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Stress Analysis of Bridge Girder of a Single Girder Electrically Operated Travelling Crane using Ansys Workbench

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***Abstract*: EOT (Electrically Operated Travelling) crane is an overhead rail mounted travelling crane used for lifting heavy equipment's and weights. Single girder EOT crane has a bridge girder along which the hoist of crane moves laterally. The wheels of the hoist will be underslung on the bottom flange of the bridge girder. The purpose of this study is to analyze different stress conditions and deformation of the bridge girder of a single girder EOT crane of 15T lifting capacity. In this paper, finite element analysis is done using ANSYS workbench and areas of higher stress concentration and weak zones are identified.**

***Keywords*: EOT cranes, stresses, deformation, wheel load, Finite Element Analysis, ANSYS workbench, SolidWorks.**

1. Introduction

EOT cranes are commonly used in factories, workshops, power plants, steel plants, process industries etc. There are three types of motion associated with an EOT crane- Lifting/hoisting movement, long travel/LT motion and cross travel/CT motion. The hoisting of weights which are connected to the hooks is called lifting motion. The movement of weights along the hoists, bridge girders and other accessories on rails mounted on girders along the longer side of the room is known as LT motion. The movement of weights along with the hoist trolley across the width of the room is known as CT motion. Hence hoisting, LT and CT motion covers the 3 axes of translation. Geared motors are the prime movers for these 3 motions.

Table 1
Parts of single girder EOT crane

Part Marking	Description
1	Bridge girder/Cross beam
2	LT End Carriage
3	LT wheel assembly
4	Hoist assembly
5	Hook assembly

In the problem under consideration following are the parameters:

a) Lifting weight= 15T
b) Weight of the hoist block= 1.2T
c) Number of wheels for CT= 6
d) Span of the crane= 11m
e) Length of bridge girder= 11.4m
f) Material of construction of bridge girder: Mild steel E250 BR conforming to IS-2062 with yield stress of 250 MPa and UTS (Ultimate Tensile strength) of 410 MPa.

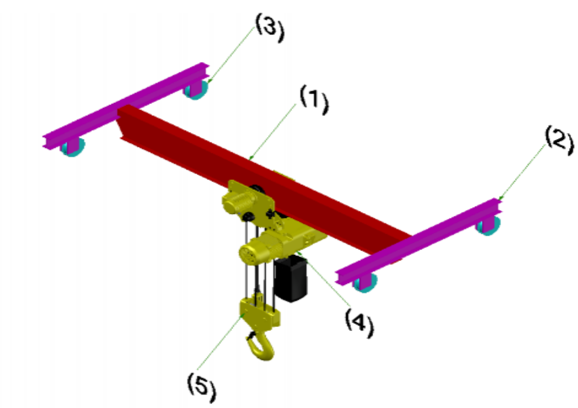

Fig. 1. Single girder EOT crane with part marking

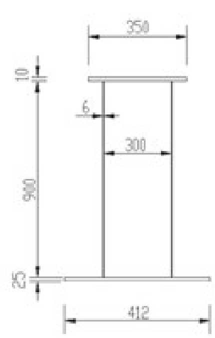

Fig. 2. Cross section of bridge girder

The top flange of the crane beam is 350mm wide x 10mm

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thick. There are two web plates of 900mm height x 6mm thick. The bottom flange consists of 25mm plate. The cross section of the beam is a box construction of rolled plates as shown below:

For providing sufficient flexural rigidity, full diaphragm plates and half diaphragm plates of 6mm thickness are welded inside the hollow section in a staggered manner at every 1m.

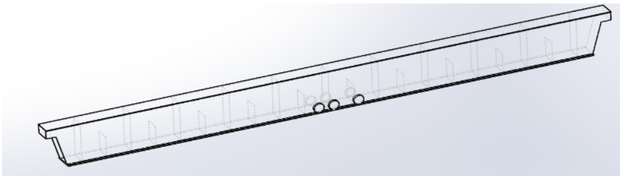

Fig. 3. Isometric view (SolidWorks extract) of the bridge girder

The crane bridge girder is assumed to be a simply supported beam. The wheel loads act as transverse forces exerted on the bottom flange of the beam resulting in deflection generating bending stresses. We have considered the static analysis with the worst-case scenario (i.e., the loads acting at the mid span of the beam).

As the beam is not prismatic, manual stress calculations and manual finite element analysis are cumbersome and time taking. In order to reduce the time, analysis is done in ANSYS Workbench 2023.

2. Methodology

A. Load Cases

As per IS-3177 [1], following are the three load cases:

a) Case I: Normal service without wind
b) Case II: Normal service with wind
c) Case III: Crane out of service

As the crane is enclosed in a closed building, only case I is considered. For Case-I Load to be considered for the design R= Rd + Rh + Rm + Rf.

Rd= Load due to the dead weight of the mechanism= 1.2T

Rh= SWL of hook= 15T

Rm= Load due to the skewing interaction= 10% of SWL= 1.5T

Rf= Loads due to frictional force= 0.01 x SWL= 0.15T

R= Total load= 17.85T; Hence load per wheel= 17.85/6= 2.975T= 29184N

B. Procedure of Static Analysis

The isometric model of the beam with wheels are developed in SOLIDWORKS. The format for importing to Ansys is *.STEP 2014. Among the ANSYS analysis systems Static structural is chosen from the toolbox. Next in the workflow we select the engineering data module inside which structural steel is selected. The parameters like Young's modulus, Poisson's ration, Yield stress, Ultimate tensile stress are cross checked with Indian standard IS-2062.3D model of the beam is then imported to the geometry module

C. Meshing Criteria

Tetrahedral mesh elements with a target quality of 0.05mm and minimum edge length of 0.006m are used. Adaptive mesh sizing is chosen so that the shape function is automatically generated based on the geometry of the model. As the elements are program controlled, the shape function is quadratic. Total number of nodes is 56211 and elements is 29717.

D. Boundary Conditions for Analysis

The bridge girder of crane is simply supported. So, on one end face is "Fixed support" and other end face is defined with following displacement condition:

Displacement along x-direction (cross travel direction) = Free

Displacement along y-direction (lifting/lowering direction) = 0 mm

Displacement along z-direction (long travel direction) = Free

E. Load Application

Here we have considered the static analysis with wheel loads applied at the mid span of the beam. Self-weight of the beam is applied throughout the body.

3. Analysis and Report

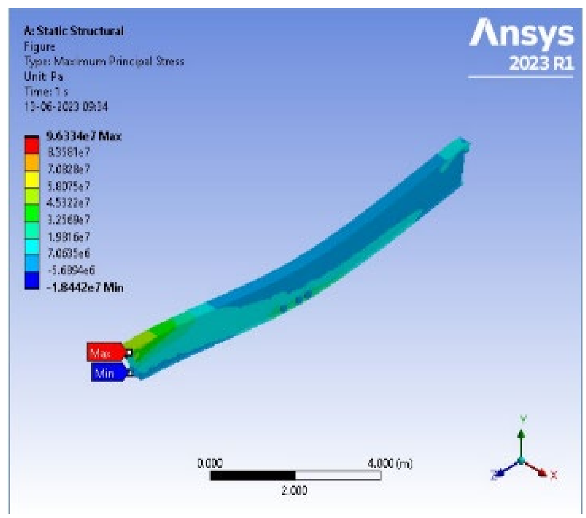

Fig. 4. Maximum principal stress plot

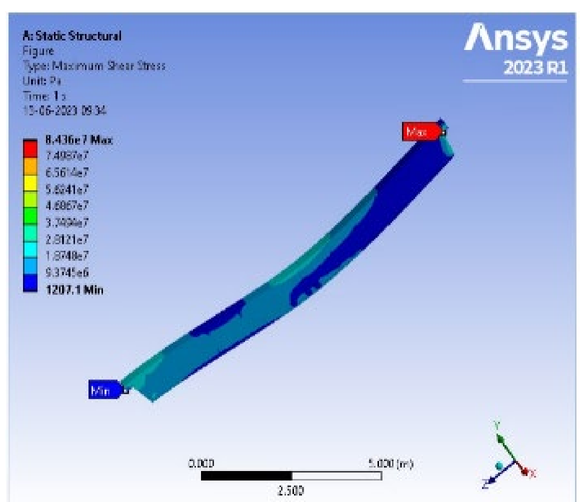

Fig. 5. Max shear stress plot

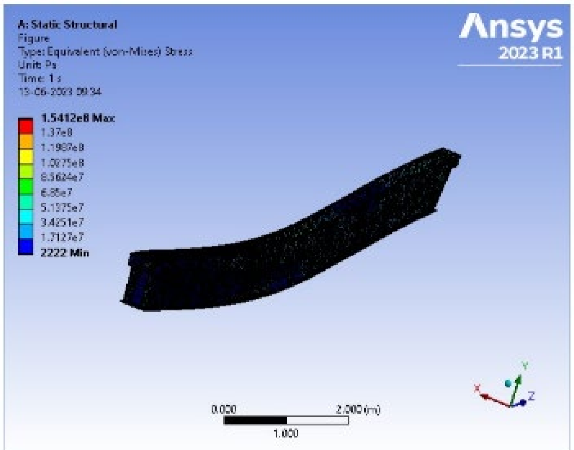

Fig. 6. Von misses stress plot

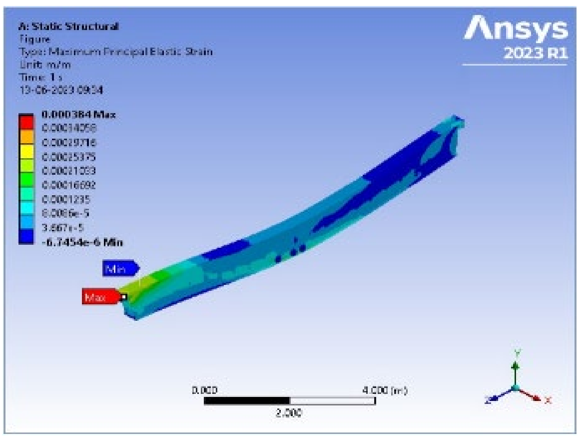

Fig. 7. Principal strain plot

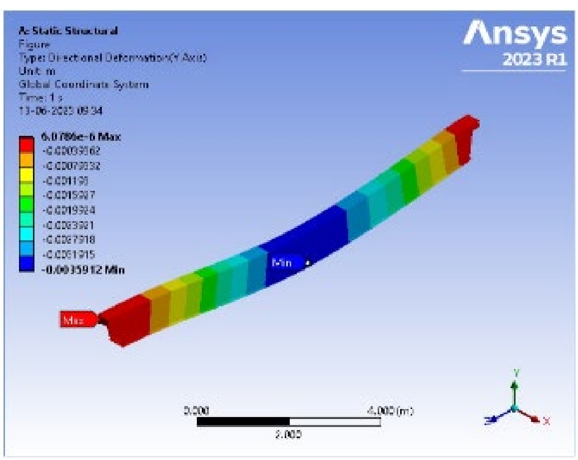

Fig. 8. Deformation plot

A. *Maximum Principal Stress*

As per Rankine's theory, the failure of material happens when the maximum principal stress in a complex state of stress exceeds the maximum stress at yield point during simple tension test.

Table 2
Maximum principal stress comparison

σ_{max} (MPa)	σ_y(MPa)	FS
96	250	2.60

$\sigma_{max} \leq \sigma_y/FS$

B. *Maximum Shear Stress Theory*

As per Guest- Tresca's criterion, the failure of material happens when the maximum shear stress a complex state of stress exceeds the maximum shear stress at yield point during simple tension test.

Table 3
Maximum shear stress comparison

τ_{max} (MPa)	σ_y(MPa)	FS
84	125	1.49

$\tau_{max} \leq \sigma_y/2.FS$

C. *Distortion Energy Theory*

As per Von misses criterion, the failure of material happens when the shear strain energy per unit volume in a complex state of stress exceeds the shear strain energy per unit volume at yield point.

Table 4
Von misses stress comparison

σvon (MPa)	σy(MPa)	FS
154	250	1.62

$\sqrt{[\{(\sigma1^2-\sigma2^2) + (\sigma2^2-\sigma3^2) + (\sigma1^2-\sigma3^2)\}/2]} = \sigma von \leq \sigma y/FS$

D. *Principal Strain Theory*

As per Saint Venant's theory, the failure of material happens when the maximum principal strain in a complex state of stress exceeds the maximum strain at yield point during simple tension test.

Table 5
Von misses stress comparison

Max. Strain	Strain at yield	FS
0.000384	0.00125	3.25

$\{\sigma1 - 2\mu.\ (\sigma2 + \sigma3)\}/E \leq \sigma y/E$

E. *Deflection Check*

As per IS-3177, the maximum permissible deflection is L/900 where L is the span (hence 12.6mm).

Table 6
Deflection comparison

Max. deflection (mm)	Permissible deflection (mm)	FS
3.59	12.6	3.51

4. Analysis of Modified Crane Beam and Comparison of Results

Analysis is also performed for crane beam with additional 8 mm plate welded through out on the 25mm thick bottom plate.

Cross section is as follows:

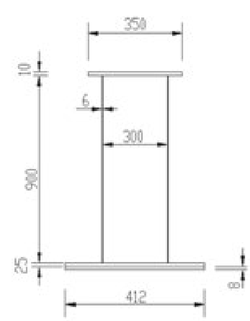

Fig. 9. Cross section of beam with additional 8mm plate on the bottom flange

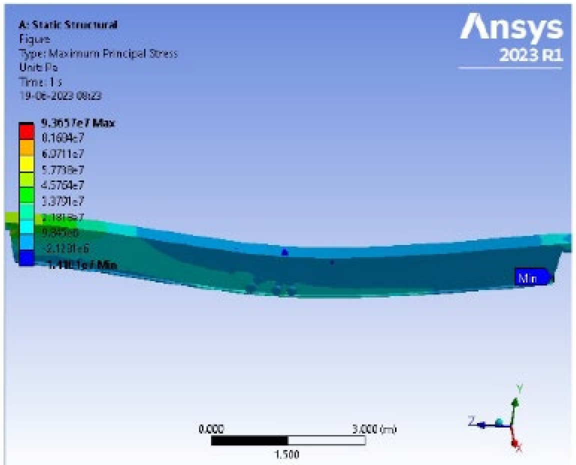

Fig. 10. Max. principal stress

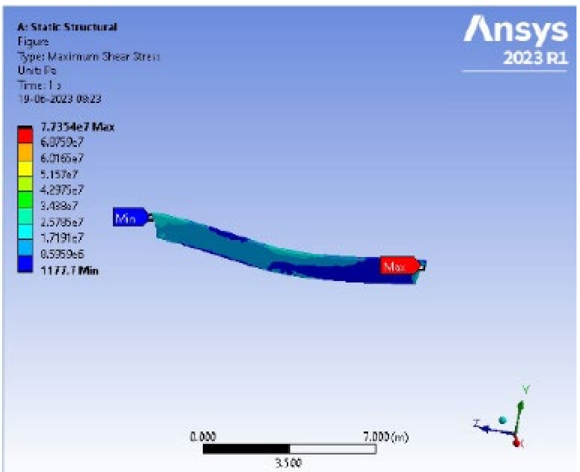

Fig. 11. Max principal stress

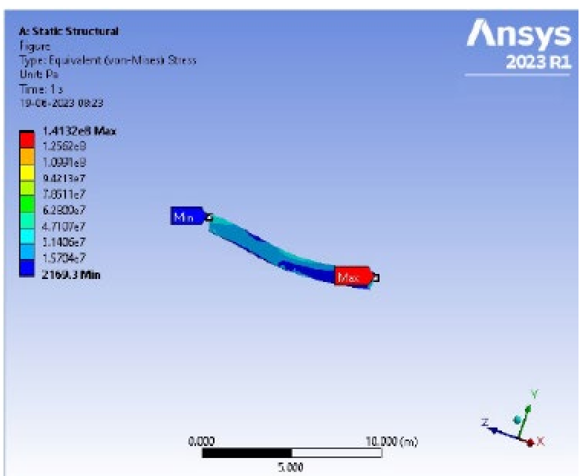

Fig. 12. Von Mises Stress

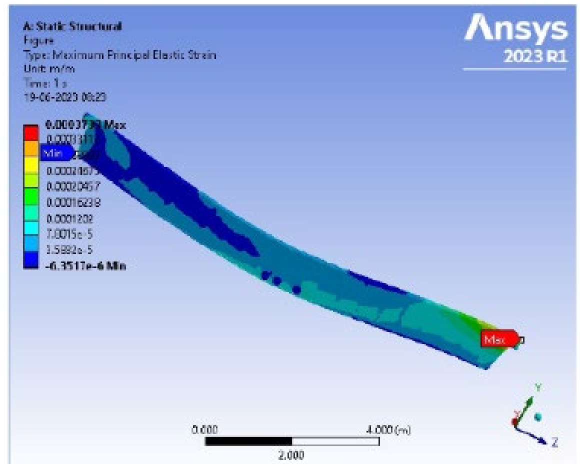

Fig. 13. Maximum principal strain

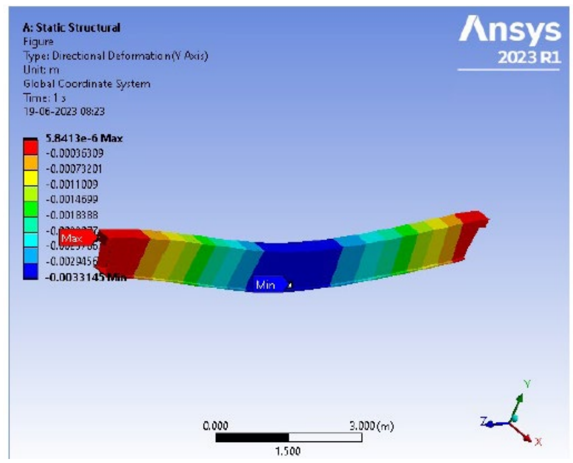

Fig. 14. Directional deflection

Comparison of results is shown on table 7.

5. Interpretation of the Results

The crane beam selected has sufficient factor of safety as per all the theories of failure and the limiting value of deflection. While performing the analysis, there is no additional factoring done for the welded joints. Hence it is of utmost importance that the weldments are continuous and the required throat thickness is maintained. Hence NDT (Non-Destructive Testing) for the welded joints are to be done in order to ensure that the welded joints are proper. Dye Penetrant Test is an acceptable method for weld quality check. As the load is acting directly on the 25mm thick plate, Ultrasonic testing (UT) for the plate is required so as to ensure that there are no surface defects/flaws.

Maximum principal stress, shear stress and Von mises stress are occurring at the corners near the end supports. Highest deflection is at the middle of the beam.

Referring to Table 7, with the addition of bottom flange plate

Table 7
Stress and deflection comparison between beam with 25mm thick bottom plate and beam with 25mm + 8mm thick bottom plate

S. No.	Parameter	Beam with 25mm plate	Beam with 25mm +8mm plate
1	Maximum principal Stress (MPa)	96	93.6
2	Maximum Shear stress (MPa)	84.6	77.35
3	Von Mises stress (MPa)	154.12	141.32
4	Maximum Principal strain	0.000384	0.000373
5	Maximum deflection (in mm)	3.59	3.33

of 8mm thick all the critical values have reduced. The bridge girder is having better resistance to the applied loads and hence is more reliable with extra plate welded.

6. Conclusion

This paper presented stress analysis of bridge girder of a single girder electrically operated travelling crane using Ansys workbench.

References

[1] IS 3177 (1999): Code of Practice for Electric Overhead. Travelling Cranes and Gantry Cranes other than Steel Work.
[2] B. M. Kwak and S. W. Cho., “Optimal Design of Electric Overhead Crane Girders,” J. Mech., Trans., and Automation, 106(2), 203-208, 1984.
[3] Omkar K. Sakurikar, D.V. Kushare, “Review of Overhead Crane and Analysis of Components Depending on Span”, International Research Journal of Engineering and Technology, vol. 3, no. 5, May 2016.
[4] IS 2062 (2011): Hot rolled medium and high tensile structural steel specification.