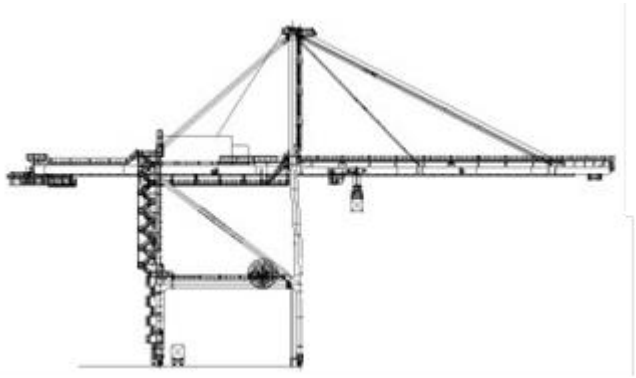
Dynamics of Mechanical Systems – Harbour crane



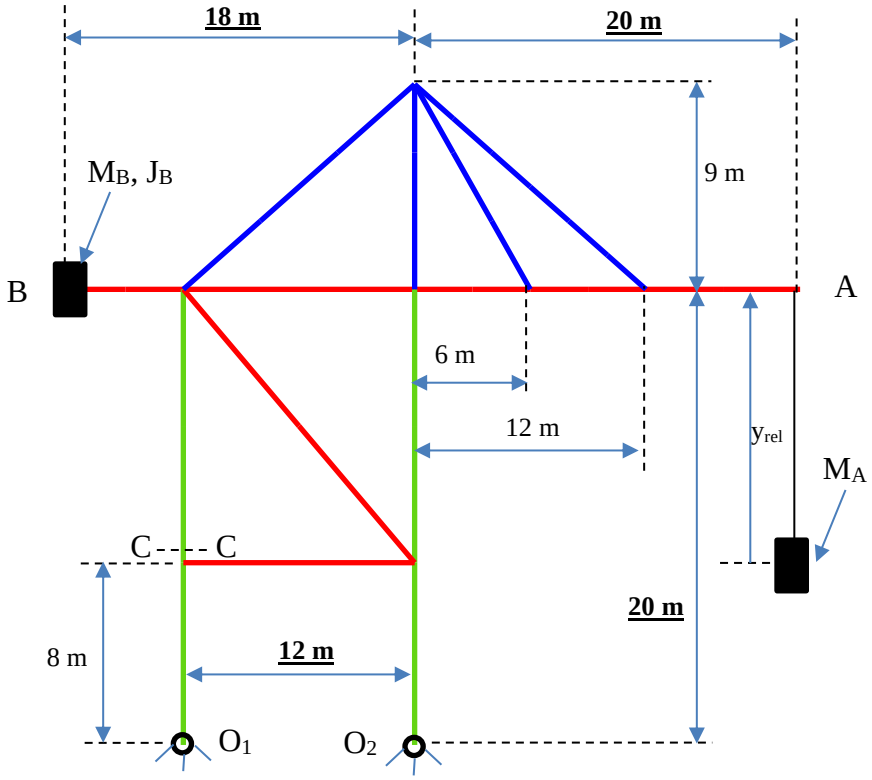


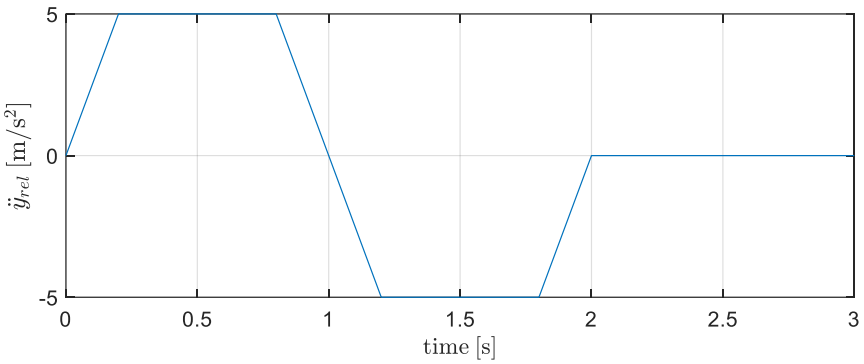
Figure 1

Consider the harbour crane shown in Fig.1. All beams are made of steel (E=2.06e11 N/m^2, ρ=7800 kg/m^3). Beams in blue have ipe240 (A=3.912e-3m^2, I=3.892e-5 m^4) cross section, beams in red have IPE300 cross section (A=5.381e-3m^2, I=8.356e-5 m^4) and beams in green have IPE550 cross section (A=1.344e-2 m^2, I=6.712e-4 m^4). A rigid body having mass M_B=2000 kg and mass moment of inertia J_B=80 kgm^2 is rigidly attached to the red horizontal beam at point B. Damping is defined according to the "proportional damping" assumption: [C]=α[M]+β[K], with α=0.2 s^{-1} and β=4e-4 s.

1. Define a FE model of the unloaded crane (i.e. <u>without mass M_A</u>) suitable for analysing its dynamic response in the **0-10 Hz** frequency range (***using a safety coefficient 2***). Plot the undeformed structure.
2. Compute the natural frequencies of the undamped system (unloaded crane <u>without mass M_A</u>) in the **0÷10 Hz** frequency range. Plot the modal shapes associated to the natural frequencies up to **10 Hz**.
3. For the unloaded crane (i.e. <u>without mass M_A</u>), plot the Bode diagrams (in linear scales) of the following frequency response functions (FRF) in the frequency range 0 ÷ 10 Hz with step 0.01 Hz:
    a. Input: vertical force at point A; output: vertical displacement of point A;

b. Input: horizontal force at point A; output: horizontal displacement of point B;
c. Input: vertical force at point A; output: vertical acceleration of point A;

4. Compute the natural frequencies of the damped system (unloaded crane <u>without mass M_A</u>) up to **10 Hz** and the related non-dimensional damping ratios.
5. Compute the same FRFs as in point 3 <u>developing a model in modal coordinates limited to the first four modes</u>. Plot the Bode diagrams superimposed (with two different colours) to those of point 3.
6. For the unloaded crane (i.e. <u>without mass M_A</u>), plot the Bode diagrams (in linear scales) of the following frequency response functions (FRF) in the frequency range 0 ÷ 10 Hz with step 0.01 Hz.
   a. Input: vertical force at point A; output: vertical component of the constraint force in the hinge O_1;
   b. Input: horizontal force at point A; output: vertical component of the constraint force in the hinge O_2.
7. For the unloaded crane (i.e. <u>without mass M_A</u>), plot the Bode diagram (in linear scales) of the following frequency response function (FRF) in the frequency range 0 ÷ 10 Hz with step 0.01 Hz.
   a. Input: horizontal force at point A; output: bending moment at section C-C, belonging to the vertical green beam and located just above the connection with the red transverse beam
8. Consider a winch placed at A which lifts a mass M_A=800 kg according to the time history of acceleration $\ddot{y}_{rel}(t)$ shown in the plot below



$y_{rel}(t)$ being the displacement in vertical direction of the load relative to point A (positive if upwards directed). Compute the corresponding time history of the absolute vertical displacement of point A for time t=0÷20 s.

9. Define a change in the unloaded crane (i.e. <u>without mass M_A</u>) to reduce **<u>by 30% at least</u>** the maximum amplitude of the FRF of the vertical acceleration of point A for a unit vertical force applied at A (see point 3.) **<u>without increasing the total mass of the system by more than 5%</u>**. The following modifications are not allowed:
   - changing any of the four dimensions shown in Fig. 1 using underlined boldface font:
   - Changing material properties (steel must be the material used);
   - Using additional constraints, except in case they are placed at the same height of hinges O1 and O2 and within a distance of ±4 m from these hinges.

   If the section of one or more beam is changed, unified beam sections such as IPE, HPE etc. shall be used.

Have with you at the oral exam **<u>a printed copy</u>** of the following:
1) all plots mentioned above
2) the .inp input file of the system (and of the modified system at point 9, if needed)
3) any .m script used to answer points 4, 5, 6, 7, 8 (9 if needed)