INVESTIGATIVE ANALYSIS ON THE IMPACT OF ZIRCONIA COATING ON FATIGUE LIFE OF AISI 316L STEEL

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Abstract - *AISI 316L steel is extensively used in marine application such as boat rails and hardware, facades of buildings, pharmaceutical and bio-processing, dairy and food, brewery and other beverage industries due to high corrosion and heat resistance along with outstanding fabricability and formability.*

In the present work, the effect of Zirconia powder coating on the fatigue life and corrosion resistance of AISI 316L steel was examined. The characterization of base material and coating is done in terms of chemical composition, microstructure, surface roughness and hardness. Thereafter, low cycle fatigue tests and corrosion tests are conducted to examine the fatigue life and corrosion resistance.

It was found that the there was a reduction in fatigue life of the chosen material by around 5% due to the HVOF coating of Zirconia. However the corrosion resistance can be improved by around 30% due to the same. It is hence a trade-off conclusion between fatigue life and corrosion resistance, to be taken by engineers based on the application requirements.

Key Words: **AISI 316L steel, Zirconia, HVOF coating, Fatigue life, Corrosion resistance**

1. INTRODUCTION

Machine is mechanical arrangement which utilises power for applying forces in order to manage movement as well as other parts which we utilize in on a regular living were frequently undergone to multiple forces enclosed. Stresses as well as strains formed were occasionally periodic relative to direction of forces. Although degree of strain is less than their yield limit since they result in failure while they were used a number of schedules at regular intervals. If Material was undergone to continuous series of stress or else strain, failure happens with foremost towards fracture at a few deficiencies, this kind of failure was known to be fatigue.

Fatigue deformation was formed with adaptive steps of rotating stress, tensile stress in addition to plastic strain. The plastic strain happening since cyclical stress initiate crack, tensile stress promote crack increase. Careful calculation of strain represent to minute plastic strains might be present on low level based on stress since the strain may or else emerge into completely elastic. Even if compressive stresses mayn't reason fatigue failure, Compressive loads will induce local tensile stresses. This was required for implementing few steps for developing fatigue life for components also with varying geometry for components otherwise decreasing Resistance divergent close to material. Geometry adjust was never answer, particularly because of a few limitations. Thus fatigue life for element was raised with reducing strains of substance. Several methods like heat treatment, coating etc., will improve fatigue life for substance yet beneath study all of us have to move ahead within consideration strains.

2. EXPERIMENTAL DESIGN

2.1. Material

Stainless steels were low carbon alloy steels by chromium being main blend component. Corrosion resistance for steels was because of presence for a considerable amount for chromium which creates formation for skinny, effective deposit for chromium-oxide that defends exterior among decay.

AISI 316L Austenitic Stainless Steel was substance where corrosion resistance, fatigue life were analyzed over project. The Steel was mainly utilized for naval as well as marine practices since this contains outstanding corrosion resistance, large strength via weight proportion.

Table -1: Equipment used during the research study

S.No	Equipment
1	High Velocity Oxy-Fuel facility
2	Plug N Play for fatigue testing

2.2 Thermal spray coating

Thermal Spray coating is used globally in defending commercial parts among decay, abrasion, erosion, wear, surface fatigue, to guard substrates operating in high temperatures. Thermal spray coating procedures were divided as follows: plasma spray Process, flame thermal spray, high velocity oxy fuel (HVOF) spraying, cold spraying, arc spray process, and detonation gun method. In the current project, the selected component was laminated by ZrO_2 using high-velocity oxy-fuel coating apparatus. ZrO_2 was moved across central orifice of Torch, fuel gas combined by oxygen pass via channel for Torch. Later becoming warmed near end of Torch, molten ZrO_2 was sprinkled over job in order this is sprayed over specimen.

Fig -1: HVOF coating equipment

2.3. Fatigue Testing Machine

Plug-N-Play Fatigue Testing Machine in ITW was used to detect fatigue life for specimens. Apparatus consist of condition for using different Tensile, Compressive important reversed loads. This was given by computer data logger for notify amount of series enforced throughout Test.

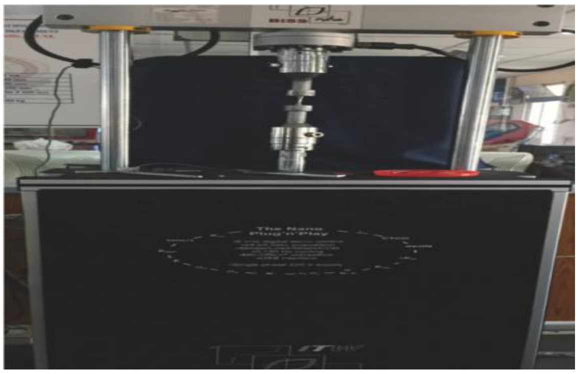

Fig -2: Specimen mounted on the Plug-N-Play Fatigue Testing Machine

2.4 Test Specimens and types used in experimental work

(1) Uncoated Specimens

Solid round samples are used for Low fatigue tests. Tests are done for calculate Low cycle fatigue life analysis on uncoated material.

Material	Type
Uncoated AISI 316L Specimens	Round solid bars

Figure 3: Uncoated AISI 316L Specimens

(2) Zirconia Coated specimens

Chosen amount for samples containing Solid round bar fatigue samples of type AISI 316L Stainless steel are shop cut to required length and diameter. The size included 66 mm length through the complete specimen diameter of 10mm thickness. The complete specimens are prepared accordingly by ASTME 606 – 92 (Reapproved 1998) Standard. The properly machined investigation samples are subjected to HVOF spraying with zirconia powders.

Material	Type	Number of coated specimens
300 microns Zirconia coated AISI 316L Specimens	Round solid bars	**3**

Figure 4: 300 microns AISI 316L specimens just sprayed with the coating powder.

2.5 LCF test on specimens

Initially the specimens are placed on to Plug N play Fatigue testing apparatus .The Specimens are gripped into the jaws and locked tightly.

Table 2: Plug N Play Fatigue testing parameters

Load capacity	3 KN
Cyclic wave forms	Sine, Triangle, Square, HSine, HTriangle and HSquare
Ramp waveform	Single, Dual and Trapezoidal
Frequency range	0.4 Hz
Gap among columns	400mm
Testing type	Low Cycle Fatigue
Drive unit	Hydraulic System
Amplitude	250 Mpa
Mean	0

2.6 Fatigue Specimen

Samples were made according to ASTM E606 grades by means of CNC lathe.

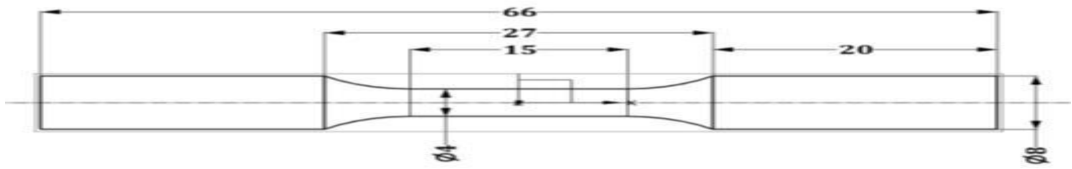

Figure 5: Specimen geometry used for fatigue tests.

2.7. Finite Element Fatigue Analysis

Finite Element Method was done for calculate Fatigue or Tolerance barrier for selected components, for estimating 'Stress (vs.) Fatigue Life' arc. ANSYS 18.1 was utilized like instrument in order for carry out Finite Element Analysis. Strain life approach obtainable over ANSYS 18.1 Fatigue instrument was used to analysis. Strain-Life method extracts for consideration, local plastic strains brought at localized points.

3. FINITE ELEMENT AND EXPERIMENTAL INVESTIGATIONS

3.1. Stress (vs) Fatigue Life Curve through Finite Element Approach

Tolerance limits, Stress (vs.) Fatigue Life curve are calculated by ANSYS 18.1. For replicate circumstances for trial conducted, axial load with form for outward pressure is kept over right face, permanent assist is given to left face for sample.

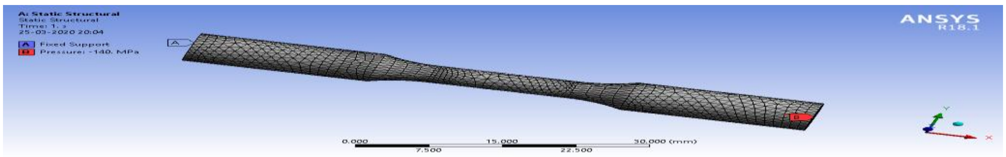

Figure 6: Boundary Conditions used for the analysis

Parameters utilized for finite element fatigue analysis for AISI 316L in ANSYS:

Modulus of Elasticity (E) = 193 GPa

Poisson's Ratio (μ) = 0.27

Tensile Strength (UTS) = 719 MPa

Fatigue Strength Coefficient (σ_f') = 1078.5 MPa *(taken as 1.5*UTS for steels)*

Fatigue Strength Exponent (b) = -0.087 *(standard value of steels)*

Fatigue Ductility Coefficient(ε_f') = 0.59 *(standard value of steels)*

Fatigue Ductility Exponent (c) = -0.58 *(standard value of steels)*

Cyclic Strain Hardening Exponent (n') = 0.15 *(taken as b/c)*

Cyclic Strength Coefficient (K') = 1167.21 MPa *(taken as*$[\sigma_f'/(\varepsilon_f')^{n'}]$*)*

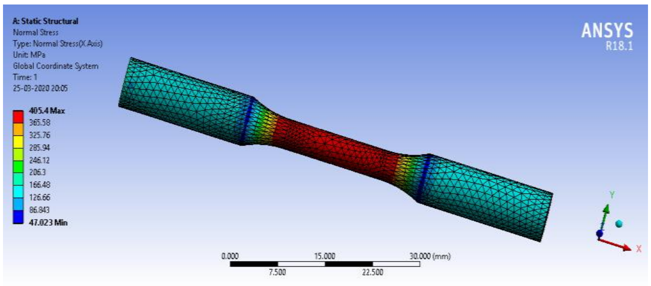

Figure 7(a): Normal **s**tress in x-direction

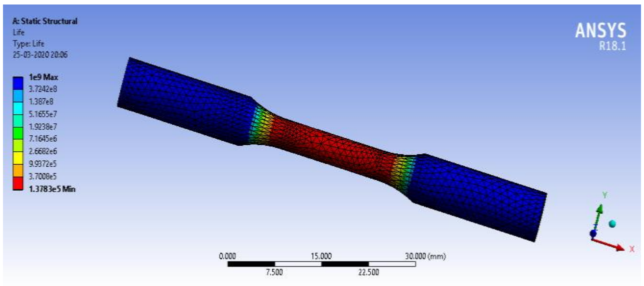

Figure 7(b): Fatigue Life in cycles

Finite element fatigue runs were taken among 40 variable loadings, the stress (vs) fatigue life curve was drawn through corresponding stress, fatigue life results. Table 4.1 encloses stress, fatigue life values also curve was drawn in Figure 4.4. Magnified direction for Low cycle fatigue area for stress (vs.) fatigue life curve was revealed in Figure 4.5. Tolerance boundary was seen as 321.45 MPa of AISI 316L because this was stress value got over fatigue life for nearly 10^6 cycles. Equivalent will be seen over bold line of Run 2 in below Table.

Table 3: Finite Element Fatigue results for AISI 316L

Run	Pressure (MPa)	Normal Stress of X-direction (MPa)	Fatigue Life (cycles)
1	110.5	319.98	1045300
2	**111.01**	**321.45**	**1000700**
3	115	333.01	720080
4	120	347.48	490440
5	125	362.94	343930
6	130	377.46	247690
7	135	391.84	182760
8	140	406.46	137830
9	145	420.84	106040
10	150	435.48	83030
11	155	449.82	66080
12	160	464.32	53360
13	165	478.70	43667
14	170	493.28	36155
15	175	507.76	30256
16	180	522.24	25567
17	185	536.72	21798
18	190	551.19	18734
19	195	565.67	16210
20	200	570.13	14138
21	205	584.81	12390
22	210	609.13	10938
23	215	623.59	9699

24	220	638.06	8642
25	225	652.54	7735
26	230	667.02	6952
27	235	681.46	6273
28	240	695.98	5670
29	245	700.46	5169
30	250	724.94	4705
31	255	748.48	4301
32	260	753.84	3943
33	265	768.13	3624
34	270	782.85	3330
35	275	797.33	3085
36	280	811.84	2855
37	285	826.29	2649
38	290	830.76	2462
39	295	855.24	2292
40	300	869.72	2138

3. CONCLUSIONS

From the above research, it can be concluded that the Endurance limit value obtained from finite element method is accordance by real value for components. For AISI 316L, tolerance limit through finite element process (ANSYS 18.1) result was 321.45 MPa. Hence we can conclude that Finite Element Method can approximate the endurance limit with good accuracy. It can also be concluded that the Coating of ZrO_2 over AISI 316L steel decreased fatigue life by 5%. HVOF coating method done, created oxide films evolution over foundation substance AISI 316L, as a result decreased their fatigue life. Therefore, this was trade-off conclusion among fatigue life as well as corrosion resistance through engineering design stand point.

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