ME 635 – Modeling and Simulation

Homework 9

Transient and Dynamic Models

11/21/2022

"I pledge my honor that I have abided by the Stevens Honor system"

Submitted by,

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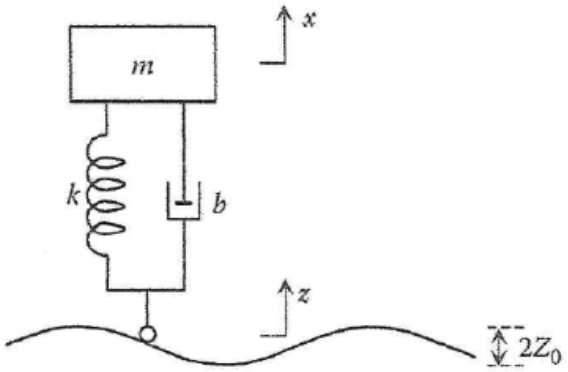
Problem 1

The mass spring damper system shown in Figure represents a vehicle traveling on a rough road. Assume that the surface of the road can be approximated as a sine wave $z = Z_o \sin(\omega t)$, where $Z_o = 0.01$ m and $\omega = 3.5$ rad/sec. The mathematical model of the system is given by an ordinary differential equation

$$m\ddot{x} + b\dot{x} + kx = b\dot{z} + kz$$

Lets m = 3000 kg; b = 2000 N.s/m; k = 50 KN/m



- Build a Simulink model of the system based on the mathematical representation and plot the displacement output x(t) of the vechicle.

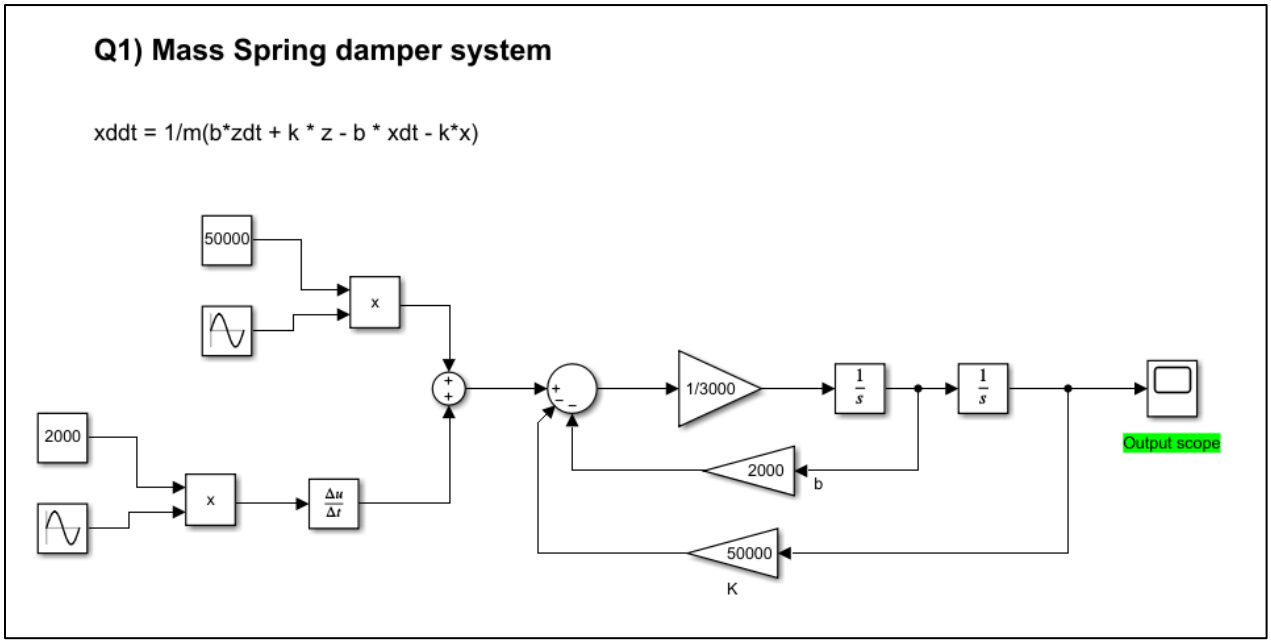
Solution:

The equation can be simplified as;

$m\ddot{x} + b\dot{x} + kx = b\dot{z} + kz$ …(Given)

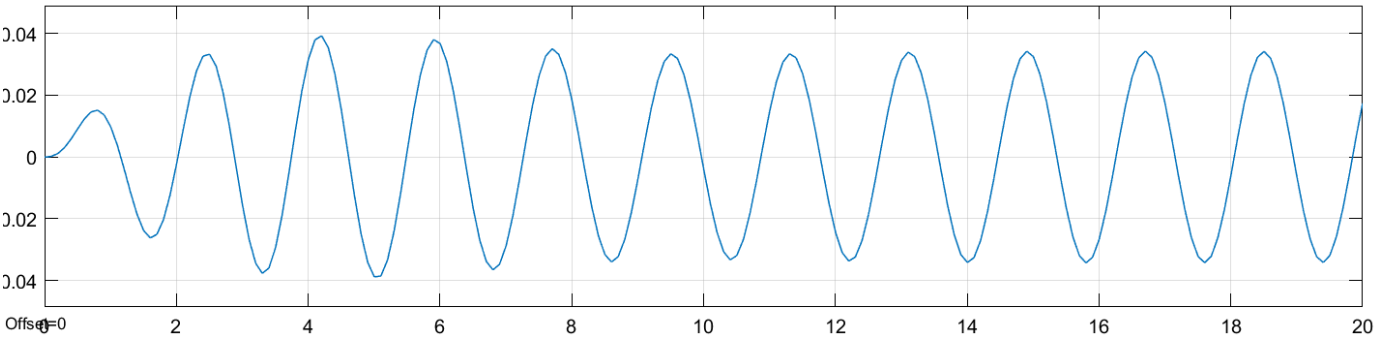
$\ddot{x} = \frac{1}{m} * (b\dot{z} + kz - b\dot{x} - kx)$ …(eq.1)

Simulink Model:



The stop time for the model was set as 20s.

Model Output:



Above figure shows the displacement for the given mass spring damper system for 20s considering the given gain values.

Note: Q1_Simulink_file

Problem 2

A copper spheres with 25, 75 and 100 mm in diameter with K = 400 W/m.K are immersed in a fluid with a film coefficient of h = 10 W/m^2.K, one at a time. The spheres are initially at 300° C and the fluid is at 25° C. The density of copper is 8.96 gm/cm^3 and specific heat 0.386 J/gm.K.

- Build a Simulink model of the system based on the mathematical representation
- Show a comparative plot of how each sphere cools down with time (Temperatures vs. time on a single plot).
- Save each response in Matlab and plot all of them on one plot.

Note: the thermal resistance [R = 1/(hA)]. A is the area exposed to the oil. This problem is solved with one unknown ($T_{sphere}(t)$) with one thermal capacitor (sphere) and one resistance (convective film on the surface). Assume that the bath is so large that its temperature does not change, remains at the ambient temperature.

Solution:

Diameters: a) 25mm b) 75mm c) 100mm

Initial temperature (Sphere) = 300^{o}C

Initial temperature (Fluid) = 25^{o}C

Density of copper (tau) = 8.96gm/cm^3

Film coefficient (h) = 10 W/K.m^2

Specific heat = 0.386 J/gm.K

The mathematical equation formed based on the above given details is as follows.

$$m = \frac{-8.96 * 10^{-6} * 2}{d}$$

where, d = diameter

m = mass

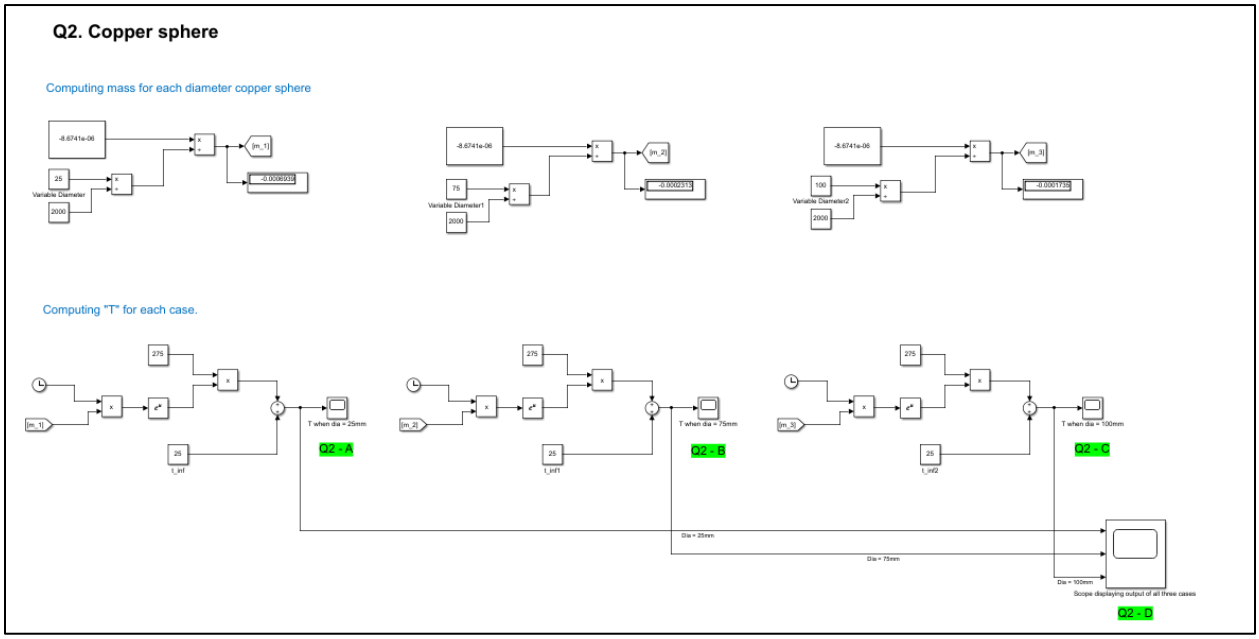
$$\frac{d\theta}{dt} = \gamma_{each} * A\ (T_S - T_\infty)$$

$$T = 275 * e^{m*t} + T_\infty \qquad \text{…(Derived from the previous equation)}$$

where, t = time

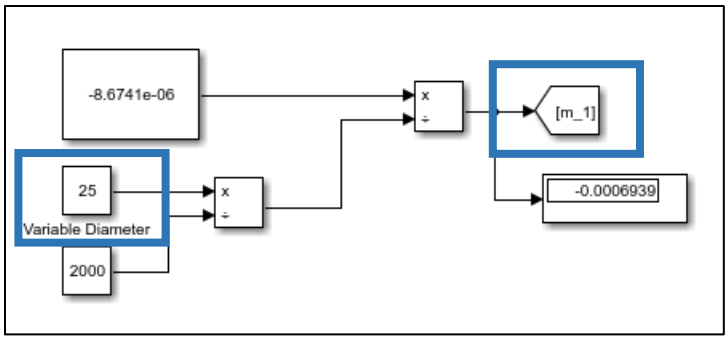
T = temperature

Simulink model



The figure above shows the Simulink model for all the diameters for this question. Below, individual model for each case is provided and the corresponding plot achieved is also presented.

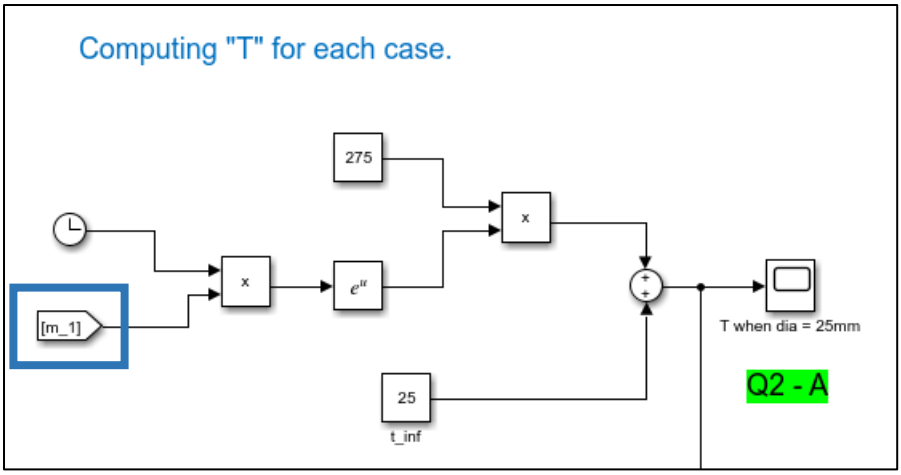
A) For dia = 25mm



Getting the mass for the copper sphere when the dia = 25mm

The only varying block in in this section are the “constant block” in the input side which will vary for each case. And the second difference in the “goto” block at the output side to save the mass for each case with different tags.

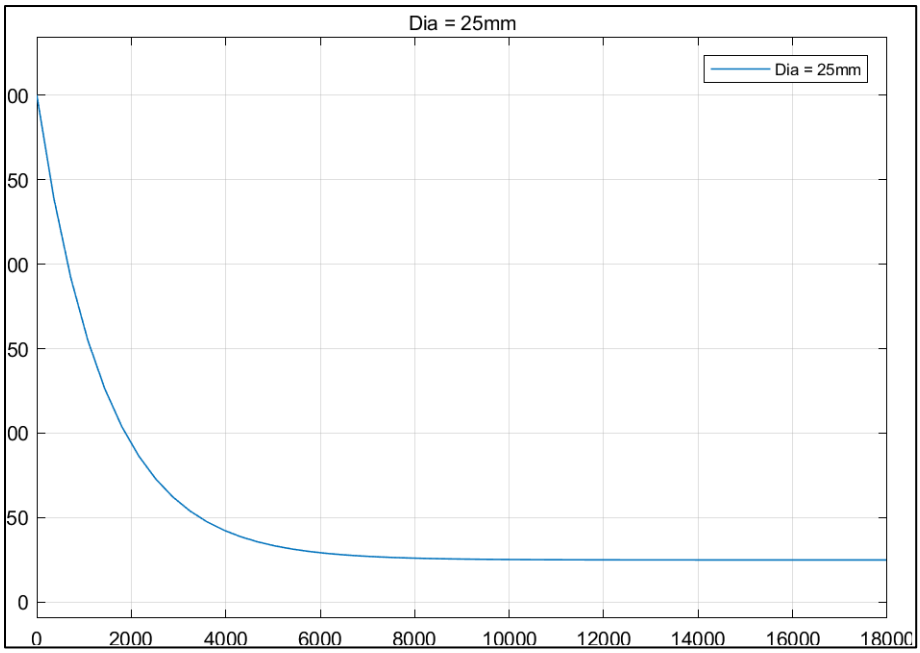
m_1 = -0.0006939



Simulink model for computing T and plotting.

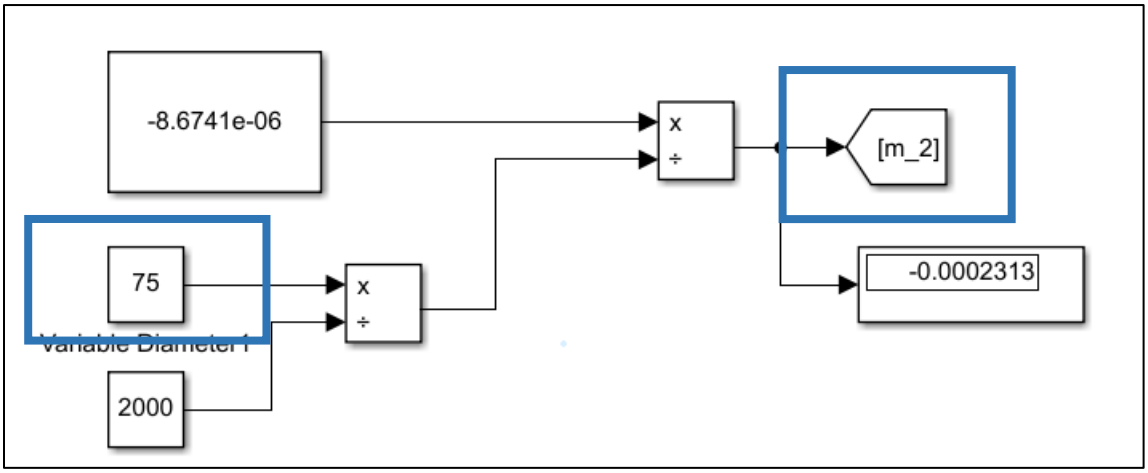
Only the “from” block is different for this section of the Simulink model for all the cases. Tag name is same as what was set in the previous mass computation model.

Output for case 1:

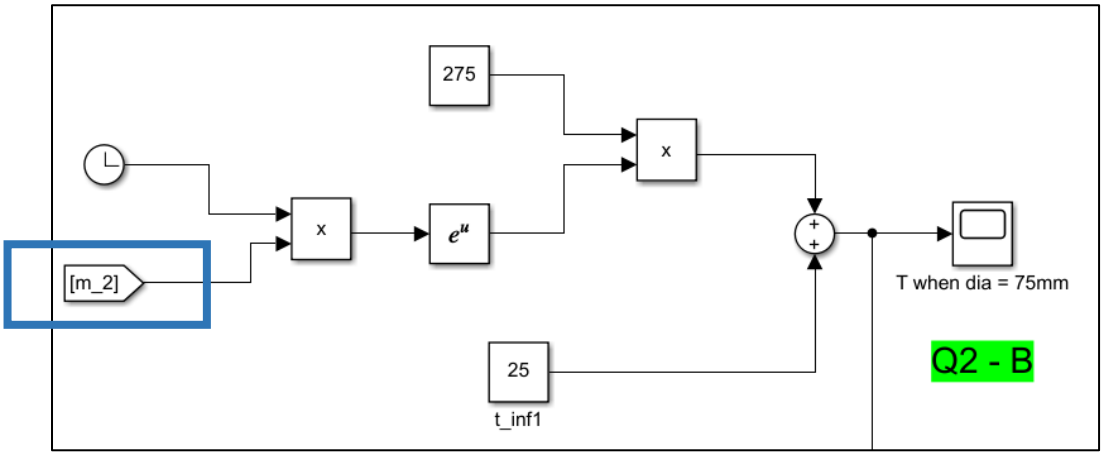


Scope for dia = 25mm

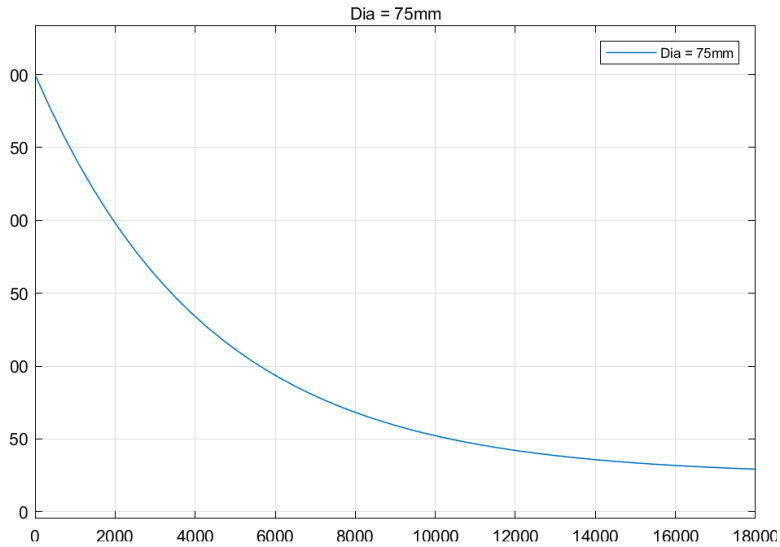
B) For dia = 75mm



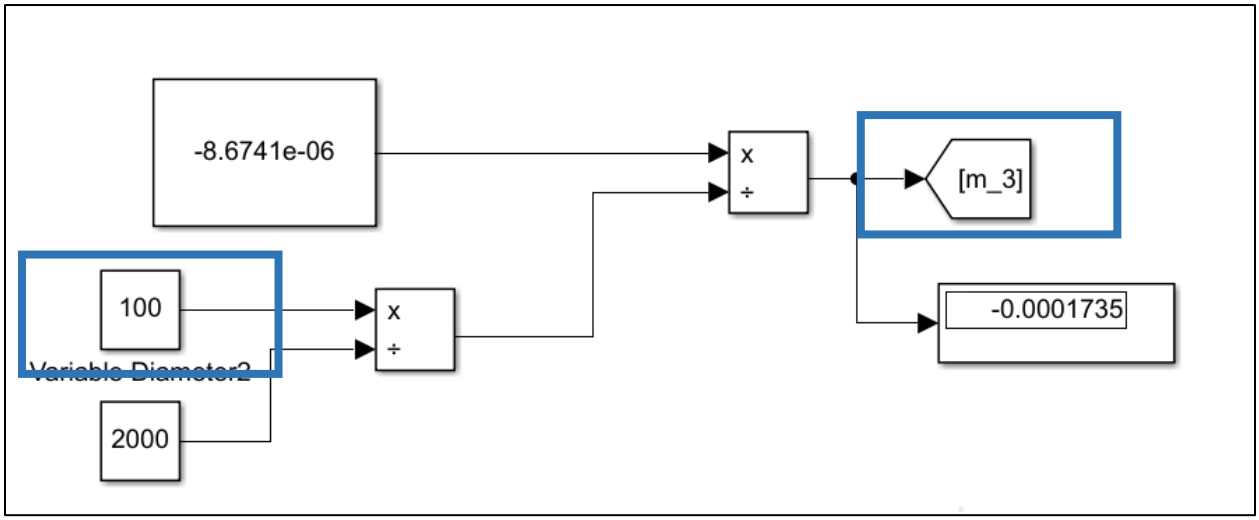
M_2 = -0.0002313



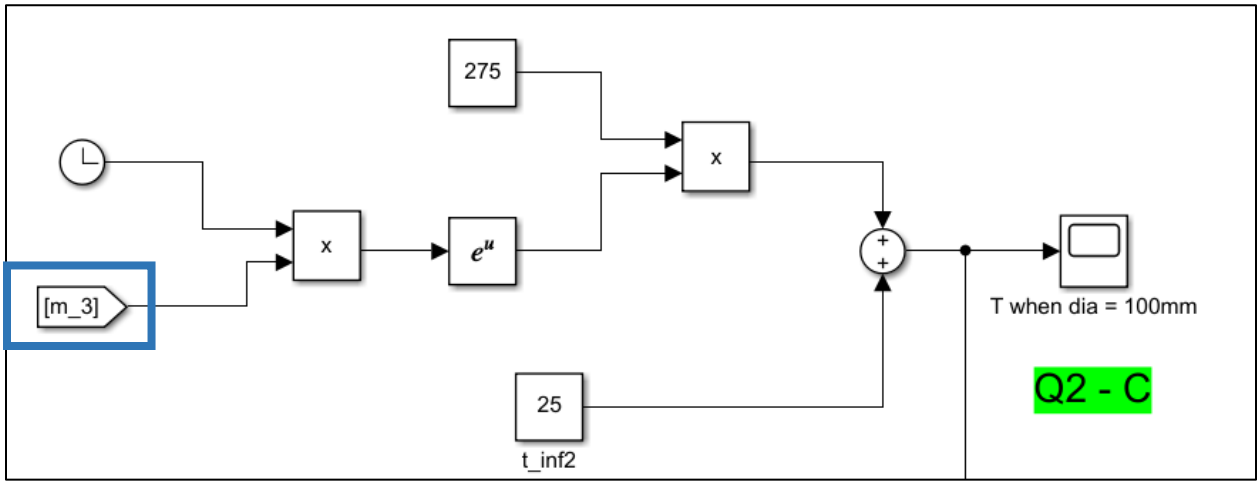
Output for case 2:



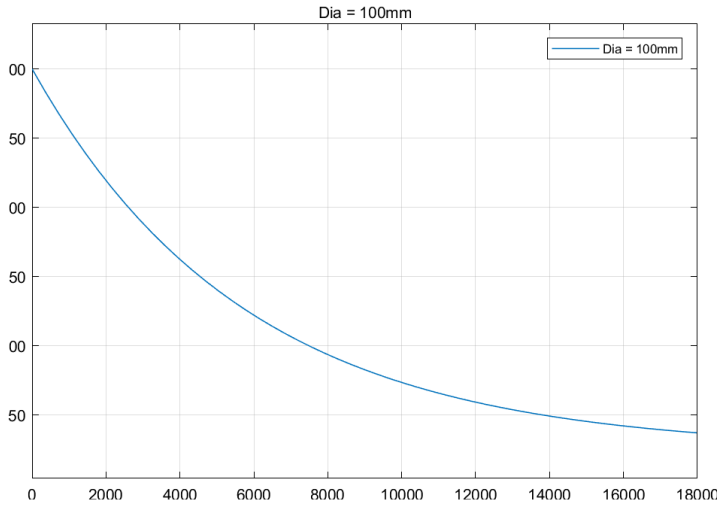
C) For dia = 100mm



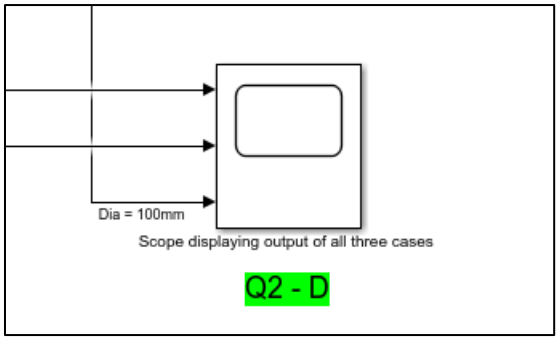
M_3 = -0.0001735



Output for case 3:

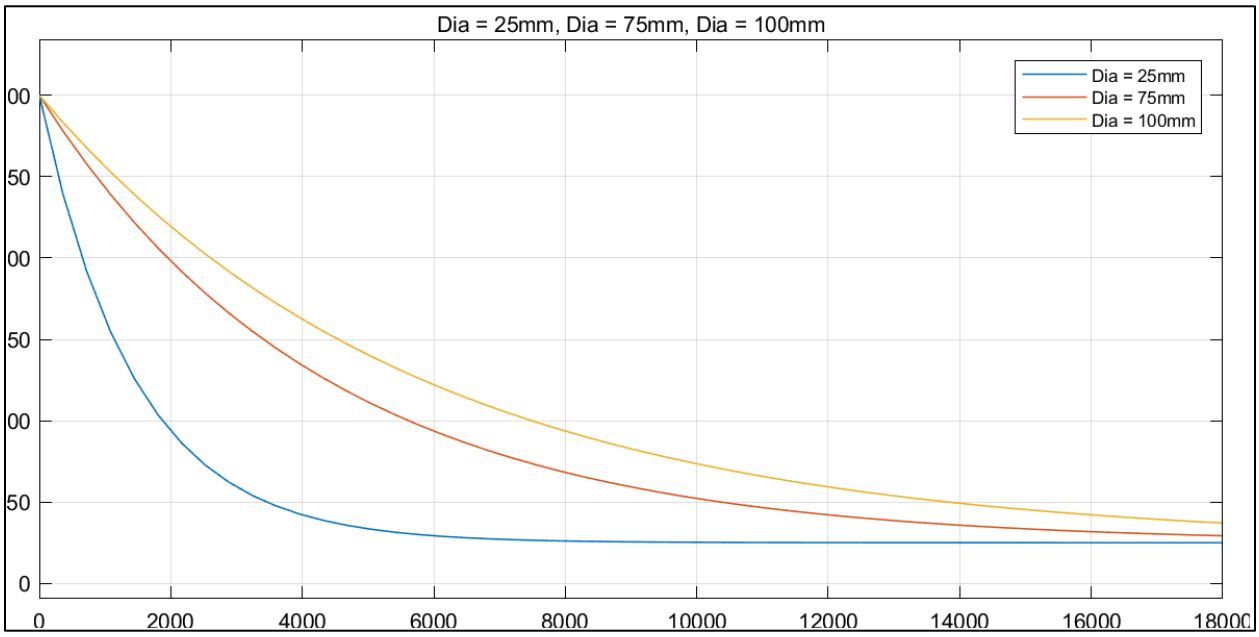


Output for all the plots in one scope:



Increasing the number of inputs in scope for this part.

Plot achieved is shown below:



Note:

The stop time for this simulation was set to 18000s (5 days). The reason the stop time was set to such high magnitude is because, on small magnitudes of the stop time, the model gave a linear reducing plot than a curve which was desired since the equation has an exponential term.

Simulink always cropped the magnitudes on the Y-axis. But for reference the highest magnitude received on running the model is 300.

Q2_Simulink_File