Design and Analysis of Crane Hook - Review

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ABSTRACT: Crane hook is very significant component used for lifting the load with the help of chain or links. Crane hooks are highly liable components and are always subjected to failure due to the amount of stresses concentration which can ultimately lead to its failure. 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 fatigue failure of the crane hook. The review of previous publications enable to conclude that components with complex geometry as crane hooks require a more extensive investigation in view of the fact that a very few articles have been published so far regarding stress analysis of this curved beam (crane hook).

Keywords: Crane hook, Curved beam, fatigue failure.

I. INTRODUCTION

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. One reason is that such an excavator is convenient since they can perform the conventional digging tasks as well as the suspension works. Another reason is that there are work sites where the crane trucks for suspension work are not available because of the narrowness of the site. In general an excavator has superior maneuverability than a crane truck. However, there are cases that the crane-hooks are damaged during some kind of suspension works. From the view point of safety, such damage must be prevented. Identification of the reason of the damage is one of the key points toward the safety improvement. If a crack is developed in the crane hook, mainly at stress concentration areas, it can cause fracture of the hook and lead to serious accidents. In ductile fracture, the crack propagates continuously and is more easily detectable and hence preferred over brittle fracture. In brittle fracture, there is sudden propagation of the crack and the hook fails suddenly. This type of fracture is very dangerous as it is difficult to detect [1-5].

II. FAILURE OF CRANE HOOKS

Strain aging embrittlement [6] due to continuous loading and unloading changes the microstructure. Bending stresses combined with tensile stresses, 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 increase the magnitude of these stresses and eventually result in failure of the hook. All the above mentioned failures may be prevented if the stress concentration areas are well predicted and some design modification to reduce the stresses in these areas.

III. LITERATURE SURVEY

In this section, contribution of different researchers is discussed.

❖ *M. Shaban et. al* **(2013)**, 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 [7].

❖ *E. Narvydas et. al* **(2012)**, 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 [8].

❖ *Ram Krishna Rathore et. al* **(2012)**, this paper involves A general approach for the multiple response cases optimization start with using the regression models to calculate the correlations between response functions and control factors. Then, a system for collecting various response functions together into a one quantity, such as an objective function, is engaged and at last, an optimization technique is used to calculate the best combinations for the control functions. A different method proposed in this paper is to use an artificial neural network (ANN) to calculate the parameter response functions. At the optimization stage, a multi objective genetic algorithm (MOGA) is used in combination with an objective functions to establish the optimum conditions for the control functions. A crane hook example has been taken to optimize multiple shape parameter responses to with stand a new loading condition. The results estimate the reduction in mass and sufficient factor of safety to show the proposed approach for the optimization of multi- disciplinary shape optimization problems. This paper proposes a method for the optimization of multi-response. The approach considers an artificial neural network for every response function to calculate its relation with control functions, unrestrained objective functions to combine diverse responses into single, and a multi objective genetic algorithm (MOGA) to perform the multi-disciplinary optimization. The projected method is novel because of three things. First, it utilizes design of experiment with central composite design method. Second, it usage artificial neural networks to calculate the responses for every parameter with respect to the output function. Finally, it utilizes the multi objective genetic algorithm for optimize the responses created with artificial neural networks. This has been shown with the help of the crane hook example through which the shape responses are estimated for the mass and the factor of safety. Especially, the projected optimization method only involves estimating outcome of the responses. Therefore, one can extend the proposed method to include the more number of parameters for the responses. In this condition, manufacturable constraints are needed to estimate the different responses at various settings of the control factors [9].

❖ *Rashmi Uddanwadiker* **(2011)**, studied stress analysis of crane hook using finite element method and validated 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 [10].

❖ *SpasojeTrifkovic' et. al* **(2011)**, this paper 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 [11].

❖ *Bhupender Singh et al* **(2011)**, Work presented involves 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 Software to get the variation of stress and displacement in the various parts of the crane boom and possible actions are taken to avoid the high stress level and displacement. By using Finite Element Analysis the following objectives have been achieved.

- Weight Reduction (4.86 kg, approx.5kg).
- Stresses are within limits (at higher load points).
- Cost cutting (Rs-180/- for a single component).

The analysis also concluded that maximum stress is coming near the fixing position [12].

❖ *Y. Torres et. al* **(2010)**, initially 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. It was concluded that the accident was caused by the strain-aging embrittlement of the used steel. The brittle fracture was originated from a crack in the material, generated during the welding performed on the lifting hook [13].

❖ *Takuma Nishimura et. al* **(2010)**, 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 [14].

- *C. Oktay AZELOGLU et. al* **(2009)**, this paper presents the different methods of stress calculation for lifting hooks based on different assumptions. They applied curved beam theory, Finite Element Method and photo elasticity experiments to obtain the stress field on the hook. As a result, different methods used to obtain the stress field on the hook are compared. Some recommendations were suggested for lifting hook calculations on the field applications [15].

- *Yu Huali et. al* **(2009)**, the structure-strength is the key index to response the load-bearing ability of the elevating equipment. Researching and analyzing the static characteristic of the hook that functions at the limited load has an important meaning to design larger tonnage hook correctly. In this study, hook of drill well DG450 were analyzed. Firstly, based on the characteristic modeling technology, the 3-D entity model of the hook was built using Pro/E. Secondly; the static analysis on three dangerous work conditions at ultimate load of the hook was preceded by FEM software ANSYS. This work illuminates the instructional meaning and engineering application value to the design and development of the larger tonnage drill well hook [16].

- *Bernard Ross et. al* **(2007)**, this paper describes the comprehensive engineering analysis of the crane accident, undertaken to disprove the Mitsubishi theories of failure as confirmed by jury verdict. Among the topics discussed were: wind tunnel testing, structural analyses of the boom, metallurgy of failed parts from a critical king-pin assembly, and soils engineering work related to ground loads and displacements during the lift. Crucial role of the SAE J1093, 2% design side load criterion and Lampson's justification for an 85% crawler crane stability criterion were presented [17].

IV. ANALYTICAL METHOD FOR STRESS CALCULATION

Curved beam flexure formula is used when the curvature of the member is pronounced as in case of hook for different cross sections mathematical analysis of stress [3].

$$\sigma = \frac{F}{A} + \frac{M \times y}{I}$$

Where, *M*=maximum bending moment.

Y=Distance between centroidal axis to neutral axis.

I=Moment of inertia for different cross sections.

V. CONCLUSION

The stress concentration factors are broadly used in strength and durability evaluation of machine elements. In order to minimize the failure of the crane hook, the stress induced in crane hook must be studied. The review of previous publications permit to conclude that the curved beam such as crane hook needs more broad investigation since a very few articles in this field have been published yet. The study of the earlier publications enables us to conclude that among all the different methods, the Finite Element Method (FEM) is one of the most effective and powerful method for the stress analysis of the crane hook.

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