Finite Element Fatigue Analysis of a Crane Hook

K. Srikanth , G. Seshanth , P. Pranay , J. Jagadesh Kumar

Abstract*: The aim of the current research is to evaluate the fatigue life of a crane hook made of two materials AISI 316L (austenitic stainless steel) and AISI 4140 (forged steel) using Finite Element Method package ANSYS 18.1 workbench. The analysis is performed considering an ambient temperature of 25°C in order to replicate normal working conditions. The fatigue lives of both the crane hooks are evaluated at different load and a comparative analysis if performed to arrive at the better material for the crane hook keeping cost and availability as criteria. It is found that the fatigue lives of both crane hooks (made of AISI 316L and AISI 4140) are not very different, however, AISI 4140 displayed marginally more fatigue life when compared to AISI 316L. When cost is taken as criterion, AISI 4140 is three times cheaper than AISI 316L. However, AISI 316L has better corrosion resistance than AISI 4140 and hence is suggested for the crane hook when used in chemical plants and sea shore areas.

***Keywords* : Fatigue failure, Finite element methods, life cycles, ANSYS 18.1.**

I. INTRODUCTION

Cranes are industrial equipments that are primarily utilized for material transfer in the industry. Crane hooks are the components which are used to lift heavy loads using wire ropes and cranes in constructional sites and industries [1]. Hence, such an important component in an industry must be manufactured and designed in a way so as to deliver maximum performance without failure [2], [3]. Crane hooks mainly fail due to three major factors i.e. dimension, material, and overload. Trapezoidal, circular, rectangular and triangular cross sections are commonly used in crane hooks [4]. Crane hooks often fail due to accrual of large stresses [5] as cranes undergo continuous loading and unloading. This causes fatigue failure of the crane hooks [6]. Cracks develop in the crane hook, propagate and subsequently lead to fracture if they are inadequately designed. The fatigue failure can lead to serious accidents. In the case of ductile fracture, crack propagates continuously and easily visible and is therefore better than brittle fracture as in the latter case there is sudden propagation of the crack and the hook fails suddenly. This type of fracture is risky as it is difficult to detect [7], [8]. Even under fatigue loading, the life of the crane hooks can be increased with proper design modifications and taking some steps to reduce stress concentration areas [9].

The aim of the current research is to evaluate the fatigue life of a crane hook made of two materials AISI 316L and AISI 4140 using Finite Element Method package ANSYS 18.1 workbench. The analysis is performed considering an ambient temperature of 25°C in order to replicate normal working conditions. The fatigue lives of both the crane hooks are evaluated at different load and a comparative analysis if performed to arrive at the better material for the crane hook keeping cost and availability as criteria.

II. MATERIALS & METHODS

Material AISI 316L austenitic stainless steel is the material for which the corrosion resistance and fatigue life are analyzed in the current research. This steel is primarily used in naval and marine applications as it possesses excellent corrosion resistance and high strength to weight ratio [10]. The chemical composition and mechanical properties of the material used are given in Tables 1 and 2, respectively.

Material AISI 4140 Forged steel is used in chemical plants and sea shore areas as it possesses high strength to weight ratio. And it is three times cheaper than AISI 316L. The chemical composition and mechanical properties of the material used are given in Tables 1 and 2, respectively.

Table 1. Chemical Composition (wt%)

Element	AISI 316L	AISI 4140
C	0.03	0.43
Mn	2	1
Si	0.75	0.3
Cr	17	1.1
Ni	12	-
Mo	2.5	0.25
P	0.045	0.03
S	0.03	0.04
N	0.1	-
Fe	Balance	Balance

Revised Manuscript Received on Jan 26, 2020.

* Correspondence Author
K. Srikanth*, Dept. of Mechanical Engg., Vidya Jyothi Institute of Technology, Hyd, India, Email: srikanthkatukojwala328@gmail.com
G. Seshanth, Dept. of Mechanical Engg., Vidya Jyothi Institute of Technology, Hyd, India, Email: seshanth6711@gmail.com
P. Pranay, Dept. of Mechanical Engg., Vidya Jyothi Institute of Technology, Hyd, India, Email: pranay.reddy1710@gmail.com
J. Jagadesh Kumar, Assoc. Prof., Dept. of Mechanical Engg., Vidya Jyothi Institute of Technology, India, Email: jagadesh@vjit.ac.in

Table 2. Mechanical Properties

Material	AISI 316L	AISI 4140
Hardness (BHN)	146	197
UTS (MPa)	560	655
Yield Strength (Mpa)	235	415
Poisson's Ratio	0.25	0.29
Elastic Modulus (GPa)	193	205

A. Solid Model

The three-dimensional model of the specimen is prepared in SOLIDWORKS and exported to Initial Graphics Exchange Specification (IGES) format. The 3-D solid model of the specimen is shown in the Fig. 1.

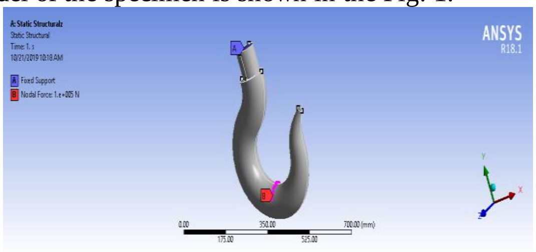

Fig. 1. 3-D solid model of the specimen

B. Finite Element Fatigue Analysis

The finite element fatigue analysis is carried out using ANSYS 18.1 workbench. It is employed to evaluate the applied pressure on the job in order to get the estimated fatigue life in cycles.

C. Finite Element Model

The specimen's 3-D model in IGES format is imported into ANSYS 18.1 and then the finite element model of the specimen is prepared by using the ANSYS mesh tool with a refinement level of 3. The finite element (FE) model is shown in Fig. 2.

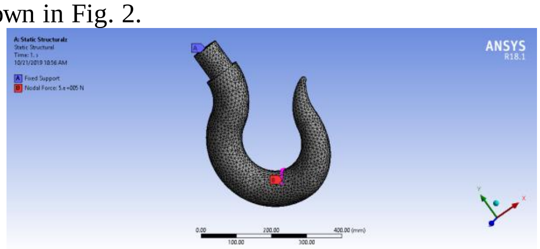

Fig. 2. Finite Element model of the specimen

D. Boundary Conditions

The Top end of the specimen is fixed by applying a support at that end. A pressure of required magnitude is applied on the Named Section of the specimen. The maximum Von-Mises (Equivalent) stress induced is maintained at approximately 1568MPa so that the fatigue life is always around 229 cycles. This is achieved by the iterative approach of altering pressure so that the maximum Von-Mises stress is around 1568MPa. The boundary conditions of a typical specimen are shown in Fig. 3.

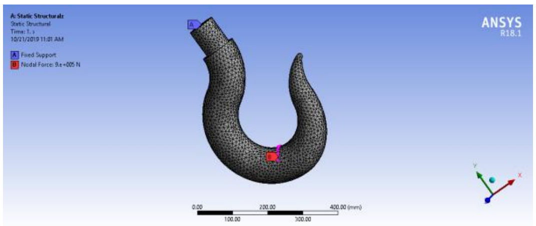

Fig. 3. Typical specimen with boundary conditions

E. ANSYS Fatigue Tool

The strain life approach available in ANSYS 18.1 Fatigue tool out-of-box is considered for the analysis which is undertaken for the current research due to the presence of curvature on the geometry of the specimen. Strain-Life approach takes into account, the local plastic strains induced at localized spots. Smith-Watson-Topper method of the strain life approach is used for the research as it gives conservative fatigue life value when compared to Morrow's approach [11], [12].

III. RESULTS AND DISCUSSION

The Von-Mises stress and fatigue life results of the AISI 316L austenitic stainless steel Hook. A Nodal Force of 900 KN was required to be applied on the Named Section of the specimen so that the maximum Von-Mises stress induced was around 1568 MPa. The fatigue life obtained for this boundary conditions was 229 cycles.

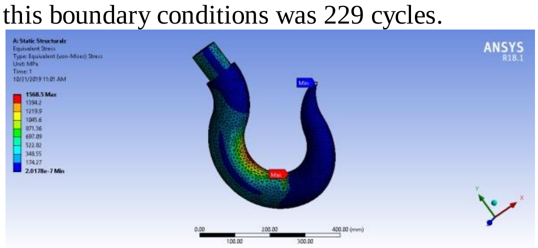

Fig. 4. Von-Mises stress of AISI 316L austenitic stainless steel Hook.

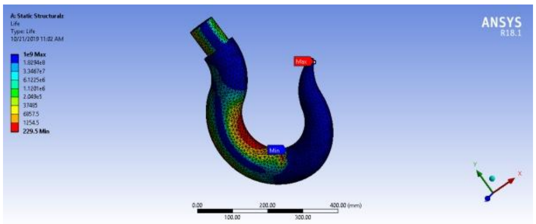

Fig. 5. Fatigue Life of AISI 316L austenitic stainless steel Hook.

Retrieval Number: D1706029420//2020©BEIESP

DOI: 10.35940/ijitee.1706029420

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The Von-Mises stress and fatigue life results of the AISI 4140 Forged steel Hook. A Nodal Force of 900 KN was required to be applied on the Named Section of the specimen so that the maximum Von-Mises stress induced was around 1569 MPa. The fatigue life obtained for this boundary conditions was 249 cycles.

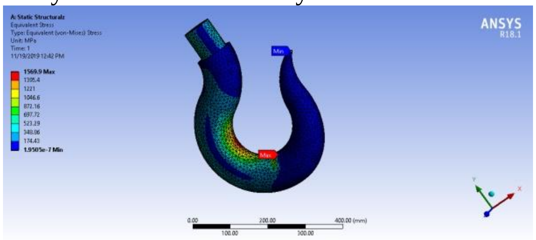

Fig. 6. Von-Mises stress of AISI 4140 Forged steel Hook.

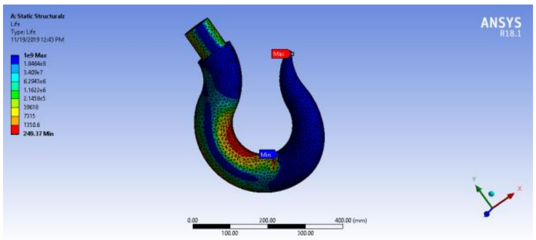

Fig. 7. Fatigue Life of AISI 4140 Forged steel Hook.

Table 3. Finite Element Results for AISI 316L

Step	Force Applied (KN)	AISI 316L	
		Equivalent Stress (MPa)	Fatigue Life (cycles)
1	100	174.27	640060000
2	200	348.55	429040
3	300	522.82	23389
4	400	697.09	5291
5	500	871.36	2007
6	600	1045.60	979
7	700	1219.90	553
8	800	1394.20	344
9	900	1568.50	229

Table 4. Finite Element Results for AISI 4140

Step	Force Applied (KN)	AISI 4140	
		Equivalent Stress (MPa)	Fatigue Life (cycles)
1	100	174.43	634250000
2	200	348.86	438570
3	300	523.29	24725
4	400	697.72	5669
5	500	872.16	2164
6	600	1046.6	1059
7	700	1221	600
8	800	1395.4	374
9	900	1569.9	249

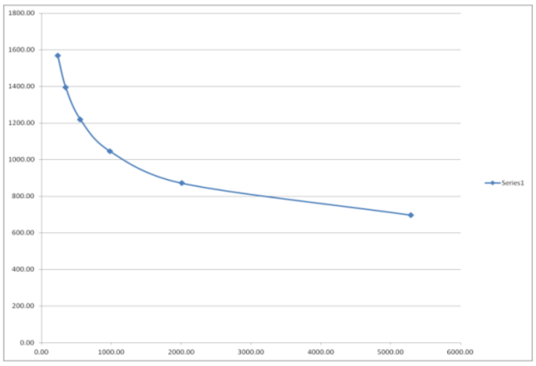

Fig. 8. S-N Curve for AISI 316L austenitic stainless steel Hook.

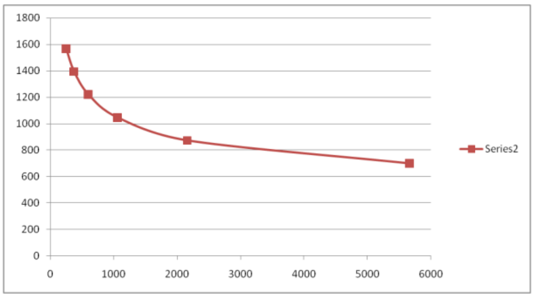

Fig. 9. S-N Curve for AISI 4140 Forged steel Hook.

IV. CONCLUSIONS

It is found that the fatigue lives of both crane hooks (made of AISI 316L and AISI 4140) are not very different, however, AISI 4140 displayed marginally more fatigue life when compared to AISI 316L. When cost is taken as criterion, AISI 4140 is three times cheaper than AISI 316L. However, AISI 316L has better corrosion resistance than AISI 4140 and hence is suggested for the crane hook when used in chemical plants and sea shore areas.

V. ACKNOWLEDGEMENTS

The authors express their deep sense of gratitude to the Head of the Mechanical Engineering Department, Vidya Jyothi Institute of Technology for their continuous support during the execution of the current research.

REFERENCES

[1] Sushovan Ghosh, Biswaranjan Pati, Rohit Ghosh, Ashutosh Palo, Dr. Rabindra Nath Barman, Static Analysis of Crane Hooks With Different Cross Sestions – A Comparative Study Using Ansys Workbench, International Journal of Mechanical Engineering and Technology, 8(4), 2017, pp. 474–482.
[2] B Nagaraju, M RajaRoy, P Venkatesh Reddy, K Satyanarayana, Stress analysis of Crane Hook Using FEA, India Technical Research Organisation, Volume-2, Issue-2,2015.
[3] Amandeep Singh, Vinod Rohilla, Optimization and Fatigue Analysis of a Crane Hook Using Finite Element Method. International Journal of Recent advances in Mechanical Engineering (IJMECH) Vol.4, No.4, November 2015.
[4] E.Sai Krishna and Dr. S .Suresh Kumar, Design and Analysis of Crane Hook with Different Materials, International Journal of Mechanical Engineering and Technology, 9(4), pp. 786–791, 2018.
[5] Patel Ravin B, Patel Bhakti K, Patel Priyesh M, Patel Dixit H, Patel Hirak S, Design and Analysis of Crane Hook with Different Material, International Journal of Advanced Computer Technology (IJACT), Vol 4.
[6] Osman Ashraf Ansari, Dr. P. Sampath Rao, Design and

Analysis of Crane Hook for Load Conditions, International Journal of Mechanical Engineering and Technology (IJMET) ISSN Print: 0976-6340 and ISSN Online: 0976-635.

[7] Chetan N. Benkar explained the "Finite Element Stress Analysis of Crane Hook with Different Cross Sections" International Journal for Technological Research in Engineering ISSN (Online): 2347 – 4718 Volume 1, Issue 9, May-2014.

[8] M.N.V Krishnaveni, M.Amareswari Reddy, B.Nagaraju, Static Analysis of Crane Hook with I – Section Using Ansys, International Journal of Engineering and Management Research, Volume-5, Issue-3, June-2015.

[9] Abhijit Devaraj, Design of a Crane Hook of Different Materials and Stress Analysis Using ANSYS Workbench, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 3 Issue VII, July 2015.

[10] J. Jagadesh Kumar, G. Diwakar and Vaddi Venkata Satyanarayana, Impact of High-Velocity Oxy-Fuel ZrO2 Coating on Corrosion Resistance and Fatigue Life of AISI 316L Austenitic Stainless Steel, Hindawi Advances in Materials Science and Engineering Volume 2019.

[11] J. Jagadesh Kumar, G. Diwakar, V. V. Satyanarayana, Impact of Notch Geometry on the Pressure Bearing Capacity of AISI 316L Austenitic Stainless Steel under Fatigue Loading, Universal Journal of Mechanical Engineering 7(6): 336-347, 2019.

[12] V. T. Troshchenko and L. A. Khamaza, Srain–Life Curves of Steels and Methods for Determining the Curve Parameters, Strength of Materials, Vol. 42, No. 6, 2010.

Retrieval Number: D1706029420//2020©BEIESP

DOI: 10.35940/ijitee.1706029420

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication