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# on Ship Design and Economics

## by

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1- "Structural and Economical Consequences of Ship Deflection", Seminar on the Application of Science & Technology in Marine Transport, A.M.T.A., J. Res. and Consultation Centre, July. (Egypt-1974), Shama, M. A.,
2- "Optimizing Hull Steel Weight for Overall Economic Transportation", Marine Week, May 2, (UK-1975), Shama, M. A.,
3- "The Cost of Irrationality in Ship Structural Design", PRADS. Int. Conference on Practical Design in Shipbuilding, SNAJ, Tokyo Oct. (Japan-1977), Shama, M. A.,
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# Optimising hull steel weight for overall economic transportation

Dr. M. A. Shama* investigates the effect of structural optimisation on the economy of transportation, emphasising the loss of income associated with deviation from the optimum hull steel weight—a criterion for determining the latter is presented

THE STRUCTURAL DESIGN of a ship has a direct influence on her operation, safety and economy of transportation. Therefore, the design procedure should be rationalised with particular emphasis on structural safety and optimisation. A ship should have adequate strength to resist the loads imposed by the hostile sea environment and at the same time she should have the lightest possible steel structure (1). Ship structure optimisation thus becomes an essential part of the design process.

Structural optimisation has direct and indirect effects on the economy of transportation: the direct effects are the increase in deadweight carrying capacity and the reduction in initial ship cost; the indirect effects are the loss in deadweight carrying capacity, resulting from increased hull flexibility, and the increase in maintenance and repair costs, resulting from the frequent breakdowns and failures of local structural details. The delays associated with these failures also have an adverse effect on the earning time of the ship.

This article outlines the economical consequences of structural optimisation and provides a criterion for the determination of the optimum hull steel weight. It also emphasises the need for data collection on structural failures and associated costs and delays.

Much work has been done in recent years on various approaches to ship structural optimisation (2, 3). However, it is not the purpose here to examine any of these approaches, but to illustrate the impact of optimisation procedures on the economy of ship operation.

An outline of an optimisation procedure is illustrated in Fig. 1. It is shown that it should be possible to obtain the optimum structural configuration which gives the lightest hull steel weight satisfying the requirements for safety as well as economy. For large ships, structural optimisation becomes very desirable as a saving of more than 1 000 tons of steel is feasible. This is confirmed by the reduction of about 600 tons of steel in a 47 000 tons dwt tanker of the "pudgy type" (4). This saving of steel is achieved just by using optimum ship dimensions—much more saving could be realised through structural optimisation.

Weight saving of hull steel means lower initial cost (material and constructional costs) and higher revenue through increased deadweight carrying capacity. Alternatively, structural optimisation may have an adverse effect on structural reliability, particularly for local details. The deficiency of these local details may lead to local failures which, when accumulated or propagated, may induce serious structural failures. These failures will increase maintenance and repair costs and at the same time will reduce the earning time of the ship.

Structural optimisation may also have an adverse effect on hull girder stiffness. The reduced stiffness will increase ship deflection. Sagging deflections cause a reduction in the deadweight carrying capacity of a ship (5).

In order to appreciate the economical consequences of structural optimisation, the present worth of lost income resulting

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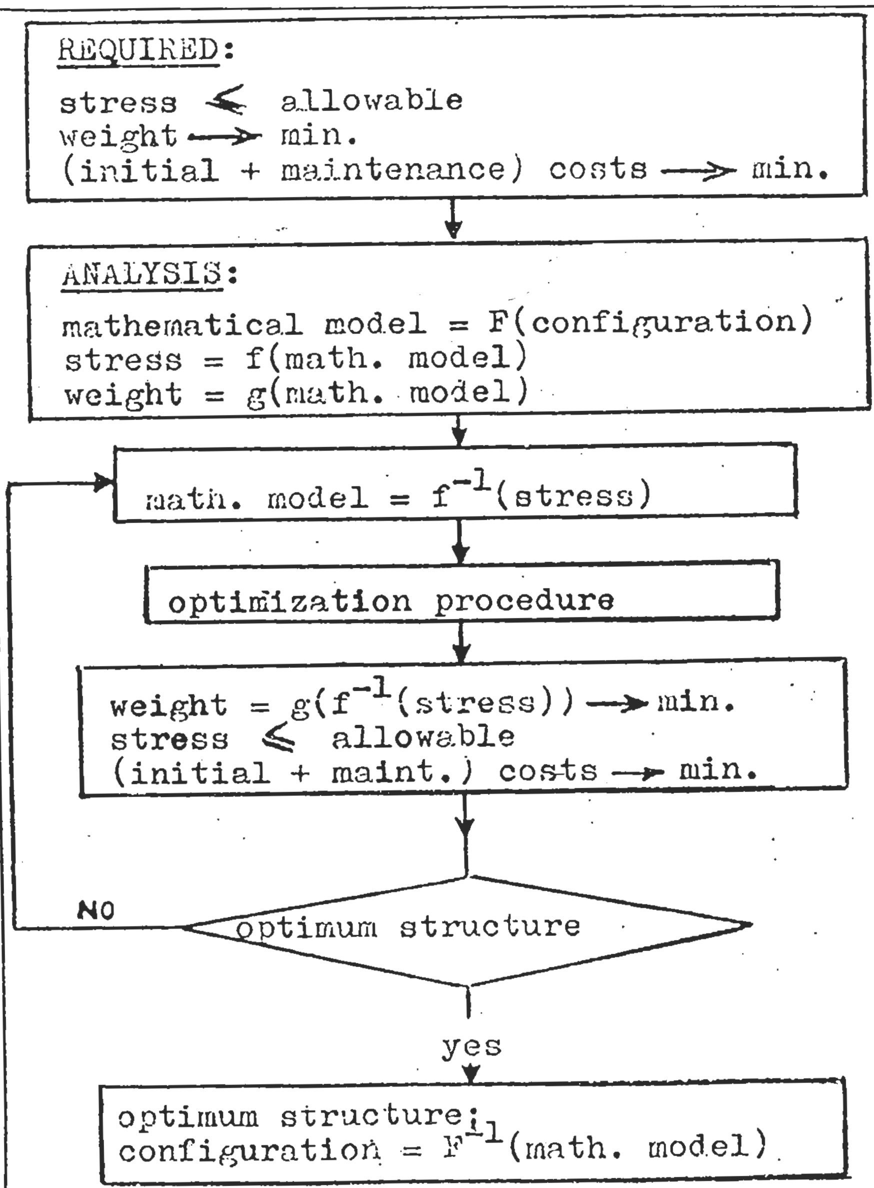


Fig. 1. Optimisation procedure

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directly and indirectly from the reduction of hull steel weight is considered:

- economical consequences of increased hull steel weight:

  Let: W = weight of extra steel.
  $C_1$ = cost of steel/ton.
  $C_2$ = cost of fabrication/ton.
  f = freight rate in \$/ton.
  N = ship's life in years.
  n = number of return trips/year.
  i = rate of interest.

Thus, cost of extra steel =

$$R_s = (C_1 + C_2) \cdot W \ \$$$

Lost income/year = $R_1 = W \times n \times f$ \$

Using the methods given by Benford (6), the present worth of lost income is given by:

$$P_1 = [UPWF]^i_N \cdot R_1 + R_s \quad \ldots (1)$$

where UPWF = uniform present worth factor.

The variation of P. with W is illustrated diagrammatically, Fig. 2.

- economical consequences of reduced hull steel weight:

  (i) lost income due to ship delays and the increase in repair and maintenance costs:

  Let K = number of days lost for repair work/year.
  e = earning capacity of ship/day. \$
  $C_R$ = total cost of repair work/year. \$

  Hence, last income/year =

$$R_2 = K.e. + C_R. \ \$$$

The present worth of lost income over N years is given by:

$$P_R = \sum_{j=r}^{D} [SPWF]^i_j \cdot R_2 \ldots\ldots (2)$$

where SPWF = single present worth factor;

r and D are the first and last years in which the ship is stopped for repair.

It is evident that the frequent stoppage of a ship for repair work has an adverse effect on her economics. Therefore, small cracks that may not immediately threaten the safety of a ship may subsequently have a deleterious effect on ship economics.

  (ii) lost income due to increased ship deflection:

  Let Δ = sagging deflection amidships.
  $C_W$ = waterplane area coefficient.
  $A_W$ = waterplane area.

  Hence, loss in deadweight, δ, due to a sagging deflection Δ is given by (4):

$$\delta = \Delta \cdot A_W \rho \left(1 - \frac{0 \cdot 24}{C_W}\right)$$

Thus, lost income/year = $R_3 = \delta \cdot n \cdot f$

and $P_D = [UPWF]^i_N \cdot R_3 \ldots\ldots\ldots (3)$

From (2) and (3), the present worth of lost income due to structural optimisation, $P_2$,

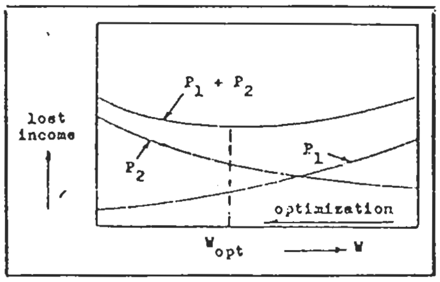


Fig. 2. Optimum hull steel weight

is given by: $P_2 = P_R + P_D \ldots (4)$

Fig. 2 illustrates the effect of structural optimisation on $P_2$.

## Structural optimisation

The criterion for optimisation of hull steel weight should be based on economical considerations. The minimum lost income resulting from increased, or decreased, hull weight could be used as the optimisation criterion. Thus $P_1 + P_2 \rightarrow \min$.

Fig. 2 illustrates the variation of total lost income with the degree of optimisation. From the curve of $(P_1 + P_2)$, the optimum hull steel weight could be determined.

In this connection, it should be realised that this approach cannot be used for the determination of the optimum hull steel weight for a projected ship, as the maintenance and repair costs will not be available. However, the optimum hull steel weight could be determined only after the analysis of records for maintenance and repair costs, delays, variation of freight rate, etc., over the expected service life of the different ship types and sizes.

Consequently, in order to calculate the lost income resulting from structural breakdowns and failures, it is necessary to have sufficient data on these failures. These data, however, are not available in the form to be used directly for economical evaluation. Accordingly, it is recommended that steps be taken to classify ship structural damages as follows: local damages (such as those resulting from stress concentration, fatigue failures, local buckling, etc.); major damages (such as those occurring to strength deck, shell plating, longitudinal girders, bulkheads, etc.); total damages (which includes all cases of total ship losses where failure of the hull girder is known or suspected to be the cause of ship loss). The collection of this data should also include costs of repair, period of repair, years of service, causes of failure or damage, etc.

Optimisation of hull steel weight has a direct influence on the loss of deadweight, due to the reduction in hull girder stiffness, and on the maintenance and repair costs. It also has a direct influence on the initial cost of the ship as well as her earning capacity. Therefore, optimisation of hull steel weight should be based on its economical consequences, regarding the initial and running costs of a ship. This requires the collection and analysis of data on causes and types of structural failures as well as the maintenance and repair costs for different ship types and sizes.

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