Assignment Dynamic of Structure under Moving Loads – Part B: Hyperloop

In this assignment, you will use different methods to model a hyperloop system. There are two problems in this assignment. You only need to choose **ONE problem** to solve.

Modelling methods used in each problem:

- Problem 1: one analytical and one finite element model (using ANSYS).
- Problem 2: two finite element models (using Matlab and ANSYS).

Problem 1

Model the hyperloop structure as an infinite beam on discrete periodic supports, see Figure 1. The parameter values are listed in the Appendix.

a. Derive the dispersion equation, compute its roots and plot the dispersion lines. For this question, you can assume the system is undamped (c_s = 0). Please plot the dispersion lines for the frequencies between 0 and 1000 rad/s. Please include three Brillouin zones in your plot. Interpret the results.

(Hint: refer to the lecture slides of canonical problem 4. Note that you should write the determinant of the system of equations in the form of a 4th order polynomial of $\xi = \exp(-ikd)$. You can then determine the numerical value of the coefficients of the polynomial, and then compute its roots numerically.)

b. Build a finite element model in ANSYS (with a total length of 160 m), based on the 1-layer model on Brightspace (Content/Week 4.5/The FEM in dynamics/1-layer model under moving load). Calculate and plot the dispersion lines and compare them to the result in 1a.
c. Determine the critical velocity of a constant moving load F_0 based on the dispersion lines. Verify the critical velocity and assess its influence on the dynamic response of the hyperloop structure by conducting time domain simulations.

(Hint:

- You may determine the critical velocity by placing the kinematic invariant line tangent to the primary dispersion lines (which give rise to waves with more energy compared to all the other branches). The dispersion lines identified using the ANSYS model can be considered as the primary dispersion lines.
- Vary velocities in the time domain simulations: higher and lower than, or/and equal to the critical velocity. You can use the ANSYS model for the time domain simulations.)

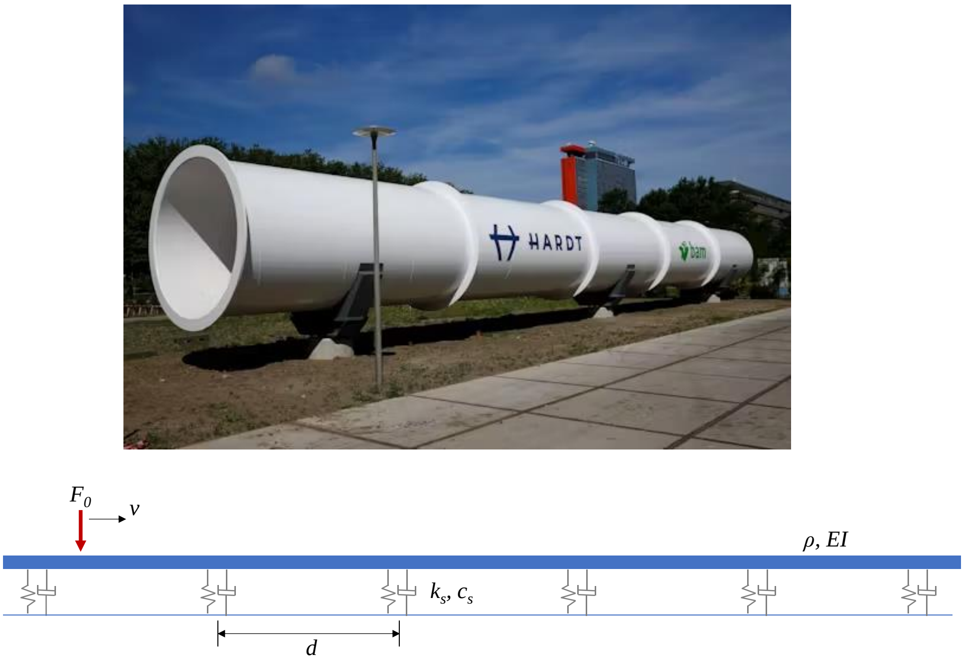

Figure 1. Hyperloop structure (top) and model (bottom) for problem 1.

Problem 2

Model the hyperloop structure as a beam on discrete periodic supports with concentrated masses at each support, as shown in Figure 2. The masses are used to model the inertias of the supports. The parameter values are listed in the Appendix.

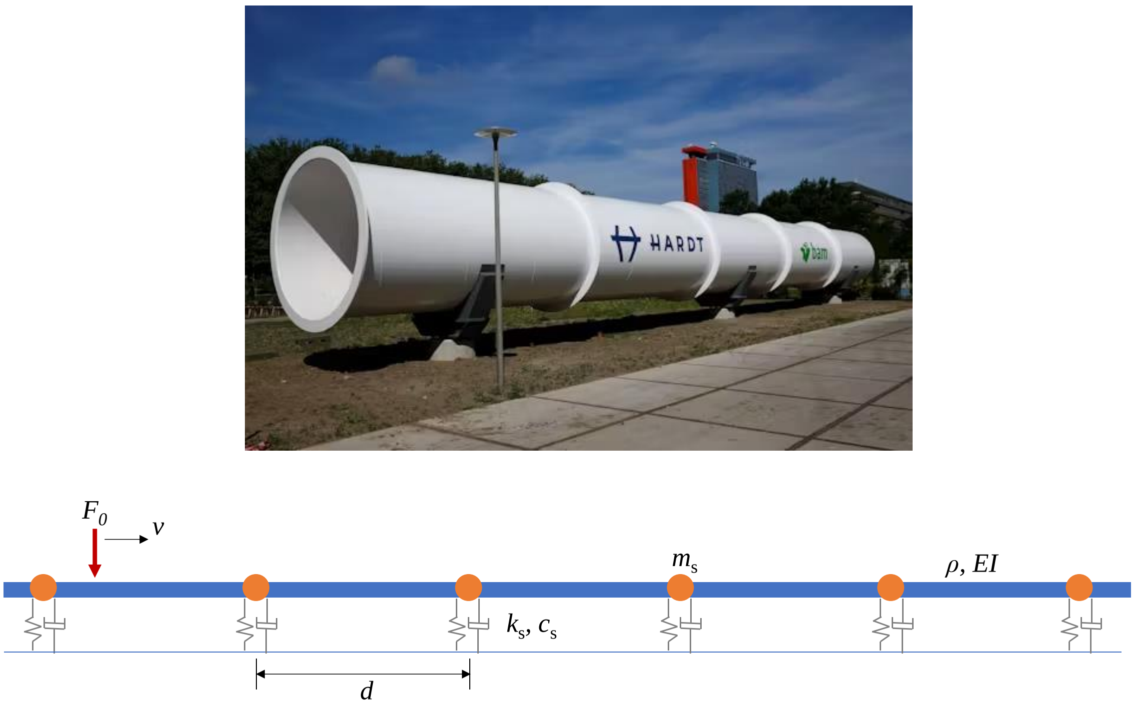

Figure 2. Hyperloop structure (top) and model (bottom) for problem 2.

a. Use the Matlab model from canonical problem 6 (a two-layer railway track) to create a model for the hyperloop structure shown in Figure 2 (with a total length of 160 m). Calculate and plot the dispersion lines. Please plot the dispersion lines for the frequencies between 0 and 1000 rad/s, and include three Brillouin zones in your plot. Interpret the results.

(Hint: Download the latest simulation package from github https://github.com/chetshen/TRACK_v3.0/tree/ciem5220. Run the following codes to obtain the system matrices.

```
clear
inp = get_input_hyper_loop(); % read input file
[nodeCoord]=node_coor(inp,1); % generate node coordinates, 1 means only one
tube is modeled
btypr = inp.mesh.btypr; % beam element types for the tube: 1 for Euler, 2 for
Timoshenko
[geo] = mesh_trk_full(btypr,btypr,nodeCoord); % generate the geometry
properties
mat_trk = form_mat_trk_2(inp,geo); % generate system matrices
```

Note that the input values have already been correctly set in the file ‘`get_input_hyper_loop.m`’. You can see that the ‘railpad stiffness’ has been set to a very high value to model the hyperloop system shown in Figure 2.)

b. Similarly, build a finite element model in ANSYS (finite length of 160 m), based on the two-layer track model on Brightspace (Content/Week 4.5/The FEM in dynamics/2-layer model modal analysis). Calculate and plot the dispersion line and compare it to the results in 2a.
c. If you want to increase the critical velocity of the moving constant load, how would you change the support stiffness k_s? Motivate your answer.

(Hint:

- You may determine the critical velocity by placing the kinematic invariant line tangent to the primary dispersion lines (which give rise to waves with more energy compared to all the other branches). The primary dispersion lines can be identified by the brighter branches in the results of the Matlab model.)

Appendix. Parameter values of the hyperloop system

Parameter	Symbol	Value	Unit
Bending stiffness*	EI	2.5e10	Nm^2
Mass per unit length**	ρ	1330	$\mathrm{kg/m}$
Dead weight	F_0	30e3	N
Support mass	m_s	2330	kg
Support stiffness	k_s	44e7	$\mathrm{N/m}$
Support damping	c_S	10e3	$\mathrm{Ns/m}$
Support spacing	d	16	m

* For the FE models, you need to set E and I separately. You can assume $I = 1\ \mathrm{m}^4$.

** For the FE models, you need to set density *D* and cross-section area *A*, so that $\rho = D * A$. You can assume $A = 1\ \mathrm{m}^2$.