Structural Analysis of Cradle Construction

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***Abstract*- This present paper gives the analytical overview of stress and fatigue behaviors for cradle construction. The main objective of this research is to analyze the static and fatigue characteristics of cradle constrcution under designed maximum working load. The static characteristics studied here are equivalent stress and total deformation, while the fatigue characteristics are safety factor and estimated stuctural life. The finite element method is used to analyze both characteritics. The cradle construction is modeled as solid beam element. The maximum working load used is modeled as two concentrated loads and the support type used is cylindirical type. Results show that all characteristics comply with the standard requirements, especially for yield requirement and deformation. However, due to small value difference of safety factor, it is advisable to reduce the maximum working load.**

Keywords— equivelent stress; total deformation; fatigue; safety factor; finite element method; structural life

I. INTRODUCTION

Cradle is part of slipway construction having significant role in ship docking and launching process. In most steel construction activities, the minimum requirements regarding stress are very mandatory to be considered. Several types of stress to be considered such as bending stress, shear stress, axial stress and combined stress [1]. All stresses have to be fulfill the minimum criteria of allowable stress, which is function of yield criteria. Due to cyclic load applied, the fatigue characteristic should be considered also in cradle construction other than static characteristics.

The implementation of finite element method for analyzing stress and fatigue behavior of steel structure have been widely used. Hu, *et al.* [2] have used the finite element to investigate the ultimate behaviors of steel heavy clip-angle connection. Hu [3] also implement the finite element method combined with LRFD method used to evaluate the design and strength of critical gusset plate in steel bridge. Ye *et al.* [4] have studied the fatigue life assessment of steel bridge. He used the finite element method to determine the stress concentration factor. Aygul [5] also analyzed the fatigue of welded structure using finite element method. He has developed the hot spot stress method to accurately estimate the load effects for fatigue strength. Currently, the classification societies have issued special rules and regulation in term of finite element method using in ship and offshore structure design [6-7].

II. CRADLE CONSTRUCTION

Figure. 1 shows the model of cradle construction. The cradle is costructed by structural steel with 7850 kg/m^3 density and 3.55 x 10^8 Pa yield strength. The cradle construction is designed to be able to lift 50 kN weight. The length of cradle is 2.5 m totally.

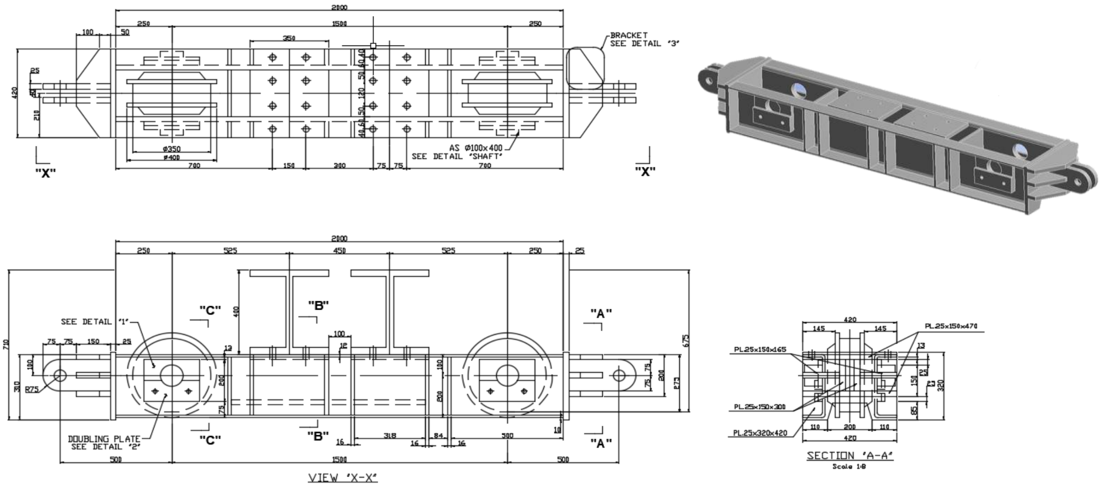


Figure 1. Cradle Construction

III. Stress and Fatigue of Steel Structure

A. Stress in Flexural Beams

In every vertical section of a loaded horizontal beam a shear force and/or bending moment will occur. The effect of developed shear force and bending moment is occurrence the internal resistances of beams. The internal resistances are function of the shape and area of the cross section of the beam. It will be expressed as shear stress and bending stress [8]. Equation (1) is general shear formula. It is used to determine the magnitude of shear stress. Equation (2) is general flexure formula and it is used to determine the magnitude of bending stress [8].

$$\sigma_s = \frac{VQ}{Ib} \tag{1}$$

$$\sigma_b = \frac{Mc}{I} \tag{2}$$

σ_s is the horizontal (vertical) computed shear stress on any given plane of a given cross section of beam (psi, ksi, Pa), σ_b is the bending stress developed at the outer fiber (psi, ksi, Pa), V is the computed vertical shear force at given cross section (lb, kips, N), Q is the statical moment about the neutral axis (in^3, m^3), I is the moment of inertia of the entire cross section with respect to neutral axis (in^4, m^4), b is the width of the cross section (in, m), M is maximum bending moment due to external loads (in-lb, ft-kips, N.m) and c is the distance from the neutral axis to the outer fiber (in, m). The developed stresses above have to comply with the minimum requirement of allowable stress. For beams and other flexural members, the magnitude of stress has to be less than 0.66*Fy* for bending stress and 0.4 *Fy* for shear stress [1].

In complex structure, the external loads applied on streel structures will result many types of stress. The developed stresses will no more acting alone but will interact each other. It means that the developed stresses are combination from several types of individual stress. One of combine stress types is equivalent stress or von Mises stress. The equivalent stress is constructed by combination of normal and shear stress developed on planes. Eqution (3) is the formula used to calculate the equivalent (von Mises) stress [7]. σ_x and σ_y are element of normal stress and τ_{xy} is element of shear stress.

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2} \tag{3}$$

B. Beams Deflection

When a simple beam is subjected to vertical loads, the beam will not only create bending but also will sag or deflect [8]. There are two basic methods can be used to calculate the deflection of beam, the formula method and moment-area method. The magnitude of deflection of beam should be less than the magnitude of allowable deflection considered by codes or standards. For example, the allowable deflection according to AISC [1] is 1/360 of span.

C. Fatigue Assesment of Steel Structures

The three major fatigue life methods used in design and analysis are the stress-life method, the strain-life method, and the linear-elastic fracture mechanics method. These methods attempt to predict the life in number of cycles to failure, N, for a specific level of loading. Life of $1 \leq N \leq 10^3$ cycles is generally classified as low-cycle fatigue, whereas high-cycle fatigue is considered to be $N > 10^3$ cycles. The stress-life method, based on stress levels only [9].

IV. Finite Element Analysis

Finite Element Analysis (FEA) process has been thought of as following the logic set out in Figure. 2. In this overview the four input parameters i.e. geometry, materials, loading and constraint are regarded as having similar functions to produce stress and fatigue life of construction.

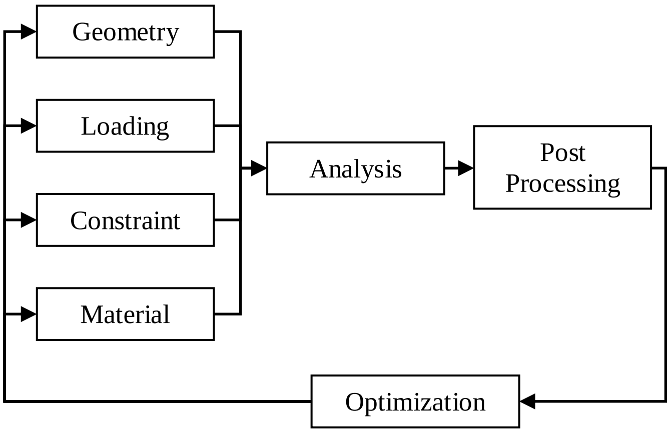


Figure 2. Flowchart Of FEA Process

A. Finite Element Modeling

Geometry model of cradle construction was developed according to dimensions in Fig. 1. Main body structurals and other supported structurals are modeled as 3D solid element. Mechanical properties of the structure is taken based on S355 properties as shown in Table 1. The loads is modeled as two concentrated loads.

Table 1. Mechanical Properties Of S355 Material

Mechanical Porperties	**Value**	**Unit**
Density	7850	Kg/m^3
Tensile Yied Strength	3.55E+08	Pa
Tensile Ultimate Strength	4.60E+08	Pa
Young's Modulus	2.10E+11	Pa
Poisson's Ratio	0.3	-

B. Meshing and Boundary Constraint

The next step after developing the 3D solid model of cradle construction is performing meshing process. In order to gain the best result of meshing, we have to properly define the boundary conditions. Model is constrained using frictionless constrain type located in area of wheel housing. With refer to the cradle operation capacity, the total load of 50 ton (include weight of H-Beam) is applied and distributed in two locations as two concentrated loads. Fig. 3 shows the load and constrain modelling of cradle construction. The coarse global meshing in this analysis is generated at element size of 10 mm with total number of element 199,343 element. The element is defined by 356,039 nodes while each node has three degrees of freedom. Result of meshing is shown in Figure 4.

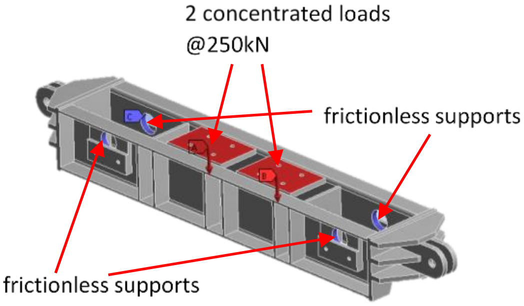
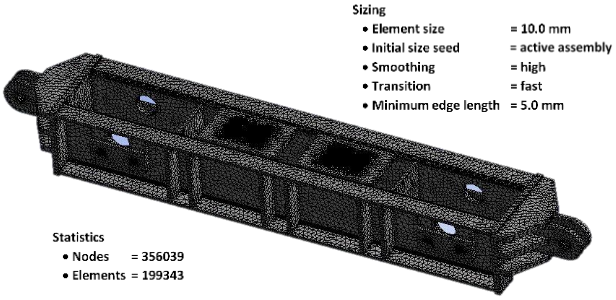


Figure 3. Load and Support Modeling



Sizing
- Element size = 10.0 mm
- Initial size seed = active assembly
- Smoothing = high
- Transition = fast
- Minimum edge length = 5.0 mm

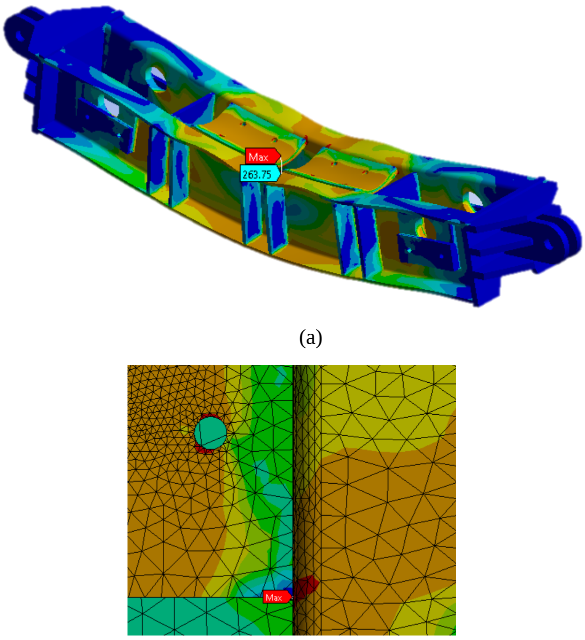
Statistics
- Nodes = 356039
- Elements = 199343

Figure 4. Meshing Computation Result

V. RESULT AND DISCUSSION

The performed analysis results show the distribution or contour of occurred Von-Mises stress for the whole structure based on applied load and constraint described in the previously section as well the deformation. The Fig. 5 shows the analysis result for global structure of cradle construction. Fig. 5a shows the distribution of von-Mises stress developed and Fig. 5b shows the developed maximum stress magnitude in specified location. The magnitude of maximum von-Mises stress resulted is 263.75 MPa. The location of maximum stress occurred at the connection of pad-plate and side body of cradle. The magnitude of safety factor is 1.34, since the yield strength is 355 MPa. The magnitude of total deformation of cradle construction is 1.248 mm (Fig. 6). This value of total deformation is less than the value of allowable deformation according to AISC [1] requirement (6.94 mm).

The expected damage can be computed if the distribution of stress ranges and intensity of cycles are known. The cradle construction, especially at the maximum stress location, has a number of cycle of 27,547 cycle until failure (Fig. 7). Considering the operating time of the cradle construction for ship launching 2160 cycle per years, the actual cycle also can be estimated. By using the estimation of 10 years design lifetime, the final result of this fatigue analysis shows the actual lifetime is exceed the value i.e. 12.71 years.



(a)

(b)

Figure 5. Von-Mises Stress (a) Maximum Stress In Specified Location (b)

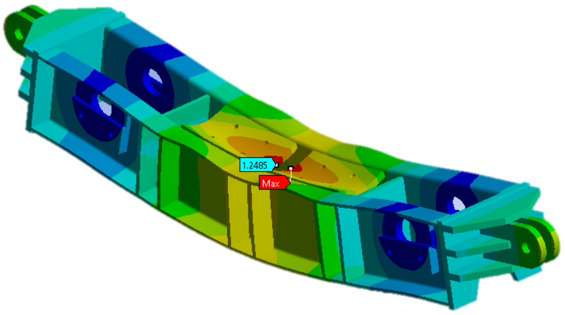


Figure 6. Total Deformation

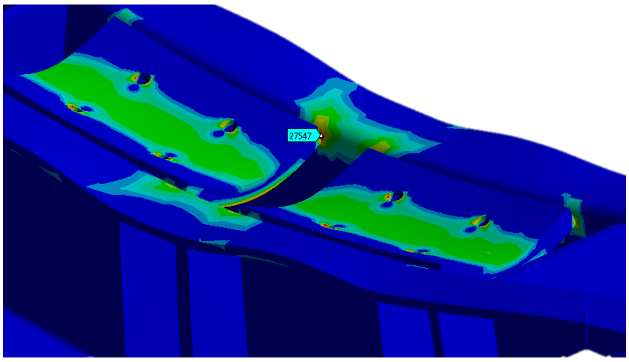


Figure 7. Cycle To Failure

VI. CONCLUSIONS

The numerical study using Finite Element Analysis was conducted. The results of stress calculated show that the use of finite element method in analyzing the static behaviors of cradle construction both equivalent von-Mises stress as well total deformation able to represent its strength capacities due to real operation mode. Further Fatigue Analysis determined by stress-life approach is done on cradle construction. It is found that the construction can withstand the maximum number of designed fatigue cycle before failure.

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