Design and Static Stress Analysis of Lifting Hook

A. OZDEMIR[1] and Y.A. ONUR[2]

[1]Turkish Hardcoal Enterprise, Zonguldak/Turkey, ozdemiralp@gmail.com
[2]Bulent Ecevit University, Zonguldak/Turkey, aytaconur@beun.edu.tr

***Abstract* - Lifting hooks are the components that ensure reliable and economical lifting and transport of loads. By selecting the shapes, dimensions and appropriate materials to be used, a reliable and economical lifting hook is obtained. In this study, stress analyzes of lifting hooks were carried out primarily with two different analytical approaches. Then, modeling of the hook was made in computer environment and the finite element analysis was done in the computer environment. The analysis results and standardized values for different loads are compared under the same conditions. The study shows that computer-aided finite element analysis can be applied reliably and economically in studying the stress states of lifting hooks.**

***Keywords* – Lifting hook, static stress analysis, 3D modeling.**

I. INTRODUCTION

Lifting hooks are the most reliable and economical load carrying elements and used to be most commonly for lifting or transporting of loads. It is expected that the lifting hooks will be able to connect and grasp the load in a short period of time to provide work safety. At the same time, it is expected that the cargo handling operations will be carried out with minimum labor. It is basically a hoisting fixture that is designed to engage a ring or link of a lifting chain or the pin of a shackle or cable socket and it must be suitable for health and safety guidelines [1]. Choosing the proper shape of hook and proper material increases the load capacity of the hook and makes the transport operations easier [2-4]. The lifting hooks are complex and curved machine elements in terms of their geometric structure. Due to the hook construction, it is difficult to reliably determine the stress caused by the load effect on the lifting hooks. There are many alternative approaches for calculating the tension in the lifting hooks. Some of the analysis methods in the hooks are the simple beam theory method, the curved beam theory calculation method, the finite element analysis method in the order of historical development. In recent years the development of computer technology has also been used frequently for complex stresses in the computer environment. In this study, the lifting hook with number 05 where numbers are described in DIN 15401 norm is used. Maximum stress values of the lifting hook considering 25 kg, 250 kg, 500 kg and 1000 kg have been calculated and presented. 1000 kg load is the maximum working load of the lifting hook with number 05. The stress analysis of the number 05 hook was made according to the approximate calculation method, the curved beam theory method and the finite element analysis (FEA). As a result of the comparison of the stress analyzes, it has been determined that the design of the lifitng hook is safe and economical with FEA.

II. LIFTING HOOKS AND ANALYTICAL STRESS CALCULATION

The lifting hook geometries have complex curved axes for easy handling of the load and it enables maximum load transfer with small hook sizes. In general, simple lifting hooks and ramshorn hooks are widely used. It is produced from materials specified in DIN 15400 [5]. The simple lifting hooks are standardized in accordance with DIN 15401 norm [6]. There are many kind of hooks for special purposes such as point hooks, ramshorn hooks, eye hooks, cargo hooks and cross hooks.

It is difficult to calculate stresses occurred on lifting hooks due to having curved geometry. There are two basic analytical approaches to calculate maximum stresses in lifting hooks.

The first approach is known as approximate calculation method. In approximate calculation, the simple hook is assumed to be like a beam which is loaded on its axis with a small force and the stress distribution is assumed to be linear. The control calculations of the two critic cross-sections are done separately. Force should be calculated as if the load is hanged on the sling [7].

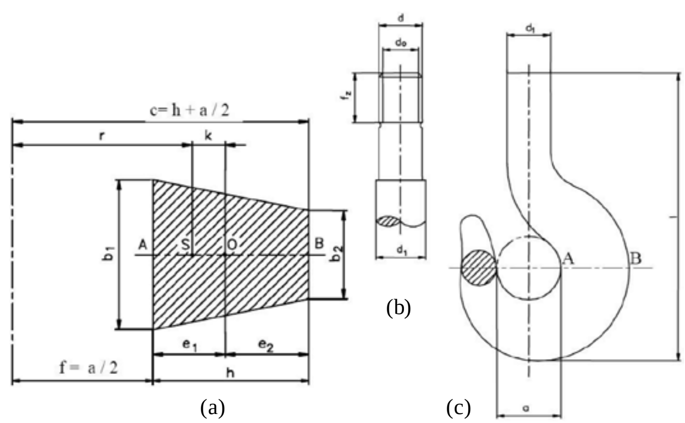

Figure 1: Cross-section and dimensions of a simple hook

Figure 1a, 1b, 1c show the dimensions of the hook section. In Figure 1a and Figure 1b , values of b_1, b_2, h, f, c, a are taken from simple hook standard [5]. Q is the lifted load, A is the cross-sectional area of the trapezoidal section, M is the bending moment. Accordingly, the distances to the center of curvature are; distance of outer fibers is c, distance of the inner fibers is f, distance between S neutral axis and center of curvature is r, the

S-O distance is expressed as k and the distance between O centroidal axis and center of curvature is R. Equations (1) to (6) show required maximum stress calculation equations of lifting hook considering approximate calculation method. Maximum stress (σ_{max}) occurs inner curved point A.

$$I = ((b_1^2 + 4.b_1.b_2 + b_2^2)/(b_1 + b_2)).(h^3/36) \quad (1)$$

$$e_1 = ((b_1 + 2b_2)/(b_1 + b_2)).h/3 \quad (2)$$

$$W = J/e_1 \quad (3)$$

$$M = Q.R \quad (4)$$

$$A = ((b_1 + b_2)/2).h \quad (5)$$

$$\sigma_{max} = (M/W) + (Q/A) \quad (6)$$

In the second analytical stress approach, the hook curve is treated as curved beam. This method is called as curved beam theory where centroidal axis and neutral axis are not coincident. Analysis is made by assuming that the cross section has an axis of symmetry in a plane along the length of the beam, plane cross sections remain plane after bending, the modulus of elasticity is the same in tension as in compression. Equations (7) to (9) show required maximum stress calculation equations of lifting hook considering curved beam theory. Maximum stress (σ_{max}) occurs inner curved point A.

$$r = \frac{A}{b_2 - b_1 + \left[(b_1 c - b_2 f)/(c - f)\right]\ln(\frac{c}{f})} \quad (7)$$

$$R = r + k \quad (8)$$

$$\sigma_{max} = (M.h_1)/(A.k.f) + (Q/A) \quad (9)$$

$$h_1 = r - f$$

III. COMPUTER AIDED LIFTING HOOK MODELING AND FINITE ELEMENT ANALYSIS

The development of computer technology in recent years has resulted in high processor power and high memory capacities that enable computers to use in engineering calculations. Through finite element analysis these sophisticated simulations provide valuable information for designing and developing new products [8]. In order to perform stress analysis in a computer environment, the lifting hook must first be reliably modeled. In this study, the hook with DIN 15401, 05 number is modeled in Solidworks 2016 software [5].

The finite element method is used reliably and efficiently in the computer environment, especially in the stress analysis of solids with complex geometries. In this study, Ansys Workbench 16.0 finite element analysis software was used to analyze the modeled hook.

IV. STRESS ANALYSIS WITH DIFFERENT APPROACHES

Investigated lifting hook with 05 number has 1000 kg lifting capacity according to the 2_m drive group [9] and strength class S [5]. The material of the hook is selected to be 34CrMo4 (Young's Modulus (E) is 2.1×10^5 N / mm^2, yield strength is 390 N / mm^2 and Poisson's ratio is 2.88 [10].

25 kg, 250 kg, 500 kg and 1000 kg loads were applied to the designed lifting hook respectively. The static analysis of the hook was made by the approximate calculation method, the curved beam method and the finite element method. In the FEA, the tetrahedron finite element with 10 nodes having 7 mm size is used in ANSYS Workbench software. The hook model is divided into 20574 elements with 31218 nodes. Results obtained by using different calculation methods are presented in Table 1.

Table 1: Results obtained by using different approaches

Load	Maximum stress values (MPa)		
	Approximate calculation method	Curved beam theory	FEA
25 kg	2.17	3	3.53
250 kg	21.65	30.01	35.32
500 kg	43.31	60.02	70.65
1000 kg	86.61	120.03	141.22

In this study, safety factor is also calculated and presented in Table 2 where allowable maximum working load of 1000 kg is considered.

Table 2: Safety factors of investigated hook

Load	Safety factor		
	Approximate calculation method	Curved beam theory	FEA

1000 kg	4.50	3.25	2.76

Approximate calculation method and curved beam theory are used to calculate maximum stresses occurred on lifting hook investigated for 4 specific loads. In the same way, the FEA was carried out considering boundary conditions.

For the lowest applied load of 25 kg, the approximate calculation method gives a lower maximum stress value than the other methods (2.17 MPa) and the maximum stress value in the FEA is the highest (3.53 Mpa). The maximum stress (141.22 MPa) is obtained by FEA at 1000 kg, which is the maximum allowable load of the hook according to the operating standards, is still 17.65% higher than curved beam. There is a good harmony in the results between curved beam theory and FEA. Approximate calculation method results give lowest maximum stress values among other methods.

V. Conclusion

This study demonstrates the calculation of the stress values of lifting hooks which are used as load holding and lifting duties. The static stress analyzes of the number 05 hook have been done when the hook was exposed to loads of 25 kg, 250 kg, 500 kg and 1000 kg under certain operating conditions. Two different analytical methods are used to determine maximum stresses. The FEA of the designed hook is then carried out. One of the remarkable results that approximate calculation method results are quite different and low stress value compared to other methods. The reason for this is that in the approximate calculation method, the curved structure of the hook is assumed to be straight.

FEA at 1000 kg load results in 141.22 MPa maximum stress and 2.76 safety factor. There is a good harmony in the results between curved beam theory and FEA. Approximate calculation method results give lowest maximum stress values among other methods. With finite element analysis, stress analysis of the lifting hook can be made economical as well as reliable.

References

[1] Rashmi Uddanwadiker; "Stress Analysis of Crane Hook and Validation by Photo-Elasticity," *Engineering*, 2011, vol.3, pp. 935-94.

[2] N. N., *DIN Taschenbuh 185 Krane und Hebezeuge 2*, Beuth Verlag, Berlin, 1995.

[3] H. Ernest, Die Hebezeuge Band 1, *Grunderlagen und Bauteile,* Verlag, Braunschweig, Germany, 1973.

[4] H.J. Zebich, Fördertechnik 1 Hebezeuge, Vogel, Verlag, Germany, 1975.

[5] DIN 15400, Lifting hooks; materials, mechanical properties, lifting capacity and stresses, *Deutsches Institut für Normung*, 1990.

[6] DIN 15401, Lifting hooks for lifting appliances; Single hooks; Unmachined parts, *Deutsches Institut für Normung*, 1983.

[7] . Ozer Derya, A. B. Erdil, I. Gerdemeli Ismail, "Finite element approach to 3-D modelling and stress analysis for crane lifting hooks," *Eleventh International Research/Expert Conference Trends in the Development of Machinery and Associated Technology*, Hammamet, Tunisia, pp. 1007-1010, 2007.

[8] Y. A. Onur, C. E. Irmak, "Design and static stress analysis of elevator car suspension during operation," *12th International Research/Expert Conference Trends in the Development of Machinery and Associated Technology*, pp. 821-824, Istanbul, August 2008.

[9] FEM 9.511/86, Rules for the design of lifting equipment series; Classification of mechanisms, *European Materials Handling Federation*, 1986.

[10] DIN 17100, Steels for General Structural Purposes, *Deutsches Institut für Normung*, 1980.