Influence of the Cut-out Shape on the Fatigue Ship Structural Detail

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Abstract: Damage structured mostly occurred caused by the crash. One of the causes of the accident is the fatigue of the hull side of the ship. The composition of the side hull structure comprises a detailed structure that often experiences a wave pressure load failure. In this study, the load given is the dynamic load of the wave. The structural pressures generate the stress used to evaluate the strength and determine the fatigue life of the structure. This study involves modelling details structured with 3 variations of the model. The modelling is conducted using Finite Elements Analysis software by calculating the pressure load that adjusts the location of the model. The model of each cut-out is created variations. These variations resulted in the estimate fatigue life. The fatigue life calculation used several approaches i.e. Simplified Fatigue Analysis and Fracture Mechanics.

1 INTRODUCTION

Generally, the ship structure may be longitudinally stiffened or transversely stiffened with stiffeners and bulkheads. In its entire life is complex structure will be accepted to distinguished load conditions beginning with the ship launching and continuing with each sailing and interval; docking for survey and repair (Joem, 2010). Although a ship may be designed to withstand the ultimate imposed by a wave, failure can occur due to apparently low stresses generated by the continuous load (Mathews, 2013).

Fatigue of structural components in ships is a long known problem and has been investigated in depth owing to its relevance in design. Fatigue design became an important subject due to use of higher strength materials, serve environmental conditions and optimized structural dimensions (Hughes, 2010). The factors with contributing to the fatigue of ship structure are the local configuration and geometry of details structured (DNV, 2010). In ship structure, a major fraction of the total number of fatigue damages occurs in panel stiffeners on the ship side and bottom on the boundaries of ballast and cargo tanks. In tankers, cracks occur mostly on the side longitudinals at the connections to transverse webs (CSR, 2012).

The aim of this paper is to evaluate fatigue life using three geometry shape of slot design. Analyze from the model using finite element analysis. The goal of the Finite Element model was to successfully predict the stress value with various of geometry shape. The best of geometry shape can be assumed based on the age resulted from the calculation process.

2 LITERATURE REVIEWS

In general, the design of a construction must be able to withstand loads and other factors that cause failure in the structure itself. At sufficient loads, secondary construction in particular, on construction details can be made simple and save production but still meet the required strength requirements. Based on several construction designs in this research, an evaluation of the strength and age of the cut-out design was carried out. cut out is a structure on a ship classified as a small construction on a ship or commonly called structural intersection. Cut out itself has an important role as a constituent of construction.

Cut out is a part of the construction that serves to blow reinforcement to another structure or support, for example, which is located in a non-impermeable bulkhead in addition to providing strength to the construction ring which is circular in a transverse position. Cut out is located on the web frame or side

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transverse. The cut-out design is adjusted to the shape of the profile that penetrates into it. Cut out has several types of shapes for L profiles as can be seen in Figure 1.

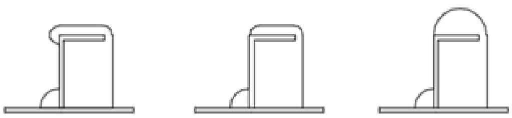

Figure 1: Cut-out design shapes.

2.1 Loading

In this research, the quasi-static loading is used, this type of load is a compressive load caused by waves regardless of the roll angle. Then the formula used to calculate is according to the equation as follows (CSR, 2012):

$$P_1 = 2 f_{prob} f_{nl-P1} \left[\left(P_{11} + \frac{135 B_{local}}{4(B+75)} - 1.2(T - z) \right) f_1 + \frac{135 B_{local}}{4(B+75)} f_2 \right] \quad (1)$$

The load applied to the model is added with a dynamic pressure load in the tank to see the response given from the cut-out. Calculations used are appropriate with the rules.

2.2 Stress

The level of accuracy in the process of finite element analysis is directly proportional to the increase in the number of elements used. But the increasing number of elements used also affects the amount of time needed during the analysis process. In many cases, this problem is solved by changing the element size to obtain more detailed results in the area of the structure. The relationship between the number of elements can be seen in Figure 2.

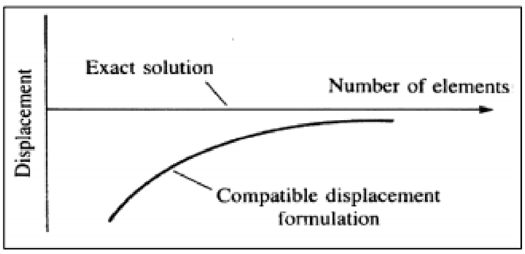

Figure 2: Diagram number of elements and function parameters.

Many variations between structure and load make it difficult to determine the size of elements that can provide results with the best accuracy. Determination of element size is based on the experience carried out in the analysis that has been done before.

Fatigue is a typical phenomenon in structures (both structures on land and structures located in waters), especially those made of steel material. Fatigue is a combination of dynamic local stresses (residual stress), defects, surface roughness, and other parameters. In welded structures, the area on the weld is the weakest condition, where crack growth begins. Local stresses that cause fatigue include nominal stress, stress hotspots, and notch stress. The nominal stress is a conventional approach to fatigue analysis, where the type of stress that occurs is included in a beam theory for simple structures so that nominal stress equations are formulated as follows:

$$\sigma = \frac{F}{A} \quad (2)$$

Where,

σ = nominal stress (MPa)

F = Force (N)

A = Area (mm2)

Generally, the loading can be divided into two parts, namely constant-amplitude loading and variable amplitude loading. The constant-amplitude loading can be seen in Figure 3.

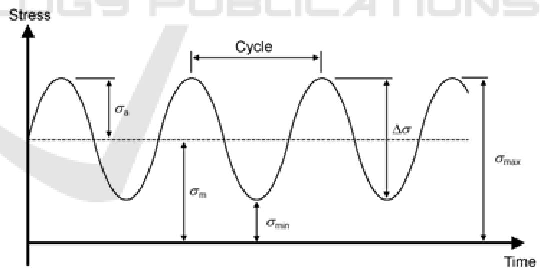

Figure 3: Constant-amplitude loading.

The main parameter in fatigue calculation is the stress range (Δσ), mean stress (σm) and stress ratio (R). The stress range is formulated as follow

$$\Delta\sigma = \sigma_{max} - \sigma_{min} \quad (3)$$

$$\Delta\sigma = 2 \,.\, \sigma_a \quad (4)$$

The mean stress and stress ration are formulated as follow

$$\sigma_m = \frac{(\sigma_{max} - \sigma_{min})}{2} \quad (5)$$

$$R = \frac{\sigma_{min}}{\sigma_{max}} \quad (6)$$

In the type of loading with variable amplitude loading different from the load that occurs in the type constant amplitude loading. Variable amplitude loading has a very complex function, where the probability of the order of magnitude of stress range during the interval has very little time. The type of loading with the variable amplitude loading can be seen in Figure 4.

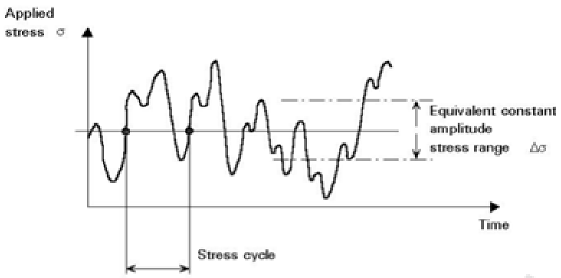

Figure 4: Variable-amplitude loading.

3 METHODOLOGY

Fatigue is a very complex analysis of ship structures problem. It results from many factors along with the following are most important is the interaction of structural element geometry, material (mechanical properties, it's structured), loading mode (its magnitude, effect of condition, mean stress), and stress directions. The models for the local detail just discussed. With assumptions are shown in Figure 5, the load contributions are reduced to deformation of the web frame due to external sea water pressure, internal pressure exerted by the vertical acceleration of cargo oil, and sea pressure on the side shell (Elhewy, et.al, 2016).

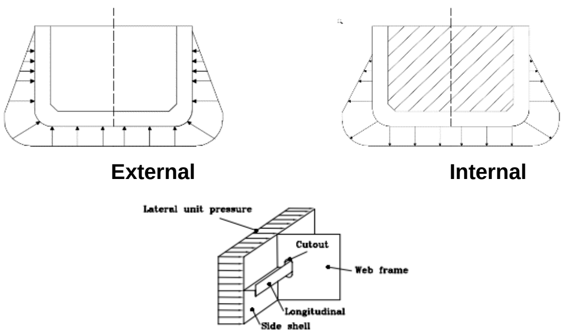

Figure 5: Loading condition.

The finite element analysis is carried out to analyse the directions stress of details structured. The variations of details structured were modelled using finite element software. In this case, using three-dimensional finite element models were developed. twenty nodes solid element brick with six degrees of freedom per node was used to all the models because it is considered the most stable. The local structure models were analysed for various structural details geometry. The models and meshing process of details structured are shown in Figure 6.

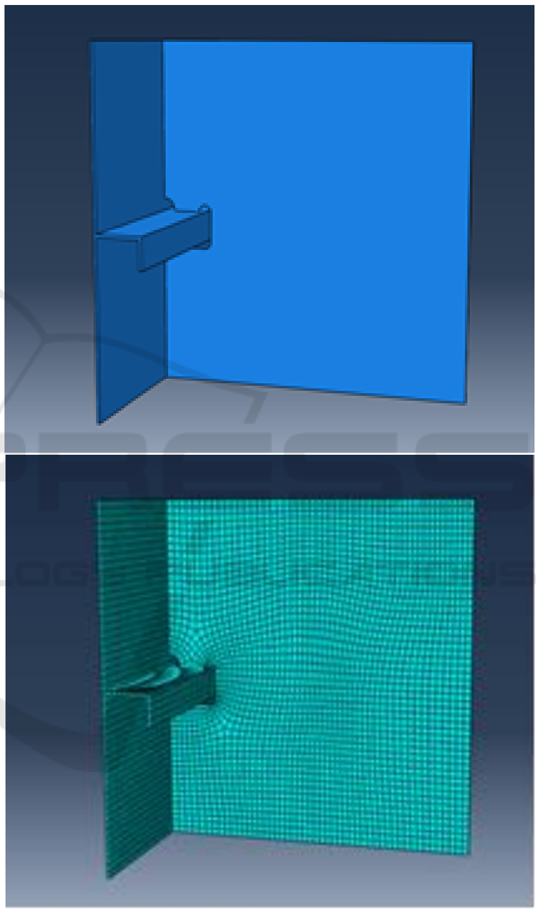

Figure 6: Structural finite element model.

By loading on the shell, load from sea pressure and inner tank pressure will be transferred to the variation of models from shell and web frame (Bai, 2003). The boundary conditions pin (displacement x, y, z =0) and free rotations or following Figure 7. Because, the structured of web frame and side shell have the free edge in vertical and horizontal following plate, i.e. the y-axis (web frame) and z-axis (side shell). Defining boundary conditions is one of the most important steps in finite element analysis. For this condition or local analysis models, the boundary conditions imposed by the surrounding structures should be based on the deformation or forces calculated from the global models (ABS, 2002).

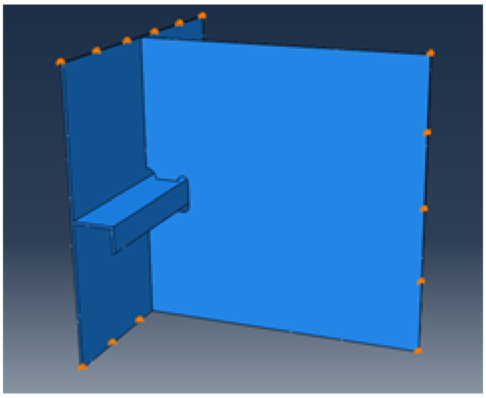

Figure 7: Boundary condition.

4 RESULT AND DISCUSSION

In this paper, the fatigue life calculation can be accomplished in two methods. First, the value of maximum stress as shown in Figure 8 to Figure 10 determined to calculate fatigue simplified method. The second step is the calculation of fatigue load cycles from initial to the final crack. The calculation is carried out to estimate the number of load cycles that occur each year for a ship with a crack in details structured.

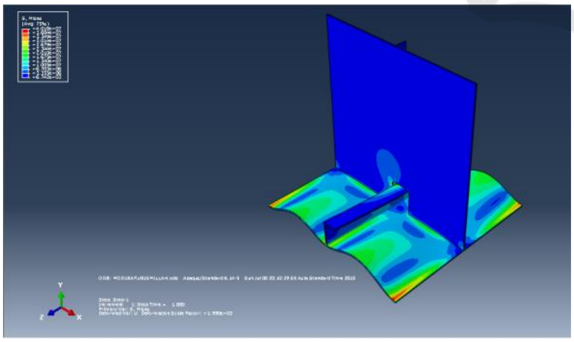

Figure 8: Stress distribution on the 1st design cut-out.

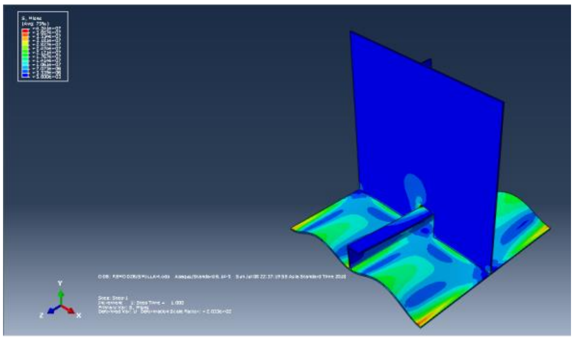

Figure 9: Stress distribution on the 2nd design cut-out.

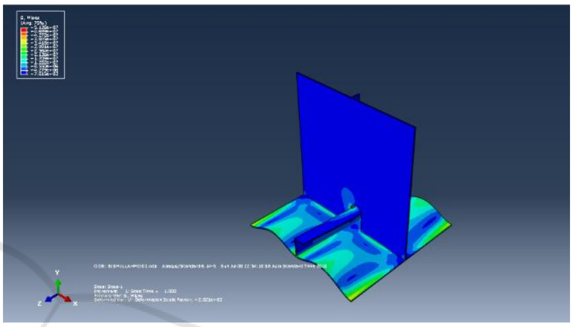

Figure 10: Stress distribution on the 3rd design cut-out.

According to the maximum stress on the design cut-out the fatigue life of the structural details was calculated with two methods. The fatigue life calculation result using simplified method is on the design cut-out are given in Table 1.

Table 1: Fatigue life calculation using the simplified method.

Cut-out design	T (Year)
1st Model	77
2nd Model	65
3rd Model	36

5 CONCLUSIONS

According to the analysis results presented in Table 1 and Table 2, it can be concluded that the lifetime in the 1st design is 77 years is the longest time. Therefore, the variation of the cut-out design can be recommended for details structured is the 1st design.

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