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COMPUTER-AIDED MODELLING AND STRESS ANALYSIS FOR CRANE CROSSHEADS

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ABSTRACT
The crosshead is a materials handling equipment, which is pivoted in the side plates of casing usually reinforced with straps or shackles made of plate steel. This enables the hook to be turned in two inutually perpendicular directions. In this study by the aid of prepared software of crosshead selection, the hook type is determined considering the entries such as the material of the crosshead, operating conditions and hoisting load. The developed software constitutes the parametric solid model of the crosshead. The geometrical center of the half cylinder is considered and the load acting on the crosshead is assumed to be uniform for the finite element analysis. In this study, finite element static stress analysis of crosshead is discussed. Both finite element method and exact solution method as an application of resultant of uniformly distributed load on crosshead are investigated. In order to compare the results from both exact solution and finite element methods, illustrative examples of crossheads are considered.
Keywords: crane crosshead, finite element method, stress analysis

1. INTRODUCTION

Engineering problems are usually mathematical models of physical situations.Finite element method is a numerical solution method which is trying to find approximate solution with an acceptable approach.Even though the mathematical basic of these numerical methods were known before, the application of these methods came to reality with the production of computers with more memory and speed.

2. CALCULATION OF HOOK CROSS-PIECE

In simple calculation method of hook crosspieces, it is assumed that the force(Q) is applied on only from one single point.But in reality, Q force is applied not from a single point but from the axial rolling bearing seat surface to the crosspiece..In exact solution,this situation should be taken into account.

2.1. Simple hook travers calculation

The calculation of the cross-piece is done as a bending stress of a beam which issupported on both sides.(7,8)In simple calculation method, it is assumed that force (Q)is applied on from a single point. The maximum bending moment occurs in the middle section of the hook cross-piece.When we calculate the bending moment due to the central axis of the hole and if we describe the resultant force of distributed loads on the semicircle as (Dm/π) and the distance between 2 bearings of rope pulleys is as L (9-11), the bending moment is calculated as:

$$M_e = \frac{Q}{2}\left(\frac{L}{2} - \frac{D_m}{\pi}\right) \qquad (1)$$

The centeroid of the semicircle is $D_m/2$ value using the first fig. taken an arc (2α) symmetric to the X axis , the component of it according to X axis is D_m / π .will be as shown below.

$$\bar{x} = \frac{\int_{-\alpha}^{\alpha} r\cos\theta \, r\, d\theta}{2\alpha r} \qquad (2)$$

When we solve the integral in expression (2) and substitute α=π/2 for semicircle and Dm for the central axis of the bearing in formula,

$$\overline{x} = \frac{2r}{\pi} = \frac{D_m}{\pi} = \frac{D+d}{2\pi} \qquad (3)$$

is obtained.Here, the major diameter of the axial rolling bearing which the hook is supported is D and the minor diameter is taken as d.In this case, the bending stress formed on the section in the 3rd figure is equal to

$$\sigma_e = \frac{6 \cdot M_e}{(b - d_i)h^2} \qquad (4)$$

Here, b is the weight of cross-piece and h is the height of the cross-piece and d_i is the minor diameter of the cross-piece.

2.2. The exact calculation of hook cross-piece

In the exact solution of hook crosshead, it is assumed that the force(Q) effects not on one single point but from the axial Rolling bearing seat surface to the crosshead.(12,13)

If the crosshead is designed with a seat for antifriction, the pressure on the contact surface of the loaded area can be assumed as distributed over a half cylinder according to $p_C = p \cdot \cos\varphi$.

Considering P is a force on the axle, the equation can be written as down below.

$$p = \frac{2}{\pi}\frac{Q}{R} \qquad (5)$$

Here,the value R is equal to $(b - d_i)/4$ .As seen in figure 1, passing a section through I-I section, the elastic forces over the ring sections (N_1 , N_2) and the bending moments are M_1 and M_2, the equation of equlibrium can be written as ;

$$N_1 - N_2 - \frac{2}{\pi} P \int_0^{\frac{\pi}{2}} \cos\varphi . \sin\varphi . d\varphi = 0 \qquad (6a) \qquad \frac{Ql}{4} + M_1 - M_2 - (N_1 + N_2)R = 0 \qquad (6b)$$

$$N_2 = N_1 - \frac{p}{\pi} \qquad (7)$$

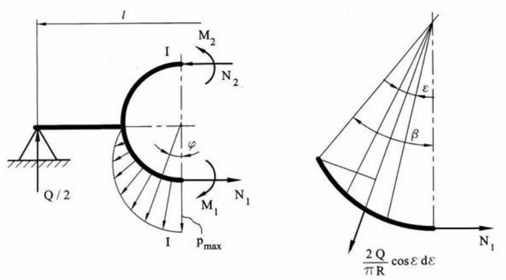

Figure 1. Calculation diagram for a cross-head.

$$4\pi N_1 R - P(R + 2l) = 0 \qquad (8a) \qquad \pi M_1 - \pi N_1 R + P\left(2\frac{R}{\pi} + \frac{\pi}{8}l\right) = 0 \qquad (8b)$$

$$N_1 = \frac{1}{4\pi}\left(1 + 2\frac{l}{R}\right)Q, \qquad (9) \qquad M_1 = \left(-0{,}12 + 0{,}034\frac{l}{R}\right)QR \qquad (10)$$

$$M_2 = 2N_1 R - \left(\frac{1}{4}\frac{l}{R} + \frac{1}{\pi}\right)QR - M_1 \quad (11) \qquad \sigma = \frac{M_2}{W} + \frac{N_2}{F} \qquad (12)$$

3. MODELLING AND FINITE ELEMENT ANALYSIS

In the developed program, CATIA and Solidworks software are used to design the cross-piece of the hook block parametrically.Using the datas from the cross-pieceselection sofware, cross-piece is formed as seen in figure 2 in CATIA. The solid model of the crosspiece as shown in figure 2 is formed in CATIA as a computer aided engineering software.The discrimination of the crosspiece is performed using octree tetrahedron elements and the boundary conditions and loads are applied inthe program.(13)As a result, Von Misses Stress Distribution as shown in figure 3 is obtained .

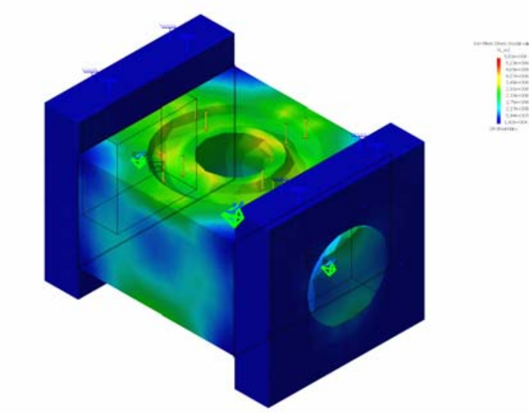

Figure3. Stress Distribution on cross-piece

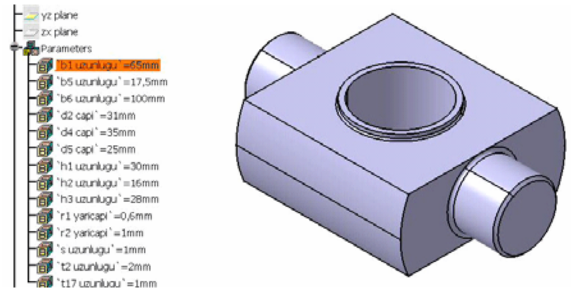

Figure 2. Solid Model 0f Cross-Piece

4. NUMERICAL EXAMPLE

In order to compare the results from both exact solution and finite element methods, an example of cross-piece is considered.A typed and 05 numbered crosspiece from S power group is selected as an example.The hook group number is 05 for a lifting mechanism with a capacity of 1 ton and service group M2.The calculations are carried out considering DIN 15412 which is about the design of cross-piece.

Table 1. Dimensions of A typed hook crosshead.

b_1 (= b)	45	d_{14} (= D_m)	31
b_2	12.5	d_2 (= d_i)	21
b_6 (= l)	70	h_3 (=h)	25

4.1. Approximate solution of cross-piece

Using the approximate solution, in technical calculations of A typed hook crosspiece
The bending moment is:

$$M_e = \frac{10000}{2}\left((22.5 + 6.25) - \frac{31}{\pi}\right) = 94412\,\text{Nm}$$

And the bending stress of in the middle section of the cross-piece can be calculated from Eq.4 as down below:

$$\sigma_e = \frac{6 \cdot 94412}{(45 - 21)25^2} = 37{,}8\,\text{N/mm}^2$$

4.2. Exact solution of cross-piece

Cross-piece of the hook block is designed with a seat from antifriction bearing. In the exact solution of hook crosshead, it is assumed that the force(Q) effects not on one single point but from the axial rolling bearing seat surface to the crosshead.From the Eq. of normalforce effecting on the lower part of the ring(9),

$$N_1 = \frac{1}{4\pi}\left(1 + 2\frac{70}{(45 + 21)/4}\right)10000 = 7547{,}8\,\text{N}$$

and from the Eq.(10) of bending moment acting on lower part of the ring;

$$M_1 = \left(-0{,}12 + 0{,}034\frac{70}{(45 + 21)/4}\right)10000(45 + 21)/4 = 4000\ \text{Nmm}$$

and the normal force effecting on the upper part of the ring is found as shown down below from Eq(7),

$$N_2 = 7547{,}8 - \frac{10000}{\pi} = 4364{,}7 \text{ N}$$

The bending moment on the upper part of the ring can be calculated from Eq.11:

$$M_2 = \left(2 \cdot 7547{,}8 - \left(\frac{1}{4} \frac{70}{(45+21)/4} + \frac{1}{\pi} \right) 10000 \right) \cdot \left(\frac{45+21}{4} \right) - 4000 = 17556{,}3 \, \text{Nmm}$$

and the bending stress value is:

$$\sigma = \frac{6 \cdot 17556{,}3}{25 \cdot 12^2} + \frac{4364{,}7}{25 \cdot 12} = 43{,}75 \text{ N/mm}^2$$

4.3. Finite element analysis of hook cross-piece

The solid model which is formed with the parametric design software is performed by using octree tetrahedron elements.As a result, the maximum stress value is found as 42,10 N/mm^2 In figure 4, the print screen of analysis of a A typed and 05 numbered crosspiece is given.
in CATIA.

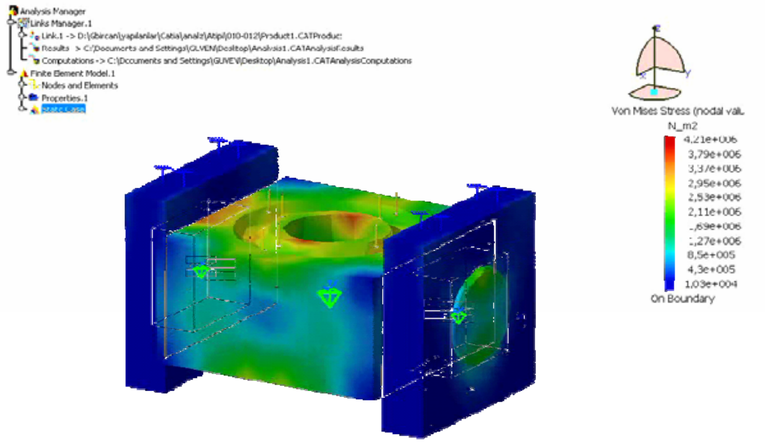

Figure 4. The analysis of a A type and 05 numbered Cross-piece

5. THE CONCLUSIONS

In this study, the bending stress of a hook cross-piece has been calculated with 3 methods.
An illustrative example of cross- piece is considered.A typed 05 numbered crosspiece is selected as an example.The bending stress is calculated as 37,8 N/mm^2 with single method 43,81 N/mm^2 and 37,8 N/mm^2 with exact solution method and 42,10 and 37,8 N/mm^2 with the finite element analysis method.Finite element analysis is performed for the static state of the hook cross-piece and in the analysis, the axial rolling bearing is assumed to be a part of the hook cross-piece and the calculations are performed according to this state.
The difference between the analytical and finite element method calculations comes from the consideration of the gravity center of the half cylinder in simple calculation , while the load acted on the cross-piece is assumed to be uniform in computer analysis.

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