STRESS ANALYSIS OF CRANE HOOK USING FEA

B Nagaraju [1], M RajaRoy[1] , P Venkatesh Reddy[1] , K Satyanarayana[1]
[1] Department of Mechanical Engg, Anil Neerukonda Institute of Technology and Sciences, Sangivalasa, Visakhapatnam-531162,Andhra Pradesh.
Email: [1]anitsnagaraju@gmail.com, [2]anitsrajaroy@gmail.com, [3]venkateshreddy348@gmail.com,

Abstract— Crane hook is very significant component used for lifting the load with the help of chain or wire ropes. Crane hooks are highly liable components and are always subjected to bending stresses which leads to the failure of crane hook. To minimize the failure of crane hook, the stress induced in it must be studied. A crane is subjected to continuous loading and unloading. This may causes structural failure of the crane hook. In the present work, an attempt has been made by considering four different type's of cross sections of crane hooks and are designed theoretically by using curved beam concept. CATIA software is used for modeling the crane hook and ANSYS software used to find out the stresses. As a conclusion, the results obtained from ANSYS and theoretical calculations are compared.

***Index Terms*—crane hook, static analysis , FEA.**

1. INTRODUCTION

Crane Hooks are highly liable components that are typically used for industrial purposes. It is basically a hoisting fixture designed to engage a ring or link of a lifting chain or the pin of a shackle or cable socket and must follow the health and safety guidelines. Thus, such an important component in an industry must be manufactured and designed in a way so as to deliver maximum performance without failure. Thus, the aim of the work is to study the stress distribution pattern of a crane hook using finite element method and to verify the results using caustic method.

The lifting of objects generally occurs on construction sites, in factories and other industrial situations. Correct lifting can move large objects efficiently and reduce manual handling operations. Incorrect lifting however, can lead to disastrous accidents. Every year, incorrect lifting procedures cause injuries, loss of work time and property. People, machinery, loads, methods and the work environment, are all important factors for correct lifting. Provided that enough safety measures are fully implemented, lifting accidents can be reduced. The Fig 1.1 as shows the general diagram of crane hook.

Fig 1.1 Crane Hook

2. LITERATURE REVIEW

Crane hooks are the components which are generally used to elevate the heavy load in industries and constructional sites. Recently, excavators having a crane-hook are widely used in construction works site. *M. Shaban et al [1]* studied the stress pattern of crane hook in its loaded condition, a solid model of crane hook is prepared with the help of ABAQUS software. Real time pattern of stress concentration in 3D model of crane hook is obtained. The stress distribution pattern is verified for its correctness on an acrylic model of crane hook using shadow optical method (Caustic method) set up. By predicting the stress concentration area, the shape of the crane is modified to increase its working life and reduce the failure rates. *E. Narvydas et al* [2] investigated circumferential stress concentration factors with shallow notches of the lifting hooks of trapezoidal cross-section employing finite element analysis (FEA). The stress concentration factors were widely used in strength and durability evaluation of structures and machine elements. The FEA results were used and fitted with selected generic equation. This yields formulas for the fast engineering evaluation of stress concentration factors without the usage of finite element models. The design rules of the lifting hooks require using ductile materials to avoid brittle failure; in this respect they investigated the strain based criteria for failure, accounting the stress triaxiality . *SpasojeTrifkovic' et al* [3] analyzes the stress state in the hook using approximate and exact methods. They calculated stresses in various parts of the hook material firstly by assuming hook as a straight beam and then assuming it as a curved beam. Analytical methods were used with the help of computers, using FEM. *Bhupender Singh et al* [4] presented the solid modeling and finite element analysis of crane boom has been done using PRO/E WILDFIRE 2.0 and ALTAIR HYPER MESH with OPTISTRUCT 8.0 SOLVER*Y. Torres et al* [5] studied the probable causes which led to a failure of the crane hook in service. The study of accident includes: details of the standards governing the manufacturing and use of lifting hooks, experimental analysis, mechanical behavior of steel of reported hook and simulation of the thermal history of the hook. From the literature survey it is understood by this author that there is a lot of scope for studying the stress analysis with different cross sections. Taking into this consideration, the author has embarked on studying the stress analysis of crane hook with four different cross sections such as rectangle, trapezoidal, triangle and circular cross sections.

3 DESIGN OF CRANE HOOK

Machine frames having curved portions are frequently subjected to bending or axial loads or to a combination of bending and axial loads. With the reduction in the radius of curved portion, the stress due to curvature become greater and the results of the equations of straight beams when used becomes less satisfactory. For relatively small radii of curvature, the actual stresses may be several times greater than the value obtained for straight beams. It has been found from the results of Photo elastic experiments that in case of curved beams, the neutral surface does not coincide with centroidal axis but instead shifted towards the Centre of curvature. It has also been found that the stresses in the fibers of a curved beam are not proportional to the distances of the fibers from the neutral surfaces, as is assumed for a straight beam.

The design of crane hook was done by assuming the data pertaining to load(w), C.S.A and curvatures which are used in industrial applications of crane hook as shown in Figs 3.1 to 3.4

3.1 Theoretical Design of Crane Hook with Rectangular C.S.A

W = 20 KN = 20×10^3N; Ri= 50 mm; R_o= 150 mm; h = 100 mm; b = 60 mm

ri = Distance of inner fibre from centre of curvature, C

ro = Distance of outer fibre from centre of curvature

rc = Distance of centroidal axis (CG axis) from centre of curvature

rn = Distance of neutral axis from centre of curvature

The neutral axis is shifted towards the centre of curvature by a distance called eccentricity 'e'. The value 'e' should be computed very accurately since a small variation in the value of 'e'

causes a large variation in the values of stress.

e = rc – rn

ci = Distance between neutral axis and inner fibre = rn – ri

co = Distance between outer fibre and neutral axis = ro – rn

Resultant stress at the inside fibre,

$\sigma_t + \sigma_{bi}$= 3.33+30.66 = 33.99MPa (tensile)

∴ Resultant stress at the outside fibre,

$\sigma_t - \sigma_{bo}$ = 3.33-14.66 = -11.33MPa (compressive)

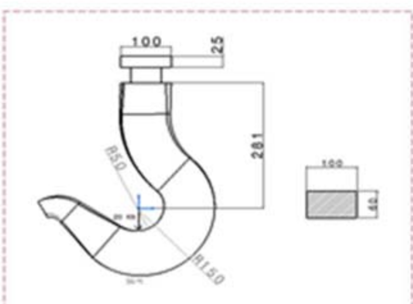

Fig 3.1 Design of Crane Hook with rectangular C.S.A

3.2 Theoretical Design of Crane Hook with Trapezoidal C.S.A

W = 20 KN = 20 × 10^3N; R_i= 50 mm ; R_o= 150 mm ; h = 100 mm ; b_i=90 mm; b_o=30 mm

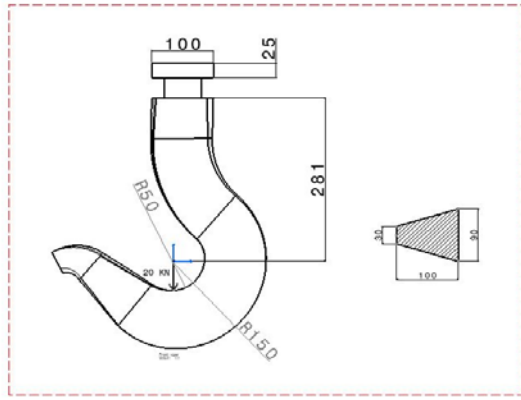

Fig 3.2Design of Crane Hook with Trapezoidal C.S.A

∴ Resultant stress at the inside fibre

σ_{bi}= 3.33+25.169 = 28.499 MPa (tensile)

Resultant stress at the outside fibre

$\sigma_t - \sigma_{bo}$ = 3.33-16.63 = -13.3MPa (compressive)

3.3 Theoretical Design of Crane Hook with Triangular C.S.A

W = 20 kN = 20 × 10^3N; R_i= 50 mm ;R_o= 150 mm ; h = 100 mm ; b_i =90 mm;

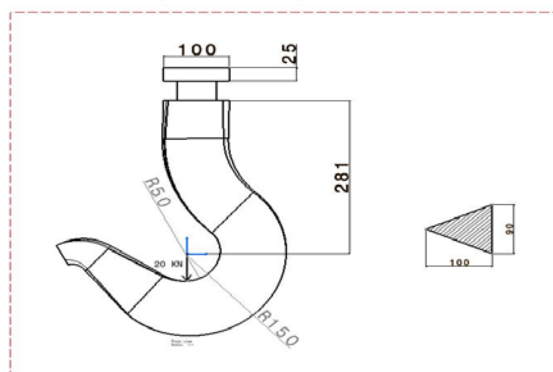

Fig 3.3 Design of Crane Hook with Triangular C.S.A

∴ Resultant stress at the inside fibre

$\sigma_t + \sigma_{bi}$= 6.163+32.654 = 38.817MPa (tensile)

∴ Resultant stress at the outside fibre

$\sigma_t - \sigma_{bo}$ = 6.163-29.177 = -23.014 MPa (compressive)

3.4 Theoretical Design of Crane Hook with circular C.S.A

W = 20 KN = 20 × 10^3N;R_i= 60 mm ; R_o= 150 mm; d=90mm

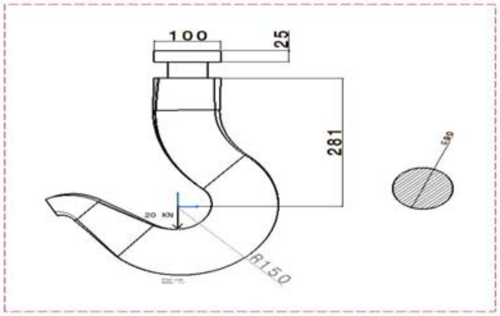

Fig 3.4 Design of Crane Hook with circular C.S.A

∴ Resultant stress at the inside fibre

$\sigma_t + \sigma_{bi}$= 3.143+43.31 = 46.461MPa (tensile)

∴ Resultant stress at the outside fibre

$\sigma_t - \sigma_{bo}$ = 3.143-21.73 = -18.587 MPa (compressive)

4. MODELLING OF CRANE HOOK USING CATIA

CATIA serves the design tasks by providing different workbenches. A workbench is defined as a specific environment consisting of a set of tools, which allows the user to perform specific design tasks in a particular area. The basic workbenches in CATIA V5 are Part design workbench, Wireframe and Surface Design workbench, Assembly Design workbench, and Drafting workbench.

.

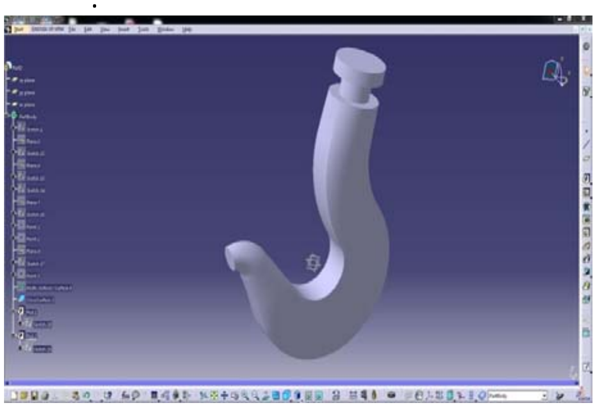

Fig 4.1 CATIA Model of Crane Hook with Rectangular C.S.A

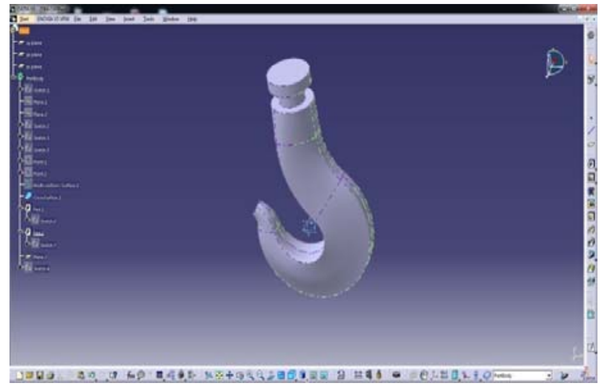

Fig 4.2 CATIA Model of Crane Hook with Trapezoidal C.S.A

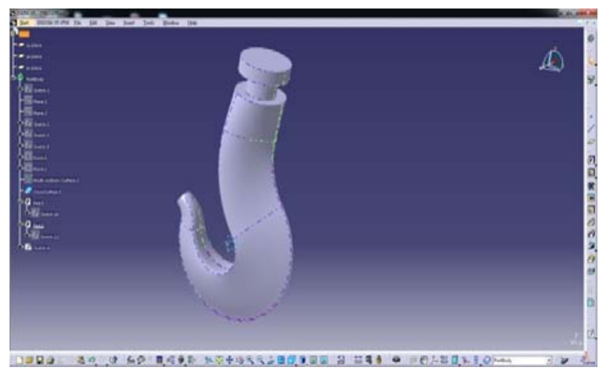

Fig 4.3 CATIA Model of Crane Hook with Triangular C.S.A

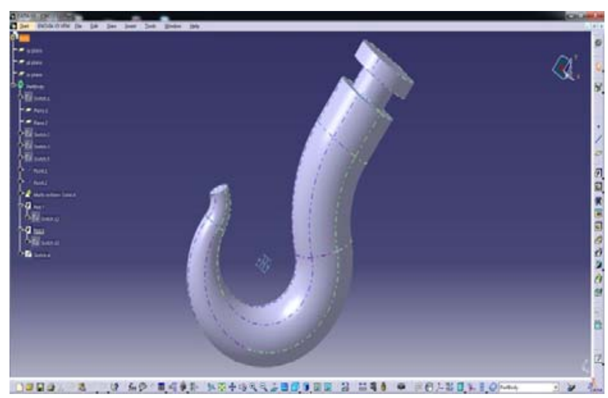

Fig 4.4 CATIA Model of Crane Hook with circular C.S.A

5 FINITE ELEMENT ANALYSIS OF CRANE HOOK USING ANSYS

The finite element method has become a powerful tool for the numerical solution of wide range of engineering problems. Applications range from deformation and stress analysis of automotive aircraft, building, and bridge structures to field analysis of heat flux, seepage and other flow problems, with advances in computer technology and CAD systems, complex problems can be modeled with relative ease.

In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements. The material properties and the governing relationships are considered over these elements and considering the loading and constraints, results in a set of equations. Solution of these equations gives us the approximate behavior of the continuum.

6 RESULTS AND DISCUSSION

In this work, four different types of sections of crane hook are designed successfully by using curved beam concept. The induced Stresses are determined for a load of 20 KN using curved beam concept.

The solid modal was prepared using CATIA V5 R20 version and exported to ANSYS using IGES format. The hook is fixed at the top end in x,y and z directions and are fully constrained. The inner curvature of hook is subjected 20 KN load and is applied on nodes. The results of stresses obtained for a crane hook which is made up of steel material are plotted in the Figs 6.1 to 6.4. The results obtained through analytical and theoretical methods are good in agreement with minor deviation and shown in Table 6.1.

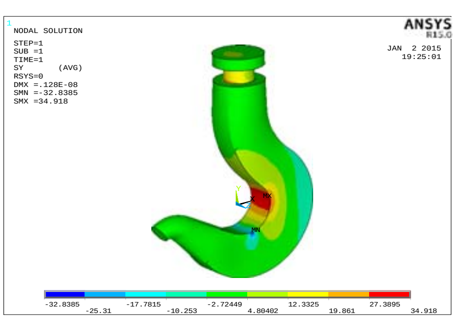

Fig 6.1 variation of Stresses for a crane hook made of steel with Rectangular C.S.A along Y-Direction

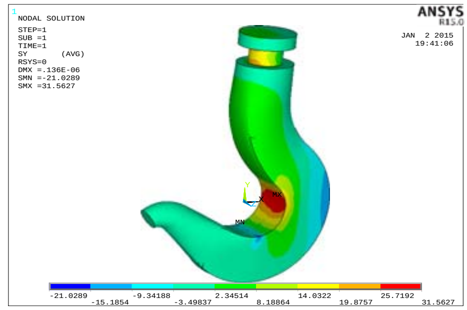

Fig 6.2 variation of Stresses for a crane hook made of steel with Trapezoidal C.S.A along Y-Direction

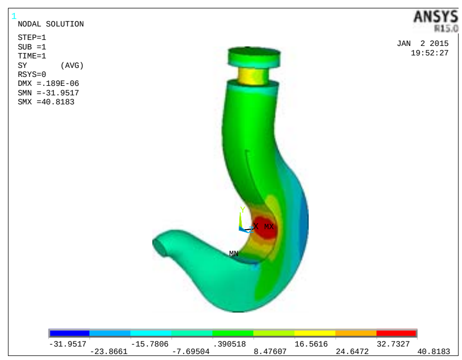

Fig 6.3 variation of Stresses for a crane hook made of steel with Triangular C.S.A along Y-Direction

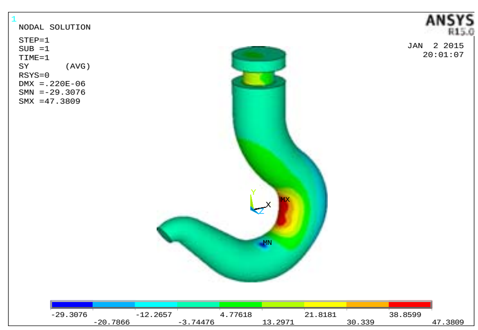

Fig 6.4 variation of Stresses for a crane hook made of steel with Circular C.S.A along Y-Direction

7.CONCLUSION

1. The crane hooks are successfully designed for four different cross sections such as rectangular, trapezoidal, triangular and circular by using curved beam concept.
2. The model was prepared using CATIA software and analysis has been carried out using ANSYS.
3. The trapezoidal cross section gives better results in comparison with other three cross sections as because stresses induced are less in trapezoidal cross section.
4. The stresses obtained in theoretical and analytical methods are in good agreement. The model prepared is used for further studied with different loads and also for different materials.

Table 6.1 Comparison of Stresses obtained in Theoretical and analytical methods

SECTION	THEORITICAL		ANSYS	
	COMPRESSIVE	TENSILE	COMPRESSIVE	TENSILE
RECTANGLE	11.3	33.99	10.25	34.91
TRAPEZOIDAL	13.3	28.49	15.18	31.56
TRIANGULAR	23.01	38.81	23.86	40.81
CIRCULAR	18.58	46.46	20.78	47.38

REFERENCES

[1] M. Shaban, M. I. Mohamed, A. E. Abuelezz and T. Khalifa, “Determination of Stress Distribution in Crane Hook by Caustic”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 5, May 2013.

[2] E. Narvydas, N. Puodžiūnienė, “Circumferential stress concentration factors at the asymmetric shallow notches of the lifting hooks of trapezoidal cross-section”, ISSN 1392 - 1207. MECHANIKA. 2012 Volume 18(2): 152-157.

[3] SpasojeTrifković, NebojšaRadić et. al, “Stress analysis of crane hook using FEM”, INFOTEH-JAHORINA Vol. 10, Ref. C-2, p. 244- 248, March 2011.

[4]Bhupender Singh, Bhaskar Nagar, B.S. Kadam and Anuj kumar, “Modeling and Finite Element Analysis of Crane Boom”, International Journal of Advanced Engineering Research and Studies, Vol. I/ Issue I/October-December, 2011/ 51-52.

[5] Y. Torres , J.M. Gallardo , J. Domínguez , F.J. Jiménez E, “Brittle fracture of a crane hook”, Engineering Failure Analysis 17 (2010) 38–47.

[6] Takuma Nishimura, Takao Muromaki et. al, “Damage Factor Estimation of Crane Hook (A Database Approach with Image, Knowledge and Simulation)”, 4th International Workshop on Reliable Engineering Computing (REC 2010).

[7] C. Oktay AZELOĞLU, Onur ALPAY, Investigation Stress of A Lifting Hook with Different Methods, “Verification of The Stress Distribution with Photo elasticity Experiments”, Electronic Journal of Machine Technologies, Vol: 6, No: 4, 2009 (71-79).

[8] Yu Huali, H.L. and Huang Xieqing, “Structure-strength of Hook with Ultimate Load by Finite Element Method”, Proceedings of the International Multi-Conference of Engineersand Computer Scientists, 2009 Vol II IMECS 2009, March 18 - 20, 2009, Hong Kong.