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Website: www.aarf.asia Email : editor@aarf.asia , editoraarf@gmail.com

EVALUATION OF FATIGUE AND CORROSION, ANALYSIS AND COMPARISON WITH HARDNESS FOR STAINLESS STEEL – 304.

R P Singh[*], Prashanth T[*], Irfan Shaikh[*], Ani Daniel[*], Vilas Bhosle[*].

[*] Birla Institute of Technology, Off shore Campus, RAK, UAE

ABSTRACT

Stainless steels possess a useful property in resisting corrosion in oxidizing conditions which are most harmful to un alloyed steel and to many of the non-ferrous metals and alloys. It is also seen that the stainless steels demonstrate practically complete resistance to the corrosive effects in most commonly encountered environment. These alloys however are impervious to corrosion in different conditions pertaining to temperature. In the light of the above, this current research work focusses on exposing SS 304, important and commonly used steel to sea water corrosion at room temperature for a period of seven days and then evaluation of fatigue life of the same. The work also focusses on evaluation of fatigue life by ansys and then verification with the experimental values. Corrosion rate and its correlation to hardness and comparison with values obtained by analysis software are the important findings reported in the paper.

KEY WORDS: Corrosion, Fatigue Life, Thermal Stress Corrosion Cracking, Ansys, SS304

1.0 INTRODUCTION

A perusal of the broken parts in almost any scrap yard will reveal that the majority of failures occur at stresses below the yield strength. This is a result of fatigue which has been estimated to be responsible for up to 90% of the in-service part failures which occur in industry. If a bar of steel is repeatedly loaded and unloaded at say 85% of its' yield strength, it will ultimately fail in fatigue if it is loaded through enough cycles. Also, even though steel ordinarily elongates approximately 30% in a typical tensile test, almost no elongation is evident in the appearance of fatigue fractures.

The word fatigue is derived from the Latin fatigare which means "to tire". In engineering terminology fatigue is a progressive structural damage of materials under cyclic loads. There are a few main types of fatigue. Mechanical fatigue is the focus of this study and could be described as damage induced by application of fluctuating stresses and strains. Among other types of fatigue are: creep fatigue – cyclic loads at high temperatures; thermal fatigue – cyclic changes in material's temperature; thermo-mechanical fatigue – a combination of mechanical and thermal fatigue; corrosion fatigue – cyclic loads applied in chemically aggressive or embrittling environment; fretting fatigue – cyclic stresses together with the oscillation motion and frictional sliding between surfaces. The devastating power of the fatigue phenomenon is underlined by the fact that very often final fatigue failure occurs at stresses that are well below the yield point of the material. Fatigue life is an important characteristic of an engineering component and is measured by a number of cycles it can withstand before fatigue failure takes place (1). The material properties obtained from fully-reversed fatigue testing under total strain-controlled conditions are of fundamental importance when designing components which are expected to experience repeated loading during their service lives many studies have been performed to investigate the cyclic response of materials subjected to cyclic inelastic loading [2-5]. The behavior of stainless steels in natural seawater is of great interest since they are widely used in marine structures. Stainless steels such as 316L, 304..., present poor corrosion resistance in seawater. Their durability is altered by the corrosive nature of the marine environment. It is well-known that exposure of stainless steels, as well as any kind of material in natural seawater induces the development of a microbial film, the biofilm. Another theory that proves the sea water corrosion is by pitting corrosion failure.

2.0 EXPERIMENTAL PROCEDURE

2.1HARDNESS (ROCKWELL B SCALE)

Stainless steel (SS304) pieces were ground on a belt and emery to obtain a flat surface. A load of 100 kg was applied. The load was applied for 15 seconds and then released. The readings obtained gives the hardness of the sample on the Rockwell 'B' scale.

2.2 IMMERSION CORROSION TEST

The corrosion behaviour of the cast samples were studied by static immersion corrosion test to measure the weight loss. Cylindrical specimens of the composites and the pure metal were weighed before and after immersion in 3.5% sodium chloride solution. The immersion corrosion test was conducted as per standards ASTM D-6943-10 on the samples and weight loss for thirty five days were estimated. After the time duration of thirty five days the samples were cleaned with distilled water, rinsed with acetone, dried and weighed.

Corrosion rates were computed using the equation

Corrosion rate = 534W/DAT mills per year.

Where W is the weight loss in mg, D is the density of the specimen in gm/cm^3, A is the area of the specimen in sq-inch and T is the exposure time in hours. [6]

FATIGUE TEST

A rotating bending testing machine is used for fatigue testing and the test is done as per ASTM E466-15. The Rotating Bending Testing Machine is similar to the original railroad axle-type, Wohler, used where the bending moment is constant along the beam length. Each point on the Surface of the Rotating Bend Specimen is subjected to fully-reversed cycling ($\sigma m = 0$) and the tests are generally Constant Amplitude. A schematic of the fatigue testing machine is as shown.

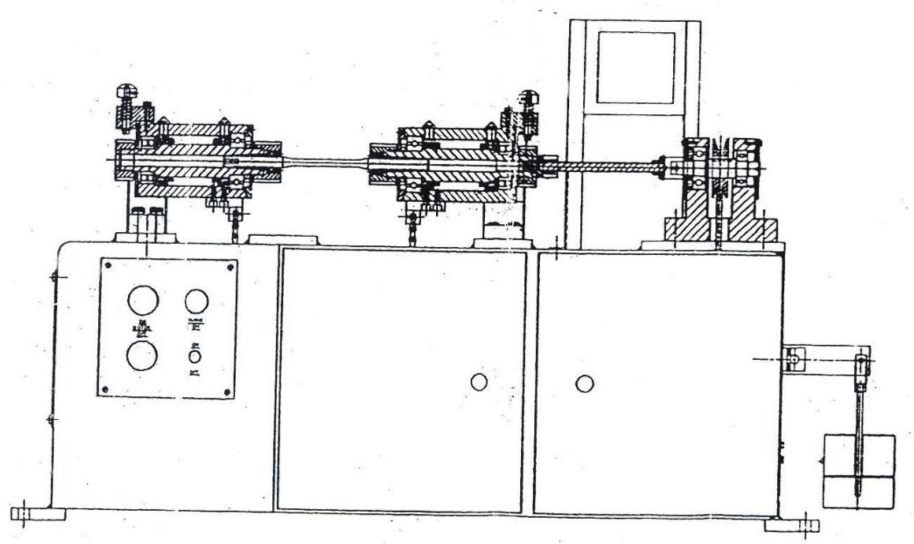


Fig 1: Experimental set up for fatigue

The experimental results obtained are therefore compared with results obtained from ansys (release 14). Fig 2 shows the fatigue specimen used for the mentioned test.

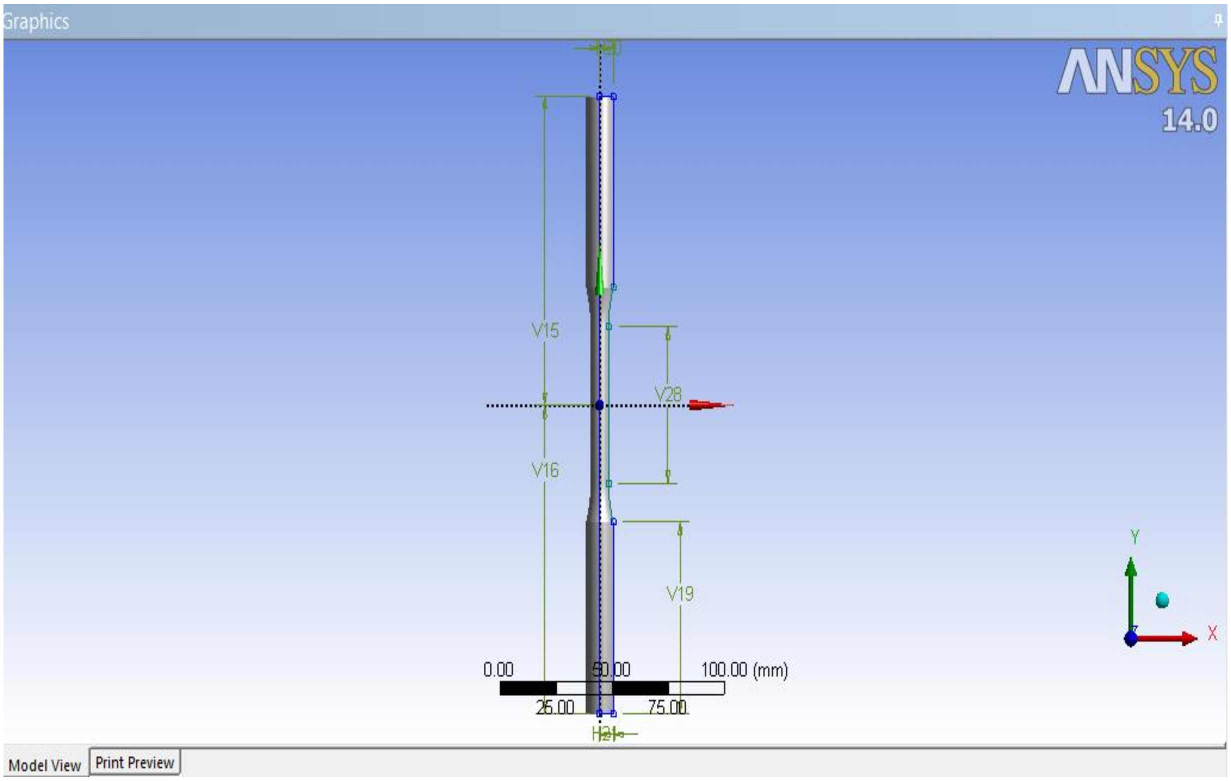
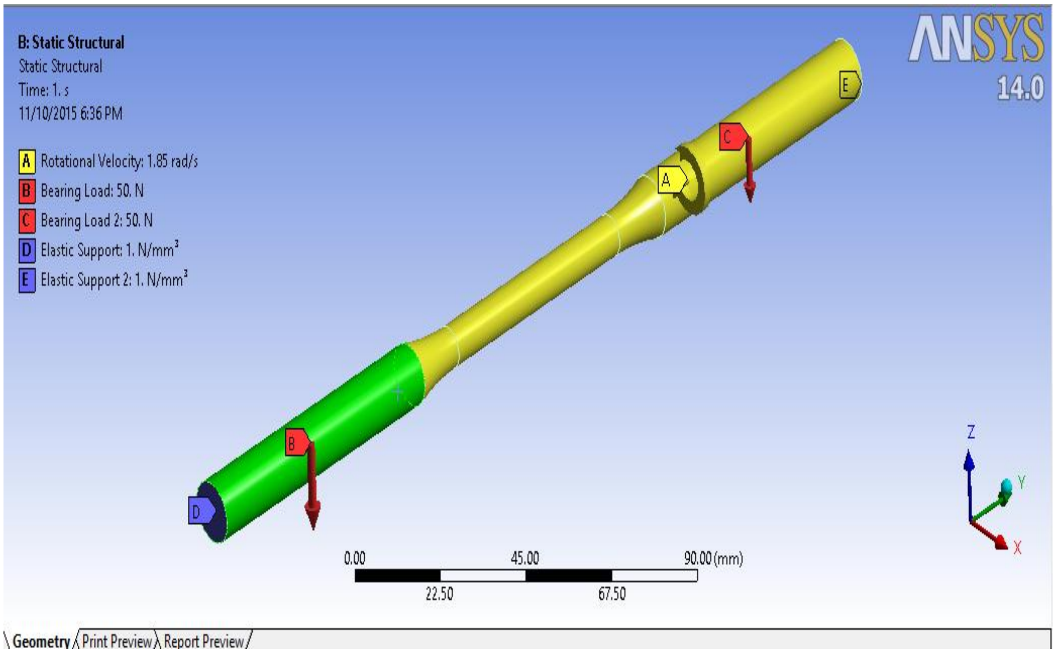


Fig 2 : Fatigue test sample

3.0 RESULTS AND DISCUSSIONS

3.1 FATIGUE TEST

As discussed in the previous section, fatigue tests were carried out on samples for an applied load of 100kg, 150 kg and 200kg on stainless steel samples. The results have clearly shown that the stainless steel sample enters into a state of infinite cycles (> 10^7 cycles) when the sample is subjected to the above mentioned loads. For similar boundary conditions (Fig 3)as observed in the experimental set up, the results as obtained by ansys also shows the sample progressing towards infinite life (Fig 7-9). In addition the variation of Von Mises stress for three different load parameters are also observed (Fig 4-6)


B: Static Structural
Static Structural
Time: 1. s
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A Rotational Velocity: 1.85 rad/s
B Bearing Load: 50. N
C Bearing Load 2: 50. N
D Elastic Support: 1. N/mm³
E Elastic Support 2: 1. N/mm³
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14.0
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X
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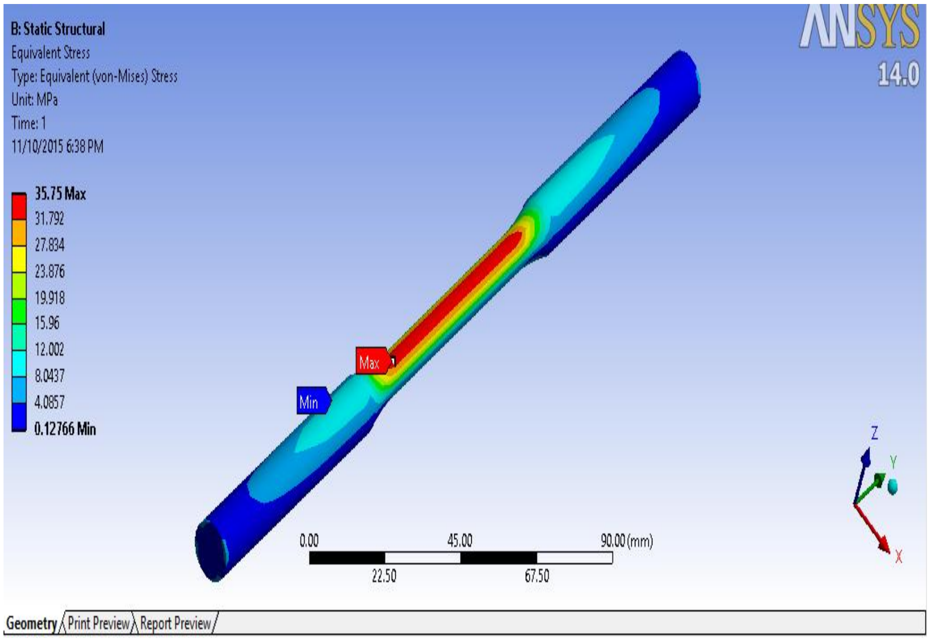

Fig 4 : Von mises stresses at 100 kg load

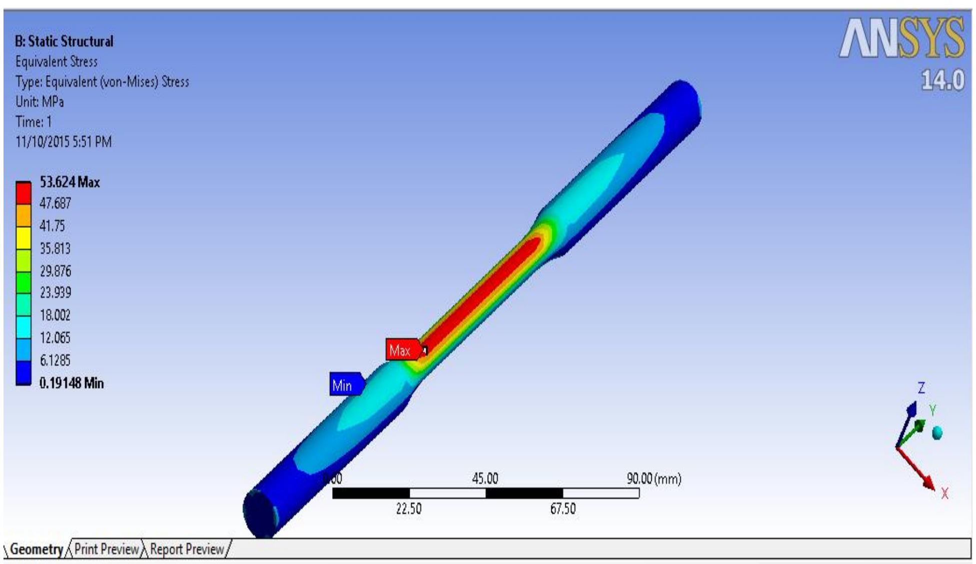

Fig 5 : Von mises stresses at 150 kg load

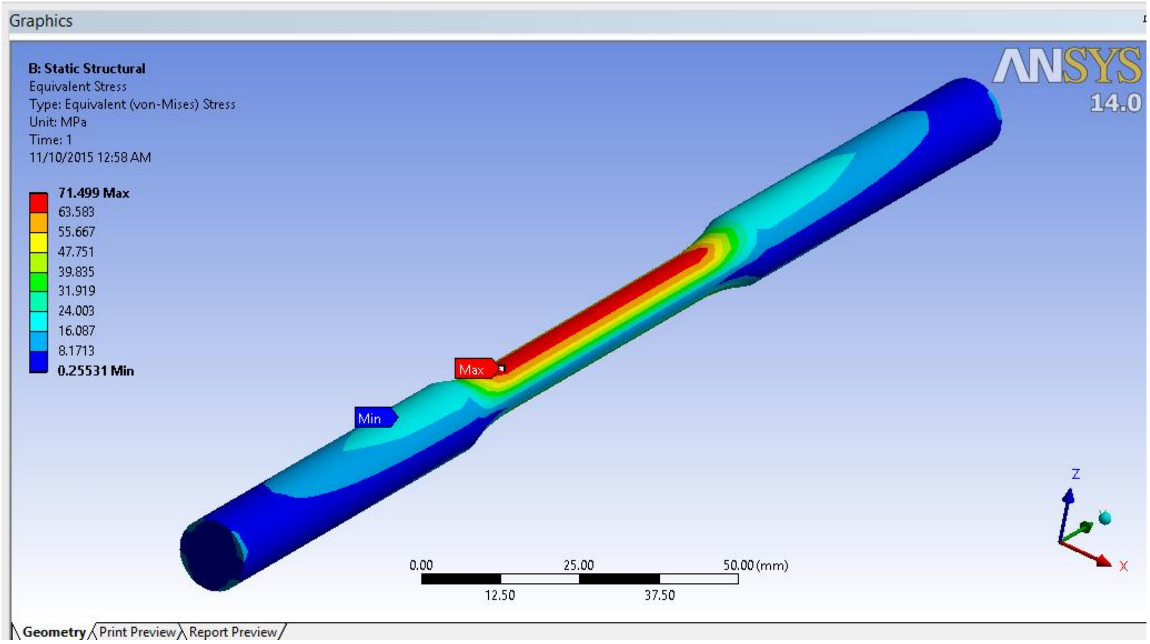

Fig 6 : Von mises stresses at 200 kg load

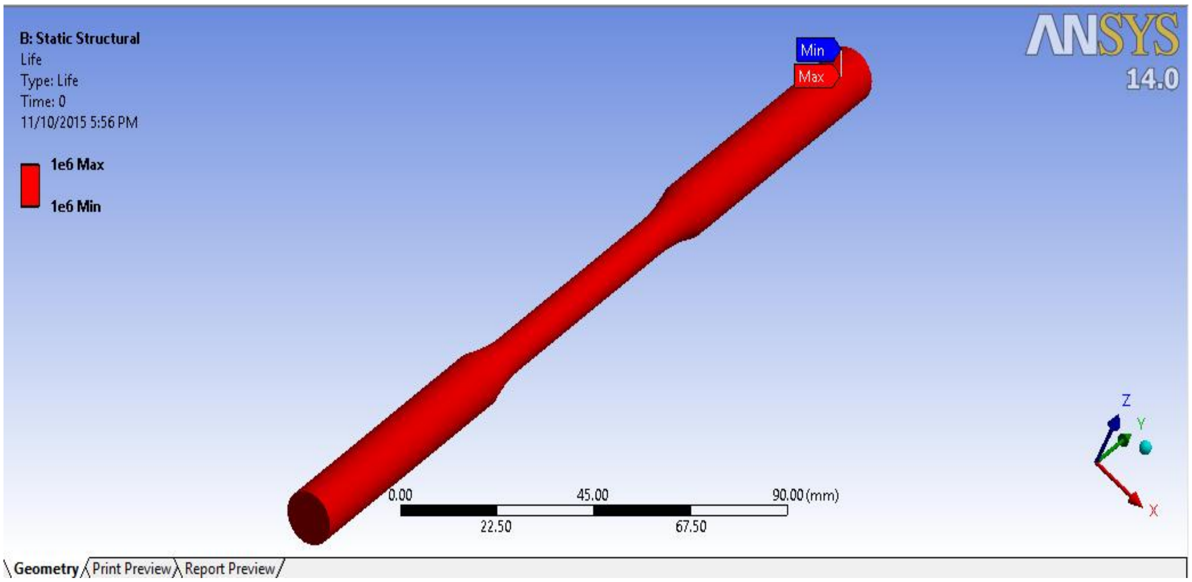

Fig 7 : Fatigue life at 100 kg load

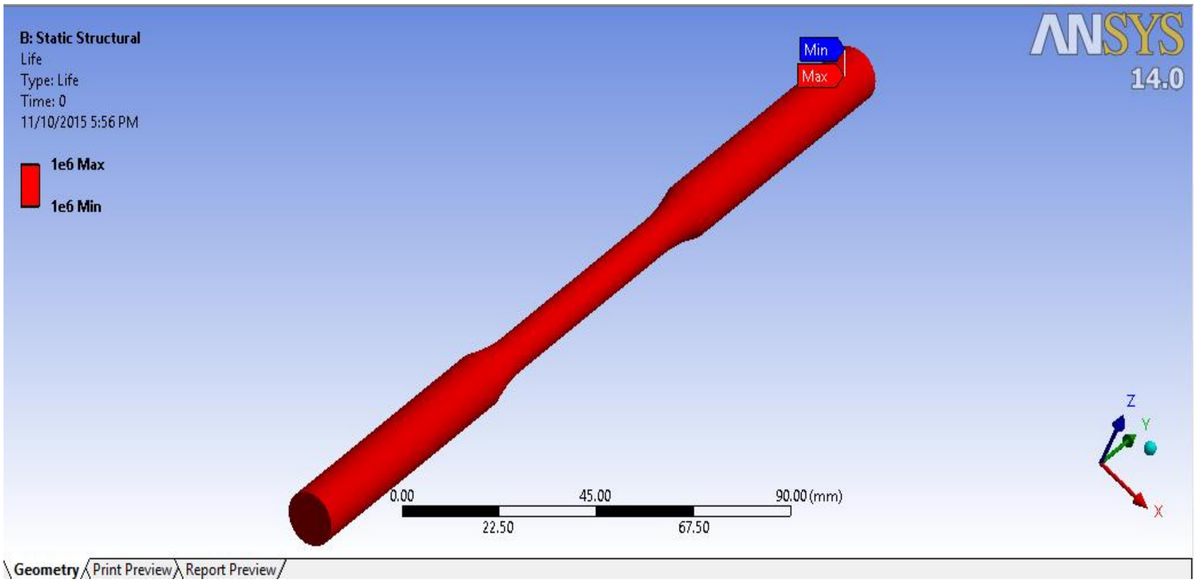

Fig 8 : Fatigue life at 150 kg load

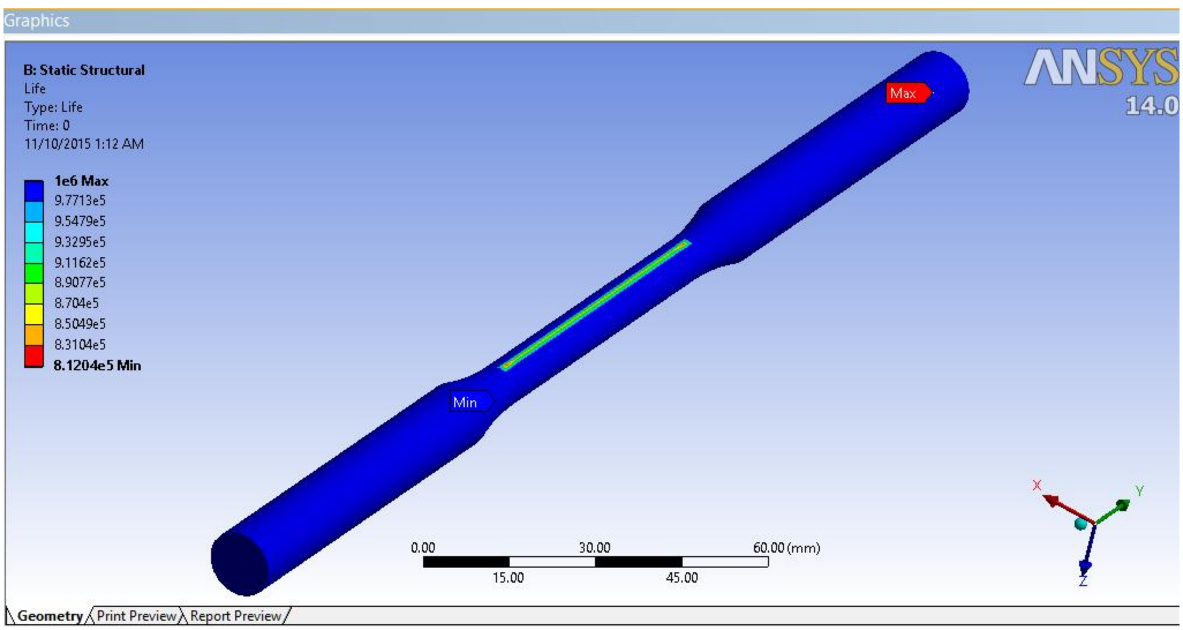

Fig 9 : Fatigue life at 200 kg load

3.2 CORROSION KINETICS

Stainless steel samples were immersed in sea water for a period of seven days. The table shows three samples of SS-304 and the corrosion life in mills per year. It is observed that the corrosion resistance of stainless steels is reduced owing to sea water corrosion. The reason for the corrosion is attributed as follows. Since stainless steel contains at least 10.5% chromium, the oxidation of the iron is changed to produce a complex oxide that resists further oxidation and forms a passive layer on the surface. This is a very thin layer (microns in thickness) but very tenacious and will reform if it is removed by scratching or machining. The addition of nickel to the structure (8% minimum in 304 and 10% minimum in 316) broadens the range of passivity established by the chromium. The further addition of molybdenum (2% minimum in 316) furtherexpands the passivity range and improves corrosion resistance, notable in acetic, sulfuric, and sulfurous acids and in neutral chloride solutions including sea water. Stainless steel will, however, corrode under certain conditions. It is not the same type of corrosion as experienced by carbon steel. There is no wholesale "rusting" of the surface and subsequent reduction of thickness. If stainless steel corrodes, the most likely form of corrosion is "pitting." Pitting occurs when the environment overwhelms the stainless steel's passive film and it cannot heal the interruption. It usually occurs in very tiny dark brown pits on the surface (hence the name pitting), and does not interfere with the mechanical properties of the stainless steel (7).

Sl. No.	Sample Designation	Weight loss (gms)	Corrosion rate (mills /year)
1	SS-304- Initial	0.0	5.4×10^{-3}
2	SS- 304- after seven days	0.7	5.18×10^{-3}

Table 1: Immersion corrosion test

3.3 HARDNESS

SS-304 samples were subjected to hardness measurements before immersion corrosion, before and after fatigue tests. It is observed that there is no change in the hardness values of the specimen when subjected to fatigue stress or change in the environment conditions (sea water corrosion). This clearly shows that corrosion or cyclic loading has no profound effect on hardness. This also indicates that the passive film formed during corrosion has practically no effect on the hardness.

Sl. No.	Sample description	Rockwell Hardness- B scale
1	SS-304- Initial	98.3
2	SS- 304- After corrosion	98.5
3	SS-304, after fatigue failure	98.4

Table 2: Rockwell Hardness

4.0 CONCLUSIONS

- It is clearly observed that the fatigue life of the stainless steel specimens enters infinite cycles when subjected to three different loads.
- Similar boundary conditions when simulated in ansys also shows similar trends in fatigue life.
- Decrease in weight was observed when subjected to immersion corrosion tests in sea water.
- No appreciable change in hardness was observed after subjecting the samples to corrosion and cyclic loading

5.0 REFERENCES

1. Vitaliy Kazymyrovych, “Very high cycle fatigue of engineering materials – A literature review”, Karlstad University Studies 2009:22.
2. Dowling Norman E., Mechanical behavior of materials (2), Prentice-Hall (1993).
3. El-Madhoun, Y., Mohamed, A., and Bassim, M. N., “Cyclic stress-strain response and dislocation structures in polycrystalline aluminum,” Materials Science and Engineering, Vol. 359, pp. 220-227 (2003).

4. Gupta, C., Chakravartty, J. K., Reddy, G.R., and Banerjee, S., "Uniaxial cyclic deformation behaviour of SA 333 Gr 6 piping steel at room temperature," International Journal of Pressure Vessels and Piping, Vol. 82, pp. 459-469 (2005).
5. Li, C., Ying, S., Shen, B., Qiu, S., Ling, X., Wang Y., and Peng, Q., "Cyclic stress-strain response of textured Zircaloy-4," Journal of Nuclear Materials, Vol. 321, pp. 60-69 (2003).
6. H C Anand Murthy, et al, " Influence of Chlorides, Nitrate and sulphate media on Corrosion behaviour of TiO_2 particulate Reinforced Al 6061 Composites", *Portugaliae Electrochimica Acta 2010, 28(5), 309-320.*
7. Stainless steel Designer Hand book.
8. I. N. Nawia, Saktiotob, M. Fadhalic, M. S. Hussaind, J. Alie and P. P. Yupapinf, "Nd: YAG Laser Welding of Stainless Steel 304 for Photonics Device Packaging," Procedia Engineering, Vol. 8, 2011, pp. 374-379.
9. G. Apostol, G. Solomon and D. Iordchescu, "Input Pa- rameters Influence on the Residual Stress and Distortions at Laser Welding Using Finite Element Analysis," Series D: Mechanical Engineering, Vol. 74, 2012, pp. 153-164.
10. C. Suh, M. Suh and N. Hwang, "Growth Behavior of Small Surface Fatigue Cracks in AISI304 Stainless Steel," Fatigue and Fracture of Engineering Materials and Struc- tures, Vol. 35, No. 1, 2012, pp. 22-29.