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# Surface Crack Growth Rate Evaluation for Oil Drilling Pipe using Finite Element Analysis

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**Abstract**

Most structures and mechanical assemblies are subjected to sporadic or uninformed loads while in operation. Evaluating the time a fatigue crack growth FCG is basic in planning components to be subjected to variable loads. Fundamental information on fatigue crack growth rate FCGR and the general crack propagation CP behavior concerning genuine crack cases empowers the designer to recognize the risks of crack right on time in the improvement period of recently outlined machines and parts. The FCG behavior and alternate components demonstrate an extraordinary effect on the life of the oil drilling pipe. The pipes used for drilling in the oil wells are a hollow circular cylinder. There are subjected stresses and different pressures depending on the earth nature and the drilling direction. The main reason of pipe fatigue in work is due to bending and tension of the tube during rotation. This work, is to study how to crack propagate and grows in the surface wall pipe using ( Zencrack software) to reproduce crack growth CG and to calculate the stress and the stress intensity factor (SI).

**Keywords:** FCG; oil drilling pipe, Variable loading; FEM

## INTRODUCTION

A FL investigation created on the stress life (SL) method were monitored to obtain an assessment of the estimated life and focus is to investigate how a crack propagates and grows in steel oil drilling pipe using variable loading. The hypothetical revisions of fatigue life (FL) prediction are recognized, using FEM analysis for modelling based on the rain flow counting technique with fatigue analysis codes. Then the modelling results analysis of using variable loading will be analyze and discussed in observation of above scope. The basic point in fracture valuation of (oil drilling pipe) the nature of stresses in them is generally (tension or compression) type, even of exposed to global bending moments (GBM). Usually, three-dimensional solid finite elements (TDSFE) is working in discrete the pipe structure for the purpose of tracking and accounting the crack.Although, the FLB predicting that is a relatively old subject, it is still an empirical art relatively than a science, and this is mentioned in a huge number of books and analysis papers [1]. Fatigue and damage are main aspect in the structural reliability and service life of these components. There are three stages (crack initiation, crack propagation and final failure) to determine the FL of components structural [2]. The curves of fatigue design in the American Society of Mechanical Engineers (ASME) Code it was developed for more than 20 years and have been created on a simplified method. Specifically, the stress - life (S-N) statistics given in section XI of the ASME pipes and vessel pressure base [3] comparative materials used in the pipes subjected to different time pressures, still need to updated in order to develop fatigue design approach for more precise investigation of life predictions of pipes components. The FL of element can be modelled consuming the level-crossing approach LCA supposing that CG can be displayed with Paris model [4], also can be used, effective SL and E$\Delta \varepsilon$ -life statistics [5], Crack Tip Opening Displacement (CTOD) [6]. The crack opening stress COS level consistent to the stress which decreases COS to a level get hold of 1/200 of the cycles number, (rainflow count) method usually used of critical the loads as cycles [7]. For the purpose of evaluating flexible local behavioural responses from elastic-stress, most researchers use commercial programs to estimate FL[8,9]. In service, a rotating oil drilling pipe is normally exposed to a bending moment and tension due to its self-weight. Practically, any random crack shapes initiation could be propagate and a semi-elliptical shape [10]. At that time, LEFM has been used to investigate SIFs along the front of crack. The FE technique is applicable to calculate the SIF for LEFM issues. For the purpose of finding the SIF value, in this study the most extreme method a displacement extrapolation (Apaqus, 2016) has been used. Figure 1 displays the random crack form when the CF regular to the axis of x, and equivalent to the axis of $x$ for axis of $z$ plane. Figure 2 demonstrate the procedure of solitary FE about the CT has been utilized as a part this study when ($c$ and $d$) represent the quarter space from point $e$ (crack tip) and $L$ is the length of element.

## METHODOLOGY

Figure 3 demonstrate the oil drilling pipe body is considered as a hollow circular cylinder. The oil drilling pipe is exposed to a compressive or tensile mean stress. The rotary bending moment RBM and produces the cyclic twisting loading in the oil drilling pipe, that is the fundamental driver of drill pipe fatigue amid the drilling operation. Prediction crack growth PCG can't be effortlessly, the prediction of crack growth PCG through a structure under time ward or fatigue based loading has turned challenge in the numerical recreation world. Figure4 demonstrates the SEC shape is the most used to investigate a surface crack for hollow cylinder, and demonstrated that all of the deformities of any initial shape get SE shape after a few cycles of loading in a procedure of FCG. This work investigates how to crack propagate and grows rate in the surface wall pipe using Zencrack software, the FEM technique has been used for the modelling and simulation. In addition, ABAQUS software has been used to develop a FM model to the crack tip by using 20-node quadratic brick elements (QBE). The experimental procedures in this work divided to conduct the tensile strength, fatigue life and FCG behavior testes.

## EXPERIMENTAL PROCEDURE

The material used in this study is as – received according the ASTM A335. The mechanical properties of the material are listed in table 1. The synthetic composition of the material (wt. %) is recorded in (Table 2). In the present study, the fatigue crack growth (FCG) test specimen was machined from ASTM A335 stainless steel sheets into a Single Edge Crack Tension (SECT) specimen by using an electrical discharge machining (EDM) wire cut. The width and length of the gauge area were 10 and 30 mm, respectively with a notch U-shape of 1.25 mm in depth and 0.5mm in width as shown in Figure 5. Prior to introducing a FCG, both sides of width specimen surface are ground using emery papers of 800 to 1200 grade, then buffed to mirror surface with diamond paste and metal polish in order to obtain a smooth surface. The smooth and mirror surface of the specimen is useful to observe and measure clear crack growth that require to produce along 0.4 ~ 0.6 of specimen width ($W$) while applying fatigue loads. The FCG procedure for thickness specimen was carried out using servo-hydraulic test machine (INSTRON 8874) with a capacity of 25kN. The FCG is performed until a crack length ($a$) reach 0.4 ~ 0.55 of specimen width ($W$) or until the specimen is broken. The details of SECT specimen configuration, test procedure, and calculations are followed the ASTM E647 standard. The stress intensity factor range (ΔK) is constantly controlled to satisfy the requirements of the ASTM E647. The value of ΔK is measured from the $K_{max} - K_{min}$ which $K$ follows Equations (1 and 2).

$$K = f(\alpha).\sigma.\sqrt{\pi.a} = 1.8\frac{Pa^{1/2}}{t.W} f(\alpha) \qquad (1)$$

$$\alpha = \frac{a}{W} \qquad f(\alpha) = f\left(\frac{a}{W}\right)$$

Where, σ is the stress, $a$ is the crack length and therefore, the geometry factor then $P$ is the load, $t$ the specimen thickness, $W$ the specimen width.

$$f(\alpha) = 1.12 - 0.231\,\alpha + 10.55\,\alpha^2 - 21.72\,\alpha^3 + 30.39\,\alpha^4 \qquad (2)$$

**Table 1:** Mechanical and fatigue properties of ASTM A335

| | |
|---|---|
| Yield strength [ MPa ] | 827 |
| Ultimate strength [ MPa ] | 965-1138 |
| Modulus of Elasticity [ GPa ] | 180 |
| Hardness [Brinell ] | 285 |
| Elongation at Break [ % ] | 13 |

**Table 2:** Chemical composition (wt. %)

| C | Mn | F | S | Si | Cr | Ni |
|---|---|---|---|---|---|---|
| **0.15** | 0.60 | 0.025 | 0.025 | 1.0 | 1.0-1.50 | 8.0-11.0 |

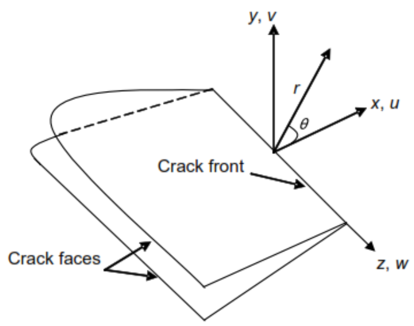


**Figure 1.** Random crack profile

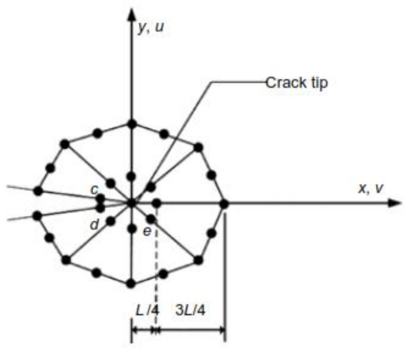


**Figure 2.** Particular essentials around the CT


**Figure 3.** The oil drilling pipe body

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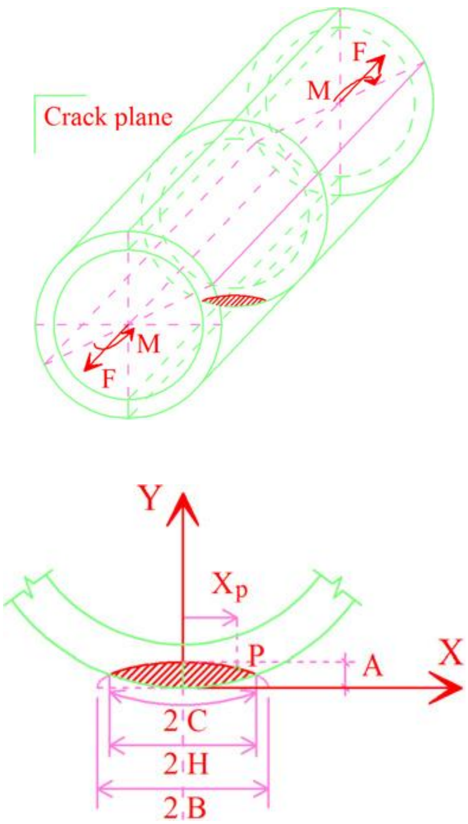
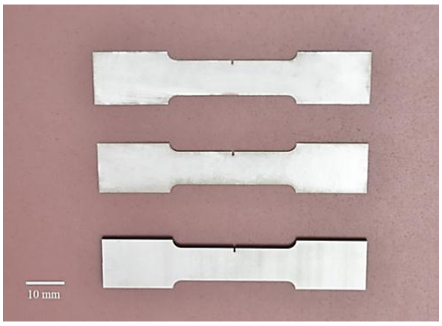
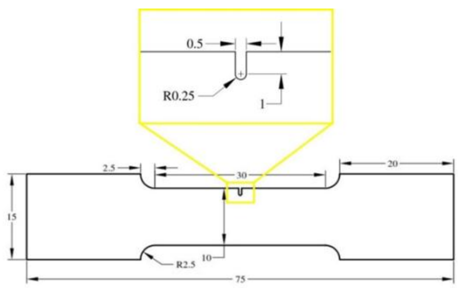



**Figure 4.** Crack plane and the crack propagation after one circulation




(a)




(b)

**Figure 5.** Tensile test specimen for tensile test: (a) bulk material. (b) micro size material

## RESULTS AND DISCUSSION

Stress distribution around the tip is located on the external surface as shown in Figs. 6 and 7. The cracks deformed meshes subjected to pure bending moments and torsion loading. Clearly, the cracks on the surface are open subjected to bending moment, and completely closed when the cracks are subjected to torsion loading. Figure 8 shows the comparison between experimental and different FCG model findings after using the experimental cyclic material properties under bending loading. In principle, the Zencrack software result shows a better match with the experimental data over the entire data domain compared to the FEM results. It is possible to easily to observe the effect of FIS on the crack depth. While, we can observe in Figure 9 the different models findings have a good matching with experimental result under torsion loading because of the strongly related between FIS and the comparative crack depth. Based on the experimental results, the same behaviour is concluded as shown in Figure 10. The experimental findings coincided with each other (bending and torsion moment), from which it can be concluded that the FCG rate steadily increases with increasing crack length where it is a linear and continuous incremental relationship until failure.

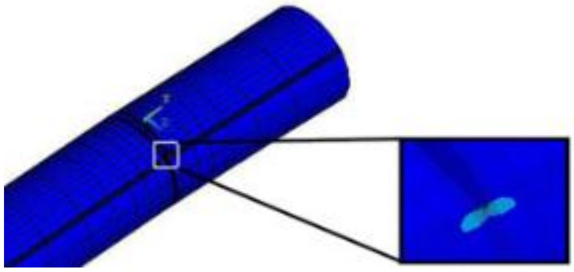


**Figure 6.** Crack meshes under bending moment

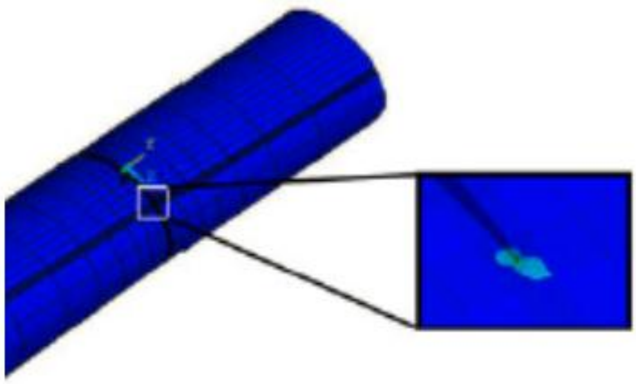


**Figure 7.** Crack meshes under torsion moment

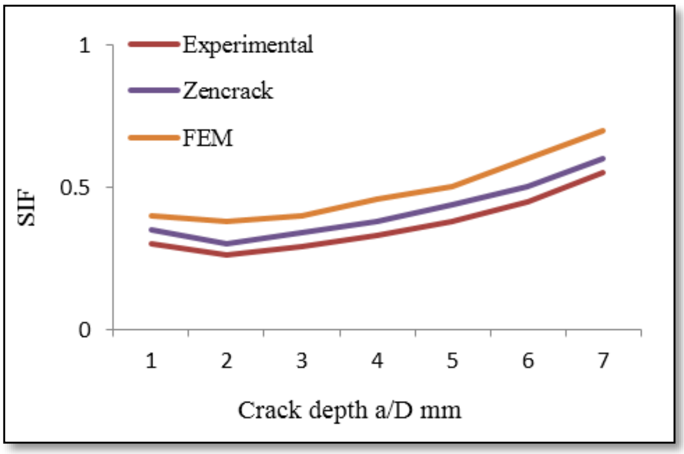



**Figure 8.** Crack behaviour under bending moment

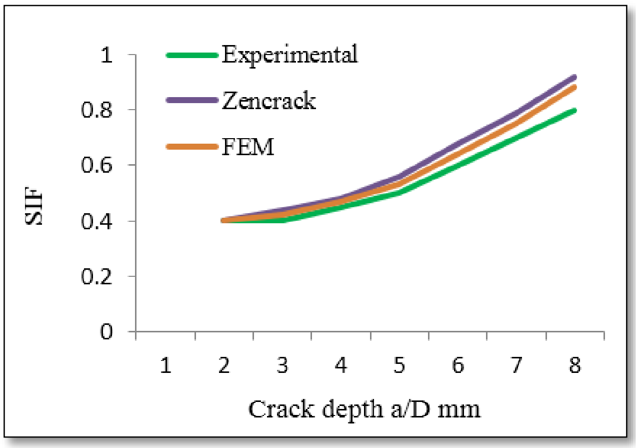



**Figure 9.** Crack behaviour under torsion moment

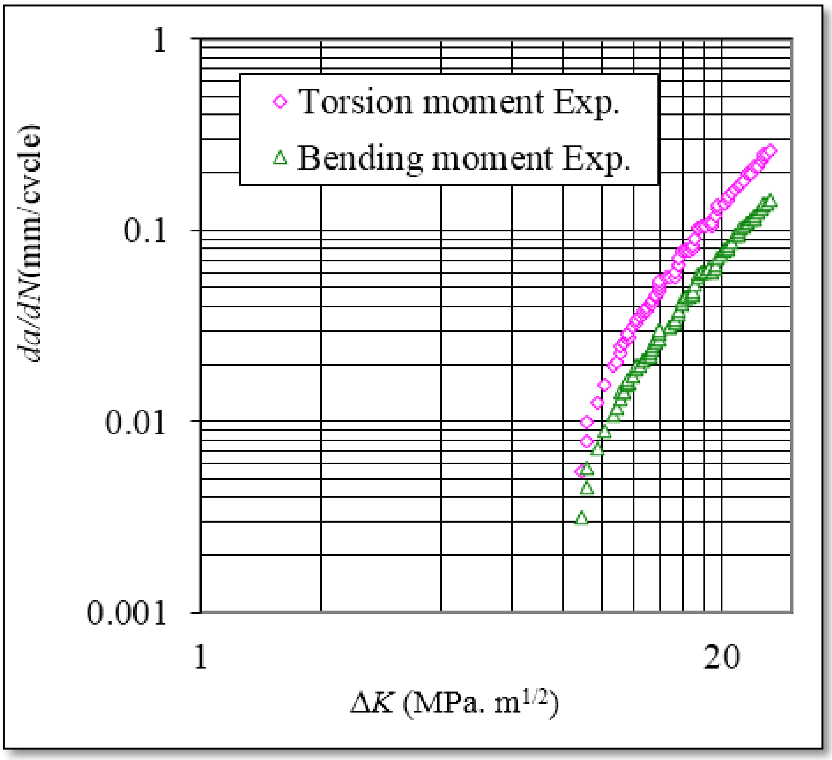



**Figure 10.** FCGR comparison between bending and torsion moment

## CONCLUSION

The present study focused on studying Surface Crack Growth under variable amplitude loadings. This work investigates how to crack propagate and grows rate in the surface wall pipe using Zencrack software, the FEM technique has been used for the modelling and simulation. In addition, ABAQUS software has been used to develop a FM model. The material used in this study is as – received according the ASTM A335. The differences in the finding using FEM under bending and torsion moment we can clearly observe the effect of SIFs on crack opening mechanisms by the deform meshes. The crack faces were opened under bending loading while completely closed when the cracks are subjected to torsion loading. Abaqus then used relative distances to calculate the stress intensity factor FIS.

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