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Research Paper

DESIGN AND BUCKLING STRENGTH EVALUATION OF A LIFTING BEAM FOR 350 TONNES THROUGH FEA

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The objective of project is to perform the design calculations for the lifting beam for a capacity of 350 Tonnes as per the specifications. Create 3D model as per the design calculations in UNIGRAPHICS. Perform Structural analysis on the 3D model with Symmetric and Asymmetric Loading of 350 Tonnes using Ansys. The project also deals with evaluating the structural stability for buckling loads. In this project design recommendations for buckling of flat steel plate structures intended for lifting applications are taken from DNV Offshore standards, DNVOS-C101 which is intended to be used for design of structures. The structural stability for buckling is checked for the structure according to this standard.

Keywords: Lifting Beam, Strength evaluation, 3D model

INTRODUCTION

A lifting beam is a solid or fabricated metal beam, suspended from a hoist/crane or from forks of a forklift, designed to provide multiple lifting points. The lifting beam enables the user to attach the load at more than one point therein securing and controlling the load's movement.

Lifting beams are designed to be loaded in bending. A simple lifting beam will have an eye or link on the top side to connect to the lifting machine hook and two or more lifting points on the underside to connect to the load. They are ideal for lifting loads which are too weak or flexible to be lifted without support. This is important to minimize unwanted erection stresses or to prevent reversal of stress in certain portions of the lifted object. So the design of lifting beam plays a crucial role in the wellness of the lifted object. Another major consideration is load distribution. Whenever a load is supported at several points there is likely to be a degree of inequality in the share of load imposed on each. The likely variation should be taken into account when specifying or selecting the equipment. If the load is rigid, then some flexibility of the lifting beam may be desirable unless fine adjustment of the connections.

PROBLEM DEFINITION

The objective of project is to perform the design calculations for the lifting beam for a capacity of

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350 Tonnes as per the specifications. Create 3D model as per the design calculations in NX-CAD. Perform Structural analysis on the 3D model with Symmetric and Asymmetric Loading of 350 Tonnes using Ansys. The project also deals with evaluating the structural stability for buckling loads as per DNV Offshore standards.

METHODOLOGY

- Perform design calculations for 350 Tonnes of lifting load.
- Create 3D model using NX-CAD software as per the design calculations.
- Convert 3D model into parasolid format and import into Ansys to perform Structural analysis on the lifting beam with Symmetric Loading of 350 Tonnes. Plot deflections and stresses.
- Perform Structural analysis on the lifting beam with Asymmetric loading of 350 Tonnes using Ansys. Plot deflections and stresses.
- From the results obtained from analysis, evaluate the structural stability for buckling loads as per DNV Offshore standards.

DESIGN OF A LIFTING BEAM

Design Calculations for 350 Tons Loading

Loading Conditions**:**

Total Load (W) = 350 Tons

No. of Load Bearing Pins per support (N) =2

No of Load Bearing Pins per Support Bottom (N1) =2

Distance between top Supports (L1) = 11000mm

Distance between bottom Supports (L2) = 6096mm

DESIGN OF THE BEAM

Distance between the Supports L1= 11000 mm

Distance between the Load points L2 = 6096 mm

Load at Each Load Point

$$W3 = \frac{1000w}{2} = 175000\text{kgs}$$

Load at Each Support

W3 = 175000kgs

Maximum Bending Moment at the Center

$$\text{of the Beam} = \left(\frac{W3L1}{2}\right) - \left(\frac{W3L2}{2}\right)$$

= 4291000 N-mm

Bending Stress on the Beam = 71.9 N/mm^2

ASYMMETRICAL LOADING

Load at Each Load Point =

$$W3 = \frac{1000w}{2} = 210000 \text{ Kgs}$$

Load at Each Support = W3 = 140000 Kgs

Maximum Bending Moment at the Center of

$$\text{the Beam} = \left(\frac{W3L1}{2}\right) - \left(\frac{W3L2}{2}\right)$$

= 0.476E + 08N-mm

Bending Stress on the Beam =0.7978309 N/mm^2

BEAM DEFLECTION

Total Load on the Beam (W1) = 1000W = 350000 Kgs

Support to Load Point (L2)

$$= \frac{L1 - L2}{2} = 2452 \text{ mm}$$

$$\text{load point1} = \text{wa1} = \frac{w1}{2} = 210000 \text{ Kgs}$$

$$\text{load point2} = \text{wa2} = \frac{w2}{2} = 140000 \text{ Kgs}$$

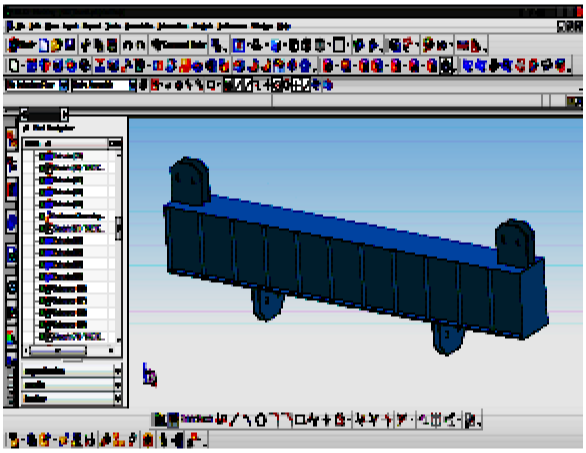
Left Support Reaction = 194396.4 Kgs

Right Support Reaction = 155603.6 Kgs

3D MODELING OF LIFTING BEAM

A lifting beam is a solid or fabricated metal beam, suspended from a hoist/crane or from forks of a forklift, designed to provide multiple lifting points. The 3D model of the Lifting beam assembly is created using UNIGRAPHICS NX software from the design calculations.

Figure 1: D Model of the Lifting Beam from Rear View



FINITE ELEMENT ANALYSIS OF LIFTING BEAM

Finite Element Modeling (FEM) and Finite Element Analysis (FEA) are two most popular mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is perhaps the most popular numerical technique for solving engineering problems. The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems and designs where closed form solutions are governing equilibrium equations are not available. In addition it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

Material Properties of the Lifting Beam

The material used for the construction of Lifting Beam is IS:2062 grade steel.The mechanical properties are mentioned below

Young's Modulus (Ex) =2e5N/mm^2

Poisson's Ratio = 0.3

Density = 7850Tons/mm3

Yield Strength – 240 N/mm2

Weld Strength – 0.7 x 240 = 168 N/mm2

Weld Shear Strength – 0.5 x 168 = 84 N/mm2'

Element Type Used

10 Node Solid 92

Number of Nodes: 10

Number of DOF: 3 (Ux, Uy, Uz)

Boundary Conditions for Symmetric Loading

The boundary conditions applied on the Lifting Beam are as follows and are shown in the below figures.

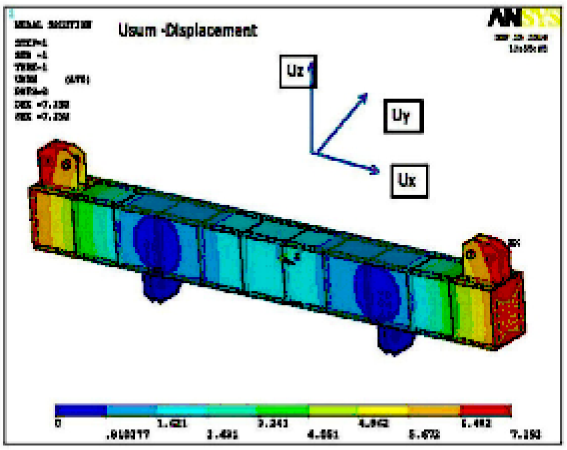
- Total load of 350 Tonnes applied symmetrically.
- Load is applied as distributed load on a span of 180 mm on the 4 Top Pins.

- Bottom Pins constrained in all DOF.

RESULTS FOR SYMMETRIC LOADING – DISPLACEMENT

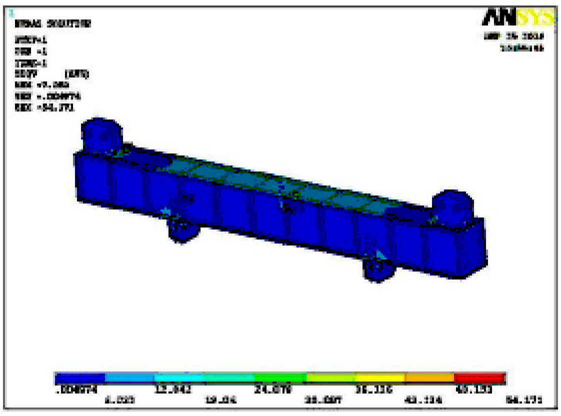
From the static analysis a total displacement of 7.2 mm and deflection in Z- direction of 6.8 mm is observed on the ends of the lifting beam.

Figure 2: Total Deflection for Symmetric Loading



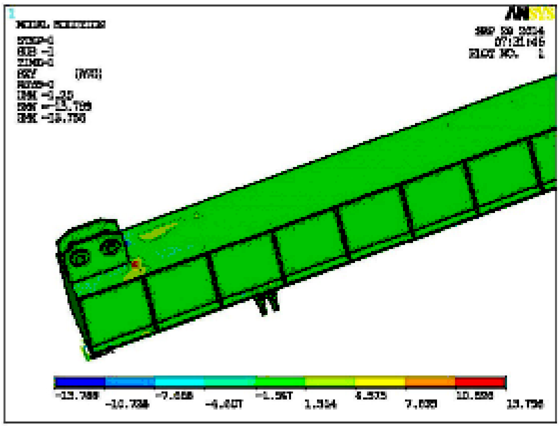
Stresses: From the static analysis VonMises stresses and bending stresses are plotted. Maximum VonMises of 54 Mpa is observed on the top support of the lifting beam as shown in the below figure.

Figure 3: VonMises Stress of Lifting Beam for Symmetric loading



From the static analysis maximum shear stress of 13 Mpa is observed on the top support plate of the lifting beam as shown in the below figure.

Figure 4: Shear Stress Plot of Top Support Plate for Symmetric Loading



The summary of the results obtained from the static analysis of lifting beam for symmetric loading was tabulated in Table 1.

Table 1: Results of Symmetric Loading

S.No.	Symmetric Loading	
1	Total deflection (mm)	7.2
2	Deflection in Z-dir (mm)	6.8
3	Max Von Mises stress (Mpa)	23
4	1st principle stress (Mpa)	56
5	2nd principle stress (Mpa)	35
6	shear stress (Mpa)	13

Static analysis is carried on the lifting beam with asymmetric loading to calculate the deflections and stresses. The boundary conditions and loading details are described below.

Boundary Conditions for Asymmetric Loading

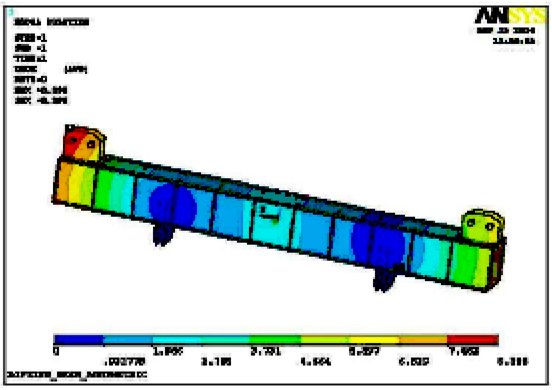
The boundary conditions applied on the Lifting Beam are as follows:

1. Total load of 350 Tonnes applied Asymmetrically.
2. Load is applied as distributed on a span of 180 degrees on the 4 Top Pins.
3. Left side pins are loaded with 60% of the total load and right side pins with 40% of total load to simulate the asymmetry.
4. Bottom Pins constrained in all Dof.

RESULT FOR ASYMMETRIC LOADING-DISPLACEMENT

From the static analysis a total displacement of 8.3 mm and deflection in Z- direction of 7.8 mm is observed on the one end of the lifting beam as shown in the below figure.

Figure 5: Total Deflection of Lifting Beam for Asymmetric Loading



VonMises Stress

Figure 6: VonMises Stress of Lifting Beam for Asymmetric Loading

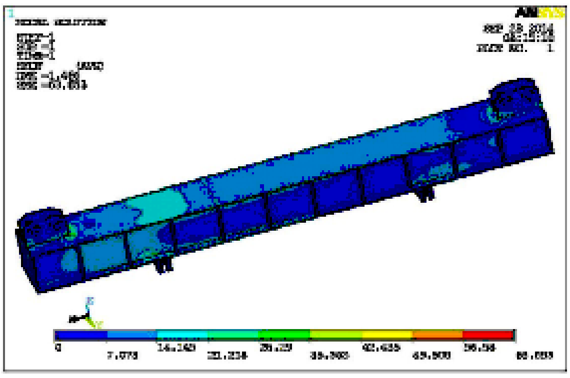


Figure 7: Linearized Stress Plot of top Supports for Asymmetric Loading

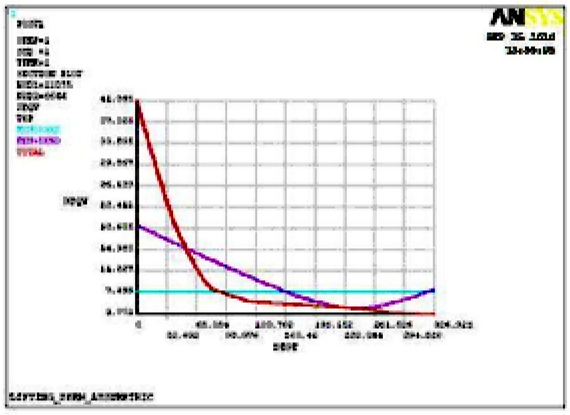
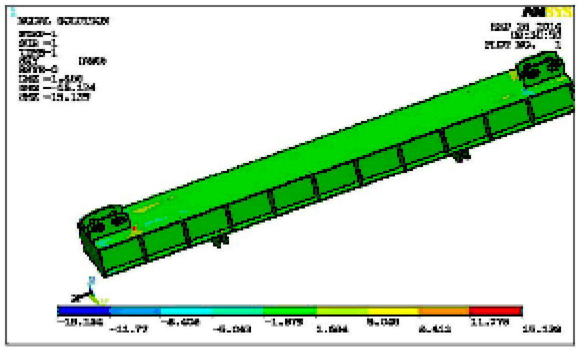


Figure 8: Shear Stress Plot of Top Support Plate for Asymmetric Loading



From the static analysis maximum shear stress of 13 Mpa is observed on the top support plate of the lifting beam as shown in the below figure.

The summary of the results obtained from the static analysis of lifting beam for asymmetric loading was tabulated in Table 2.

Table 2: Results of Asymmetric Loading

S.No.	Asymmetric Loading	
1	Total deflection (mm)	8.3
2	Deflection in Z-dir (mm)	7.8
3	Max.VonMises stress (Mpa)	24
4	1st principle stress (Mpa)	90
5	2nd principle stress (Mpa)	39
6	shear stress (Mpa)	15

The values obtained are further used to check for the buckling safety as per DNVOS-C101 standards.

By substituing the inputs in the above equations

$\bar{\lambda}_w$ = 0.02 (slenderness)

Kl =6.24 (buckling factor)

τ_{Rd} = 195.37 Mpa

A plate subjected to biaxially loading with shear should fulfil the following requirement

$$\left(\frac{\sigma_{x,Sd}}{\sigma_{x,Rd}}\right)^2 + \left(\frac{\sigma_{y,Sd}}{\sigma_{y,Rd}}\right)^2 - c_i \cdot \left(\frac{\sigma_{x,Sd}}{\sigma_{x,Rd}}\right) \cdot \left(\frac{\sigma_{y,Sd}}{\sigma_{y,Rd}}\right) + \left(\frac{\tau_{Sd}}{\tau_{Rd}}\right) \leq 1.0$$

By substituting the values we get left hand side value as 0.16.

Hence it can be said that the top support plate of lifting beam, which is having maximum stress for Asymmetric loading is safe for buckling.

CONCLUSION

Until recently the primary analysis method had been hand calculations and empirical curves. New computer advances have made finite element analysis (FEA) a practical tool in the study of Lifting Beams, especially in determining stresses.In this paper a 3D model of the lifting beam was created as per the design calculations in UNIGRAPHICS. Structural analysis on the 3D model was done with Symmetric and Asymmetric Loading of 350 Tonnes using Ansys. In this project the structural stability for buckling loads was evaluated.Design recommendations for buckling of flat steel plate structures intended for lifting applications are taken from DNV Offshore standards, DNVOS-C101 which is intended to be used for design of structures. From the analysis results it was found that the maximum stress was occuring on the top support plates for both Symmetric and Asymmetric loading conditions.The results obtained from the analysis were further used to check the structural stability for buckling for both Symmetric and Asymmetric loading. From the calculations it was found that the top support plates for both Symmetric and Asymmetric loading conditions are safe from buckling.Therefore it can be concluded that the lifting beam design is safe from buckling for Symmetric and Asymmetric loading.

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