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FEA and Experimental Analysis of Crane Hook Considering Different Cross sections and Materials

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Abstract

Crane hook is 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. Failure of a crane hook mainly depends on three major factors i.e., dimension, material, overload. To minimize the failure of crane hook, the stress occurred in it must be studied. Structural failure of the crane hook may happen as a crane hook is subjected to continuous loading and unloading. In this paper the design of the hook is done by analytical method for the different materials like aluminium, cast iron, high strength low alloy steel and Structural Steel. CATIA software is used for modelling the crane hook and ANSYS software used to find out the stresses induced in it. This result helps us for determining of stress in existing model. By predicting the stress concentration area, the hook working life increase and reduce the failure stress.

Keywords: **Crane hook, stress, ANSYS**,

I INTRODUCTION

The stress concentration factors are widely used in strength and durability evaluation of structures and ma-chine elements. A large number of research works have been performed in this field and recommendations for the engineers developed. However, the diversity of the loading cases, geometry and material characteristics to-gather with the new solution methods motivates to continue the research, as it is proved by a large number of notch problem related publications that appeared during the last decade. The review of these and earlier publications allow to conclude that the specific group of the structural members, the curved beams, need a more extensive investigation since a very few articles in this field have been published yet (perhaps, there is the one and the only publication directly related to the stress concentration factors in curved beams due to the additional discontinuity of the geometry, the circular holes, under bending load).
The present article continues the research work on the modeling of the wear damage and its influence to the stress concentration for the lifting hooks of trapezoid-dal cross-section. The article provides a set of cases of the lifting hooks of trapezoidal gross cross-section with shallow notches, where the circumferential stress concentration factors (*Kt*) were calculated employing finite element analysis (FEA). The FEA results were grouped and fitted to find the equations suitable for the fast engineering evaluation of the notch effect on the stress concentration.

Some preliminary investigation of the stress triaxiality factors is also presented. The design rules of the lifting hooks require using ductile materials to avoid brittle failure, however, the stress triaxiality reduces the ductility and the danger of brittle failure increases. In this respect, the strain based criteria for the failure prediction, accounting the stress triaxiality, appear to be more relevant.
Crane hooks are highly liable components and are always subjected to failure due to accumulation of large amount of stresses which can eventually lead to its failure. Crane hooks are the components which are generally used to elevate the heavy load in industries and constructional sites. A crane is a machine, equipped with a hoist, wire ropes or chains and sheaves used to lift and move heavy material. Cranes are mostly employed in transport, construction and manufacturing industry. Overhead crane, mobile crane, tower crane, telescopic crane, gantry crane, deck crane, jib crane, loader crane are some of the commonly used cranes. A crane hook is a device used for grabbing and lifting up the loads by means of a crane. 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. Crane hooks with trapezoidal, circular, rectangular and triangular cross section are commonly used. So, it must be designed and manufactured to deliver maximum performance without failure. Thus the aim of this research is to study stress distribution pattern within a crane hook of various cross sections using analytical and experimental methods.

PROBLEM STATEMENT

The crane hooks are critical components and large amount of stresses are subjected to crane hook, which are ultimately leading to failure. Fatigue of the crane hook is happens due to continuous loading and unloading of crane. If the crack is detected in the crane hook, it can cause fracture of the hook. The crack may lead to accident due to failure and damage will be catastrophic to personals.

OBJECTIVES

- Design the crane hook for lifting application.
- Model the crane hook in the CAD software.
- Meshing and FEA analysis of the crane hook.
- Compare the various cross-section and materials of crane hook to find out the suitable one.
- Compare the result of crane hook with experimental analysis.

I LITERATURE SURVEY

Y.Torres,J.M.Gallardo,J.Domínguez,F.J.JiménezE (**2010**) [1] The objective of paper is to identify the causes that led to a failure of the crane hook in service. The study of the accident includes: (1) a summary and analysis of the peculiarities inherent to the standards that determine the manufacture and use of this type of device, (2) metallographic, chemical and fractographic analyses, (3) assessment of the steel mechanical behavior in terms of Vickers hardness profile, its tensile strength and fracture energy, and (4) simulation of the thermal history of the hook. The visual and microstructural inspections reveal some evidences that a weld bed was deposited on the hook surface. Several cracks grew from that area into the material. Fracture surface shows features typical of brittle failures (trans granular cleavage fracture). The unalloyed, low-carbon steel contains a relatively low aluminium (<0.025%) and high non-combined nitrogen (>0.0075%) content. All the gathered evidences are in agreement with a strain-aging process triggering the embrittlement of the material, with the fracture starting from a crack generated at the heat affected zone of an uncontrolled welding of the hook.

M. Shaban et. al **(2013)**,[2] 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. The complete study is an initiative to establish a FEA procedure, by validating the results, for the measurement of stresses. For reducing the failures of hooks the estimation of stresses, their magnitudes and possible locations are very important. From the stress analysis, they have observed the cross section of max stress area. If the area on the inner side of the hook at the portion of max stress is widened then the stresses will get reduced. The caustic method is very powerful method to detect the stress distribution for complicated mechanical elements such as hooks. By drilling several distributed small holes on the hook, the caustic method can predict accurately the stress value at each hole position.

E. Narvydas et.al **(2012),**[3] 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.

Rashmi Uddanwadiker **(2011)**,[4] studied stress analysis of crane hook using finite element method and validate results using Photo elasticity. Photo elasticity test is based on the property of birefringence. To study stress pattern in the hook in a loaded condition analysis was carried out in two steps firstly by FEM stress analysis of approximate model and results were validated against photo elastic experiment. Secondly, assuming hook as a curved beam and its verification using FEM of exact hook. The ANSYS results were compared with analytical calculations, the results were found in agreement with a small percentage error = 8.26%. Based on the stress concentration area, the shape modifications were introduced in order to increase strength of the hook.

Takuma Nishimura et. al **(2010),**[5] studied the damage estimation of crane-hooks. They estimated the load conditions which were assumed to be crucial to the crane-hook damages. FEM model of the crane-hook referring to one of its actual designs was constructed. A database was prepared based on the FEM model; it was constructed as a collection of a number of various possible load conditions and the corresponding deformation values, obtained as the results of the FEM analysis. The database was used to identify the load conditions that were fatal to those damaged crane-hooks. Some of the feature points were selected on the crane-hook design; the deformation of a damaged crane-hook can be then obtained based on the feature points detected by means of the image processing.

The critical load condition of the damaged crane-hook was calculated by comparing the obtained actual deformation and the simulated deformation values in the database. On the basis of these calculated load conditions, the critical load condition for the crane-hook was estimated as a statistical distribution based on the Bayesian approach.

II WORKING PRINCIPLE

To minimize the failure of crane hook, the stress induced in it must be studied. Crane is subjected to continuous loading and unloading. This causes fatigue of the crane hook but the fatigue cycle is very low. If a crack is developed in the crane hook, it can cause fracture of the hook and lead to serious accident. In ductile fracture, the crack propagates continuously and is more easily detectible and hence preferred over brittle fracture. In brittle fracture, there is sudden propagation of the crack and hook fails suddenly. This type of fracture is very dangerous as it is difficult to detect. Strain aging embrittlement due to continuous loading and unloading changes the microstructure. Bending stress and tensile stress, weakening of hook due to wear, plastic deformation due to overloading, and excessive thermal stresses are some of the other reasons for failure. Hence continuous use of crane hooks may in-crease the magnitude of these stresses and ultimately results in failure of the hook.

During the lifting of a piece of machinery by means of an overhead travelling crane the hook fractured suddenly, resulting in serious injury to one of the workmen. The load was attached to the hook by means of fibre rope slings and rupture occurred in a plane which appeared to coincide with the sling loop nearest to the back of the hook. The rated capacity of the crane was 15 tons; at the time of the mishap it was being used to lift one end of a hydraulic cylinder with a total weight of about 27 tons, the exact weight lifted being unknown.

III FINITE ELEMEMENT ANALYSIS

3D CAD model of crane hook:-

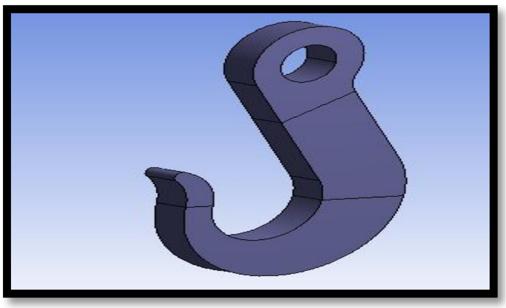


Fig. 1. 3D CAD model of crane hook

Static Structural analysis – Cross section comparison: -

Rectangular cross section:-

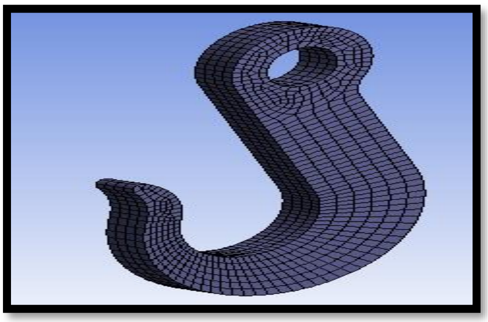
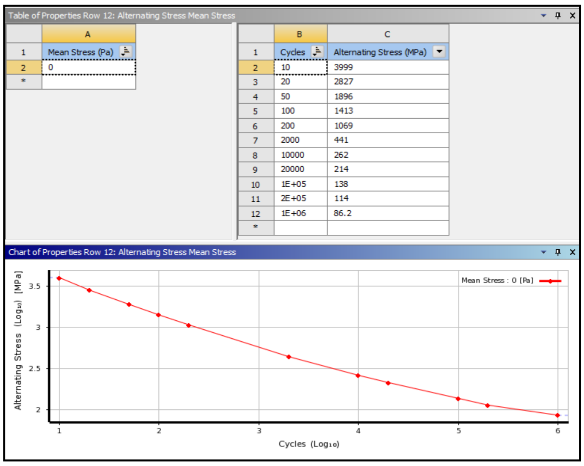


Fig. 2. Mesh

Statistics	
Nodes	12965
Elements	2420

SN CURVE



	A
1	Mean Stress (Pa)
2	0
*	

	B	C
1	Cycles	Alternating Stress (MPa)
2	10	3999
3	20	2827
4	50	1896
5	100	1413
6	200	1069
7	2000	441
8	10000	262
9	20000	214
10	1E+05	138
11	2E+05	114
12	1E+06	86.2
*		

Fig.3 SN curve

Fatigue Life settings

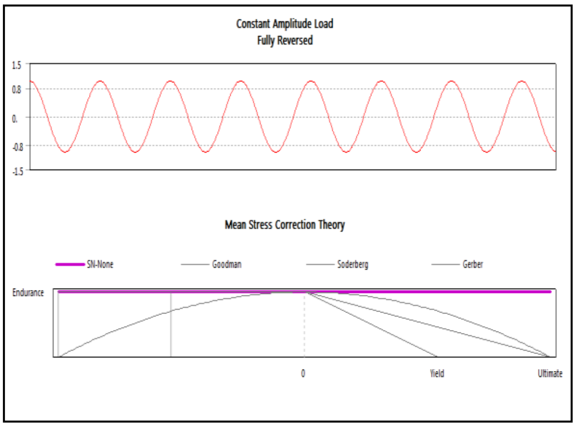


Fig. 4. Fatigue life setting

Boundary condition

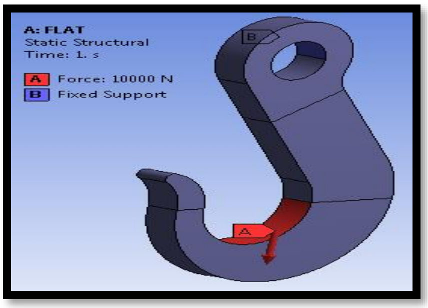


Fig. 5. Boundary conditions

Result of rectangular cross section

Equivalent stress

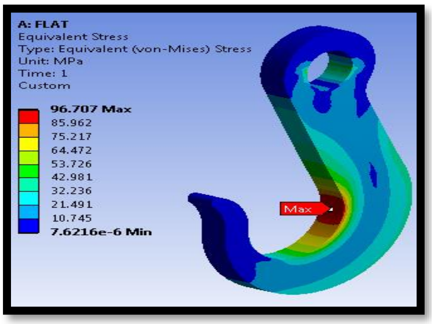


Fig.6. Equivalent stress

Total deformation

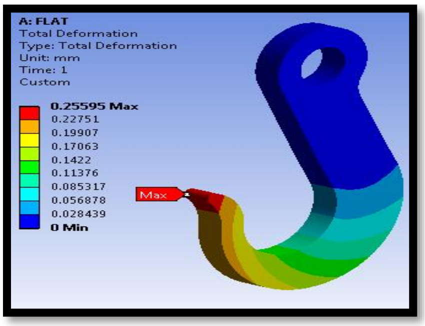


Fig.7.Total deformation

Fatigue Life

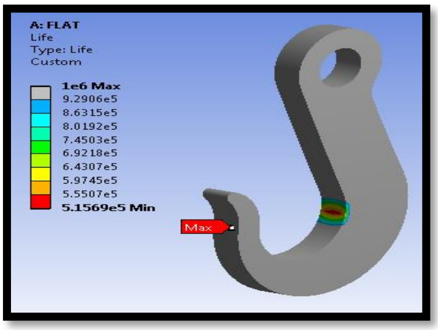


Fig.8. Fatigue life

Factor of safety

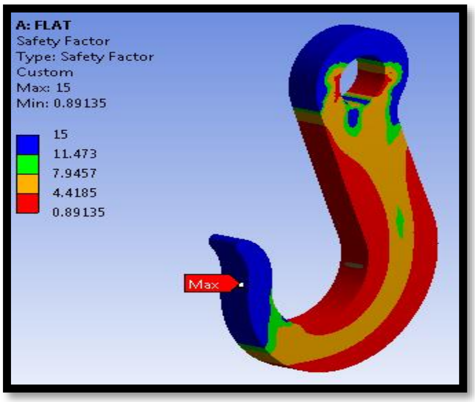


Fig.9. Factor of safety

Table 1: Results of FEA for different cross-sections

Cross-sections			
	Rectangular	**Trapezoid**	**circular**
Equivalent stress (MPa)	**96.707**	**122.25**	**170.83**
Total deformation (mm)	**0.25595**	**0.29404**	**2.0094**
Fatigue life	**5.1569e5**	**1.5521e5**	**45707**
Factor of safety	**0.89135**	**0.7051**	**0.50459**

Table 2: Results of FEA for rectangular cross-sections having different materials

Materials			
	Structural steel	**Aluminium alloy**	**Gray cast iron**
Equivalent stress (MPa)	**96.707**	**96.764**	**96.672**
Total deformation (mm)	**0.25595**	**0.721**	**0.4653**
Fatigue life	**5.1569e5**	**2.4457e7**	**brittle**
Factor of safety	**0.89135**	**0.85507**	**brittle**

IV EXPERIMENTAL ANALYSIS

Experimental analysis is done on universal testing machine (UTM). A universal testing machine (UTM), also known as a universal tester, materials testing machine or material test frame, is used to test the tensile strength and compression strength of material.

From the FEA results a rectangular cross section hook of structural steel which is made, then it is attached to fixture. The hook is then tested for compressive strength as shown in fig.10. From experimental testing it is clear that hook can sustain more than 10KN load. The graph of load v/s displacement is shown in fig.11, that validate the FEA results of rectangular hook.

Fig. 10. Experimental testing of hook on UTM

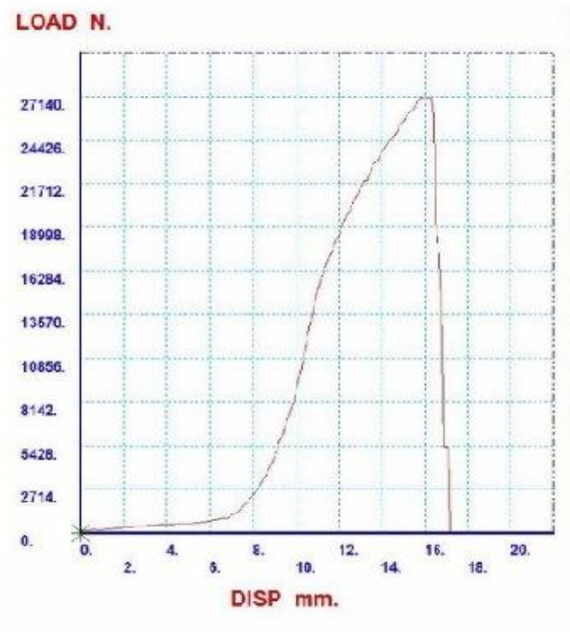


Fig.11.Graph of load v/s displacement on UTM

FUTURE SCOPE

The scope of the project is, it can be implemented on selection and manufacturing industries of crane hook.

CONCLUSION

- From comparative analysis of various materials of hook i.e. structural steel, cast iron & aluminium, it is clear that steel is most feasible for manufacturing.
- Finite element analysis also helps in defining grades of steels from stress outputs.
- From comparative analysis of stress & deformation of various cross sections, it is clear that rectangular cross section is most suitable for hook, as it is easy for manufacturing.
- Experimental analysis is done for checking load carrying capacity from that it is clear that designed hook can sustain more than 10KN load.

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