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AN APPROXIMATE METHOD FOR THE CALCULATION OF SHEAR FORCE AND BENDING MOMENT LOADING IN TANKERS AND BULK CARRIERS.

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ABSTRACT

In this paper, a method for the calculation of the approximate values of shear force and bending moment loading in tankers and bulk carriers is proposed. The data is presented in graphical form as well as practical equations to be used in the preliminary design stages. The method is based on the data obtained from more than fifty ships and it is tested on various ships not included in the original data base. It is demonstrated that the approximate results show satisfactory agreement with the results of the exact calculations. The full load still water and wave crest - wave trough conditions are separately examined in the light of the classification society criteria and the results are presented in a comparative form.

1. INTRODUCTION

In the preliminary design stage, it is useful to have as precise information as possible on the magnitudes of maximum shear force and bending moment loading. In this study, a set of approximations to maximum shear force and bending moment loading on tankers and bulk carriers is presented in the form of graphs and equations. The longitudinal strengths of more than 50 tankers and bulk carriers are calculated to obtain the information base. Each ship is evaluated in still water as well as in the crest and on the trough of a wave separately. The maximum values of the shear force and bending moment loads for each case is obtained in the graphical form and the distributions of the maximum bending moment values are depicted in comparison with those calculated by using Turkish and German Lloyd's longitudinal strength criteria. The very few extreme cases which fall outside the general character of the curves are omitted.

2. CALCULATION PROCEDURE AND ASSUMPTIONS

A computer program developed by I.T.U. Naval Architecture and Ocean Engineering Faculty is utilized in the longitudinal strength calculations. In this program package, firstly the ship form is obtained, then the distributions of buoyancy for the desired displacement for the still water, trimmed still water as well as the wave crest and trough conditions are calculated. The cargo and other weights in the holds and tanks are treated as distributed loads taking into
consideration the volumetric variations dictated by the geometry of the relevant sections of the ship hull. The trapezoidal integration rule is used for the numerical integration to carry out the calculations of the shear force and bending moment. The errors inherent in the trapezoidal integration rule are minimized by choosing smaller intervals (about 120 intervals).

For the bending moments calculated in accordance with the Turkish and German Lloyd Rules, the hogging and sagging conditions are treated separately. The general loading condition of the ships used in the analysis is the full load departure condition. The hold and tank loads are assumed to have mostly homogeneous distributions along the ship's length, therefore, the other possible loading conditions where significant discontinuities may exist are not considered.

The range of the variation of the main ship dimensions of the tankers and bulk carriers used in the study is given below:

\[ L_{pp} = 49.25 - 270.0 \text{ [m.]} \]
\[ B = 7.0 - 44.5 \text{ [m.]} \]
\[ H = 3.85 - 22.0 \text{ [m.]} \]
\[ T = 3.62 - 16.8 \text{ [m.]} \]
\[ C_B = 0.575 - 0.842 \]

The results obtained from the longitudinal strength calculations are presented in the form of various graphs with the main variables being the ship main dimensions. Some of the graphs appropriate to the case are given in the Appendix. In these graphs, the maximum shear force and bending moment values in still water, in wave crest and on wave trough are presented with respect to the length between perpendiculars and the displacement (Fig. 1-6) as the fundamental variables. In the last of the graphs (Fig. 7), the maximum bending moment results found in this study are compared with those calculated in accordance with the Turkish and German Lloyd Rules. All of the points in the graphs are approximated to suitable curves by a fitting technique. The expressions obtained through this procedure are as follows:

Distribution of maximum bending moment in still water (Fig.1.A);
\[ M_{sw} = (L_{pp})^{3.93675} \times 4.49021E-5 \text{ [t.m]} \]

Distribution of maximum bending moment in wave crest (Fig.1.B);
\[ M_{wc} = (L_{pp})^{4.55772} \times 5.33522E-6 \text{ [t.m]} \]

Distribution of maximum bending moment in wave trough (Fig.2.A);
\[ M_{wt} = (L_{pp})^{4.05716} \times 9.95739E-5 \text{ [t.m]} \]

Distribution of maximum bending moment in still water (Fig.2.B);
\[ M_{sw} = (\Delta)^{1.3147} \times 0.0240116 \text{ [t.m]} \]

Distribution of maximum bending moment in wave crest (Fig.3.A);
\[ M_{wc} = (\Delta)^{1.50919} \times 0.00872257 \text{ [t.m]} \]

Distribution of maximum bending moment in wave trough (Fig.3.B);
\[ M_{wt} = (\Delta)^{1.36507} \times 0.0583981 \text{ [t.m]} \]

Distribution of maximum bending moment in still water (Fig.4.A);
\[ T_{sw} = (L_{pp})^{2.95481} \times 0.000308901 \text{ [ton]} \]
Distribution of maximum shear force in wave crest (Fig.4.B);

\[ T_{wc} = (L_{pp})^{3.65893} \times 1.45228 \times 10^{-5} \text{ [ton]} \]

Distribution of maximum shear force in wave trough (Fig.5.A);

\[ T_{wt} = (L_{pp})^{2.9761} \times 0.000600546 \text{ [ton]} \]

Distribution of maximum shear force in still water (Fig.5.B);

\[ T_{sw} = (\Delta)^{0.991395} \times 0.032944 \text{ [ton]} \]

Distribution of maximum shear force in wave crest (Fig.6.A);

\[ T_{wc} = (\Delta)^{1.21026} \times 0.00559035 \text{ [ton]} \]

Distribution of maximum shear force in wave trough (Fig.6.B);

\[ T_{wt} = (\Delta)^{1.00842} \times 0.0601052 \text{ [ton]} \]

where,

- \( M_{sw} \) is the maximum bending moment in still water,
- \( M_{wc} \) is the maximum bending moment in wave crest,
- \( M_{wt} \) is the maximum bending moment in wave trough,
- \( T_{sw} \) is the maximum shear force in still water,
- \( T_{wc} \) is the maximum shear force in wave crest,
- \( T_{wt} \) is the maximum shear force in wave trough,
- \( L_{pp} \) is the length between perpendiculars [m],
- \( \Delta \) is the displacement [ton].

### 3. CONCLUSIONS

All the expressions derived from the graphs are tested against other tankers and bulk carriers which are not used in this analysis. These tests revealed surprisingly good results and the expressions promise to be a valuable approximation for the maximum shear force and maximum bending moment in the preliminary design stage. It must be kept in mind that the ships which constitute the information base in this analysis are assumed to be fully loaded and the loads are assumed to be distributed homogeneously without any major discontinuity along the ship length.

In the wave crest situation, if the ship length is greater than 180 m., the maximum bending moment value calculated from the relevant classification society rule is lower than that suggested by this study. It should be remembered that the wave crest condition is defined by the Turkish and German Lloyd Rules with an additional wave bending moment distribution (Fig.7.A). On the other hand, in the wave trough condition the two distributions show good agreement (Fig.7.B).

### References


Appendix

STILL WATER

\[ Y = \text{pow}(X, 3.93675) \times 4.49021 \times 10^{-5} \]

Max. Bending Moment (t.m)

WAVE CREST

\[ Y = \text{pow}(X, 4.55772) \times 5.33522 \times 10^{-6} \]

Max. Bending Moment (t.m)

Figure 1
Figure 2
Displacement ( t )

Max. Bending Moment ( t.m )

Y = pow(X,1.50919) * 0.00872257

(A)

Y = pow(X,1.36507) * 0.0583981

(B)

Figure 3
Figure 4
Figure 5

WAVE TROUGH

STILL WATER
WAVE CREST

\[ Y = \text{pow}(X, 1.21026) \times 0.00559035 \]

WAVE TROUGH

\[ Y = \text{pow}(X, 1.00842) \times 0.0601052 \]

Figure 6
Figure 7

WAVE CREST

WAVE TROUGH