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Design of optimum cross section for EOT Crane Girder

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ABSTRACT

Electric Overhead Travelling (EOT) Crane is one of the essential industrial equipment for material handling. In recent years concentration on weight reduction has been increased that motivate me to work on optimal design of Heavy Electric Overhead Travelling Crane bridges. Most of the crane manufacturers have standardized the single dimensioned box section for multiple spans and duties of Crane for manufacturing simplicity. Steel price in recent trend going upwards, that clearly demanding consumption of steel should be minimized to lower the cost of crane. Utilization of modern design optimization tools will help us to get the optimum solution. This paper explains design of optimum cross-section of EOT crane box girder. A simple procedure has been introduced to optimize various parameters of the welded box section of bridge and then comparing the results with the FE simulation. Maximum allowable bending stress, allowable shear stress and deflection are constrained to recommended limits of design norms. The size and thicknesses of plates, stiffeners and reinforcement are included as design parameters. Optimal girder designed for efficient in respect of design technique and cost-effective.

Keywords— EOT Crane Girder, Design of Crane Girder, Optimization of Cross section, Response Surfaces, ANSYS.

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I. INTRODUCTION

Crane is one of essential equipment in Industries. Crane Girder is main element which made up with steel plates .This work will explore not only optimizing the weight of girder also give the idea about how this reduce the forces acting on building, LT drives power (KW) rating and maintenance cost. One major element weight reduction leads many advantages, this motivates me to do this work. Now a day's world is running behind the custom solutions, so this work will help to reduce the equipment initial cost, maintenance cost and increase building life.

II. LITERATURE REVIEW

Part of this project I studied many papers presented various journals on Electric Overhead Travelling (EOT) Crane Structures. I am summarizing some papers below.

Optimization of crane Box Girder is a complex nonlinear problem for which a simple computational procedure has been suggested. The worksheet with solver can take more than thousand variables and very small to large scale nonlinear optimization can be performed. The results seem to be encouraging and the optimized girders are lighter than the cranes manufactured and supplied in the prevailing market. Additionally the designed spreadsheet does not cross any limit and therefore robust design can be approached. Computational work sheet as well as numerical optimizer calculates optimum parameters in millimeters and most of the time thicknesses are not in whole number. Such problem can be solved by rounding up to a nearest whole number or introducing the integer constraint in the solver which could bring about fractional rise in the weight of the crane. In crane design environment this Methodology might

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help to save precious design time, without incurring high computational cost. The Numerical optimizer has been assessed for simple unstiffened box beam to girders

With stiffener and variety of load cases and it has been established that computation time may increase to a moderate level. The APDL created for girder needs only parameter, loads and spans initialization. Later no further assistance is required for the complete model construction in FE software. The optimization is to be triggered of by another batch command which inputs design constraints and design variable limits to FE optimizer. The computational worksheet has not been considered for fatigue and weld design optimization for the plate girder which has been intentionally left for the sake of simplicity. These cases can be incorporated in the spread sheet in future.

The only input to the optimization is the span, therefore the developed relations may use to calculate the design parameters for the box-girder that result in safe stresses and deflections. It is important to note that, the other parameters like distance between the side plates, the rail parameters, the horizontal stiffeners, etc. are not studied, but, these parameters are linearly related to the maximum height of the girder, as H_{MAX} changes these parameters change accordingly. A considerable mass reduction was observed.

III. CRANE DATA

I am considering here general manufacturing industry purpose crane, class II Type. IS standards are used for Cranes design.

A. Technical data

Capacity 75T and span of the crane is 20m class II crane as per IS classification.

1.	Capacity	75000 Kg
2.	Span	20000mm
3.	Class of Duty	II-IS807
4.	Impact factor	1.3
5.	Crane wheel base	5500mm
6.	Crab wheel Gauge	3100mm
7.	C.T.Rail	70x40.Bar
8.	L.T.Rail	80lb/yd.
9.	Weight of Crab	6000 Kg
10.	Weight of platform	1400 Kg
11.	Weight of L.T.Drive	600 Kg

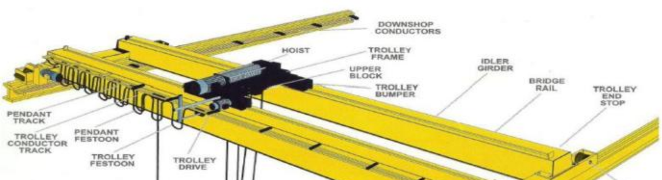

Figure 1: Crane Layout

B. Design Loads

Crab wheel loads (ref: figure 2)

Live wheel loads without impact	20.25T
Live wheel loads with impact	25.875T

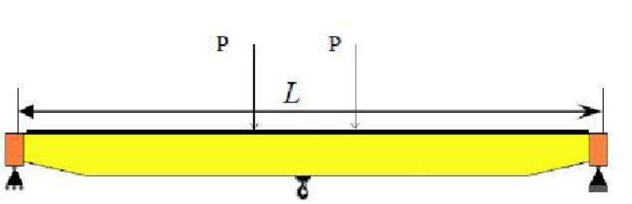

Figure 2: Loads on Girder

C. Main Girder properties

Section: 450x20 + 1750x10 + 450x20 (ref: figure3)

B=450mm T1=20mm

H= 1750mm T3=T4=10mm
B=450mm T2=20mm

F=55mm CT Rail=80x40mm

Span/width = 44 < 60 IS 807

Web- height /thick = 175 < 200 IS 800

Ixx = 2303364.174 cm Zxx = 25735.913 cm

Iyy = 143804.174 cm Zyy = 6391.303 cm

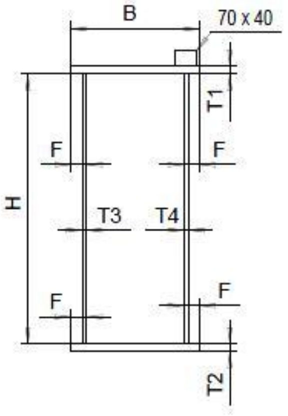

Figure 3 Box Dimensions

IV. GIRDER DESIGN CALCULATION

Combine Bending stress and deflection calculations

A. vertical bending moment

Bending moment due to live load	207.4 Kg/m
Bending moment due to self-weight	32.465 Kg/m
Total Vertical BM with Impact	239.865 kg/m

B. Moment due to Horizontal forces

Horizontal force factor = 5 % of BM without impact As per IS 807

Horizontal Bending Moment w/o Impact = 8.1 kg/m

C. Induced Stress calculation

Stress Due to:

a. Vertical BM	932.03 kg/cm^2
b. Horizontal BM	126.73 kg/cm^2
Combine (a+b) stress	1058.76 kg/cm^2

D. Allowable stress calculation

Allowable Stress based on 250Mpa- 2550Kg/cm yield Stress of St 42

Tensile stress = 2550 x 0.66 x 0.95 = 1598 Kg/cm^2

Where 0.66 factor as per IS 800 & 0.95 duty factor as per IS 807

Max. Permissible comp. stress 1159 kg/cm^2

As per IS 800

Induced Max. Stress is (1058.76 kg/cm2) less than tensile and Compressive allowable stress (1159 kg/cm2) values. Hence selected section is safe

E. Deflection calculation

Deflection due to live load	1.32 cm
Deflection due to UDl loads	0.206 cm
Total deflection	1.526 cm
Allowable deflection	2.22 cm AS per IS

Actual deflection is less than allowable hence ok.

V. DESIGN OPTIMIZATION

A. Optimization Methodology

Crane girders are designed to sustain the loads only, then process is simple but for the optimal design a long comprehensive iterative procedure is needed which is normally difficult by usual computation methods. To undertake this complex task an intelligent and automated computational procedure is needed which is discussed here.

The design optimization methodology, as viewed in figure 1, is to start the process by feeding crane specifications and previously defined box girder design variables into the pre-designed computational worksheet in Ms Excel. The work sheet instantly calculates the required bending and shear stresses, transverse and lateral deflections. Already modelled Girder in solver for objective, constraints and design parameters limits is allowed to iterate to obtain minimal mass beam as a subsequent step. The transformed initial variables are then inspected for their expediency. In case they are appropriate the solution is qualified as optimal. In certain situations if the solution is impracticable the solver is permitted to generate few more solutions by initialization of different set of variables. The Spread sheet has very elaborate answer and sensitivity reports along with scenario report capability. Consequently the results are stored easily and retrievable for future comparisons and utilization in design and fabrication drawings. Since the solver can solve continues or integer values for DV's the values of thicknesses or other dimensions may be needed to be rounded off to the nearest feasible.

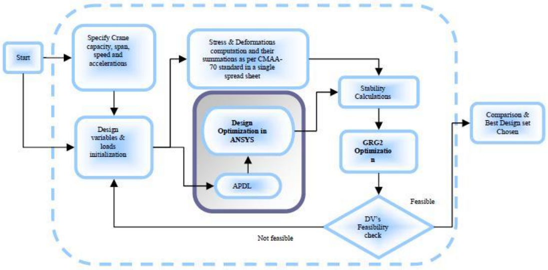

Figure 4Optimization Methodology Flowchart

The other alternative path is the numerical verification. There are two choices either we take the best design variables set from the spread sheet and try the model through FEM. The other mode which has been recommended in figure 1 is to use design optimization simulations to compute optimal volume of the girder. Later the optimized thicknesses are compared with the spread sheet optimizer. Optimized DV's suitability is left to further judgement against fabrication and practical aspects.

B. Response surface optimization with Design Exploration

Design exploration is a powerful approach for designing and understanding the analysis response of parts and assemblies. It uses a deterministic method based on Design of Experiments (DOE) and various optimization methods, with parameters as its fundamental components. These parameters can come from any supported analysis system, Design Modelling tools, and various CAD systems. Responses can be studied, quantified, and graphed. Using a Goal Driven Optimization method, the deterministic method can obtain a multiplicity of design points. You can also explore the calculated Response Surface and generate design points directly from the surface.

C. Response Surfaces

In a process of engineering design, it is very important to understand what and/or how many input variables are contributing factors to the output variables of interest. It is a lengthy process before a conclusion can be made as to which input variables play a role in influencing, and how, the output variables. Designed experiments help revolutionize the lengthy process of costly and time-consuming trial-and-error search to a powerful and cost-effective (in terms of computational time) statistical method.

A very simple designed experiment is screening design. In this design, a permutation of lower and upper limits (two levels) of each input variable (factor) is considered to study their effect to the output variable of interest. While this design is simple and popular in industrial experimentations, it only provides a linear effect, if any, between the input variables and output variables. Furthermore, effect of interaction of any two input variables, if any, to the output variables is not characterized.

To compensate insufficiency of the screening design, it is enhanced to include centre point of each input variable in experimentations. The centre point of each input variable allows a quadratic effect, minimum or maximum inside explored space, between input variables and output variables to be identifiable, if one exists. The enhancement is commonly known as response surface design to provide quadratic response model of responses. The quadratic response model can be calibrated using full factorial design (all combinations of each level of input variable) with three or more levels. However, the full factorial designs generally require more samples than necessary to accurately estimate model parameters. In light of the deficiency, a statistical procedure is developed to devise much more efficient experiment designs using three or five levels of each factor but not all combinations of levels, known as fractional factorial designs. Among these fractional factorial designs, the two most popular response surface designs are Central Composite designs (CCDs) and Box-Behnken designs (BBMs).Optimized Girder section is: 800x10 + 1550x8 + 800x10 (ref: figure3)

VI. OPTIMIZED GIRDER DESIGN CALCULATION

Combine Bending stress and deflection calculations

A. Main Girder properties-optimized section

Section: 800x12 + 1580x8 + 800x10(ref: figure3)

B=800mm	T1=12mm
H= 1580mm	T3=T4=8mm
B=800mm	T2=10mm
F=50mm	

Span/width	25 < 60 IS 807
Web- height /thick	198 < 200 IS 800

Ixx = 1636091.0 cm^4	Zxx = 19714.6 cm^3
Iyy = 410679.0 cm^4	Zyy = 10266.97cm^3

B. vertical bending moment

Bending moment due to live load	207.4 Kg/m
Bending moment due to self-weight	30.12 Kg/m
Total Vertical BM with Impact	237.52 kg/m

C. Moment due to Horizontal forces

Horizontal force factor = 5 % of BM without impact As per IS 807

Horizontal Bending Moment w/o Impact = 8.1 kg/m

D. Induced Stress calculation

Stress Due to:

c. Vertical BM	1120.94 kg/cm^2
d. Horizontal BM	78.89 kg/cm^2
Combine (a+b) stress	1199.83kg/cm^2

E. Allowable stress calculation

Allowable Stress based on 250Mpa- 2550Kg/cm^2 yield Stress of St 42

Tensile stress = 2550 x 0.66 x 0.95 = 1598 Kg/cm^2

Where 0.66 factor as per IS 800 & 0.95 duty factor as per IS 807

Max. Permissible comp. stress 1501.9 kg/cm2 As per IS 800

Induced Max. Stress is (1199.83 kg/cm2) less than tensile and Compressive allowable stress (1501.9 kg/cm2) values.

Hence selected section is safe

F. Deflection calculation

Deflection due to live load	1.85 cm
Deflection due to UDl loads	0.262 cm
Total deflection	2.112 cm
Allowable deflection	2.22 cm AS per IS

Actual deflection is less than allowable hence ok

VII. CONCLUSIONS

This work done for selection of optimal Box Girder for EOT crane. Selection of light weight girder by using traditional methods is bit time consuming task. Sometimes we are not sure that achieved girder have optimal weight or not. Here I have done this optimization practical application point of view. Section which can be directly used for production. Current work I have reduced 10 % one girder weight. Total 1872 Kgs weight is reduced. This weight makes significant in costing, forces acting on the runway beam and building.

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