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Ultimate Strength Analysis of Stiffened Plate Under Longitudinal Compression, Transverse Compression and Lateral Pressure

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Abstract: The ship hull can be considered as a thin – walled box gider constituted by stiffened panels. In order to research the ship ultimate strength, the ultimate strength of stiffened panel must be considered. Stiffened plates are typical structure of ship. Ultimate strength analysis of stiffened plate for the analysis of ships' structures. In present paper, the nonlinear finite element method is employed to predict the ultimate strength of stiffened plate model under longitudinal compression, transverse compression, lateral pressure.
Keywords: Stiffened Plate, Ultimate strength, Nonlinear finite element method

I. General introduction

Stiffened steel plate is the basic strength member in ship and offshore structures. Due to their simplicity in fabrication and excellent strength to weight ratio, stiffened plate are also widely used for construction of Land-based structures such as box girder and plate girder bridges. Since the overall failure of a ship hull is normally governed by buckling and plastic collapse of the deck, bottom or sometime the side shell stiffened panels, it is of crucial importance to accurately caculate the ultimate strength of stiffened panel in deck, bottom and side shell for more advanced structure design of ship structure.

Stiffened plates are typical structure of ship. In recent year, many researches on structural mechanics have attached a great importance to the ultimate strength of stiffened plate.
In this paper, a typical stiffened plate model of Rever - Sea ship structue will be taken as the research object using a commercial. The aim of the study is to investigate the ultimate strength characteristics of the stiffened model under combined loads. Based on the numerical results obtained a graph for the relationship between stress and strain.

II. Ultimate strength analysis of stiffened plate under combine load

2.1. Stiffened plate modeling for nonlinear finite element analysis

Dimensions and material properties of the stiffened plate model
Length of panel: a = 12800 mm
Breadth panel: b= 2800 mm
Thickness of plate:t = 15 mm
Yield stress of the material: σ_Y = 315 Mpa
Young's modulus: E = 205.5GPa
Poisson's ratio γ = 0.3.

2.2. Initial deflections

When this paper, the ultimate strength of stiffened plate under combine load , the initial deflection is considered on initial weak points while the influence of welding residual force is neglected. For the present study, the initial deflection of plating and stiffener web are assumed to be as the following formula (Jeom Kee Paik, Jung Kwan Seo, 2008).

$$W_0^p = \frac{b}{200} = 0.005b. \qquad (1)$$

Where W_0^P is the initial deflection of the plate, b is the long of the short edge or spacing between the longitudinal stiffeners.
The fabrication-related initial distortions of stiffeners are assumed as the following formula (Jeom Kee Paik et al 2008).

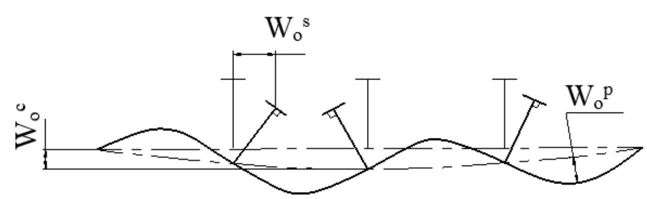

Fig 1. Stiffened plate with initial deflection

$$W_0^C = W_0^S = \frac{a}{1000} = 0.001a. \qquad (2)$$

Where W_0^C is the column-type initial deflection of stiffeners in the vertical direction, W_0^S is the sideways initial deflection of stiffeners in the horizontal direction and a is the stiffener length. In present study, the initial deflections are defined as shown in Fig. 1.

2.3. Loads and boundary conditions

Multi-point constraint way is applied as it can effectively imitate the boundary conditions of the structure. Multi-point constraint way means controlling the displacement of slave node by identifying the displacement of master node, by which all the slave nodes will have the same displacement. Here the reference master node is setting in the midpoint of the four sides. Slave node being the points of the four sides. Set reference point at the midpoint of the four sides. In this way, the displacement increment of all the slave nodes in section facing is controlled by controlling the displacement increment of masternodes.
For the present nonlinear FEA, the following boundary conditions are applied where U[x, y, z] indicates translational constraints, and R[x, y, z] indicates rotational constraints.

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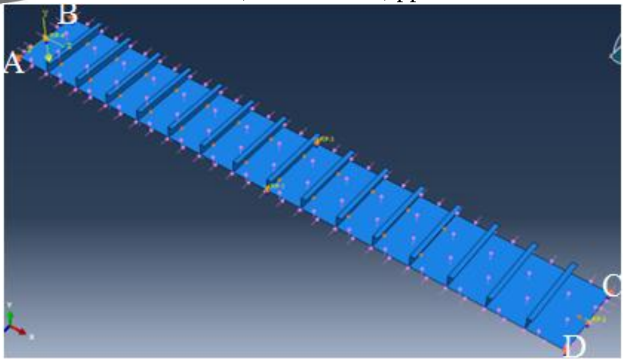


Fig. 2: Boundary condition

At B–C constraint Uy, Uz, and Ry, Ry; At B-C constraint Ux, Uy, and Rx, Ry; At A–D constraint Uy, Uz, and Ry; At C–D constraint Ux, Uy, and Ry.

At The BC side set support reaction force Fz in the z-axis, set support reaction force Fx in the x-axis.

2.4. Stiffened plate model analyze under different setting load conditions

Ultimate strength of tiffened plate under combine load: including longitudinal compression, transverse compression, lateral pressure. Caculation and analysis of ultimate strength of stiffened plate structsure. Use nonline finite element method to analysis of model.

This paper study the ultimate strength of stiffened plate under longitudinal compression, transverse compression, lateral pressure. It is calculated using the finite element software ABAQUS.

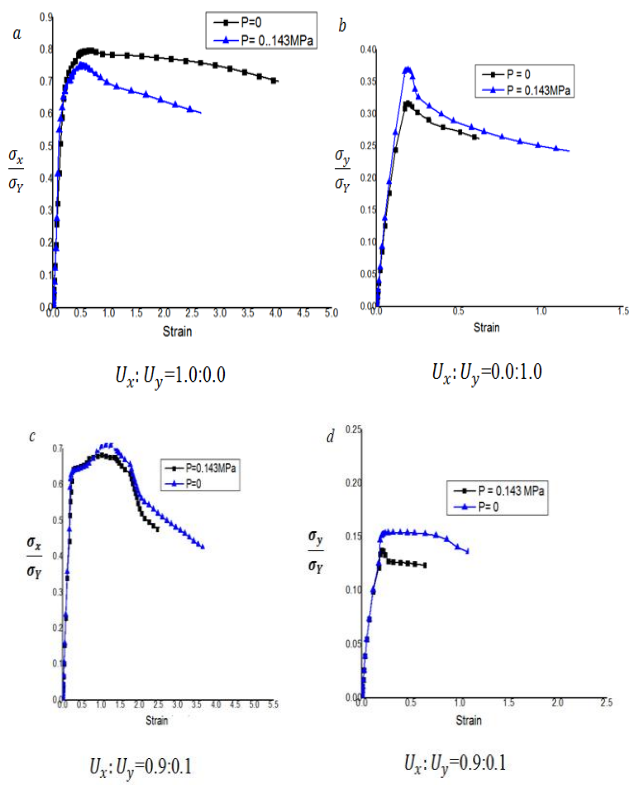


Table 1. Stiffened plate model under different load conditions

No	Water pressure P (MPa)	Ux：Uy
1	0	1.0:0.0
2	0	0.9:01
3	0	0.8:0.2
4	0	0.6:0.4
5	0	0.5:0.5
6	0	0.4:0.6
7	0	0.2:0.8
8	0	0.0:1.0
9	0.143	1.0:00
10	0.143	0.9:01
11	0.143	0.8:0.2
12	0.143	0.6:0.4
13	0.143	0.5:0.5
14	0.143	0.4:0.6
15	0.143	0.2:0.8
16	0.143	0.0:1.0

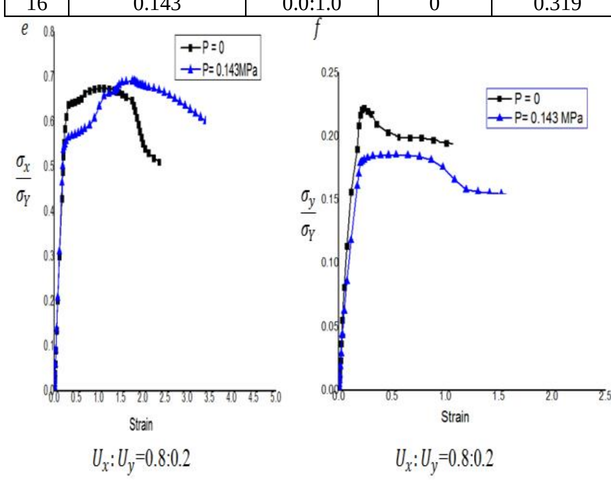
Table 1 shown ultimate strength under other longitudinal compression, transverse compression, lateral pressure. The load ratio unchanged during the calculation: Ux：Uy=1.0:0.0 and Ux：Uy=0.0:1.0.

2.5. Computational results

Computational results of stiffened plate under longitudinal compression, transverse compression, lateral pressure with the finite element method are shown in Figure 3 and Table 2

Table 2 Calculation results ultimate strength with different proportions of stiffened panels

No	Water pressure (MPa)	U_x： U_y	σ_x / σ_Y	σ_y / σ_Y
1	0	1.0:00	0.753	0
2	0	0.9:01	0.715	0.154
3	0	0.8:0.2	0.690	0.185
4	0	0.6:0.4	0.651	0.218
5	0	0.5:0.5	0.628	0.245
6	0	0.4:0.6	0.598	0.260
7	0	0.2:0.8	0.292	0.355
8	0	0.0:1.0	0	0.367
9	0.143	1.0:00	0.705	0
10	0.143	0.9:01	0.683	0.137
11	0.143	0.8:0.2	0.674	0.172
22	0.143	0.6:0.4	0.625	0.196
13	0.143	0.5:0.5	0.609	0.220
14	0.143	0.4:0.6	0.530	0.241
15	0.143	0.2:0.8	0.286	0.295
16	0.143	0.0:1.0	0	0.319



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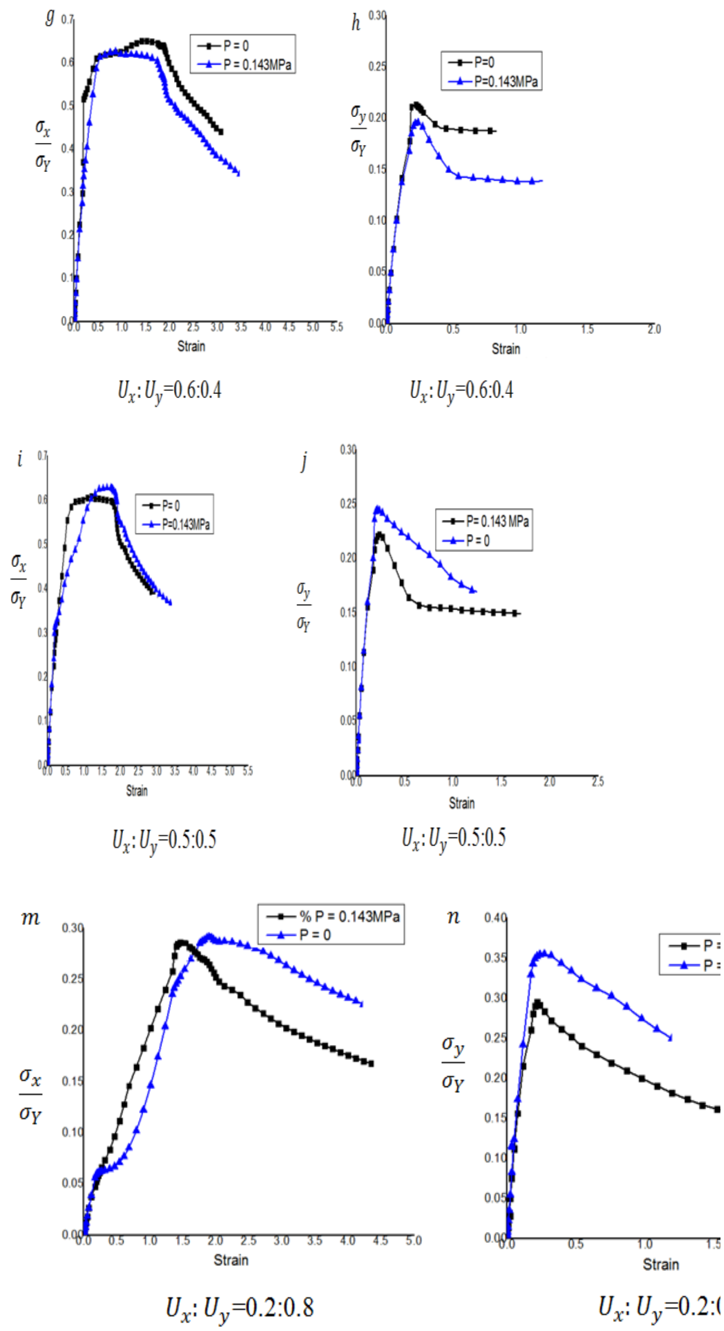

Fig 3. Stiffened plate model under different load conditions of stress - strain curve.

Fig 3a, c, e, g, i, k, m - longitudinal compression of stress – strain cuver

Fig 3 b, d, h, j, l, m longitudinal compression of stress – strain cuver

Computation results of ultimate strength of stiffened plate model are shown in Table 2.

From computation results of ultimate strength of stiffened plate model in table 2, we can buil nexus of ultimate stress in x, y axes as shown in Fig 4 and Fig 5.

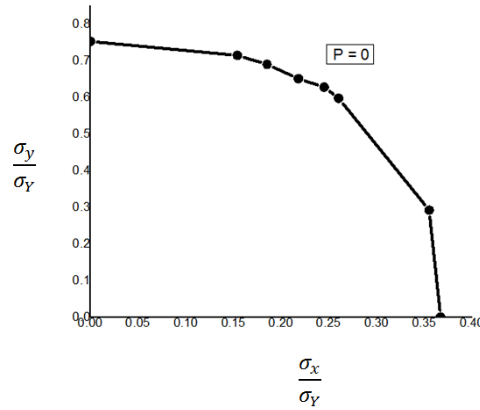

Fig 4. Comparing of calculation results
(P = 0 Mpa)

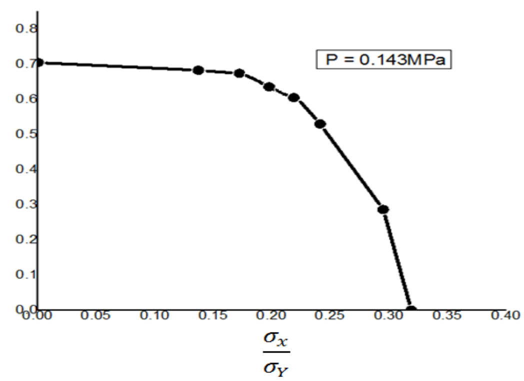

Fig 5. Comparing of calculation results
(P = 0.143 Mpa)

Fig 4 and Fig 5 and calculation results, with the side effects of water pressure, the ultimate strength of the horizontal structure is significantly decreased. Thus lateral water pressure on the ultimate strength of the existence of a negative impact.

Calculation results show in this studying,if the stress in the curve, the structure remained safe and if the stress level coincides outside curve, the structure has been stretched to the limit state. In this case, the structure can not continue working. This theory has an important role in design ship structure.

III. Conclusion

This paper studies nonlinear finite element method for ultimate strength analysis of stiffened panels under longitudinal compression, transverse compression, lateral pressure, initial defect of the model and boundary conditions…

In this paper, ultimate strength of the stiffened plate in a River-Sea Ship hull structure is calculated by FEA program. It aims to explore the influence on the ultimate strength which is made by different load types and initial deflection, after accounting the nonlinear finite element of the stiffened plate model. Finally to put up with a set of complete accumulation method, laying a foundation for accounting the ultimate strength of stiffened plate in ship structure.

This paper studies ultimate strength of stiffened plate laid the foundation for the calculation ultimate strength of bottom structure, deck structure…in the ship hull structure.

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