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Research Article

Testing and Estimation Fatigue Life of a Flange Connection used in Power Plant by ANSYS

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Abstract

*The ANSYS Fatigue Module has a wide range of features for performing calculations and presenting clear and accurate results. It is estimated that 50-90% of structural failure is due to fatigue, so there is a real need for quality fatigue design tools. However, at this time a fatigue tool is not available which provides both flexibility and usefulness comparable to other types of analysis tools. This is why many designers and analysts use "in-house" fatigue programs which cost much time and money to develop. It is hoped that those designers and analysts, were given a proper library of fatigue tools could quickly and accurately conduct a fatigue analysis suited to their needs. The objective of this work is to take the recommendations of the fatigue analysis in the body of the flange connection and it was considered as calculations of strain-life in ANSYS workbench. Three types of cycling loads were applied. Firstly, a fully reversed load was used, and the number of cycles to failure was found from 27334 minimum to 109 maximum for all the bodies, so we need wide ranges of safety factor as its found (0.25 min. to 15max.).Secondly, applying a zero based load, so the strain life cycles found to have the range (2.6*106 min. to 109max.) and safety factor range (0.5 to 15). Finally a ratio (min.stress / max. stress =0.5) fluctuating load were applied, then the number of cycles to failure were estimated and found to be equal to 109 for all the bodies and the range of safety factor is not varying too much as the other load but also it has a range (1 to 15).*

Keyword: *Flange Connection, ANSYS, Fatigue life and Fatigue sensitivity*

Introduction

While many machines parts may work initially well, they often fail in service due to fatigue failure caused by repeated cyclic loading. Characterizing the capability of a material survive many cycles that a component may experience during its lifetime is the aim of fatigue analysis. In a general sense, fatigue analysis has three main methods, Strain Life, Stress Life, and Fracture Mechanics; the first two being available within the ANSYS Fatigue Module(Raymond Browell, 2006). The Stain Life approach is widely used at present. Strain can be directly measured and has been shown to be an excellent quantity for characterizing low-cycle fatigue. Strain Life is typically concerned with crack initiation, whereas Stress Life is dealing with total life and does not distinguish between initiation and propagation. In terms of cycles, strain life typically deals with a relatively low number of cycles and therefore addresses Low Cycle Fatigue (LCF), but works with high numbers of cycles as well. Low Cycle Fatigue usually refers to fewer than 105 cycles. Stress life is based on S-N curves (Stress – Cycle curves) and has traditionally dealt with relatively high numbers of cycles and therefore addresses High Cycle Fatigue (HCF), greater than 105 cycles inclusive of infinite life (Jordan Christopher Baker, 2009). Fracture Mechanics starts with an assumed flaw of known size and determines the crack's growth as is therefore sometimes referred to as "Crack Life". Facture Mechanics is widely used to determine inspection intervals. For a given inspection technique, the smallest detectable flaw size is known. From this detectable flaw size we can calculate the time required for the crack to grow to a critical size. We can then determine our inspection interval to be less than the crack growth time. Sometimes, strain life methods are used to determine crack initiation with Fracture Mechanics used to calculate the crack life. In this situation, crack initiation plus crack life equals the total life of the part.

Fatigue Failure (John H. Bickford)

A metallic part subjected to cyclic tensile loads can suddenly and unexpectedly fail even if those loads are well below the yield strength of the material. Sooner or later the part is failed in fatigue under the influence of fatigue loading. Note that the failure occurs under tensile loads. It was known that fatigue failure under

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cyclic compressive loads is possible but is rare so it will be ignored.

Fatigue failure of a single bolt means a reduction in clamping force. This in turn, it can increase the load excursions seen by the rest of the bolts, and that can encourage them to fail too. As a result, fatigue failure often means the complete loss of the joint.

Fatigue Process

Sequence of a fatigue failure

Fatigue will be a potential problem only if four ''essential conditions'' are present: cyclic tensile loads, stress levels above a threshold value (called the endurance limit), a susceptible material, and an initial flaw in that material. If these conditions are all present, then a natural sequence of events can occur, and can lead to fatigue failure. These events are called

1. Crack initiation
2. Crack growth
3. Crack propagation
4. Final rupture

Crack Initiation

Many things can produce that first fatal flaw which starts the fatigue process. A tool mark can do it. So can a scratch produced when the part is mishandled. Improper heat treatment can leave cracks. Corrosion can initiate them. Inclusions in the material can do it. It is probably safe to say, in fact, that no part is entirely free from tiny defects of this sort.

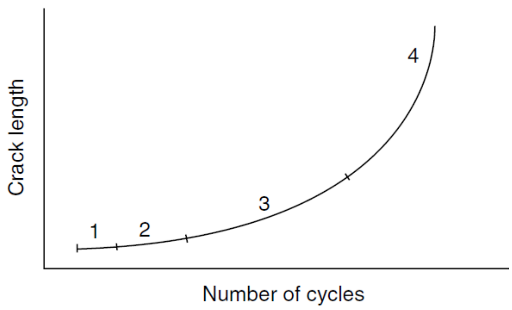

Figure 1 (John H. Bickford)

Fatigue failure occurs when a tiny crack in the bolt grows under cyclic tension loads until the crack is so large that the next cycle of load breaks the bolt. The stages of failure are (1) initiation, (2) growth, (3) propagation, and (4) rupture.

Crack Growth

A tiny crack creates stress concentrations. When the part is subjected to cyclic tension loads, these stress concentrations yield and tear the material at the root of the crack. Since most of the bolt still remains undamaged to support the load, initial crack growth is fairly slow.

Crack Propagation

As the crack grows, stress levels at the end of the crack also increase, since less and less cross-section is left to support the loads. The crack grows more rapidly as stress levels increase.

Final Rupture

There comes a time when the crack has destroyed the bolt's capability to withstand additional tension cycles. Failure now occurs very rapidly. As far as the user is concerned, failure has been sudden and unexpected because, until this part of the fatigue process is reached, there is often no visible damage or change in the behavior of the bolt. Everything appears to be fine until suddenly, with a loud bang, the bolt breaks.

The number of cycles required to break the bolt this way is called its fatigue life.

Apparently identical bolts in apparently identical applications can have, of course, substantially different fatigue lives, depending on the location and seriousness of those initial cracks as well as on apparently minor, but important, differences in such things as bolt and joint stiffness, initial preload, alloy content, heat treat, location and magnitude of external tension loads, etc. As a result, there is a lot of scatter in the fatigue life of the bolts used in a given application.

Type of Fatigue Failure (John H. Bickford)

Fatigue failures are called high-cycle or low-cycle failures, depending on the number of load cycles required to break the part. High-cycle fatigue requires hundreds of thousands or even millions of cycles before rupture occur. Low-cycle failure occurs in anything from one to a few ten thousand cycles. You can demonstrate low-cycle fatigue to yourself by bending a paper clip back and forth until it breaks.

The number of cycles required to break a bolt is determined by the magnitudes of mean and alternating stresses imposed on the bolt by external cyclic loads, as we'll see in a minute. Low-cycle failure occurs under very large loads, high-cycle failure under lesser loads.

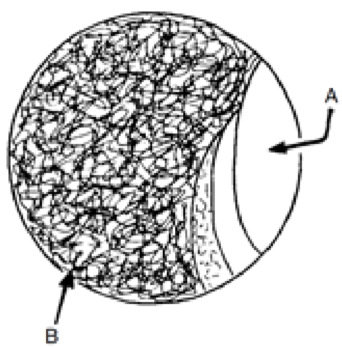

Figure 2 (John H. Bickford)

Break surface of a bolt which has failed in fatigue. (A) The surface is smooth and shiny in those regions which failed during crack initiation and growth. (B) It is rough in those regions which failed rapidly.

In many applications the bolts destroyed by relatively mild loads interrupted once in a while by a sudden shock or larger load (perhaps when the tractor hits a rock). In many cases it's difficult to know whether to characterize the failure as a low-cycle or a high-cycle failure. In most well-designed bolted joints, however, fatigue failure, if it occurs at all, will be high cycle.

Methodology

In this paper, three types of cyclic loading used on the flange connection the first one will be fully reversed load, the second one is zero based load and thirdly a ratio was taken between the maximum and the minimum value of the load around 2:4 (the static load=4Mpa). The solution will be found by using ANSYS program and the flange was drawn by Solid work program and then the results were compared as concerned with fatigue sensitivity for each type of load.

Model

In this model the standard geometry welding neck flange (W Neck Flange 900-NPS8) was used, so it is made of structural steel as shown in (Figure. 3) by using Solid Work program and we used the Gasket Linear Unloading for selling.

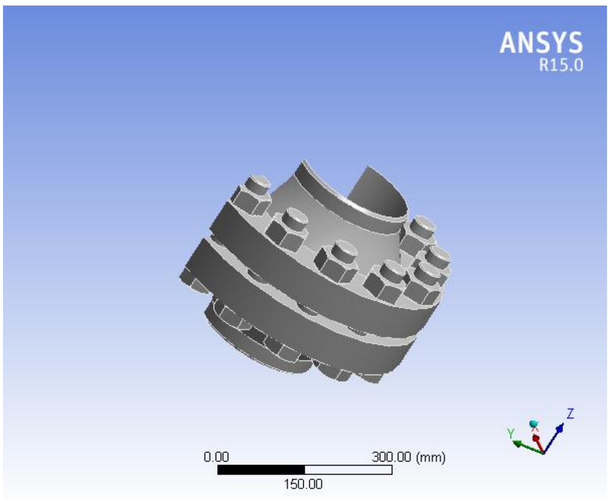

Figure 3 Image of flange connection

Firstly, cyclic load fully reversed will be applied as a cyclic pressure to see the fatigue sensitivity, life, S-N curve and safety factor. The result were compared with the other types of loads Zero based load and Ratio.

See the figure .4,5,6 and 7.

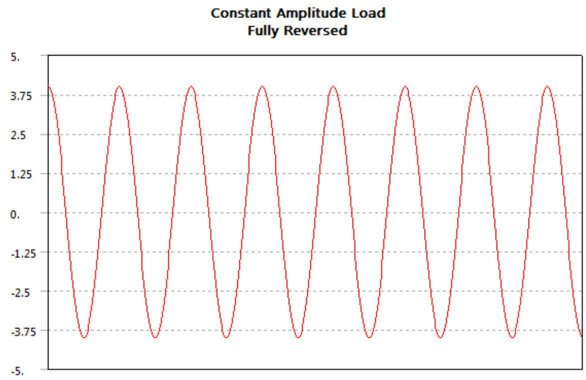

Figure.4a. Fully reversed load

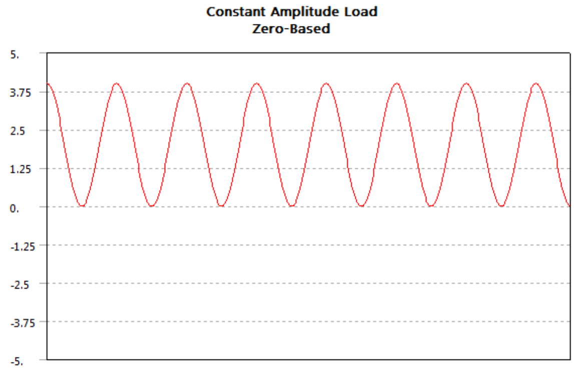

Figure.4.b. Zero based load

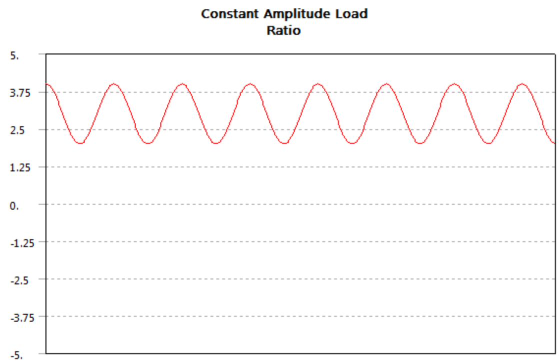

Figure.4.c. Ratio load 0.5 (fluctuating load)

Fatigue sensitivity

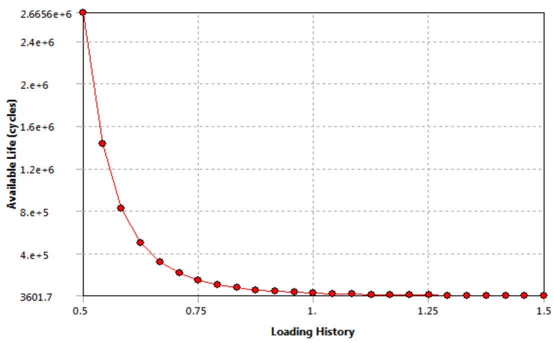

Figure.5a. Fully reversed load

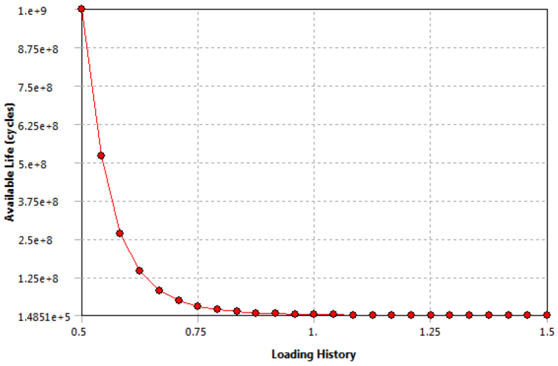

Figure.4.b. Zero based load

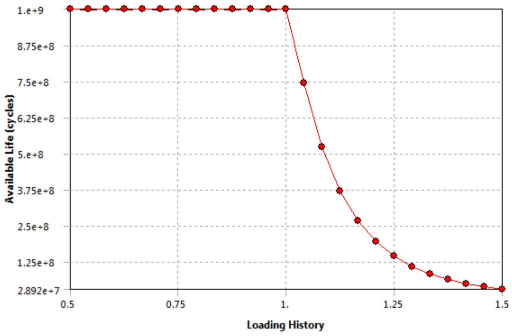

Figure.4.c. Ratio load 0.5 (fluctuating load)

Fatigue Sensitivity shows how the fatigue results change as a function of the loading at the critical location on the model. So we will compare the results of each type of load with reference to 100% of the load, from figure 5a we have around 3700 available life cycles and for figure 5b the life cycles will be1.4851*105 cycles and 109 cycles for figure 5 c . So the life cycles of the fluctuating load were more than the others.

Safety Factor

Fatigue Safety Factor is a contour plot of the factor of safety with respect to a fatigue failure at a given design life. The maximum Factor of Safety displayed is 15. Like damage and life, this result may be scoped. For Fatigue Safety Factor, values less than one indicate failure before the design life is reached.

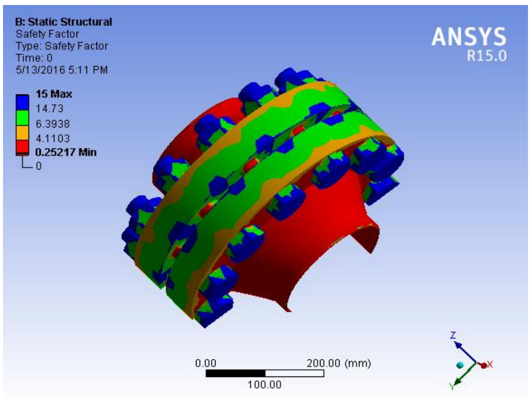

Figure 6a Fully reversed load

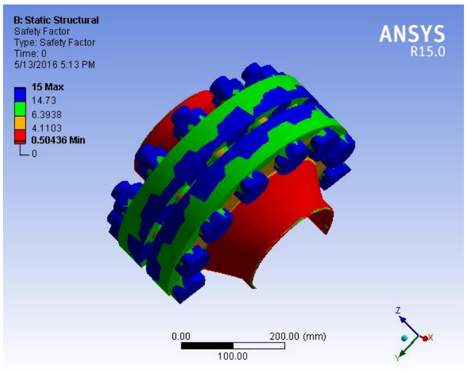

Figure .6b Zero based load

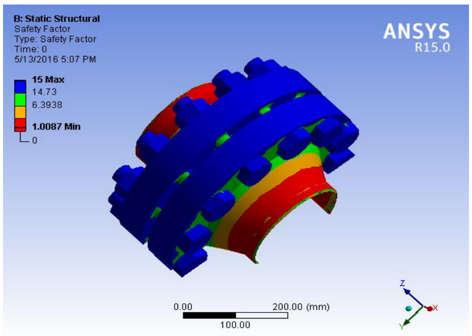

Figure .6c Ratio load 0.5 (fluctuating load)

Fatigue Strain-Life

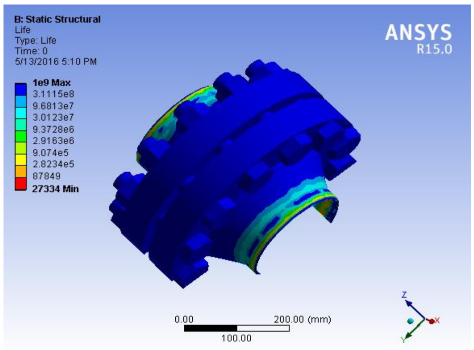

Figure 7a Fully reversed load

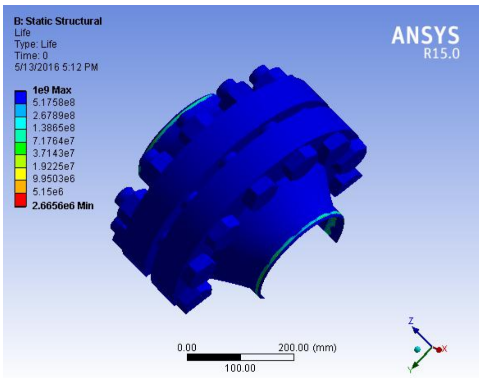

Figure 7b Zero based load

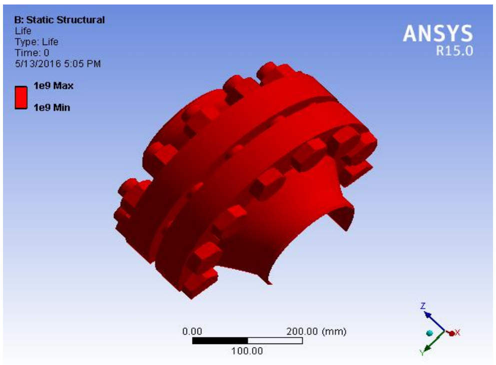

Figure .7c Ratio load 0.5 (fluctuating load)

Conclusion

The design life is 109 cycles is found by ANSYS .From Figures 7 a, b, c, we present that in the actual work (steam power plant or anywhere) ,the cyclic load on flange connections was avoided but almost that happen when the power plant is shut downed (turned off suddenly), then reduction the effect of cycling load were preferable.

So from figures above we prefer the fluctuating load because it is more safety and the other types of loading were avoid. These processes can be controlled as much as possible from the control room of the power plant by controlling the valves and at the end the trying was to reach the safety Shut down.

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