Faculty of Science, Engineering and Computing
Assessment Form

Module: ME5011 – Thermofluids & Mechanical Systems 2 **Setter: S. Khan**

Title of Assignment: <u>Preliminary design of a single girder overhead traveling crane</u>
Deadline: 23rd March 2018

Module weighting: 25%

Submission details

The student is expected to submit both a hard copy as well as a soft copy of the report along with all the programming/code files. Your final report (hard copy) should be submitted at the RoeVale Reception no later than 1600hrs on the submission date whilst all your electronic file(s) must be uploaded by the same time and date on Canvas/Turnitin/Box. Please note it is the student's responsibility to ensure submission date and time is complied with strictly and any reasons other than those stipulated as mitigating circumstances will not be entertained.

Module Learning Outcomes assessed in this piece of coursework

- Analyse complex stress problems involving combined bending, shear, torsional and axial loading and apply theories of strength, buckling, asymmetric sections, determinate and indeterminate frameworks to engineering design problems.
- Apply appropriate analytical techniques and methods to the solution of typical mechanical system problems.
- Derive and solve mathematical models for vibratory systems with one and two degree of freedom.

Assignment Brief and assessment criteria

This individual assignment is a single design and research/investigative endeavour and does not comprise any questions as such. In order for the student to complete it successfully, he(she) must be proficient at analysis as well as the computational methods associated with solid mechanics and engineering structures. It utilises all of the techniques taught during the course of the lectures/tutorials delivered in mechanical systems and expects a research-centered approach to be undertaken by the student, the final outcome of which should be a typed formal report.

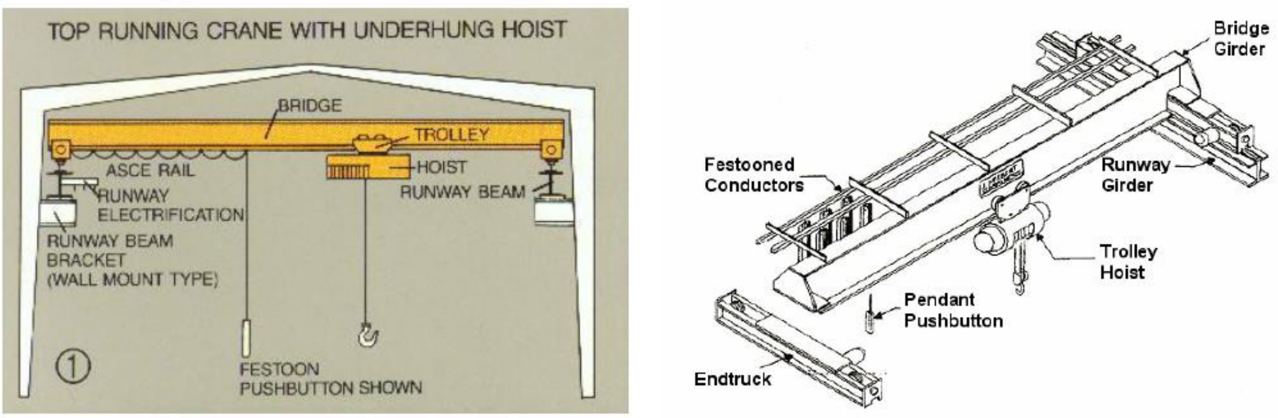
Feedback

Detailed feedback will be provided on the individual submissions 4 weeks after submission.

Preliminary design of a single girder overhead traveling crane

1. Introduction

An Overhead Traveling (OT) crane (also called 'bridge crane') consists of parallel runways with a traveling bridge spanning the gap (Figure 1). The bridge may travel along the runways. The lifting component of the crane is the hoist, which is properly attached to a trolley. The trolley may travel along the bridge. Such cranes are found in industrial environments, shipyards and machine shops and serve the purpose of transporting (lifting and moving) objects from one location to another, within a given footprint. The bridge itself is a steel structure manufactured by welding properly steel plates together. However, it is possible to use a commercially available rolled steel beam as well. In any case, a preliminary design and analysis is required in order to get quickly a first impression about the dimensions of the bridge girder cross-section.



(a) (b)

Figure 1: Typical configurations of a single girder overhead travelling crane: (a) front view and (b) isometric view

2. Aims

The aims of the present coursework are to:

- become familiar with the specific lifting devices (single girder overhead travelling cranes) and the standards used for their design
- practice the calculation of N-Q-M diagrams, the application of the singularity-functions method and the calculation of the normal/shearing/equivalent stress in a real-life engineering application
- practice the simplified calculation of the natural frequency of a real-life engineering structure

3. Considerations/Simplifications

- For the crane bridge, consider a span of 6m and a lifting capacity of 3.2tn.
- For the trolley, consider a wheel base of 600mm, a load distribution of 40%-60% between the two axles and that the trolley can approach each end of the beam at a distance of (at most) 100mm.
- The bridge girder may be ***considered as a simply supported beam***.

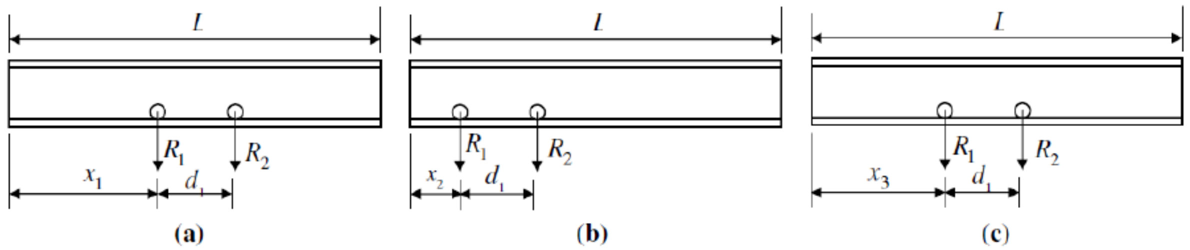


Figure 2: Trolley position for maximum (a) deflection, (b) shear and (c) bending.

4. Constraints (BS EN 1993-6:2007, BS EN 1991-3:2006)

- Maximum vertical displacement: 20mm or span/600 (whichever is smaller)
- Maximum developed stress: less than yield stress
- Partial Factor Of Safety (applied on yield stress): 1.15
- Fundamental frequency: greater than 1.2Hz

5. Calculations for a preliminary design

1. Define the load cases that must be considered. For this purpose, use the British Standard BS EN 1991-3:2006 (retrieve it using the iCAT service of our University).
2. Find the position of the trolley for which the bending moment is maximized
3. Plot the bending moment diagram for the bridge girder
4. Find the position of the trolley for which the shearing force is maximized
5. Plot the shearing force diagram for the bridge girder
6. Find the position of the trolley for which the vertical deflection is maximized
7. Plot the deflection diagram for the bridge girder
8. For the defined load cases and the selected positions:
   - Estimate the corresponding stresses
   - Check adequacy with respect to the constraints.

Note: To check the Ultimate Limit State of the bridge girder, use the following equation

$$\left(\frac{\sigma_{x,Ed}}{f_y / \gamma_{Mo}}\right)^2 + \left(\frac{\sigma_{z,Ed}}{f_y / \gamma_{Mo}}\right)^2 - \left(\frac{\sigma_{x,Ed}}{f_y / \gamma_{Mo}}\right)\left(\frac{\sigma_{z,Ed}}{f_y / \gamma_{Mo}}\right) + 3\left(\frac{\tau_{Ed}}{f_y / \gamma_{Mo}}\right)^2 \leq 1$$

where:
$\sigma_{x,Ed}$: design value of the local longitudinal stress at the point of consideration
$\sigma_{z,Ed}$: design value of the local transverse stress at the point of consideration
τ_{Ed}: design value of the local shear stress at the point of consideration
f_y: yield stress for the selected material
γ_{Mo}: partial factor of safety

For the calculations for shear and bending, it is suggested (not mandatory) to use ***singularity functions***.

6. Selection of an optimized profile for the bridge crane

Based on Sections 4 and 5, select a commercially available beam profile (from catalogues), which meets the given design specifications and is of minimum weight. To this end, use either a trial-and-error approach or an optimization procedure or a simple theoretical approach (***hint***: *calculate the minimum required value for specific cross-sectional properties, e.g. second moment of area, and for various given constraints*).

7. Deliverables

The deliverable will be a ***typed*** technical report including the analytical calculations (adequately explained and commented) and the final selection for the beam profile (adequately explained and commented).

8. References

BS EN 1991-3:2006: Eurocode 1 — Actions on structures Part 3: Actions induced by cranes and machinery

BS EN 1993-6:2007: Eurocode 3 — Design of steel structures — Part 6: Crane supporting structures

END OF ASSIGNMENT