FX) and vertical (FZ) components at different bow submergence when the velocity is 15.0 knots is shown in Fig. 1. These result are obtained using the non-lineai theory and include the effect of the bow wave.

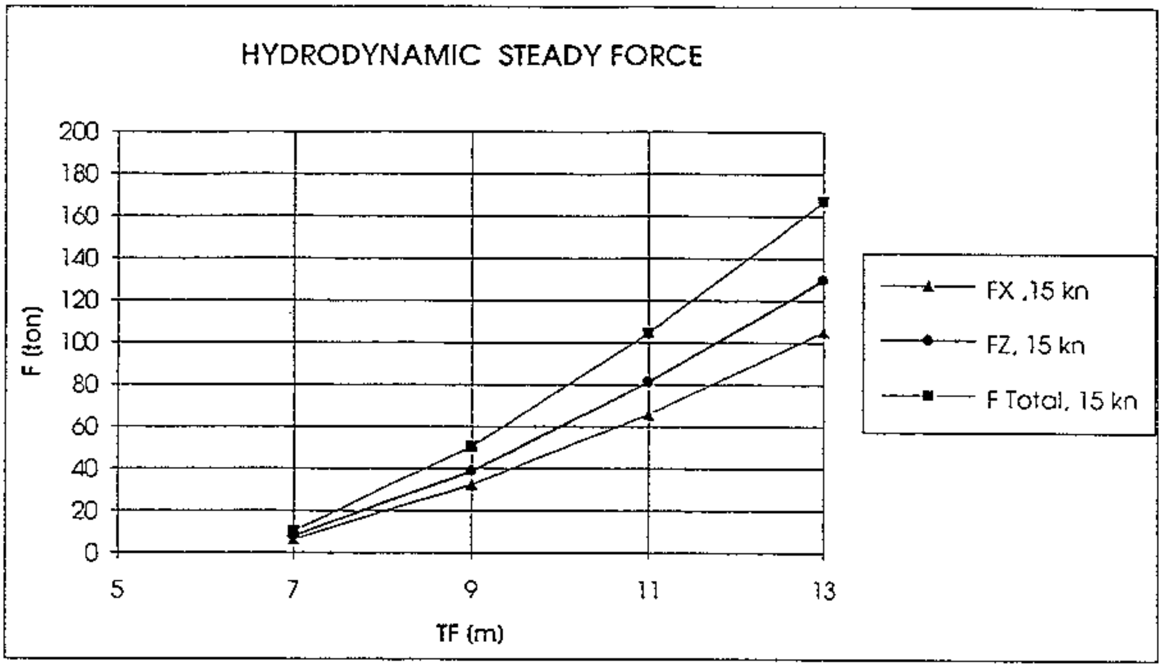


Fig. 1. *The computed hydrodynamic forces on the bow visor.*

As seen in the figure the forces seem to vary almost linearly with the bow submergence. The effect of flow velocity is seen in Fig. 2. The force velocity coupling is larger than $F \propto V^2$.

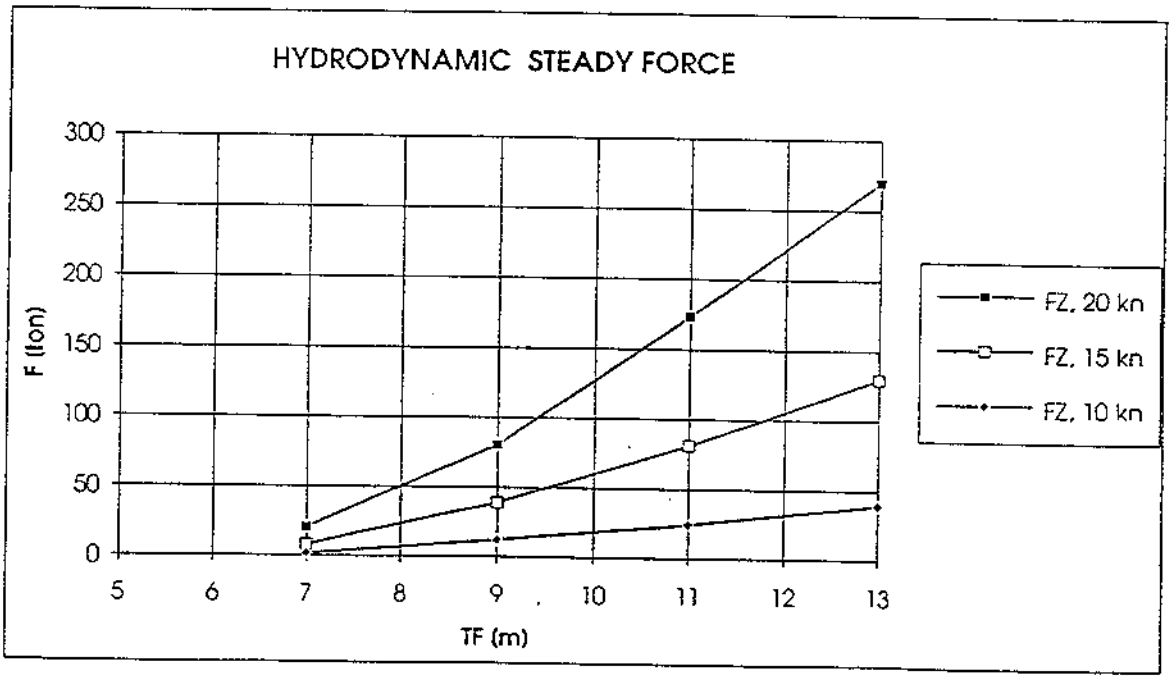


Fig. 2. *The effect of flow velocity on the vertical force*

The swellup or bow wave height for the different submergence when the speed is 10.0 15.0 and 20 knots is shown in Fig. 3. In reality the bow wave will brake and it is questionable to what extent if it has time to grow to these heights in a dynamic situation.

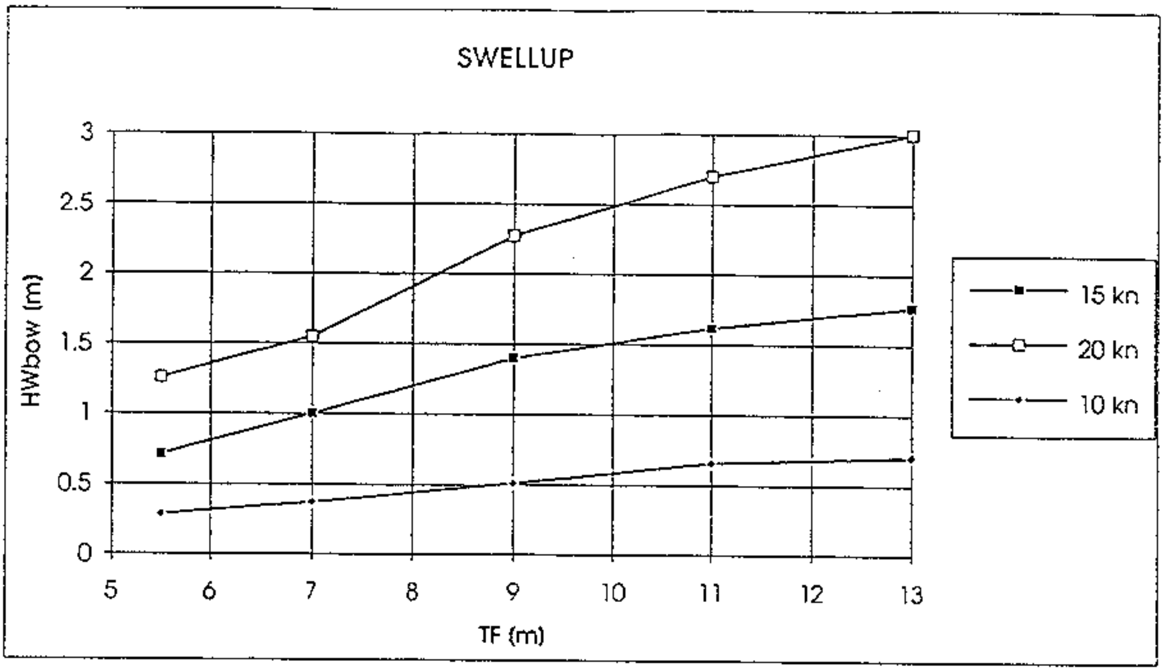


Fig. 3. *The bow wave height as a function of submergence and speed*

The submergence of the visor and the swellup in the bow results in a large hydrostatic force. In Fig. 4 the hydrostatic lifting force is plotted as a function of bow submergence. The volume shown in this figure is based on the actual visor geometry not the approximation used in the flow computations.

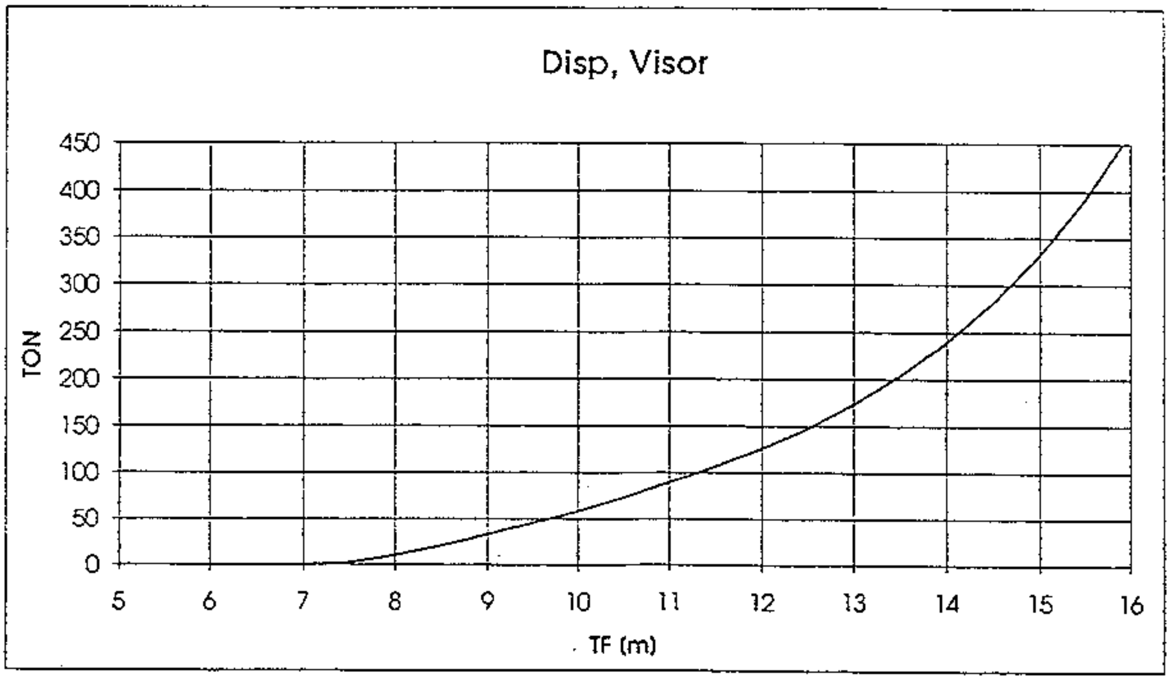


Fig. 4 *The hydrostatic lift of the visor as a function of bow-submergence*

Combining the data of figures 2,3 and 4 it is possible to estimate the approximate total vertical force in stationary flow. The estimate in Fig 5 is somewhat conservative, as the submergence of the visor is taken simply as a sum of the bow draft and swellup. In reality the maximum swellup is a local value, also the breaking of the bow wave would probably decrease the bow wave height.

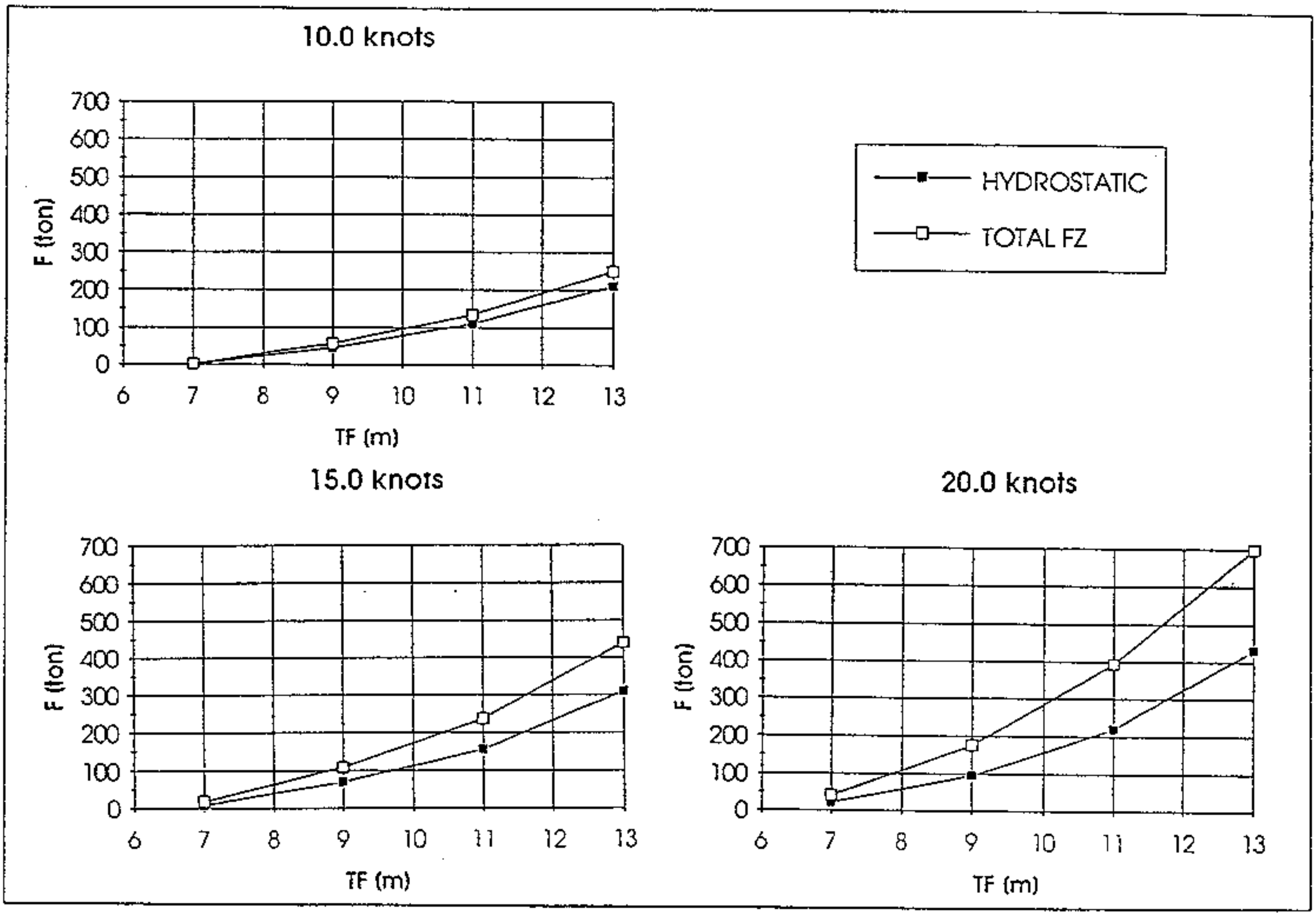


Fig. 5. *The total steady vertical force, including both hydrodynamic and -static forces*

In the most severe case when the visor is completely submerged the total computed vertical force is up to 700 tons.

As it is doubtful to what extent the dynamic swellup will develop some results without the bow wave is also presented. In these results the undisturbed free-water surface is taken as a symmetry plane and no swellup is taken into account. The computed hydrodynamic lift for the linear and non-linear cases is plotted in Figure 6.

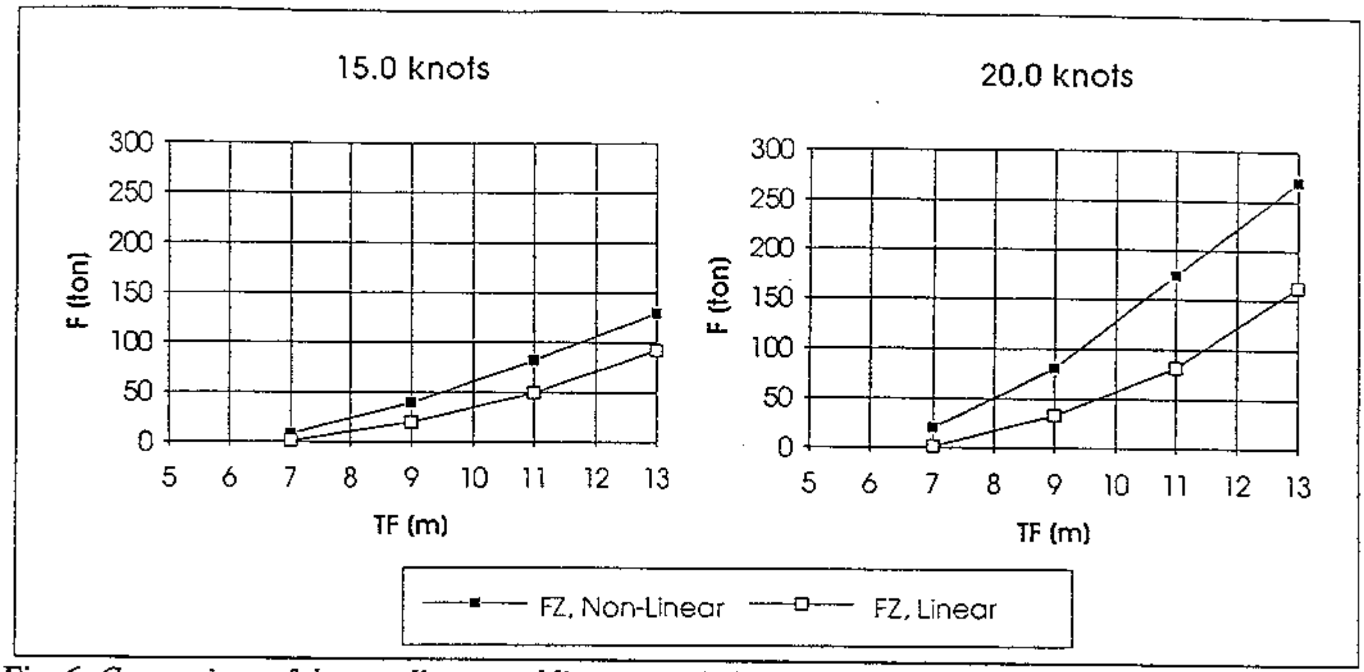


Fig. 6. *Comparison of the non-linear and linear steady* <u>*hydrodynamic*</u> *lift for both 15.0 and 20.0 knots*

The bow wave increases in size with speed and thus also the difference between the linearly and non-linearly computed vertical hydrodynamic forces. The size of the bow wave also affects the displaced volume greatly. The effect of overlooking the bow wave is shown in Figure 7.

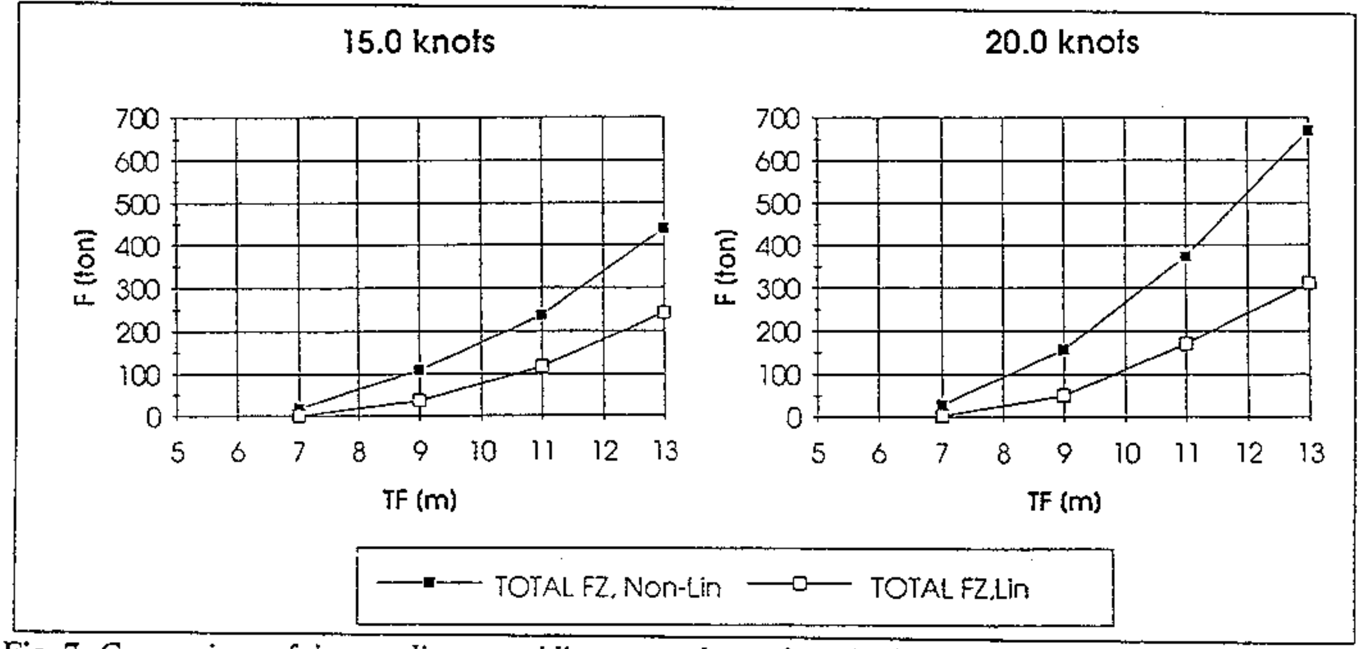


Fig. 7. *Comparison of the non-linear and linear steady* <u>*total*</u> *vertical force for both 15.0 and 20.0 knots*

From the linearly computed results for vertical force a simple equation can be derived for the hydrodynamic lift.

A lift coefficient,

$$C_{Lift} = \sqrt{\frac{T_v}{T_{DWL}}} \cdot \frac{F_{Lift}}{\frac{1}{2}\rho \cdot T_v \cdot U^2} ,$$

is defined, where T_v is the submergence of the visor, T_{DWL} is the design draught, U^2 is the flow velocity and ρ the density of the water.

The term, $\sqrt{\frac{T_v}{T_{DWL}}}$ is a scaling factor without any physical background.

The force F_{Lift} (Newtons) seems to follows well the line,

$$F_{Lift} = \sqrt{\frac{T_{DWL}}{T_V}} \cdot \frac{1}{2} \cdot \rho \cdot U^2 \cdot T_v^2 \cdot C_{Lift} .$$

The obtained value for the lift coefficient of the MV ESTONIA visor is: CLift=0.81

4. DISCUSSION

There are some central findings of this study that should be considered when estimating the forces on the visor.

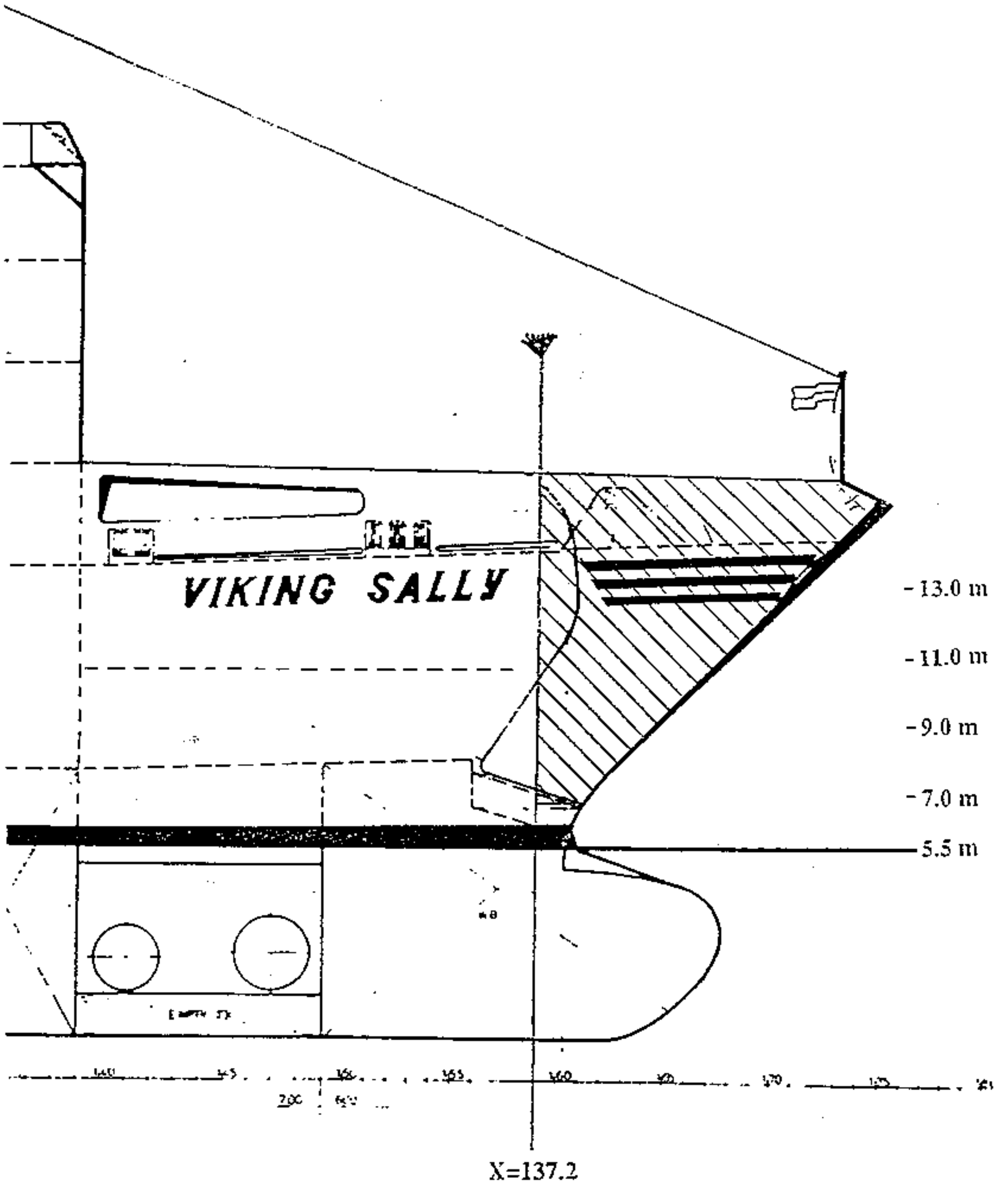
The computation indicates a nearly linear growth in the hydrodynamic steady forces with increasing visor submergence. If the pressure would be constant over the whole visor surface the force would vary approximately quadratic with the submergence. However the pressure value varies along the visor surface, attaining its highest value at the stagnation point near the water surface and in its vicinity and decreasing when moving aft and down. This high-pressure area covers a proportionally larger part of the visor for smaller submergence. Pressure distributions on the visor at bow submergence of 9 and 13 meters are shown in Appendix II.

The strong effect of the speed on the hydrodynamic lift is also interesting. Without the effect of the free-surface, the force would vary quadratic with speed. However as the bow wave grows with speed, affecting the flow and increasing the submerged area for a given draft significantly, the force will grow faster. In this case the force seems to vary with $V^{2.5-2.8}$.

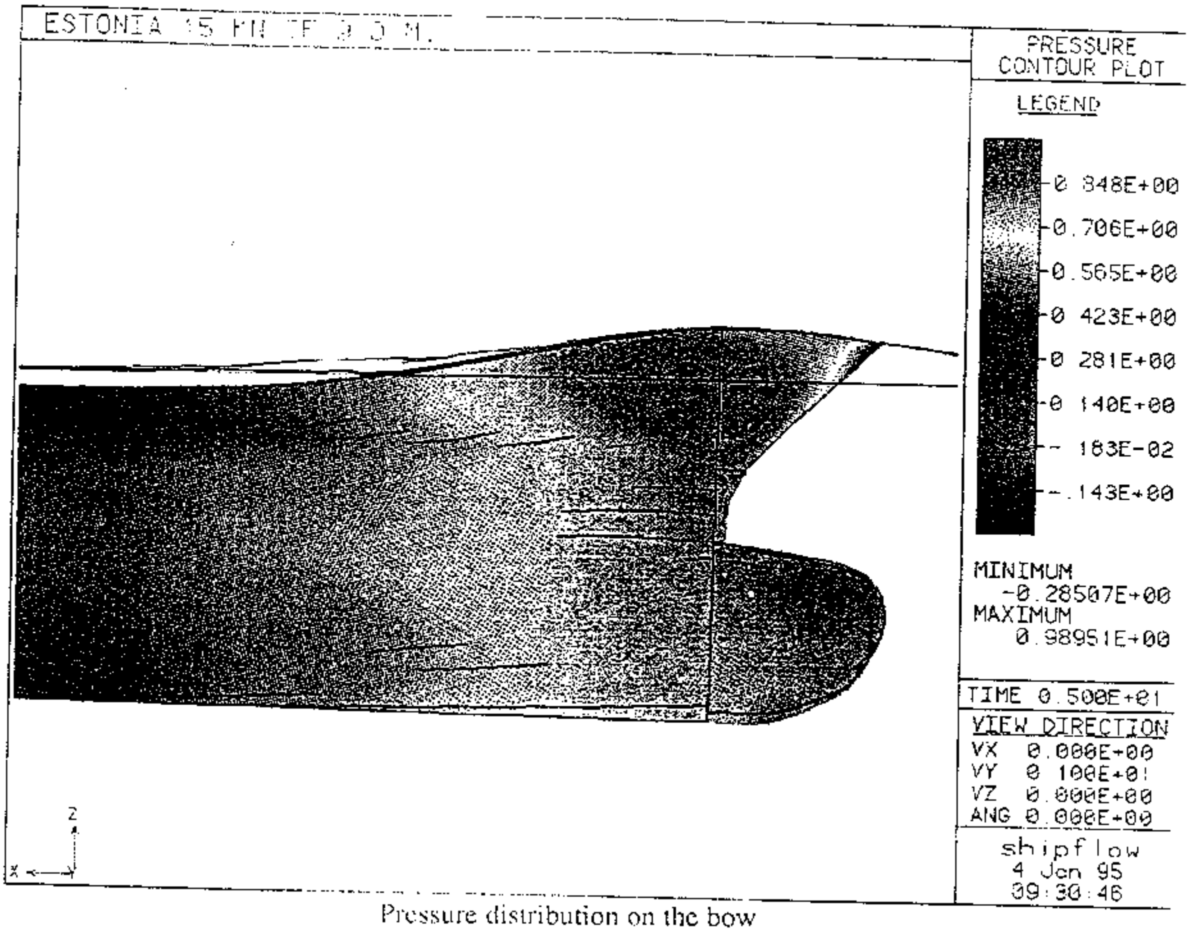
As the swellup is a function of speed the hydrostatic force is also affected by speed. The computations indicate a bow wave height up top 3.0 meters, in the most sever condition. In some cases the increase of submergence due to the bow wave could more than double the displaced volume of the visor.

The results also show how important a right estimation of the bow wave height is. The effect of the bow wave is especially important in cases, as MV ESTONIA, where both buoyancy and submerged areas increases quickly upwards. This dynamic swellup is an important field for further research.

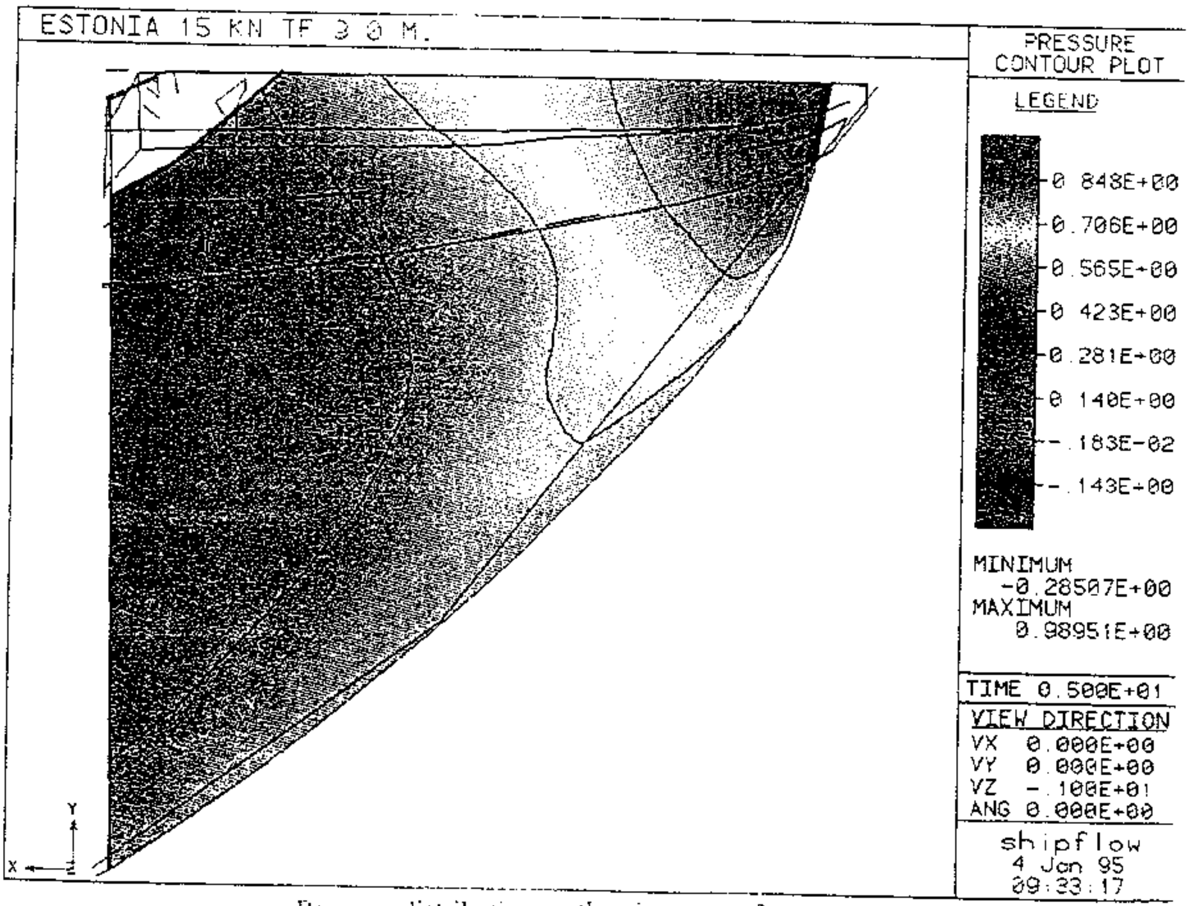
Although the performed computations include many simplifications of the time dependent situation where the vessel operates in severe conditions it seems as the steady hydrodynamic lift generated by the steady axial flow is of considerably magnitude. This force is of course strongly dependent of the bow geometry and should not be neglected in the cases of wide bow and large overhangs. In the case of MS ESTONIA this vertical force could grow up to 200 tons or 40 % of the design load in the most sever conditions.


VIKING SALLY
- 13.0 m
- 11.0 m
- 9.0 m
- 7.0 m
5.5 m
X=137.2

SPEED: 15.0 knots, TF: 9.0 m

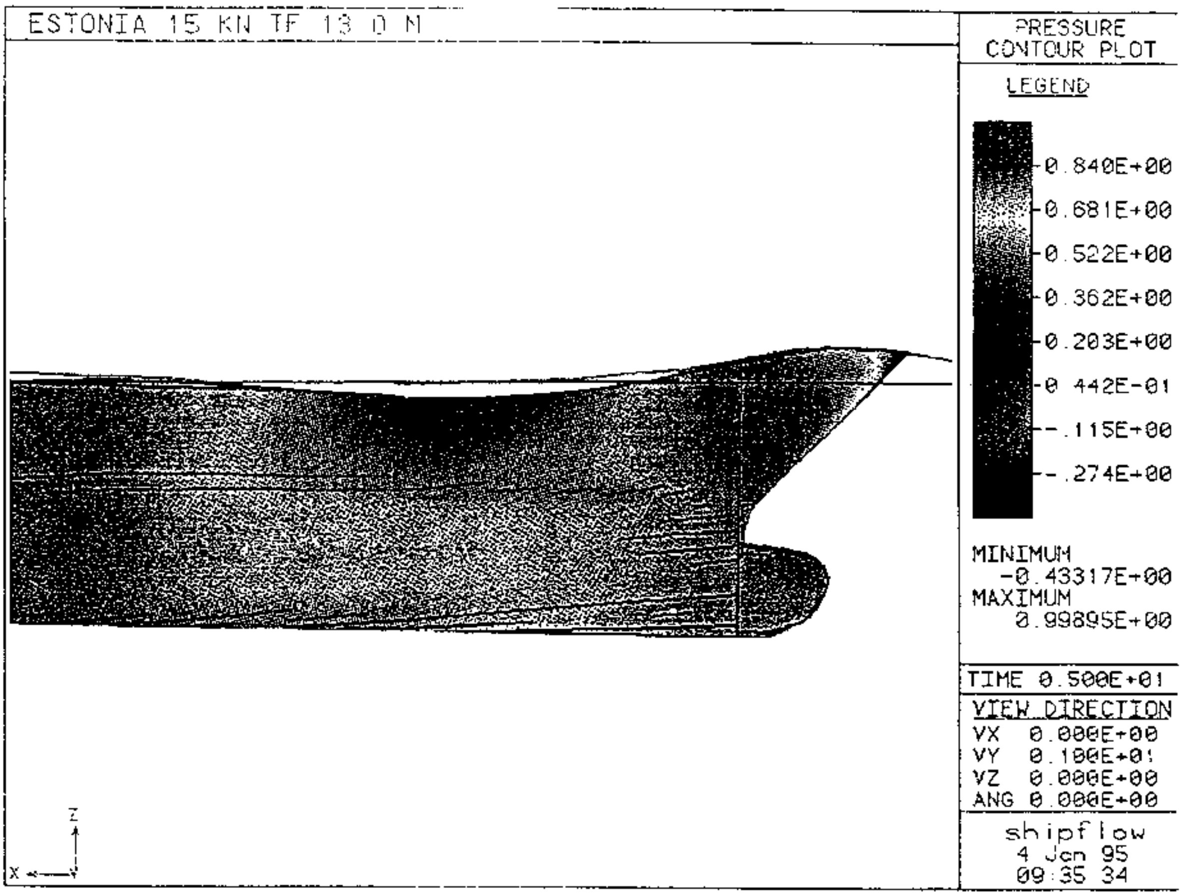


Pressure distribution on the bow

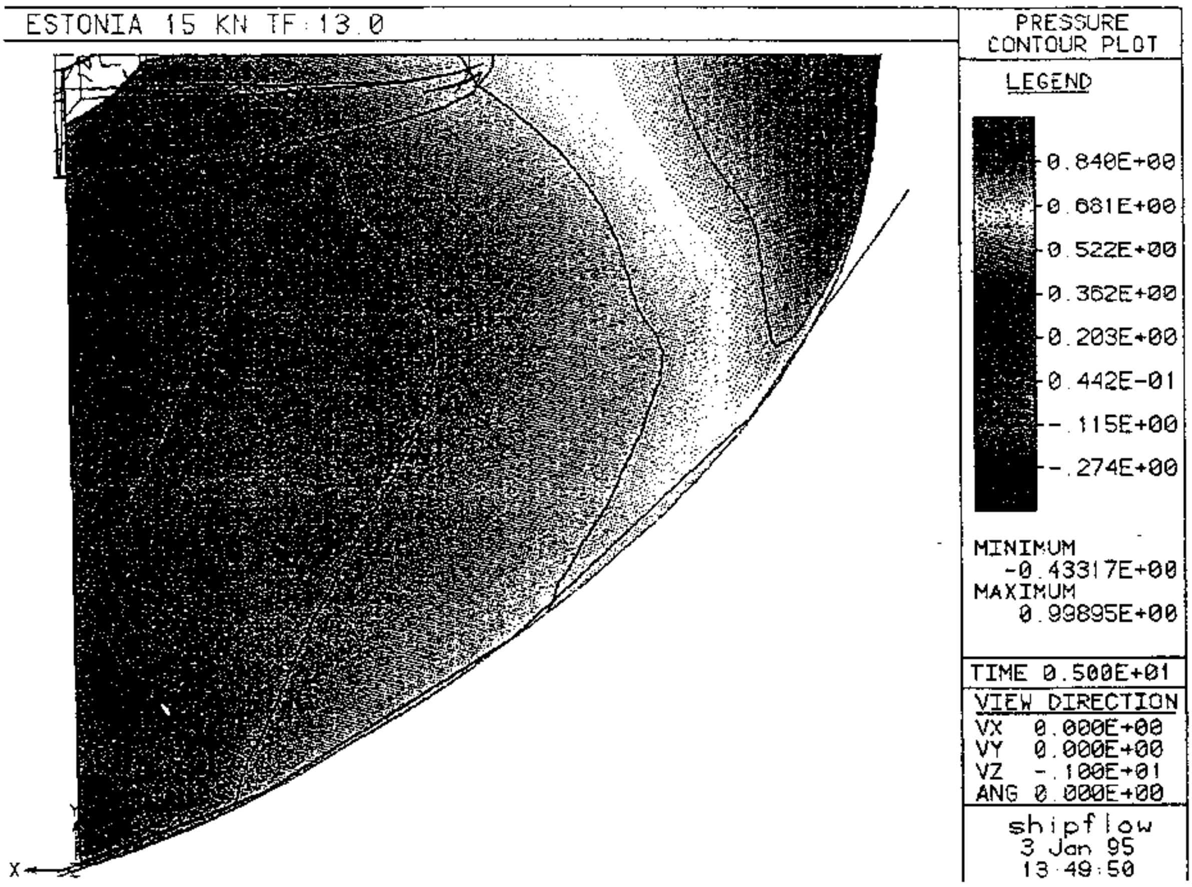


Pressure distribution on the visor, seen from above

SPEED: 15.0 knots, TF: 13.0 m



Pressure distribution on the bow



Pressure distribution on the visor, seen from above