Lab Project: Design and Selection of Tuned Mass Damper Device

(Teamwork: 2-3 members, Report: due in week 14, Presentation: due in week 15)*

Tuned mass dampers (TMD) have been widely used for vibration control in mechanical engineering systems. A TMD is a device consisting of a mass, a spring, and a damper that is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the TMD is tuned to a particular structural frequency so that when that frequency is excited, the TMD will resonate out of phase with the structural motion. Energy is dissipated by the TMD inertia force acting on the structure.

Problem Description

A rotating machine, such as turbines or compressors, is vibrating and transmitting large forces to the ground. This vibration might be due to shock or unbalanced mass of the rotor. Considering the vibration in vertical direction only, the machine can be represented as a single degree of freedom system having mass M, stiffness K and damper B, subjected to a force, shown in Figure 1. The harmonic force F is due to rotating unbalance when rotating at speed N (see Table 1). A tuned mass damper device is to be mounted on the machine in order to reduce the dynamic response (the TMD has mass m, spring coefficient k and damping coefficient b. Two newly designs were proposed for the TMD devices, as shown in Figure 2. Your task, as an engineer, is to evaluate the performance of each system in order to select the best configuration.

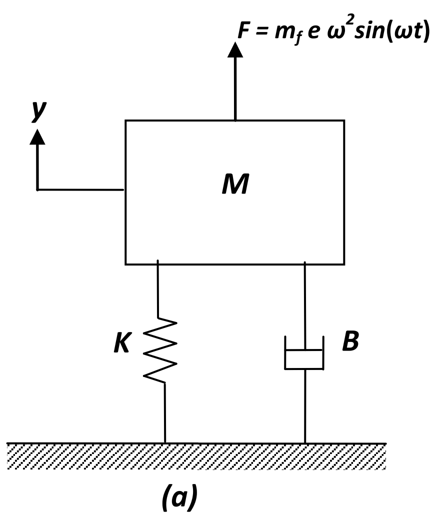

Figure 1: (a) Machine supported by a spring and damper.

Undamped System Analysis

As an initial analysis, use the model for the undamped machine system with vibration absorber (Figure 2a, with $b = B = 0$), draw FBD, find EOM, and solve for the steady-state solution y(t) due to harmonic forces. Show the amplitude as a function of force frequency, i.e. frequency response. Comment on how the secondary mass and spring are affecting the response of the machine. What are the optimum values for the mass and spring of vibration absorber?

Damped System Analysis

Including the damper in the vibrational systems is more realistic idealization of the machine. Therefore, for the damped system, Figure 2, draw the FBD, find EOM, and solve for the steady-state response y(t) as function of force frequency (frequency response). Hint: for the values of *m* and *k* of the TMD, you could use the results of the undamped system as your initial parameter. Simulate the motion of the damped machine for different values of mass, stiffness and damping coefficients (*m*, *k* and *b*) of the TMD. Compare the amplitudes of the damped machine for the two configurations shown in Figure 2. Show how the TMD is affecting the dynamic response of the machine and suggest optimum values to obtain the minimum response. Formulate a procedure for selection the optimum design values for the TMD.

Time Response

Plot the displacement response versus time (total solution) of the mass *M*, for several parameters of TMD due to impulse force. Compare the response for the system with damped TMD to the system without damping. Does TMD improve the time response of the machine due to shock input (impulse force)? Comment on the results.

Selection of TMD

Based on the previous analysis, one TMD configuration from those shown in Figure 2 has to be selected. Describe which design would provide better suppressing of the machine vibration, justify your answer by comparing the response for both TMD systems. Show your final selection of the TMD device mass, spring and damper parameters.

Notes:

- In order to avoid heavy weight on the machine, the mass of the TMD device cannot be more than 10% of the total mass of the machine, i.e. $m \leq 0.10\, M$.

- In the report, include all equations, transfer functions and simulations.
- Each group will be assigned specific parameter for the machine by the lab instructor.

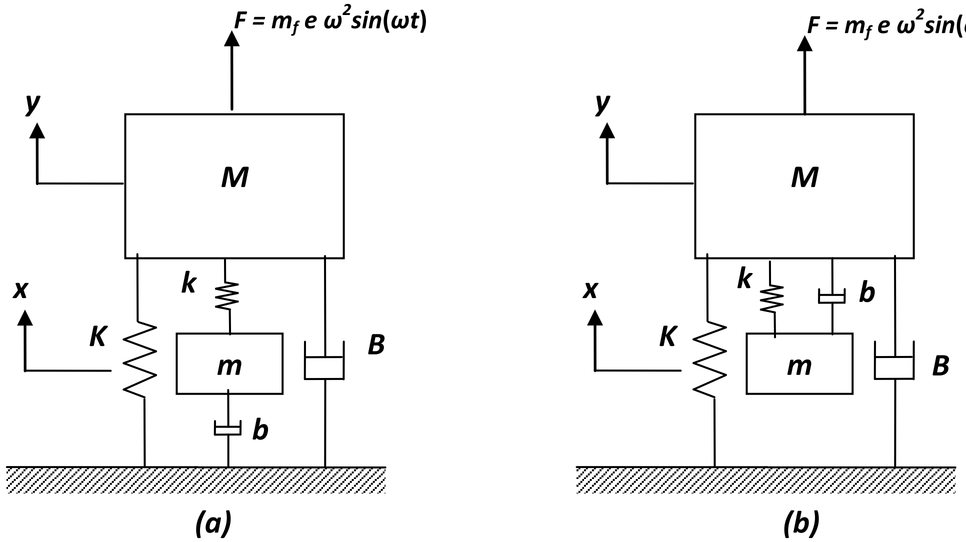

Figure 2: Two proposed design for the Tuned Mass Damper (TMD) (a): First configuration, (b) second configuration.

Table 1: Data for the Mass, spring and damper of the machine and the rotational speed of the rotor.

Group #	Machine mass *M* (kg)	Spring constant *K* (N/m)	Damping constant *B* (N.s/m)	Rotational speed *N* (rpm)	Mass unbalance $m_f.e$ (kg.m)
1	100	8400000	3000	2760	2
2	150	8650000	3000	2290	2
3	200	9900000	3000	2120	2
4	250	8950000	3000	1800	2
5	300	9100000	5000	1660	2
6	350	9200000	5000	1550	2
7	400	9350000	5000	1460	2
8	450	9500000	5000	1385	2
9	500	9650000	5000	1325	2
10	550	9800000	5000	1275	2

* This project is teamwork of 2-3 members. A technical report, *Word* processed, must be submitted in week 14, followed by a *Power Point* presentation in week 15. The grade distribution for the Lab project is: *Report* 4% + *Presentation* 2% = *Total* 6%.