ME756A Term Paper (2019)

Modelling of Dynamic Vibration Absorber

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Abstract

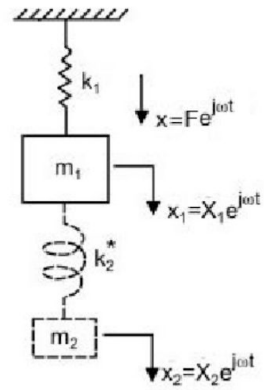
This term paper is implements the mathematical model of a dynamic vibration absorber (DVA) in matlab. Dynamic Vibration Absorber is type of tuned mass damper which is mounted on the system whose vibration needs to be reduced. The modelling is done in Simulink ®.

Introduction

Every system which have some sort moving part tend to vibrate to varying degree. Many precision industrial processes cannot take place if the machinery is being affected by vibration. However, most of the time these vibration are harmful for the system and affect the performance of the system. There are many ways to reduce vibration. Dynamic Vibration Absorber works by changing the resonance frequency of the system. DVAs are based on the concept of attaching a secondary mass to a primary vibrating system such that the secondary mass dissipates the energy and thus reduce the amplitude of vibration of the primary system.

Mathematical model

Consider the motion of a SDOF system with which a dynamic vibration absorber (in the form of a lumped mass and a spring with complex stiffness) is attached. The complete system is with two variations is shown below.



The equation of motion can be written as:

$$m_1\ddot{x}_1 + k_1(x_1 - x) + k^*{}_2(x_1 - x_2) = 0$$
$$m_2\ddot{x}_2 + k^*{}_2(x_2 - x_1) = 0$$

Let us consider the case of harmonic base excitation. Substituting, $x_1 = X_1e^{j\omega t}$, $x_2 = X_2e^{j\omega t}$ and $x = Fe^{j\omega t}$ in the above equations of motion, we get

$$(k_1 + k^*{}_2 - m_1\omega^2)X_1 - X_2 = F$$
$$(k^*{}_2 - m_2\omega^2)X_2 = k^*{}_2X_1$$

Using above equations, we get transmissibility T as

$$T = \left|\frac{X_1}{F}\right| = \left|\frac{(k^*{}_2 - m_2\omega^2)}{(k_1 - m_1\omega^2)(k^*{}_2 - m_2\omega^2) - k^*{}_2m_2\omega^2}\right|$$

Implementation

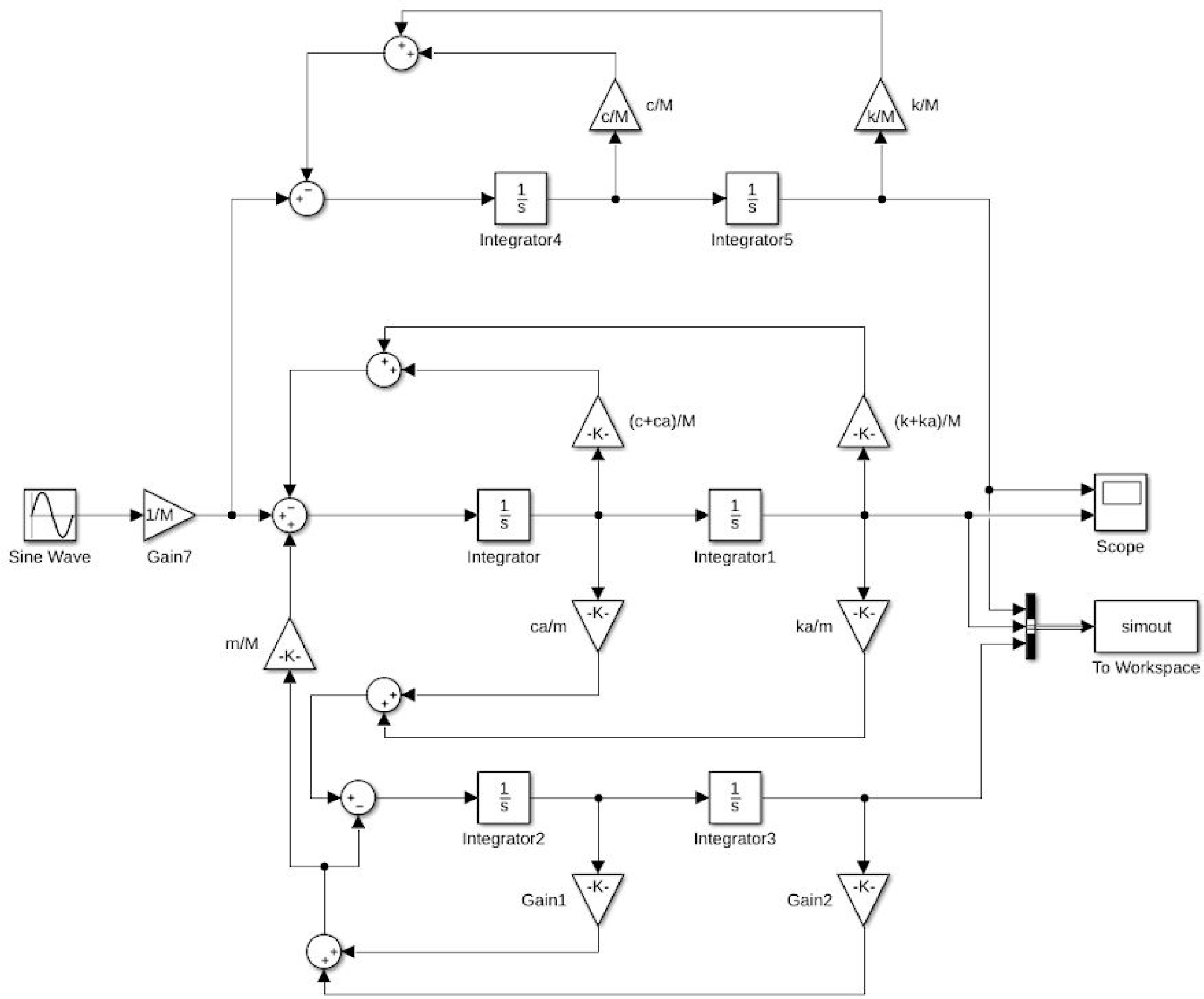
A sinusoidal force $F_0 sin\Omega t$ is applied. The complex spring constant $k^*{}_2$ can be broken into components $k_a + ic_a$. ‘a’ in the subscript represent auxiliary system variable. Mass of the auxiliary system is m_a. The primary system consists spring constant k and damping coefficient c. Rewriting the above equations with these variables

$$m\ddot{x} + (c + c_a)\dot{x} + (k + k_a)x - c_a\dot{x}_a - k_ax_a = F_0 sin\Omega t$$
$$m_a\ddot{x}_a + c_a\dot{x}_a + k_ax_a - c_a\dot{x} - k_ax = 0$$

Rearranging terms

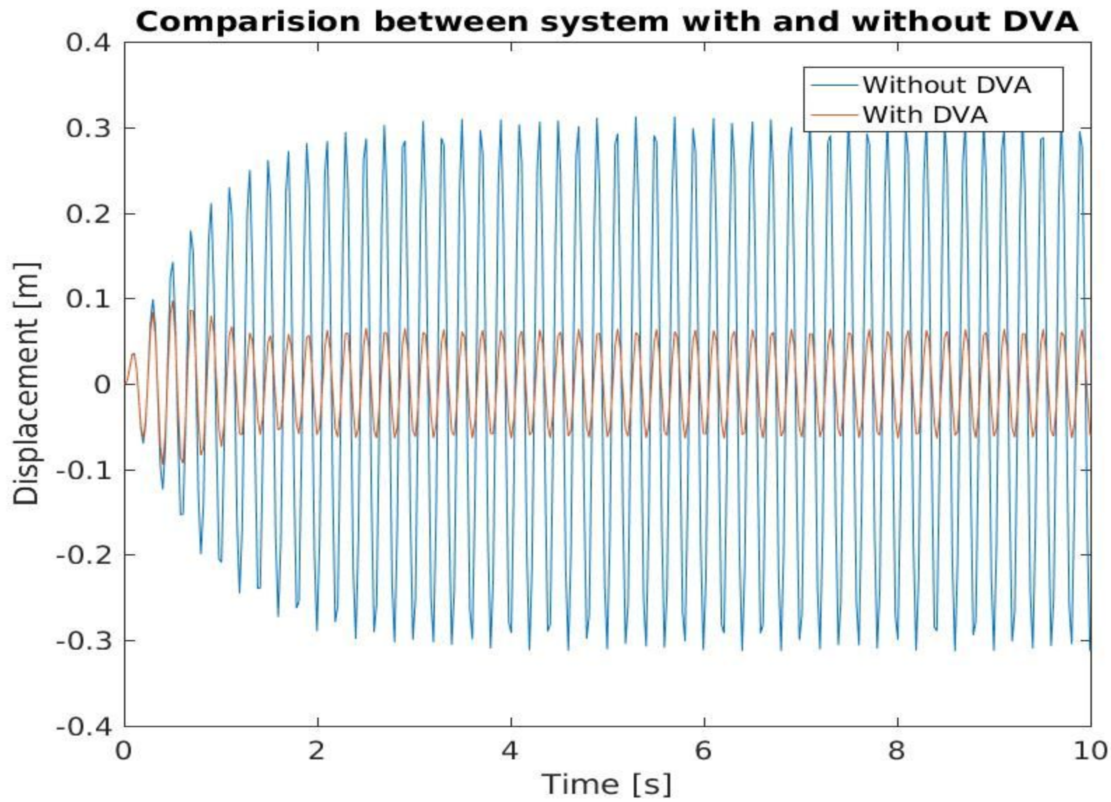
$$\ddot{x} = \frac{F_0}{m}sin\Omega t - \frac{(c+c_a)}{m}\dot{x} - \frac{(k+k_a)}{m}x + \frac{c_a}{m}\dot{x}_a + \frac{k_a}{m}x_a$$
$$\ddot{x}_a = \frac{c_a}{m_a}\dot{x} + \frac{k_a}{m_a}x - \frac{c_a}{m_a}\dot{x}_a - \frac{k_a}{m_a}x_a$$

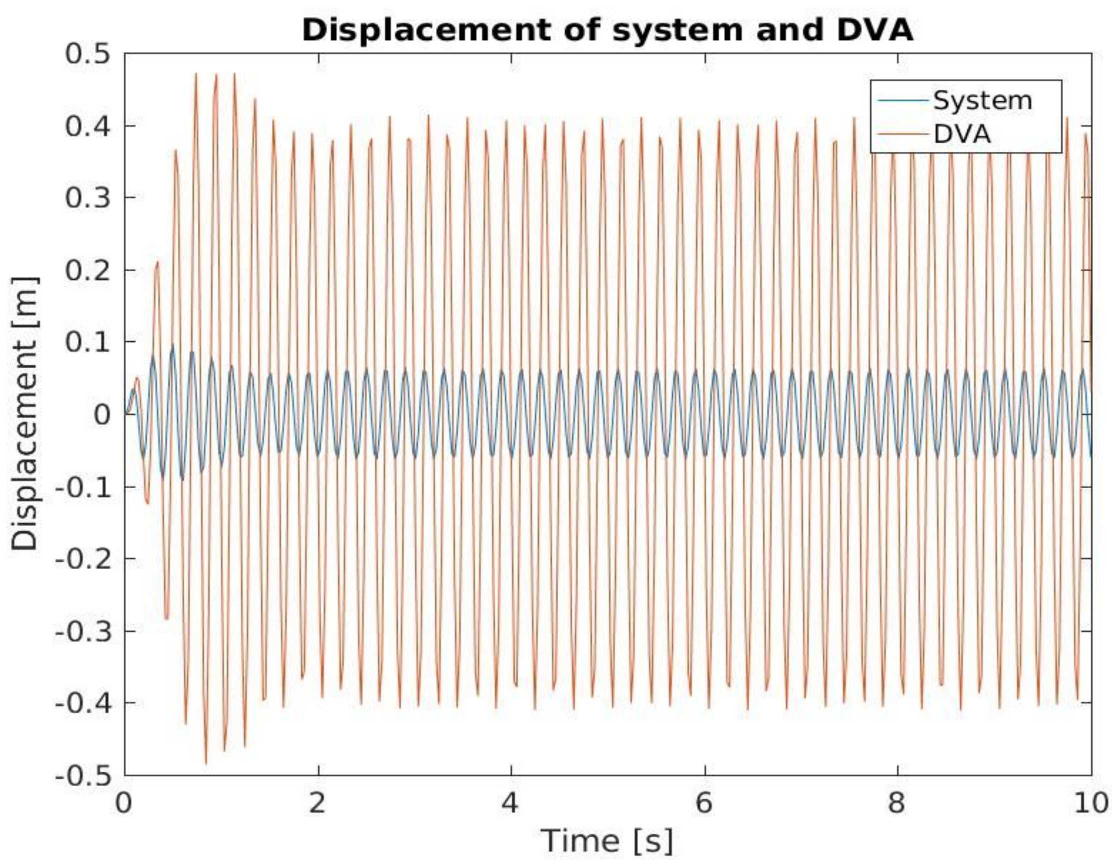
Simulink Model



Top part is primary system without DVA. The output can be viewed in the simplot or it is also plotted in the matlab script.

Results


Comparision between system with and without DVA
Without DVA
With DVA
Displacement [m]
Time [s]
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
2
4
6
8
10


Displacement of system and DVA
System
DVA
Displacement [m]
Time [s]
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
2
4
6
8
10

Conclusion

The amplitude of vibration of the system after adding the auxiliary system has reduced by a factor of 3. Second figure shows the displacement of primary system and DVA. DVA is absorbing most of the vibrations of the primary. Amplitude is larger for DVA as the mass is much less the primary system. This shows that the implementation of the DVA has been done correctly.

References

[1] Zdraveski, Filip, and Elisaveta Donceva. "Mathematical model of dynamic vibration absorber-response prediction and reduction." *Annals of the Faculty of Engineering Hunedoara* 14.1 (2016): 31.

[2] Bhattacharya B. ,Lecture Note of Course on “*Vibration Control*” (2019).