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DISCUSSION ON THE REPORT OF

COMMITTEE II.1

QUASI-STATIC RESPONSE

MANDATE

Concern for the quasi-static response of ship and offshore structures, as required for safety and serviceability assessments. Attention shall be given to uncertainty of calculation models for use in reliability methods, and to consider both exact and approximate methods for the determination of stresses appropriate for different acceptance criteria.

CONTRIBUTORS

Dr. D. Liu, Official Discusser

Prof. B. Boon
Dr. T.P.J. Mikkola
Dr. D. Gimperlein
Dr. W. Fricke
Prof. K. Suzuki
Mr. M. Toyofuku
Dr. P. Marshall
Prof. E. Rizzuto
Prof. N. Barltrop

Reply by:

Prof. Y. Sumi
Dr. Y. Iwahashi
Dr. P. Rigo
Mr. J. Waegter

Session Chair:
Prof. J.W. Lee

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detail. From a computational view point, efficient hierarchical modelling and automatical mesh generation methods for 3-dimensional solid analyses should be developed for this purpose.

2.2.6 Mr. M. Toyofuku (reply by Prof. Y. Sumi and Dr. Y. Iwahashi)

Mr. Toyofuku's first discussion also relates to the hot-spot stress calculation. In order to evaluate the hot-spot stress, we have to consider the effects of weld geometry. As was discussed by Dr. Mikkola, Dr. Gimperlein, and Dr. Fricke, several methods are proposed for the direct calculation of hot-spot stress. Although 3-dimensional analyses using solid elements are going to be more and more practical, analyses by using shell elements are common for design purpose at this moment. As Mr. Toyofuku has suggested, it might be useful to obtain some correlation between the results of shell and solid analyses based on systematic comparative studies.

With regard to our comparative study, besides the significant difference in the stresses at the weld toe between the solid element model and the shell element models, there is also a scatter in the shell element results. A possible reason for the variation is the difference of the element sizes used for the analyses. However, the coefficient of variation of stresses at the weld toe was calculated to be 5.4% for the results of shell element models, which seems to be relatively small comparing to other factors of uncertainty in the loads and the strength estimation.

In the end the committee thanks Mr. Toyofuku for his comment on the direct analysis procedure. As was recommended in our conclusion, the effects of assumptions and the expected variations in analyses should be studied in the future work of TC II.1.

2.2.7 Dr. P. Marshall (reply by Prof. Y. Sumi)

Dr. Marshall informed about an interesting on-going project on fatigue prediction of bulk carriers. We hope that the project is going to be successful so that the proposed method is verified by the measurements during the test voyages of the instrumented ship in a near future.

2.2.8 Professor E. Rizzuto (reply by Dr. P. Rigo)

We thank Dr. Rizzuto for his valuable comments that requires a reply in 2 steps. First a clarification is made to Eqs. (1) and (2) that are criticised, followed by a discussion showing a basic agreement with the Rizzuto's comments.

The equations discussed by Dr. Rizzuto are :

$$\left(\frac{M_V}{M_{VU}}\right) + 0.8\left(\frac{M_H}{M_{HU}}\right)^2 = 1 \quad \text{if} \quad \frac{M_V}{M_{VU}} > \frac{M_H}{M_{HU}} \tag{1.a}$$

$$\left(\frac{M_V}{M_{VU}}\right)^\alpha + \left(\frac{M_H}{M_{HU}}\right)^\alpha = 1 \quad \text{with } 1.50 < \alpha < 1.66 \tag{2}$$

with M_V, M_H the vertical and horizontal bending moments, and M_{VU}, M_{HU} the ultimate vertical and horizontal bending moments, respectively. Eq.(1.a) is an interaction equation between the vertical and horizontal bending moments proposed by Mansour *et al.* (1995). Eq.(2) is a similar equation proposed by Gordo and Soares (1995).

Basically the methods proposed by the two authors have a more general form than the equations presented by equations (1.a) and (2). For instance, Eqs.(1.b) and (1.c) represent the generalised form of the Mansour model. Equation (1.a) is only a simplified case based on numerical results obtained for 1 container, 1 tanker and 2 cruisers, and Eq.(2), with $1.50 < a < 1.66$, is based on 4 tankers. Therefore it is obvious that these formulations are not valid for all ships. Uncertainties of these equations for other ship types have not yet been evaluated.

$$\left(\frac{M_V}{M_{VU}}\right) + k\left(\frac{M_H}{M_{HU}}\right)^2 = 1 \quad \text{if} \quad \frac{M_V}{M_{VU}} > \frac{M_H}{M_{HU}} \tag{1.b}$$

$$k\left(\frac{M_V}{M_{VU}}\right)^2 + \left(\frac{M_H}{M_{HU}}\right) = 1 \quad \text{if} \quad \frac{M_V}{M_{VU}} < \frac{M_H}{M_{HU}} \tag{1.c}$$

with $k = \text{Function}(A_{side}, A_{deck}, A_{bottom})$.

We agree that for practical design, engineers are interested in relatively small horizontal bending moment ($0 \le M_H/M_V \le 0.3$) and not so much in the full range of variation: $0 \le M_H/M_V \le \infty$. It is true that the proposed equations are not focusing on the relevant practical range of M_H/M_V but on the full range. In that sense, the Mansour model differentiates two cases : $M_V > M_H$ and $M_V < M_H$ (Eqs.(1.b and c)). Note that Viner (1986) has studied the interaction between vertical and horizontal moment for $0 \le M_H/M_V \le 0.3$. His interaction curve looks like those proposed by Mansour or Gordo.

A third simplified formulation was also presented in TC II.1 report. It is the formulation of Paik *et al.* (1996) based on numerical results on 11 ships Eq. (3.a).

$$\left(\frac{M_V}{M_{VU}\cdot F_V}\right)^{1.85} + \left(\frac{M_H}{M_{HU}\cdot F_H}\right) = 1 \tag{3.a}$$

where

$$F_V = \left(1-\left(F/F_U\right)^5\right)^{0.5} \quad \text{and} \quad F_H = \left(1-\left(F/F_U\right)^{5.5}\right)^{0.4}$$

In order to be compared with the other two models, letting F=0, we obtain

$$\left(\frac{M_V}{M_{VU}}\right)^{1.85} + \left(\frac{M_H}{M_{HU}}\right) = 1\ . \tag{3.b}$$

We can compare equations (1.a), (2) and (3.b), and see how much these equations are different. The M_V exponent is, respectively to these 3 equations, 1.0 , 1.5 and 1.85 , and for M_H, 2.0; 1.50 and 1.0. It is clear that all of them are approximate and are only valid for a specific type and range of ships.

Regarding to Figure 2 (a) and (b) of Rizzuto comments, we completely agree with his point of view. Nevertheless we would like to mention that the simplified models (Eqs. (1), (2) and (3)) do not provide a direct estimation of Mu but only a way to assess that the wave bending moment (M_T) is smaller than the ultimate bending capacity (M_V). Moreover, we are not sure that these models are not able to behave like the dotted line of Figure 2b.

According to Figure 2 (a) we have :

$$M_T = \sqrt{M_H^{\,2} + M_V^{\,2}} \;, \tag{4.a}$$

$$tg(\gamma) = \frac{M_H}{M_V} \quad \text{or} \quad M_H = M_V \cdot tg(\gamma)\,. \tag{4.b}$$

From Eq. (1.b) , we obtain

$$M_V = \left(1 - k.\left(\frac{M_H}{M_{HU}}\right)^2\right) \cdot M_{VU}\,. \tag{5}$$

From Eq. (4.b) and Eq. (5),

$$M_H = tg(\gamma) \cdot \left(1 - k\left(\frac{M_H}{M_{HU}}\right)^2\right) \cdot M_{VU}\,. \tag{6}$$

From Eq.(6), we can calculate M_H (equation of second order). Substituting Eqs.(6) and (4.b) into Eq.(4.a), we can obtain,

$$M_T \le \text{Function}(M_H/M_V,\ M_{HU},\ M_{VU} \text{ and } k) = \text{approximation of } M_V \tag{7}$$

We do not believe that this approximation of M_V is always increasing as the continuous line in Figure 2b. The numerical results presented by Gordo and Soares (1995) on Energy Concentration confirm the Rizzuto's point of view that, in some cases, the most dangerous situation is the pure vertical bending moment (see dotted line of Rizzuto Fig. 2b).

2.2.9 Professor N. Barltrop (reply by Mr. J. Waegter)

We are aware of Prof. Barltrop's early work from 1984 and remember that the results showed a coupling between axial force and moments. The work performed by Buitrago *et al.* (1993) gives a thorough review of more recent work in relation to representing local joint flexibilities, and Buitrago presents parametric results for planar joints. His results cover single-brace, cross-brace and K-joints based on results from FE analyses. Buitrago found that the local joint flexibility can be modelled by three springs, one axial and one for each of two bending moments (in-plane and out-of-plane). Maybe the explanation lies in the fact that in the above model the springs are connected to the brace ends via a rigid link from the chord center line to the surface. Buitrago's model therefore also implies a coupling between axial force and moments.

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Edited by

T. MOAN and S. BERGE

Norwegian University of Science and Technology,
Trondheim, Norway

PERGAMON