Fatigue Life Estimation of Ship Structure of Tanker on The Operational at Peat Water and Marine Behavior

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ABSTRACT

Eventhough if the working load did not exceed on the limits strength of material but that was repeated and continous in the long time that can make failure in the structure. This condition is referred as fatigue failure. This article focus on strucure of tanker. The repeated load could come from wave or current at the sea, load and unloading operation on the ship or could come from vibration that continous from engine room. Observation would be made especially for the vessel was operating in the multi environment at the peat water and sea water, since the area in the Riau river fed bay peat water. Fatigue testing was conducted by cantilever rotating bending whereas while speciment test ratated some peat water or sea water was flowed using pumps.

KEY WORDS: *Peat Water, Sea Water, Fatigue .*

1.0 INTRODUCTION

1.1 Background

Along the development of technology recently utilization the finite element method having very significant development that tends to be used by most designers for various reasons. Coupled support of the computer program a collaboration with the finite element method can generate simulations for engineering in the form of an actual system model approach. It is advantageous in terms of financing and reduce the risks especially for extreme conditions ie nuclear reactors, pipe installation by flowing a high-temperature liquid chemicals or other hazardous conditions.

When one construction is made the question have to answer is how long the lifetime. So it is important to be able to estimate when the parts of a construction can still be used or should be replaced, (Courtin *et al.*, 2005). At first S – N curve is used to predict the lifetime of a construction, which is a material characteristic curve results from testing and connect stress that works against the number of cycles until failure. However, in many cases a failure actually occurs before the lifetime life is reached or the number of cycles that occur is small.

Some researchers have tried to approach with Linear Elastic Fracture Mechanic (LEFM) such as using Paris equation of da/dN. This equation calculates rate of crack propagation as a source of failure that can be predicted when a failure would occur. This theory states that failure occurs due to presence of cracks and followed by crack growth , usually known as failure of structure due to fatigue crack growth. However, this ways effectively if the cracks can be observed with a least $length \geq 1\,mm$.

In addition other approaches with the Intencity Stress Factor (SIF), which based on calculate working stress by loading conditions while existing cracks, this concept can be applied to condition of opening (I), sliding (II), or tearing (III). The result was shown an increase in the concentration stress indicate highly by difficult manually counted because singularity at crack tip. Otherwise many disainer was use finite element method a solution to this problem.

Some of them are (Courtin *et al*., 2005), using Abaqus software to calculate SIF with the approach through the J integral contour, to the compact test spesiment (CT) and a shaft at the ellipse crack. (Bergan and Lotsberg *et al*., 2006), calculate J integral numerically and compared with experimental for various ratios of crack spacing to the thickness (a / W). While (Tronskar *et al*., 2000), using the finite element analysts and some programs to to test assumption that the failure was initiated by fatigue crack propagation that growth in the weld toe through the HAZ and continuing into the parent metal in FPSO structure.

The important thing to get attention from the brief description above is needed a different approach for loading conditions. It still uses the concept uniform-distribution load that be seen in the form constan amplitude or overload amplitude. The real conditions would be approach like occuring actually, so we need a different oncome loading conditions that work particular especially a dynamic load as experienced by the FPSO.

Muvariz MF and Jaswar (2013), has researched characteristics of fluid around the round-shaped FPSO by Computational Fluid Dynamics way (CFD) code based on the Reynolds Average Navier-Stokes (RANS) equations and leveraging Fotran language whereas hull grid is output from Maxsurf software. It turns out the critical found in Stern ($0.6 < X/(L/2) < 1$), while the other results of pressure distribution around the hull, axial velocity, and wave elevation value while detect using Froude number. But this study needs to be developed in order to visualize the results more meaningful.

Finally this study will attempt to obtain magnitude of external load on a floating marine structure with finite element method through concept of fluid solid interaction using Computer Fluid Dynamic (CFD). External load in form of pressure or force will be used as input for commercial-software of Abaqus. So the results are expected to predict the fatigue life of floating structure more accurately.

1.2 Problem Statement

Those parts of the structure have the load much greater than the other, so the stresses will be concentrated here. This condition will getting worse and can be fatal if the part with a high stress intensity are cracked. Probably any small cracks is always possible it could be due to defects in materials or process of assembling in field. Cracks can grow and develop so that the whole structure would collapse.

Selection of the appropriate method in determining critical part was to trim the time and cost certainly should be a good level of accuracy. The best solution to approach is by using finite element method (FEM) take advantage a commercial program, of Abaqus. This study attempted to solve difficulties in determining the critical point and further try to simulate, magnitude of critical stress intensity at the crack tip if there was in that section.

1.3 Research Objectives

Some objectives would be concern in this research are as follows :

- Analysis external loading around the hull using CFD
- Determination of the appropriate mesh elements in determining the stress intensity with J contour integral method.
- Utilizing finite element method to determine the part of structure with the highest stress intensity or critical point.
- Determine the magnitude of stress at the crack tip and some surrounding areas.
- Simulate the loading condition with a crack, to be predicted fatigue life of the construction.

1.4 Scope of Study

There are two reviews that will be conducted while the research focus to combine the two methods to obtain a solution to the about fatigue life prediction of a floating structure. The first will examine the response of a floating structure because of the burden they experienced hydrodinamik the finite element method. The output of fluid structure interaction is expected to be a pressure or force that would be used to estimate the fatigue life of the floating structure by utilizing commercial software Abaqus.

2.0 LITERATURE REVIEW

In fact load on the structure of vessel during operation is dynamic, that can be sourced from changing in load current condition of cargo or ballast, the movement of ships at sea and surely from the engine itself. This tends to raise vibrations due to a periodic load on the structure, that can make development the cracks known as fatigue conditions or local progressive damage on structures. Study on fracture cause of failure in the ship structure has occurred since the early 1900s. (Rolfe ST., 1975) analyzes comprehensively about the criteria of hardness (toughness) to the hull that can be used for steels with varying levels of strength. In fact the stress concentration always occurred in the construction of complex structures by welding, such as ships. Local high voltage resulted in a discontinuity or defect will occur in the hull.

Analysis of crack initiation and crack propagation in ship structures has been conducted since 1998 (Andersen, 1998). (Ayyub and Souza, 2000) analyzed the fatigue life of ship structures based on reliability. Analysis of ship structures experienced an increase. At the beginning of the study focused on the behavior of crack initiation to failure, until the present analysis of ship structures lead to structural reliability and risk in the event of failure of the structure.

Application of fracture studies with fracture mechanics of elastic plastic approach would be more appropriate to use to analyze the behavior of embedded cracks and deformation properties of the material has a larger plastic after accruing continuous loading of a material such as Ductile. As we know that the materials Ductile material is often used as the compiler of bed material off the building structure. Based on previous research done on the tubular structure (Aulia, 2005) crack propagation behavior has adapted to the analysis results presented by (Broek, 1987) analysis based on elastic plastic mechanics fracture. This method is suitable applied in the analysis fracture in offshore structure.

According to (Barsom, 1987), cracks have been investigated in several classes of tankers. Even though according to research by (Wang, 2009) of some material and the formulation of crack propagation, propagation behavior will be more clearly observed by including a load factor of the ratio of the work.

Utilization of finite element method was also carried out by (Tasdemir and Nohut, 2012) to find high local stress concentration by comparing value from the global mess, fine mess and stress concentration. Topic case was a component a web conection between the vertical side and main deck, at the structure Pure Car Truck Carrier (PCTC), whilst a review of fatigue analysis and fatigue life is approached by hot spot stresses.

Monitas system (advisoring monitoring system) is built to predict fatigue life of a structure by compare with design calculation and correcting some deviations from assumptions after conducting observation in field. (Jeroen and Miroslaw, 2010) collected some data from the offshore FPSO Glas Dowr

(South Africa), fatigue load data, observation load on the hull, position stress of concentration, frequency wave motion and environmental influences. So the operator can take necessary actions to assure the protection and construction has a long lifespan.

Fatigue life can be modeled as a random variable because it is difficult to predict with precision. Like on a floating failure could come from fatigue damage. Damage normally found at the point with high stress concentration in the welding condition (Ang *at al*., 2001) proposed a practical procedure after the approach using Weibull distribution and the S-N curve relationship with criteria Miner cumulative damage using analytical model LNG floating structure and double-hull tankers. The result was obtained reliability level 0.85, is lower than on the land structure which is usually above 0.9. Further investigation needs by observe the structural response about environmental influences.

Distribution compression residual stress is influenced by overload and that is take retardation on fatigue crack propagation . (Jo Y.C. *et al*., 2007) had observed by basic teory plasticity at the crack tip from (Irwin GR, 1960), and made of modelling model in finite element method in elastic-plastic analysis accordance with the standards ASTM E647 to determine the Stress Intensity Factor (SIF). While using variation load : constant amplitude and overload to get close environmental fluctuating load in real conditions.

By the approach of mechanical failure theory the fracture start with nucleation in micro scale and followed by crack initiate step while in physically visible of crack propagation. (Lee *et al*., 2008), take advantages from this concept to analyze fatigue on stainless steel using finite element method with reference of S – N curve, material properties and constants of material. The results are validated using tensile curve of material STS 304, so it's worth to observe the characteristics of fatigue.

Kozak J., and Zbigniew G., (2011), is study over again to find analytical solution that may be hidden in the measurement of fatigue and fatigue life design while approach with hot spot stress or notch stress and a design approach uses σ-N curve. The curve slope on tangents will show the crack growth rate in three zones; I (initiate), II (propagation), III (damage). This propagation concept would meet the rules of the Paris law.

It's worth need to compare experimental and industrial process of result at welding connection. Until conditions are known where the position of crack initiate and crack propagation respectively. Used concept spring line in the software of vericrack, (Lebailif. D., *et al*., 2005) was done based on finite element method and continued with experiment using aluminum material. Results accordance with the approach of Paris law.

While using concept of linear elastic fracture mechanics (Souza and Ayyub 2008) investigate fatigue life of ship structures. Developed in Paris law to observe the propagation of crack and fatigue failure due to residual stresses during the process of hull in fabrication, and they advice to make improvements Paris equation with the stress intensity by superposition.

3.0 RESEARCH METHODOLOGY

3.1 Main Design

The main objective of this study to predict useful life of structures especially a marine floating structure and order to prevent fatal condition with a trying analyze structure response about a suffered various loading conditions . So some of point can be parsed which may as part of results study Define hot spot stress position (numerical / find equation / commercial sofware) ;

1. Analysis crack initiation (assembly / production process),
2. Estimate rate of crack propagation,
3. Predict life of fatigue fracture,
4. Inspection / repair element with crack,
5. Simulate and modelling structural response (hydrodynamic, pressure load),
6. Connecting properties of material database condition (welding / manufacturing) to strength of 3D structural by numerical approach.

3.2 Flowchart Design

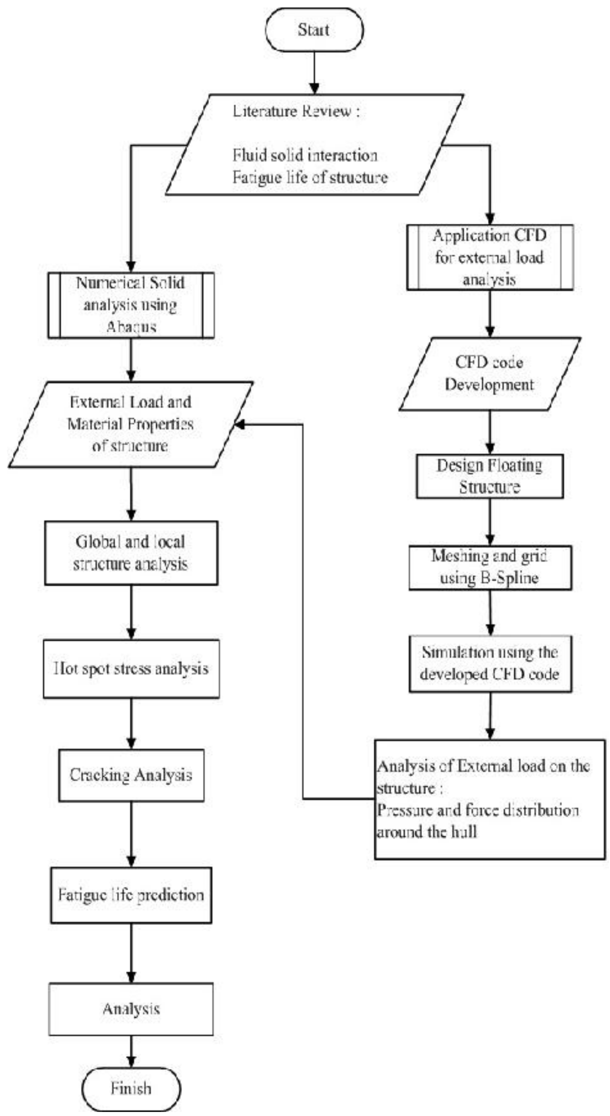

Figure 1: Flowchart Main Design

4.0 PRINCIPAL THEORY

4.1 External Load analysis using CFD

The approach will using Computer Fluid Dynamic (CFD) to find external load on research carried out by finite element method. Model will be simulated in to perform an analysis of response interactions between fluid-solid as marine floating structure to obtain the working of external pressure or force.

4.2 Structure Analysis

Required a right solution to predict life of structures that operates in sea, because in economic reason very difficult to perform maintenance and repair moreover if have stoped production. Some of recommendations have been generated for structures such as drilling platforms, FPSO and ships, but has not able to accommodate all the purposes thus untill this days some research still to be developed.

Cui W. *et al*., (2011), create a new model to determine and observe the rate of crack propagation with the aim to generate a unified formula (Unified Fatigue Life prediction / UFLP) in calculating the fatigue life of a floating structure. The concept has been developed the fatigue life of structures can be calculated theoretically is the commulative fatigue damage fatigue (CFD) or another theory by calculate crack propagation on the fatigue condition fatigue (FCP). The base usually is used hot spot stress by several factors influence such stress concentrations and define the area of operations against curve stress – cycles (S – N).

The concept of UFLP can be used for Low Cycle Fatigue (LCF) and High Cycle Fatigue (HCF) condition . The basic concept is improved at ULFP while connected crack propagation material on surrounding conditions such as effect of changes in mean working stress , effect of fundamental changes in the structure like a notch or a change in size. This would not be understood when viewed from Paris curve equation which only connect cycle with stress intensity condition . These curves like as 'S' letter describe of three conditions, early crack initiation, stable crack region and unstable failure condition .

5.0 RESULT

Saveral things must be prepared before collect some data, such as equipment test that to be used, material test, peat water and sea water to approach operational environment in which the real material is used. Some of them are grouped as follows:

5.1 Material Test

Material test as object to be used; St52-3 DIN 17100 that normal used as construction material on the ship. In this study would tested the fatigue strength of the material if the vessel operated back and forth in the peat water and sea water.

5.2 Composition test

Collection of data would begun with a test of material composition. It is intended to support the final analysis of results. The composition of the test results shown in Table 5.1 below:

Table 1: Result of composition test

Ketebalan	Carbon	Nitrogen	Posphor	Sulfur	Silicon	Mangan
16 mm	0.22 %	-	0.05 %	0.05 %	0.6 %	1.7 %

5.3 Strength of Material

In determining the amount of load to be imposed on material test, basic guidelines is yield strength and ultimate strength of material. It can be obtained after a tensile test. The results are as shown in the following table :

Table 2: Strength of Material

Yield strength	Ultimate strength	Elongation
350 MPa	505 MPa	20 %

With the refered to Shigley method for determining the fatigue strength of the material tensile strength on the table above can be a referenced for variations of load which will be given in the fatigue test. As restrictions fatigue testing machine is available only capable of holding 2100 MPa.

5.4 Standard of Specimens Test

The shape of the fatigue test specimen which will be guided by the standards of ASTM E466, as illustrated below:

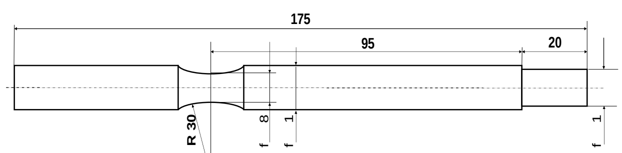

Figure 2: Specimen test

5.5 Fatigue Test

The outline of the test equipment that will be used images and components as shown below Figure 3.

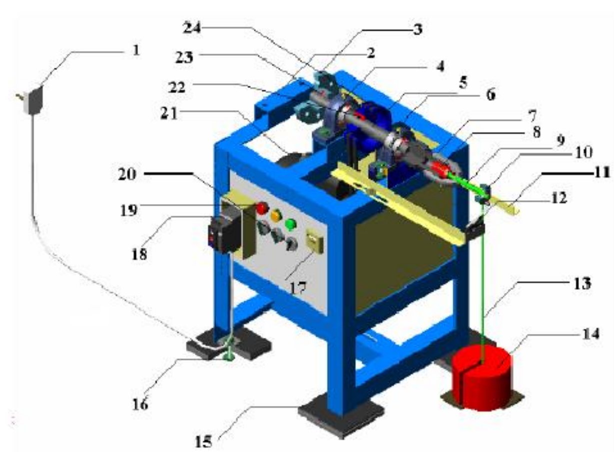

Figure 3: Machine for Fatigue Test

5.6 Result of Fatigue test

After testing the data obtained appear in graphical form a relationship between fatigue strength material in units (MPa) or N/mm2 against the number of cycles (N), which can occur up menggalami material failure / broken. In the process of testing the test object will menggalami full loading condition reversed. In short part of the test specimen will be interested because there is a load, while at the same time another part will be depressed. If it spins continuously then the part of the test specimen will menggalami alternately pull and pressure. The loading conditions or the working load limit of the amount is under tensile load is borne by a material that is capable of, as a result of objects will fail because the burden of fatigue or tired not because load that exceeds its carrying capacity.

Table 3: Result on the peat water and sea water behaviour (sea water, peat water, normal/without fluid)

air laut		air gambut		temperatur ruang tanpa fluida	
Cycle (N)	Fatigue strength (Mpa)	Cycle (N)	Fatigue strength (Mpa)	Cycle (N)	Fatigue strength (Mpa)
96556	350.494	113787	350.494	150204	350.494
284117	250.239	339911	250.239	379612	250.239
950122	210.893	1002578	210.893	1352666	210.893
9040507	80.787	9847568	80.787	11444360	80.787

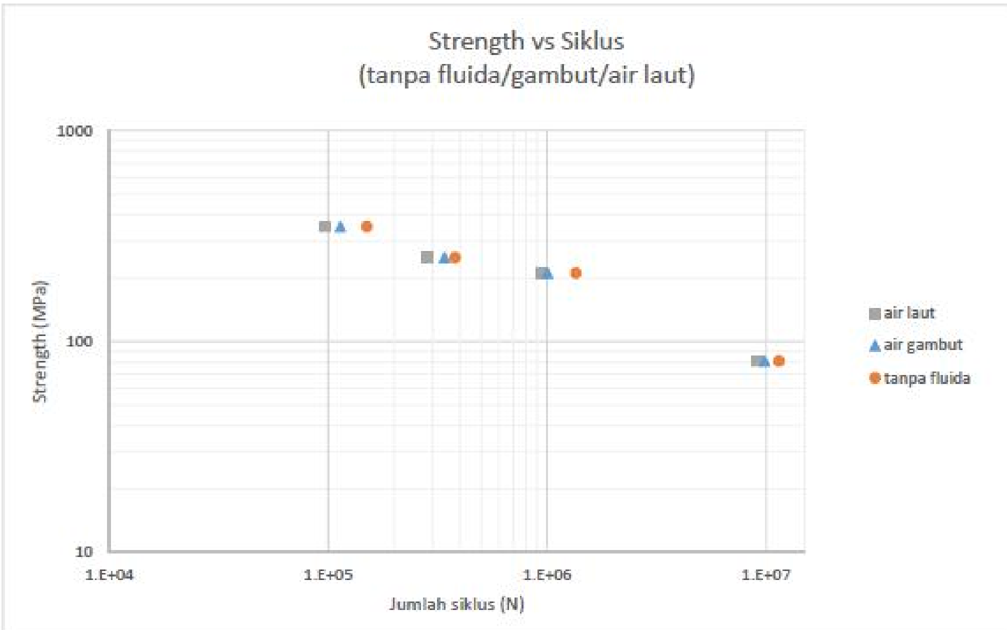

Figure 4: The curve of strength related to number of cycles

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