Journal of Materials Science & Surface Engineering Vol. 3 (4), 2015, pp 290-292

Contents lists available at http://www.jmsse.org/

Journal of Materials Science & Surface Engineering

Simulation Framework Offshore Fatigue Life: An Insight

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Article history

Received: 17-June-2015
Revised: 09-Aug-2015
Available online: 01-Oct-2015

Keywords:
Self supporting thin film,
Chromium thin film,
Fusion Nuclear Technology,
Radionuclides,
Thermal Evaporation Technique
Optimized process parameters

Abstract

Life assessment of offshore structures with high accuracy and reliability will help rig operators to design retrofit mechanism and also certification for extended operation. Fatigue life assessment is critical during design phase, inspection phase and also for midlife up gradation. Fatigue life assessment is crucial requirement for certification of majority of engineering components Cost cut down is need of in offshore industry the validated simulation methods will help decide the health of offshore structure with minimal time and effort with less dependent on expert man power. Current paper aims at developing a framework simulation of fatigue life of offshore structure. Approaches for Modelling of welding, residual stresses, ultrasonic impact treatment are explored with a view to develop simulation approach using Finite Element Tools. The fatigue phenomenon depends on material, manufacturing process, initial flaw due to joining, operating environment like corrosive nature, load pattern, duration of operation etc. Simulation can help operators, designers, regulators to gain insight into component fatigue performance. In present work an integrated framework is proposed for fatigue life assessment of offshore structure.

*The work had been presented at an international conference **Fatigue Durability India 2015**, 28-30th May 2015, JN TATA AUDITORIUM, Indian Institute of Science, Bangalore.*

Introduction

Fatigue has been a dominant mode of failure in aircraft, rail, ship, automotive industry. Historically fatigue has been mechanism of failure for many components in ship industry where small cracks lead to catastrophic failures, since 1800 onwards there has been attention given to fatigue related studies in materials and structures. Researchers in the early years of development highlighted the significance of fatigue in various components and structures. Wilhelm Albert ,Jean-Victor Poncelet, William John Macquorn Rankine,Joseph Glynn published their studies on fatigue related failures and associated mechanisms. P. C. Paris proposes methods for predicting the rate of growth of individual fatigue cracks. This equation leads mathematical basics for growth in relation to number of cycles. Tatsuo Endo and M. Mitsubishi devise the rain flow-counting algorithm and enable the reliable application of Miner's rule to random loadings. W. Elber elucidates the mechanisms and importance of crack closure in slowing the growth of a fatigue crack due to the wedging effect of plastic deformation left behind the tip of the crack. Fatigue studies on aircraft and automotive have been done to estimate the number of cycles before failure of a component. This mechanism of failure is known as fatigue. In unwelded metals and alloys the failure process consists of initiation of microscopic cracking, frequently at a surface feature such as a change of section, followed by propagation, with each load cycle causing minute crack extension. Fatigue cracks are in many cases very fine, remaining tightly closed at minimum load and hence difficult to find by visual examination alone. As the crack extends, the remaining intact area of the cross section reduces, possibly leading to complete fracture or failure by another mode such as jamming or seizure of a mechanism. In welded components, pre-existing flaws provide sites for early fatigue crack formation. The fatigue process then consists almost entirely of propagation, the initiation phase being much shorter or entirely absent. Planar fabrication flaws such as lack of penetration or lack of fusion provide ideal sites for fatigue cracking. Even joints proved free of fabrication flaws by NDT will contain microscopic planar features at the weld toe, for example entrapped slag intrusions, which allow early fatigue cracking. As a result, the fatigue performance of welded joints is generally poor by comparison with unwedded material. For example, in mild steel plate, the allowable fatigue stress range for a typical fillet welded detail is roughly one third of that for the unwedded material.

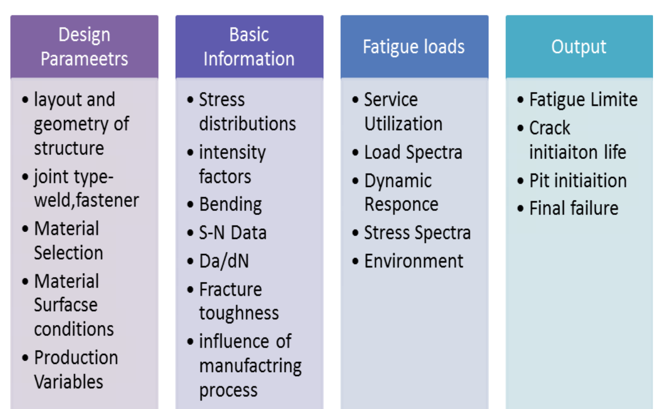

Figure 1: Generic Parameters influencing Fatigue life

Genesis of fatigue failure is a small flaw which went undetected during the inspection phase of manufactured component. The flaws in Martials during casting or during machining can be detected by a high resolution inspection technique. So that state of the art technology for flaw detection will lead to a tiny initial flaw size which forms the basis for crack growth and reaching to a catastrophic failure. Figure 2. depicts the various stages of flaw growth from initial size to final size.

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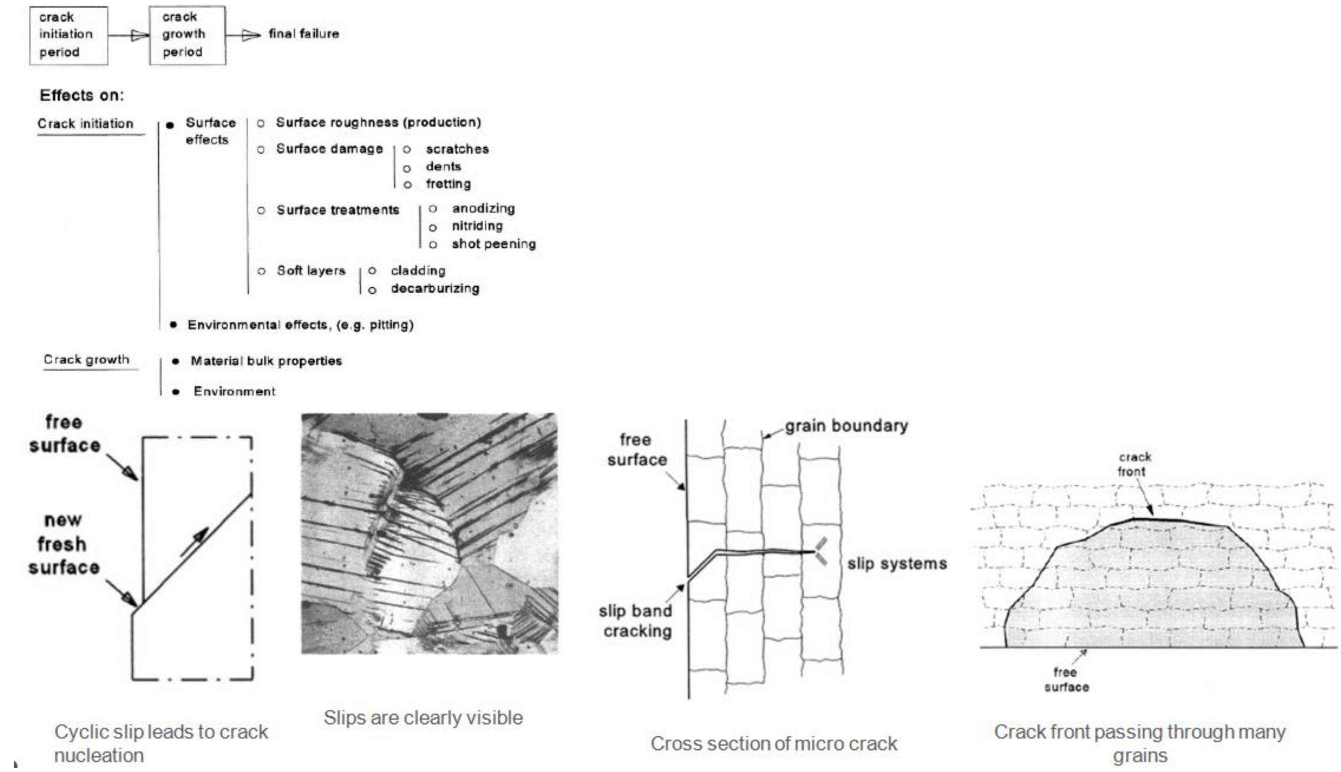

Figure 2: Crack growth mechanism flaw to failure in metals

Influence of flaws present in the material can be minimized by some of the methods like heat treatment and surface treatment. Growth of crack from initial to final has been predicted by many numerical and mathematical models. The analytical factors that helps predict the cracks in initiation period is called stress concentration factor and the factor that accounts for crack growth period is called stress intensity factor. For a given geometry and load configuration estimation of this factor is crucial.

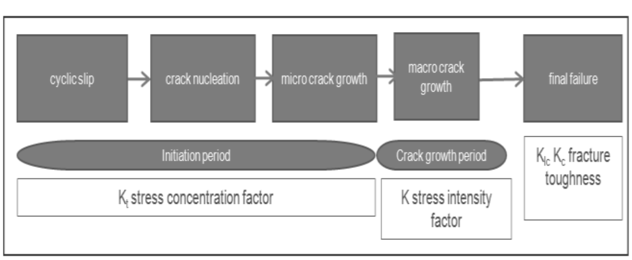

Figure 3: Generic Parameters influencing Fatigue life

Literature review

There are various uncertainties involved in simulation of offshore fatigue life assessment. There has been significant work done in developing method for estimating offshore structures. Programs and algorithms are being developed accurately predict the offshore fatigue life. Nelson Szilard Galgoul [1] conducted a study on Fatigue Analysis of Offshore Fixed and Floating Structures with a focus on modelling offshore joints also. Kristin Nielsen [2] Crack Propagation in Cruciform Welded Joints investigating how the effective notch method can be used for fatigue assessment of welded joints using commercial finite element software. Numerical results are also compared with experimental results. There has been a large scatter in experimental results. Tolga Mert [3] conducted a study on Finite Element Analysis of Effect of Weld Toe Radius and Root Gap on Fatigue Life of T-Fillet Welded Joint, solid elements are used for modelling and fatigue load is modelled as pure sine wave. Chen Lizhong [4] In-place structural strength and fatigue analysis for floating platform topsides Floating platform topside structure supports lots of heavy equipment and is subjected to substantial environmental loads during its whole life cycle. Z. Barsoum [5] et al developed a finite element based procedure for modelling the residual stresses in welded structures. The procedure was verified with temperature and residual stress measurements found in the literature on multi-pass butt welded plates and T-fillet welds.

Offshore Fatigue Life Simulation

Offshore structures Self-supporting thin films of various materials are always required as targets for the experiments in nuclear physics and nuclear chemistry. The target preparation is an essential step for getting thin and uniform self-supporting foils to be used in the experiment of nuclear reactions with ion beam and charged particles.

Factors Affecting Fatigue Life

Fatigue life of onshore structures depends on following p parameters

- NDT Technique
- Initial flaw Size
- Residual Stresses
- Manufacturing Process
- Sea State
- Chemistry
- Operating Temperature

Integrated Simulation Framework

The chamber was allowed to cool down for about 30 mins. Then the Cr deposited copper foil was removed and weighed. The weight of copper foil along with deposited Cr was 224.1 mg. The increase in weight shows that 2.5 mg of Cr got deposited on

Copper foil. The total Cr deposited area was 4.9 Cm^2 (as shown in Fig. 5). That is the thickness of Cr deposited was 0.9 mg/cm^2.
Based on the exhaustive literature survey following are some of the significant factors that needs to be addressed.

- Hydrodynamic Effects analysis
- Program to map the hydrodynamic loads onto the FE stiffness model
- Program to calculate stress transfer functions
- Program to determine joint stress concentration factors
- Program to do S-N fatigue analysis
- Program to do crack propagation analysis (probabilistic and deterministic)
- What NDT methods are available for flaw detection?
- What is the magnitude of residual stress and procedure to model it using finite element software?
- Ultra sonic Impact treatment –UIT improves the fatigue life of the components. In the literature it is mentioned that UIT improves fatigue strength by 45 to 50%.
- Acceptance of Certification agencies like DNV the Fatigue life increase?
- What magnitude of fatigue life increase is accepted, like 2 or more?
- Post manufacturing treatment like toe grinding can give around 45 to 50% life increment.
- If true, the DNV approved value can be included in the procedure.
- How is the Failure Assessment Diagram (FAD) determined?
- How will load shedding effects per BS7910 be taken into account?
- How the Crack Modelling, Weld Modelling, and Residual Stress Modelling do is conducted using finite element tools.
- Crack growth through weld
- Influence of Initial flaw
- Influence of operating environment
- Influence of Surface Treatment
- Influence of Load spectrum

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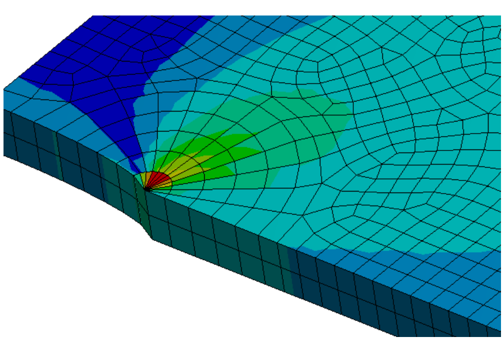

Figure 4: Stress concentration at crack tip

Crack Modelling

Crack initiation and growth modelling is crucial parameter in simulating fatigue life of offshore structure. Finite Element Methods are used for modelling cracks in offshore structure. Offshore structural steel fatigue is caused by oscillating stresses. Since waves as input are random processes steel stresses as output are random processes, too. Any estimated fatigue damage shall be considered as an empirical statistical expectation value because the source is stochastic and the S-N curves are empirical. Commonly the floating platforms are assumed to be linear systems so that any stress response PSD is just the production of deterministic squared RAO and the input wave PSD which forms the basis for many fatigue estimation methods. Steel fatigue damage is determined by the statistical distribution of the stress oscillating range and applicable S-N curve. Fatigue damage can be cumulated through Palmgren-Miner rule.

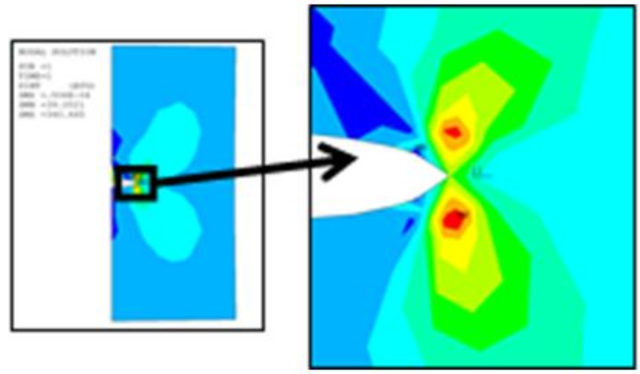

Figure 5: Stress concentration at crack tip

Conclusions

Fatigue is one of significant mode of failure for components; accurate prediction of fatigue life of components will help in design fatigue resistant structures. Unlike fatigue in aerospace and automotive components offshore structure has numerous uncertainties like sea environment, weld effects, challenges in insitu periodic inspection etc. in current paper a simulation framework is proposed to include all parameters that include fatigue life offshore structures. The framework is aimed at a single digital platform which can be used by designer, rig operators and certification agencies. An integration approach is proposed to see the combined effect of all the influencing parameters.

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