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Fatigue Life Estimation for Pressurized Base Weld Component (PBWC) A Review

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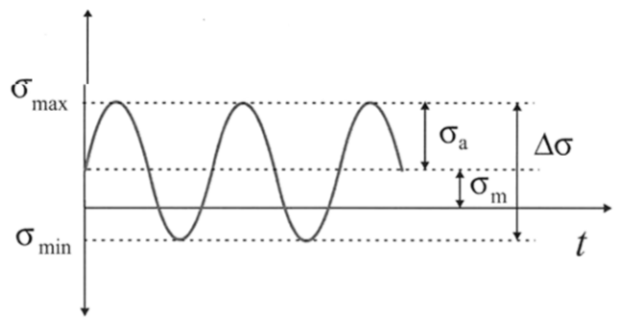
Abstract—*In nuclear power plants there are many pipe lines which run through the whole plant of the wire in circuit board. These pipes are usually made up of Zr & N alloys and at some cross sections they are welded. For the safety of the plant these pipes must be changed at a regular interval of time but this consumes a lot of time, man power and more importantly money. This takes a toll on the whole plant. There are many cross-sections in the pipes circumference which are welded and the properties of the welded joint differ to some extent from the original parent metal. Hence the fracture growth mechanism is different from that particular weld. Therefore a system is needed to carry out experiment trials for the measurement of the fatigue failure of a welded joint. This might help in estimating the life cycle of that pressurized weld pipes .This paper review the already work done in previous years that is available in open literature. The review work will help the researcher to find the existing research gap on this issue and outline the future direction for the researcher through this review analysis.*

1. INTRODUCTION

Failure in industrial term is known as not to perform the intended or desired work. For a design engineer it is very important that a part does perform its intended job efficiently and more reliably. In nuclear power plant there are various pipe lines which carries pressurized fluid and with time under certain conditions these repeated and cyclic loads can cause a fracture inside the pipe wall. Design engineer has to ensure that condition like this doesn't occur frequently because there are so much at the stake. Now these fracture will occur because of the constantly repeating cyclic loads but measuring the extent to which a pipe can function properly can make a very big difference. System level computer modeling of complex nuclear system is increasingly becoming trend due to availability of advanced computer programs and multi processer based parallel computing hardware and software. Computer based fracture analysis helps in mechanics of the material and computing the different area of the fracture growth. The present level FEA code also allows determination of other field variable. Furthermore, advances in FEA tools for 3-D fracture mechanics and crack propagation allow accurate prediction of the structural integrity of reactor components under severe accident conditions in reactor pressure vessels and other primary pressure boundary components. The effect of pressurized thermal shock (PTS) under severe accident conditions can be predicted by using 3-D FEA tools [1]. Furthermore the models will be developed using the commercially available ABAQUS FE software. Here we are assuming a pressurized weld component and are taking some sections of it we also have provided some constraints to provide a real time environment allowing free thermal expansions though it can be different for different plants. The individual sections are tied together by using tie constraints. At present, the fatigue life evaluation of nuclear power plant components has large uncertainties. Ideally if stress and strains stay under the elastic limit the component is considered safe for working. Most of the literature on fatigue modelling has focused on improving the stress-life data and related empirical fatigue design curves [2] for estimating fatigue life given the stress/strain state of a reactor component. A few studies [3] have emphasized the more mechanistic aspects of fatigue life prediction. For predicting fatigue life estimation it is necessary to understand the crack growth mechanism. Studies related to the crack propagation at constant amplitude loading in cyclically loaded structure is hardly found in most practical applications, though there are some studies done over constant amplitude loading like Paris equation[4] and Forman/Mettu[5]. In case of variable amplitude loading there might occur some load sequence effect like acceleration and retardation of crack which can affect life of the specimen significantly because of strain hardening or residual stresses at the tip of crack. Now these studies so far has been done a regular specimen or on a metal pipe, understanding the crack growth mechanism in the pressurised pipes is a different thing though the stresses might be of the same category as mentioned before. Inside a pressurised pipe because of the difference in the temperature of the fluids this causes stresses in axial and tangential direction which causes damage during thermal cycling. This phenomenon is known as Thermal Stratification. This phenomena is very common in the nuclear power plants (NPP). In the last few decades a number of failures in piping have occurred due to thermal stratification. Conventionally any nuclear power plant is designed for most of the mechanical induced loads but they are not prepared for the such type of loads.

2. FATIGUE LIFE ESTIMATION

As a tested material undergoes cyclic loading in a reactor environment, it no longer behaves similarly to monotonic loading. In monotonic loading, the yield surface only expands/contracts (isotropic hardening/softening). In cyclic loading, the yield surface changes in stress space (kinematic hardening/softening) and undergoes expansion/contraction (isotopic hardening/softening). Hence, combined isotropic and kinematic hardening is appropriate for modelling of plastic-deformation-related damage in reactor steel due to cyclic loading. The fatigue life estimation of any specimen can be done by using different approaches like stress life approach or strain life approach. These approaches are used long before paris law was introduced



The above figure shows the typical variation between the stresses and life cycle of the specimen, here we are not considering the pressurised pipe as a specimen, this here just shows the usual variation between the stresses and the life cycle.

Here important terms which should be considered are Stress range, stress amplitude, mean stresses and load ratio. These paramenters are elaborated below :-

Stress Range = $\sigma_{max} - \sigma_{min}$

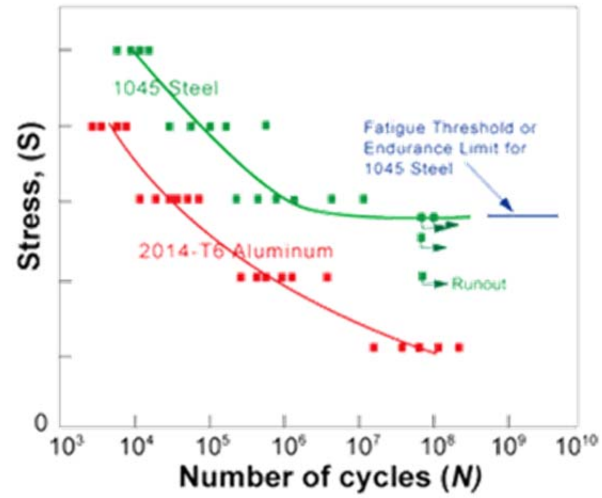
Stress amplitude :- $\sigma_a = \frac{1}{2}(\sigma_{max} - \sigma_{min})$

Mean Stress :- $\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min})$

Load Ratio :- $R = \frac{\sigma_{min}}{\sigma_{max}}$

Frequency: - In general only influences fatigue if there are environmental effects present, such as humidity or elevated temperatures.

Waveform: - As with frequency, generally only influences fatigue if there are environmental effects.



The above figure shows the variation of the life of steel and aluminium specimen according to the stresses induced on it for a number of cycles.

There have been various researches over the period of time on the life cycle of different metals. Most noticeable being Atrens et al.[6], they had reported the characteristic S–N property for a titanium alloy and a martensitic stainless steel such that the S–N curve tends to decrease again after the horizontal portion appeared around 10^6 cycles. Above fatigue tests were performed in the axial loadings at 60 Hz, 150 Hz and 20 kHz, respectively

3. LIFE ESTIMATION OF THE COMPONENT

Previous studies so far have been done over the fatigue crack growth of the different specimen weather in a notching condition or in a different conditions. For doing so they calculated different aspects of crack growth using LEFM on linear elastic fracture mechanism based on two or three dimensional model in a constant and cyclic load conditions. Preliminary analysis has been done to investigate the effect on local stress distribution. But these studies revolves around various open structures. For determining the components life we like to validate our data with the help of S-N curve. Metal fatigue typically occurs because of the long term exposure to the time varying loads, these loads might be smaller in amplitude but gradually with increase in time initiate the crack. For example, for instance railway axle experiences sinusodially varying loads on it. This was first noticed by the Wohler[7] using rotating bend fatigue rig.The rig housed two rotating shafts and, by applying different weights to the end of the rotating shafts, he was able to determine a relationship between the bending stress in the shaft and the number of rotations to failure. Subsequent work in 1910 by Basquin[8] recognized a logarithmic relationship between the amplitude of the sinusoidally varying stress and the number of rotations to failure. This work gave rise to the now familiar SN (or Wöhler) curve.

Here we are talking about the welded component that too pressurised one. Fatigue failures of welded joints also follow a familiar SN curve. In this case the micro structural properties of the material are heavily influenced by the welding process and so the performance of the base material has less effect on the SN curve of the weldment. In this case design engineer must calculate the nominal stress in the structural member ignoring the presence of the weld, and then use an SN curve appropriate to the geometry in order to determine the fatigue life

In case of a complex geometry it becomes really hard to calculate the nominal stress since stress concentration factor for different cross section would be different. Also for thin sheets it is really tough to analyse the stress concentrations. Modern analysis techniques have developed many different softwares and meshing techniques to estimate representative fatigue at a section or at a part of the welded component. International Institute of Welding [9] describes the application of FEA to the nominal stress approach and hotspot methods. It also describes how highly refined meshes can be applied to derive estimates based on both linear-elastic notch stresses and even more complex elastic-plastic notch strains. However, the use of these techniques is not applicable to general design of complex structures such as vehicle body-in-white or light-weight pressure vessels.

Furthermore, the high mesh refinement required for the notch methods is not conducive to large-scale structural modeling of complex structures such as vehicle bodies, chassis or some pressure vessels. A more pragmatic approach is therefore required to allow standard FE meshing techniques to be used without recourse to hand calculations

4. CONCLUSION

In this paper we study about the fatigue fracture of the component. how the fatigue crack propagates and about the different methods which are use For the fatigue life estimation of the component. There are many methodologies so far were use for the estimation of life 1. Use of FE analyses and Paris Law result in comparable predictions for axial and circumferential crack orientations at crown and intrados locations respectively.[10] Multiple initiations of the cracks have been observed from inside surface under compressive stress state. The crack growth predictions under compressive stress field needs different analytical approach.[10] 2.The use of an optical dynamic 3D displacement analysis technique to evaluate the crack propagation in a threaded pipe assembly. This was done by measuring the global pipe deflection and an additional measurement of the crack opening displacement . Both measurements were compared to a simplified finite element model of the cracked pipe assembly [11].

5. SUMMARY OF THE WORK

Work has been summaries in the table 5.1with reference specific objective functions and methodologies, selective parameters.

Table 5.1 summary of the work

S No.	Objective function and approach used	Reference
1	Fatigue crack growth under constant and variable amplitude loading at semi-elliptical and V-notched steel specimens using LEFM approch	David Simunek et
2	Fatigue tests and life prediction method for welded structures are proposed. Specimens were extracted from welded structures including embedded flaws detected by ultrasonic testing	Sohei Kanna, et.al
3	Fatigue bending tests have been performed on welded pipes made from an austenitic stainless steel, four types of loading taken in the analysis.	Thomas Svensson et al,
4	Finite element model is developed and verified for weld fatigue evaluation using FEA analysis	G. Pettersson , Z. Barsoum,
5	Computation of the stress intensity factors (SIFs) at the crack tip is the basis for pavement crack propagation analysis.	Zhenhua Wu, Sheng Hu et.al.
6	Two advanced methods for modelling the fatigue lifetime of welded components withan irregular distributed geometry and compares the results achieved.	Robert Lang, Gerhard
8	A long stable crack propagation phase was observed during experiments of complex welded components, very conservative estimations of the fatigue life were achieved in the past.	C. Fischer, W. Fricke,
9	Simulation of crack growth behaviour using XFEM method in a NPP	S. Taheri, A. Fatemi,
10	Understanding fatigue growth behaviour in different material specimen and paris law has been use for prediction of fatigue growth life	Punit Arora et al,
11	Fatigue crack propagation analysis based on code procedure and FEM and compares the results with experimental observations	P.Nagapadmaja et al
12	Studies have been carried out on carbon steel pipes to demonstrate the leak before break design criterion and validate the analytical procedures.	P.K. Singh et al,
13	Fatigue crack groth analysis using LEFM approach straight pipe component	S.K. Dhakad et al.
14	Life Prediction and crack propagation analysis for the Pipe weld straight component (PWSC) of power plant	S.K. Dhakad et al.

REFERENCES:

[1] Chen et al., 2014a; Qian and Niffenegger, 2013a,b, 2015; Keimet al., 2001; González-Albuixech et al., 2014.

[2] Chopra and Shack, 2007; Chopra and Stevens, 2014; Japan Nuclear Energy Safety Organization, 2011

[3] Kalnins et al., 2015; Rudolph et al., 2011; Gilman et al.,2015; Shit et al., 2013; Yun and Shang, 2011; Pirondi and Bonora,2003; Chakherlou and Ajri, 2013

[4] P.C. Paris, F. Erdogan, A critical analysis of crack propagation laws. In: Journal Basic Engineering 85 1963, p. 528-534

[5] R.G. Forman, S.R. Mettu. Behavior of surface and corner cracks subjected to tensile and bending loads in Ti-6Al-4V alloy. In: Fracture Mechanics: 22nd Symposium, Vol. 1 (Eds H.A. Ernst, A. Saxena, D.L. McDowell), ASTM STP 1131, American Society for Testing and Materials, Philadelphia 1992, 519-546

[6] Atrens A, Hoffelner W, Duerig TW, Allison JE. Subsurface crack initiation in high cycle fatigue in Ti6AL4V and typical martensitic stainless steel. Scr Metall 1983;17:601–6

[7] Wöhler, A., *Über die Festigkeitsversuche mit Eisen und Stahl, Zeitschrift für Bauwesen,* V**ol. 20**, 1870, pp. 73-106.

[8] Basquin O. H., Proc. ASTM 10, 625, 1910.

[9] The International Institute of Welding, *Stress Determination for Fatigue Analysis of Welded Components,* Abington Publishing, Cambridge, England, 1995

[10] Punit arora et al ’fatigue crack growth behaviour in pipes and elbows of carbon steel and stainless steel materials ’

[11] J. Van Wittenberghe , P. De Baets , W. De Waele , T.T. Bui , G. De Roeck ‘Evaluation of fatigue crack propagation in a threaded pipe connection using an optical dynamic 3D displacement analysis technique’

[12] Taheri S. Some advances on understanding of high cycle thermal fatigue crazing. ASME J Press Vessel Technol 2007;129:400–10.

[13] Le Duff A, Tacchini B, Stephan JM, Fissolo A, Vincent L. High cycle thermalfatigue issues in RHRs mixing tees and thermal fatigue test on a representative304L mixing zone. PVP2011-57951, Baltimore, Maryland, USA; 2011.

[14] Sonsino CM. Effect of residual stresses on the fatigue behavior of welded jointsdepending on loading conditions and weld geometry. Int J Fatigue2009;31:88–101.

[15] Ferro P, Berto F, James MN. Asymptotic residual stresses in butt-welded jointsunder fatigue loading. Theoret Appl Fract Mech 2016;83:114–24.

[16] Taheri S, Julan E, Tran XV. Fatigue crack growth and arrest under high-cyclethermal loading using XFEM in presence of weld residual stresses. In: Proc of5th conference on crack path (CP-2015) September, Ferrara Italy; 2015.

[17] Sbitti A, Taheri S. Crack arrest in high cycle thermal fatigue. Nucl Eng Des2010;240(1):30–8.

[18] J. Colin, A. Fatemi, Variable amplitude cyclic deformation and fatigue behaviour of stainless steel 304L including step, periodic, and randomloadings, Fat. Fract. Eng. Mat. Struct., 33 (2010), 205 – 220.

[19] A. Palmgren, Die Lebensdauer von Kullagern, Zeitschrift des Vereins Deutscher Ingenieure, 1924, 339–341, (In German).

[20] M.A. Miner, Cumulative damage in fatigue, J.Appl. Mech., 12 (1945), 159–164.

[21] T. Svensson, Fatigue testing with a discrete-time stochastic process, Fat. Fract. Eng. Mat. Struct., 17(1994), 727 – 736.

[22] P. Johannesson, M. Speckert (Eds.), Guide to Load Analysis for Durability in Vehicle Engineering, Wiley: Chichester, 2013.

[23] B. F. Langer, Design of Pressure Vessels for Low-Cycle Fatigue, ASME J. Basic Eng., 84 (1962), 389– 402.

[24] Kalnins et al., 2015; Rudolph et al., 2011; Gilman et al.,2015; Shit et al., 2013; Yun and Shang, 2011; Pirondi and Bonora,2003; Chakherlou and Ajri, 2013