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FINITE ELEMENT APPROACH TO 3-D MODELLING AND STRESS ANALYSIS FOR CRANE LIFTING HOOKS

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ABSTRACT
Lifting hooks may be flat-die or closed die forged or else made of a series of shaped plates. After forging and machining operations, hooks are annealed and cleaned from scale. Lifting hooks in crane handling mechanisms are used safely handle and lift the loads during the lifting operation. Appropriate solution of shape and materials of hooks enables the increase of loading capacity of hoisting machines. The inner diameter of hooks should be sufficient to accommodate two strands of chains or rope which carry the load. More often than not hooks have a trapezoidal section, made wider on the inside. The 3-D modeling and finite element model of the simple hook is formed by means of computer-aided engineering software and directly analyzed applying finite elements. Stress analysis of lifting hook as a curved beam can be calculated using Bach approach. In order to compare the stress results obtained by exact methods and finite element method, an illustrative example is given.
Keywords: Finite element method, 3-D modeling, Static stress analysis

1. INTRODUCTION
Simple hooks are material handling equipments which are used to lift the load with winches and cranes safely.Hanging and lifting the load in a safe way is very important for a crane management.It is expected from a load hook to handle and lift the load in minimum time with minumum employer.Choosing the proper shape of hook and proper material increases the load capacity of the hook and makes the transport operations easier.(1-3) Exact stress of simple hook can be calculated considering the hook as a curved beam.In curved beam method, neutral axis is displaced from centroidal axis towards the center of beam curvature by effect of forces in beam symmetry plane.

In order to make the tension and compressive stress in the outer and inner fibers equal,the cross section which is nearest to the concave surface of the beam should be used. (4-5)Gerdemeli and Imrak, made the stress analysis of the hook as a curved beam and they have discussed to choose the optimum hook cross-sections and and designs in computer .Yıldırgan(6), made the design of the hook by the help of a computer programme and made the analysis with finite element method.The drawing of a simple hook using B-splines has been done by Imrak(7).Imrak and the others had the geometry of the simple load hook and done the modelling of it by using finite elment method and they achieved this by using a computer integrated engineering programme called IDEAS .Arslan and his friends, in their research about the inspection of elasto-plastic behaviour of the hook which is appropirate to the DIN 687 standart, inspected the plastic region using the approximate calculation Ayhan (10), inspecting the complex geometry of the simple hook that has standart dimensions, examined the drawing of it by using sentetic curves and surfaces.

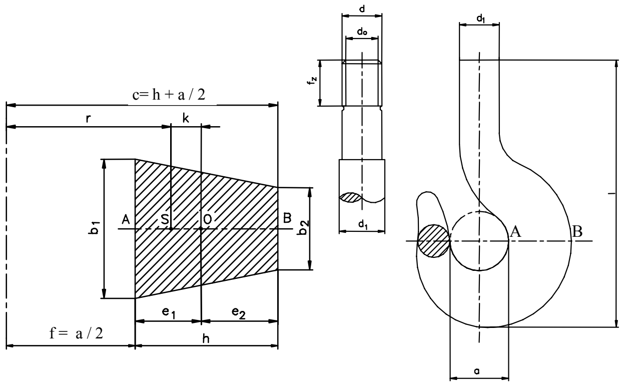


Figure 1. Cross-section and dimension of a simple hook

2. CURVED BEAMS AND STRESS ANALYSIS

The curved surface of the beam is controlled in means of unit stress.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 lineer.The control calculation of the two critic cross-section is done seperately.Force should be calculated as if the load is hanged on the sling.We have a load suspended from two legs of a sling .If we denote the weight of the load being lifted by Q and the binding angle is 2σ , the tension in each leg of the sling will be
S=Q/(2.cosσ) and the horizantal component of the tension S is S_1=(Q.tan σ)/2 and the bending stress and compressive strength. The simple hooks that are used in crane constructions are usually in trapezoidal cross-section as seen in figure 1. When the edge radius of the hook is not taken into account, the inner and outer stresses are calculated by using curved beam theory (8)

2.1. Stress analysıs of a curved beam wıth bach's approach

When the force acts on the hook curvature in symmetry plane or in an arbitary direction of the hook curvature axis, the forces that are formed on one side of the hook section can be reduced to a bending moment M due to the force couple and to a normal force(Q).(17-18)
It has been indicated by Bach that when a fibre which is (y) distant from the central axis of the trapezoidal section is forced, the following equation(1) is used:

$$\sigma = \frac{Q}{A} + \frac{M}{AR} + \frac{M}{z}\frac{y}{R+y} \qquad (1)$$

Here, the bending moment is M=-Q.R because it reduces the curvature of the hook. From the centroidal axis to the curvature center y distance will be taken (+)and in the opposite direction it will be taken (-).(2).Also, z value changes according to y distance and DIN 15400 standard and it is shown as below.

$$z = \int_{-e_1}^{e_2} \frac{x^2 s}{R+x}\,dx \ [\text{mm}^3] \qquad (2)$$

In this study, z value is calculated numerically by computer .In this case, if we write $y=-e_1$ to this equation and making a simplification, the stress on inner surface(σ_1 and if we write $y=e_2$ the stress on outer surface(σ_2), the stresses can be calculated as shown below.

$$\sigma_1 = \frac{QR}{z}\frac{e_1}{R-e_1} \text{ and } \sigma_2 = -\frac{QR}{z}\frac{e_2}{R+e_2} \qquad (3)$$

3.STRESS ANALYSIS OF A HOOK WITH 5 TON CAPACITY

3.1. Stress analysıs wıth approxımate calculatıon method

In stress analysis with approximate calculation, the hook which is chosen from DIN 15401 norm for 3m operation group is loaded with maximum 50000N force. (8) The geometry values of the hook that is chosen is shown in table 1.When we write strength moments for the hook section that is shown in figure 1, and the values in the first equation for the chosen hook is substituted into equation(1), $W_{1=}$ 71895.7N/mm^2 and..$W_{2=}$52637.9N/mm^2. in this case,the stresses are calculated by equation 2and σ_1 is found as.65.73 N/mm ^{2} and σ_1=-62.68 N/mm^2.

Table 1. The dimensions of a hook with 10 ton load capacity in DIN NORM 154001

Explanation	Symbol	Dimension(mm)	Explanation	Symbol	Dimension(mm)
Shaft screw	d_0	M45	Trapezoid section dim. B1		
Shaft diameter	d	53			
Screw length	f 40				
Hook length	l	318			

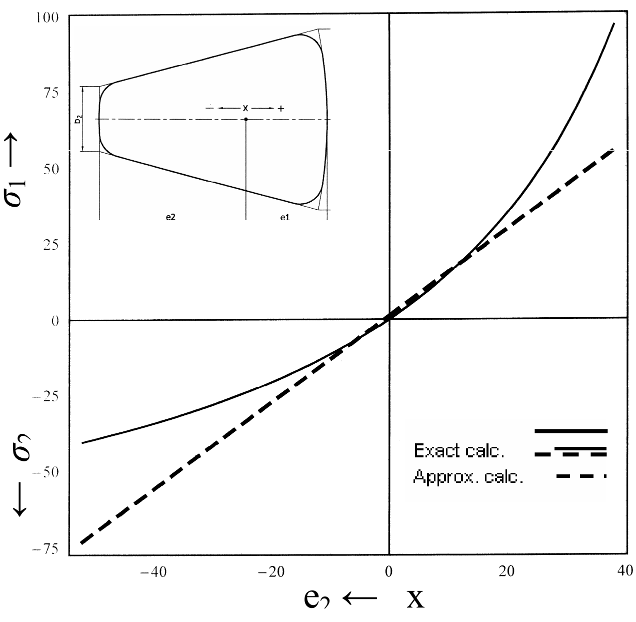
3.2. Stress analysıs wıth exact calculatıon method(tımoshenko approach)

Assuming that the hook body has a curved axis and this curvature is more than a straight beam, the minimum and maximum stresses on the inner and outer fibers are calculated.The radius of the trapezoidal cross- section is calculated with the equation r =70.11 mm.The distance between the centeroid of the hook curvature and the curvature center, R, is calculated by the equation (10) as 78.04.On the outer fiber of the hook cross-section, after substituting y=r-f into the equation(11) , maximum stress value is found as σ_1=93.62 N/mm^{2}and on the inner fiber of the hook cross-section after substituting y=c-r into equation 11, minimum stress
value is found as σ_2=-40.48 N/mm^2.

3.3. Stress analysıs wıth exact calculatıon method(bach's approach)

Integrating the eq.(13) by the help of computer, z value which takes place in stress calculation is calculated as 38525.9 mm^3 .In this case, the stress values on the inner and outer fibers are calculated from equation 14 and found as $\sigma_1 = 94.02$ N/mm^2 and $\sigma_2 = -39.51$ N/mm^2
respectively. The variation of stress value in the cross-section for approximate calculation method is represented by dashedlines and for exact method is stated with continuous lines in figure 2.

Figure 2. Stress Distribution of a simple hook with Q=5 ton lifting capacity with Exact and approximate solution Method.



In fact, the hook doesn't have a trapezoidal section.If we draw the hook in Autocad R14 program by taking the edge radius into account, the closed area which is drawn by REGION command is 4274.25 m^2. The stress values are calculated for 2 cases , for a trapezoidal section either with or without edge radius. These stresses are shown in table 2.

Table 2. Comparisons of the values that are made by different calculation methods.

Calculation method	Trapezoidal crosssec.	σ_1 [N/mm^2]	σ_2 [N/mm^2]
APP. method	Edge without radius	65.73	-62.68
	Edge without radius	65.97	-62.43
Exact cal. (Timoshenko approach)	Edge without radius	96.32	-40.48
	Edge with radius	81.37	-34.19
Exact calc.(Bach app.)	Edge without radius	94.02	-39.51
Safety value from DIN 15400 (M material group and 3m operation group)		110	45

The reason of the deviation between these results are because of the assumptions that are made when using either exact calculation method or approximate calculation method. The %30-35 deviation between these 2 methods is formed when we take the hook curvature into account. In DIN 15400 standart, the safety values in innerside and outside of the hook curvature are given in DIN 15400 standart due to the hook material and operation group in this study, M material group and 3 m operation group is accepted.) for Bach's approach.

4. CONCLUSION

In this study, it is pointed that the beam curvature theorem can be applied to the simple hook which is used on winches and cranes as a material handling equipment in industrial plants.

The approximate and exact calculation methods of the simple hook is examined based on DIN 15401 norm and an illustrative example related to this subject is given.The stress analysis of.A simple hook with 5 ton capacity is made with approximate and beam curvature method and these values are calculated.The strain stress in inner side of the hook which is calculated by exact calculation method is greater than approximate calculation method.The compressive stress on outer surface of the hook which is found by approximate calculation method is greater than the one with exact solution method.Thus, if the stresses are checked by approximate method, the section in inner surface should be thicker. There is 1.56 ratio in maximum stress between the exact and approximate stress analysis.

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