10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

AN EXACT SOLUTION OF STRESS OF UNIFORMLY LOADED CROSS-PIECES

Ismail GERDEMELI	A. Burak ERDIL	M.Cuneyt FETVACI
ITU, Faculty of Mech. Eng.	ITU, Faculty of Mech. Eng.	Istanbul University,
Mech.Eng. Department	Mech.Eng. Department	Faculty of Eng,
Gumussuyu, 34437	Gumussuyu, 34437	Mech. Eng. Dept, Avcılar,
Istanbul, Turkey	Istanbul, Turkey	Istanbul, Turkey

ABSTRACT
Crosspieces which are varied with respect to the handling capacity are used as a materials handling equipment. They retain the hooks and support the handling sheaves in hoisting blocks of cranes. The application of uniformly distributed load on semi-circular pattern of cross-pieces and finite element static stress analysis are presented. In this study, an exact solution of stress of uniformly loaded cross-piece is investigated. In order to compare the stress results obtained finite element and exact solution methods, an illustrative example is given.
Keywords: cross-piece, finite element method, stress analysis

1. INTRODUCTION
Crane cross-piece is pivoted in the side plates of casing usually reinforced with straps or shackles made of plate steel. The cross-piece if forged from steel and provided with turned trunnions at the ends. It is designed with a seat for an antifriction bearing where pressure on the contact surface of the loaded area can be assumed as distributed over a half-cylinder [1]. For the aim of increasing the handling capacity, considering all the introduced factors, the selection and the design of the cross-pieces are carried out [2].
In this study, finite element static stress analysis of hook cross-piece is discussed. Both finite element method and exact solution method as an application of resultant of uniformly distributed load on semi circular pattern on cross-piece are investigated. A-typed and 05 numbered cross-piece is selected as an illustrative example and the values of stresses obtained by finite element and exact solution methods are compared.

2. CROSS-PIECE FOR HOISTING BLOCK
A hook cross-piece is pivoted in the side plates of castry usually reinforced with steel plates. This enables the hook to be turned in two inutually perpendicular directions. The cross-piece is forged from steel and prepared with turned trunnions at the both ends. The trunnions of the cross-piece have no axial shift but they are able to turn. Fastening can be either by adjusting rings secured by taper pins or by means of a split ring inserted into a slot of truninon. Design of cross-piece is illustrated in Figure 1.
The dimensions and the design of cross-piece depend on the hook block. The material of the cross-piece is forged steel, St42 or St50 and the value of safety stress is considered as between 80 and 120 N/mm^2. A-typed cross-piece is frequently used in the loading equipment and has a groove for steel balls in stead of bearings for cheaper cost. B-typed ones are used in the handling equipment [1, 4].

1 – cross-piece
2 – ball bearing
3 – nut
4 – hook shaft
5 – washer
6 – bolt
7 – fixing part
8 – retainer

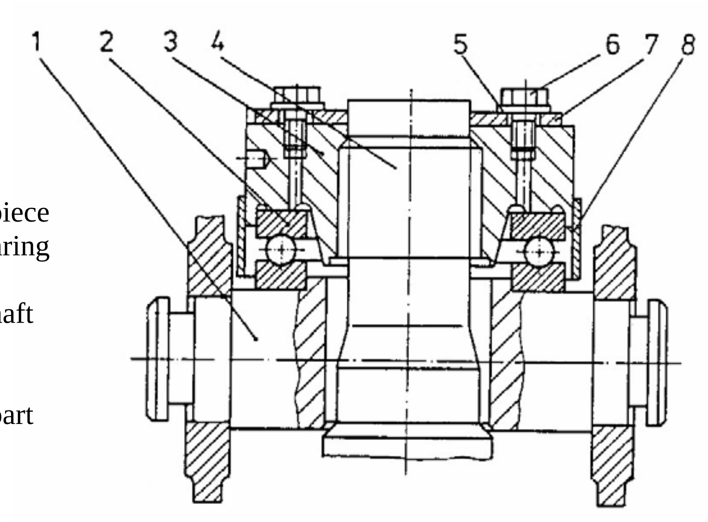

Figure 1. Cross-piece for hoisting block.

3. EXACT SOLUTION OF CROSS-PIECE

Cross-piece of the hook block is designed with a seat for antifriction bearing. The exact solution of cross-piece was introduced by A.A. Staroselsky [1]. The pressure on the contact surface of the loaded area can be assumed as distributed over a half cylinder according to $p_c = p\cos\varphi$ where p is the resultant on the axle as $2Q/\pi R$. Passing a section through A-A section, eliminating the right hand side and denoting the elastic forces over the ring sections as illustrated in Figure 2, the equation of equilibrium of the cross-piece can be written as

$$N_1 - N_2 - \frac{2}{\pi} Q \int_0^{\frac{\pi}{2}} \cos\varphi.\sin\varphi.d\varphi = 0 \,,$$

$$M_1 - M_2 - (N_1 + N_2)R = \frac{Ql}{4} \,. \qquad \ldots (1)$$

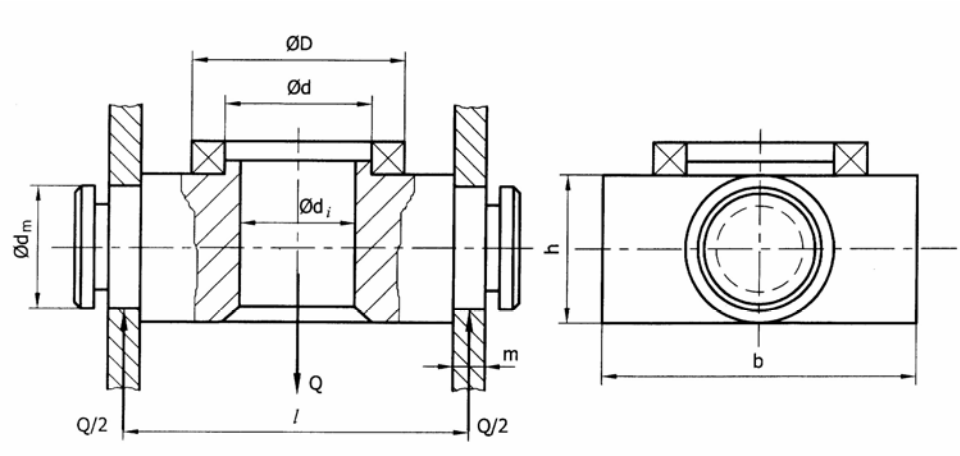

Figure 2. Force diagram for cross-piece.

The potential energy due to the action of the normal and shearing forces can be neglected because it is very small as compared with the potential energy of the bending moment. After solving systems of equations, one can find

$$N_1 = \frac{1}{4\pi}\left(1 + 2\frac{l}{R}\right)Q, \qquad \ldots (2)$$

$$N_2 = N_1 - \frac{Q}{\pi}, \qquad \ldots (3)$$

$$M_1 = \left(-0{,}12 + 0{,}034\frac{l}{R}\right)QR\ , \qquad \ldots (4)$$

$$M_2 = 2N_1 R - \left(\frac{1}{4}\frac{l}{R} + \frac{1}{\pi}\right)QR - M_1\,. \qquad \ldots (5)$$

The maximum stress can be written as follows using Eqs.(3) and (5):

$$\sigma = \frac{M_2}{W} + \frac{N_2}{F} \qquad \ldots (6)$$

where W is the moment of resistance and F is the cross-section area of the A-type cross-piece.

4. FINITE ELEMENT ANALYSIS OF CROSS-PIECE

The finite element method is a numerical procedure that can be applied to obtain solutions to a variety of problems in engineering. Steady, transient, linear or nonlinear problems in stress analysis, heat transfer, fluid flow and electro mechanism problems may be analyzed with finite element methods. Basic steps in the finite element method are defined as follows: preprocessing phase, solution phase, and post-processing phase [5]. The finite element method approximates the solution of the entire domain under study as an assemblage of discrete finite elements interconnected at nodal points on the element boundaries. The approximate solution is formulated over each element matrix and thereafter assembled to obtain the stiffness matrices, and displacement and force vectors of the entire domain.

The solid model of the cross-piece as shown in Figure 3 is formed in CATIA as a computer-aided engineering software and directly analyzed applying finite elements. During the analysis, a slider connection restriction is applied to the journals of the cross-piece and the suspension plates are supported from their upper side as the boundary conditions for finite element analysis.

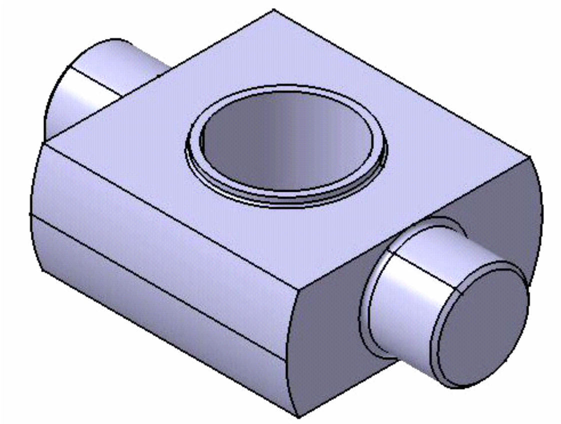

Figure 3. Solid model of A-typed cross-piece.

The discrimination of the cross-piece is performed using octree tetrahedron elements. With this method, cubes containing the geometric model are recursively subdivided until the desired resolution is reached. Tetrahedral are generated from both the irregular cells on the boundary and the internal regular cells. The octree technique does not match a pre-defined surface mesh rather surface facets are formed wherever the internal octree structure intersects the boundary. The resulting mesh also will change as the orientation of the cubes in the octree structure is changed and can also require [6].

5. NUMERICAL EXAMPLE

In order to compare the results from both exact solution and finite element methods, an illustrative example of cross-piece is considered. A-typed and 05 numbered cross-piece 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 standard which is about design of cross-piece [7]. The design values of A-typed cross-piece are: cross-piece width is 45 mm, upper section distance is 12.5 mm, distance between sheaves is 70 mm, average diameter of bearing 31 mm, inner diameter of cross-piece is 21 mm and the height of cross-piece is 25 mm. Using the values of normal forces N_1 and N_2 and bending moments M_1 and M_2 which are calculated with the exact solution method, one can find the value of bending stress of cross-piece as 43.75 N/mm^2.

The geometrical center of the half cylinder is considered and the load acting on the cross-piece is assumed to be uniform for the finite element analysis. After indicating the boundary conditions, stress distribution over the cross-piece is plotted as shown in Figure 4. The values of bending stress are 42.10 N/mm^2 by means of finite element method.

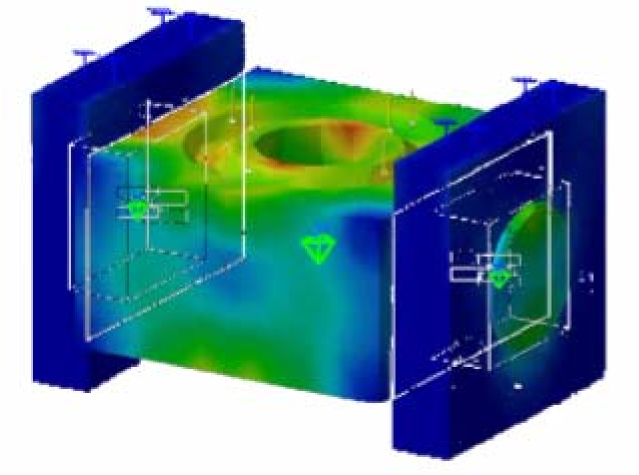

Figure 4. Stress distribution on cross-piece.

6. CONCLUSION

The design of a cross-piece has been investigated and a case study of a cross-piece with 1 ton capacity and A-typed with 05 numbers has been conducted. The application of finite element method to cross-piece stress analysis is performed with an illustrative example. The value of maximum bending stress of the cross-piece is obtained 43.75 N/mm^2 to two decimal places for exact solution method and the value of maximum Von Mises stress of the cross-piece is read 42.10 N/mm^2 to two decimal places for finite element static analysis.

7. REFERENCES

[1] Rudenko .N: Materials Handling Equipment, MIR Publ., Moscow, 1969.

[2] Demirsoz, R, Kesikci, M.K., Imrak, C.E.: Design and Static Stress Analysis of Hook Crosspiece By Means of Finite Element Method, Proc. of Advanced Manufacturing Technologies 44 (2), Rousse, 502-507, 2005.

[3] Scheffler, M., Feyrer, K, Matthias, K.: Fördermashinen Hebezeuge, Aufzüge, Flurförderzeuge, Vieweg, Wiesbaden, 1998.

[4] Torke, H-J, Zebish, H-J.: Innerbetriebliche Materialflusstechnik, Vogel Buchverlag, Würzburg, 1997.

[5] Moaveni, S.: Finite Element Analysis: Theory and Application with ANSYS, Prentice-Hall, New Jersey, 1999.

[6] Jung, Y.H., Lee, K.: Tetrahedron-based Octree Encoding for Automatic Mesh Generation, Computer Aided Design, 25, 141-153, 1993.

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