ED5330
Control of Automotive Systems

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ED15013

Hydraulic Hitch Control in Tractors Report

Problem Statement

To attenuate the pitching vibrations of the vehicle by lifting or lowering the load in accordance with the disturbance force.

1 Check for Linear Time Invariant System/Spectral Analysis

Sine sweep test is done to check whether the system is LTI or not. When a sinusoidal system is given to an LTI system, the output is another sinusoid with the same frequency as that of the input, but it is scaled and has some phase difference.

On taking FFT for the input and output, it is seen that for all (but one) inputs, the dominant frequency is same for both input and output. Fourier transform represents a time domain signal as a frequency domain signal, i.e., it breaks up a signal into the frequencies it is composed of. Magnitude plot of FFT of an ideal sinusoid has two impulse whose magnitude is half its amplitude, and they are present at positive and negative value of the frequency of the sinusoid. Hence, it is assumed that the dominant frequency is the frequency of the sinusoid and the rest is noise.

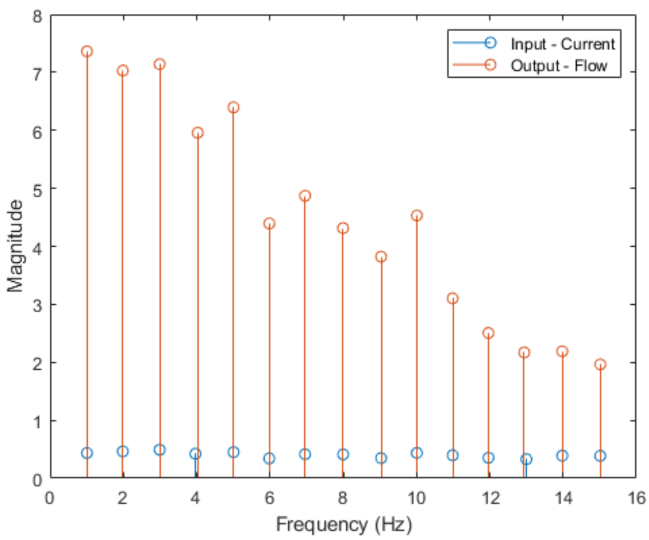

Figure 1: Frequency response or input and output

It can be seen in Figure 1 that the dominant frequency of both the input and output is same for a number of different pairs. therefore, it can be concluded that the system is LTI. The flow vs current system

2 Parameter Estimation/Step Input Analysis

The transfer function of the system is given to be:

$$P(s) = \frac{Ks}{1+\tau s}$$

Using this, the output of the system for a step input of magnitude I_0 is:

$$y(t) = \Delta f(t) = \frac{KI_0}{\tau} e^{-\frac{t}{\tau}}$$

This shows an output that decays exponentially.

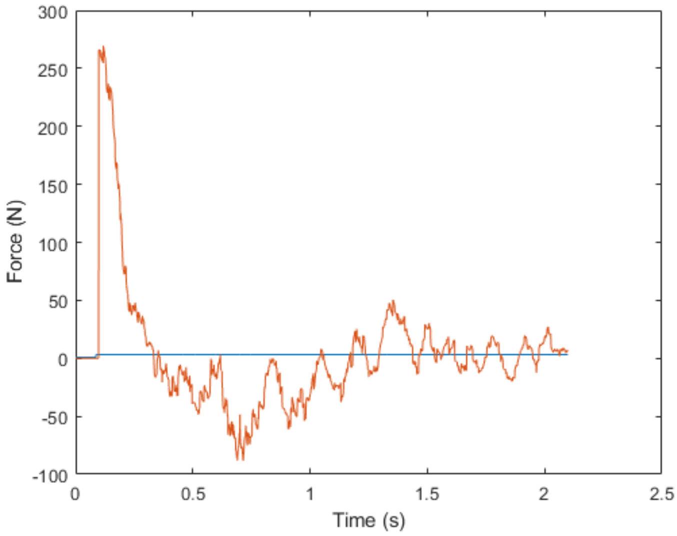

Figure 2: Response for step input of 3.3 A magnitude

The measured output in Figure 2 shows an exponential decay till it reaches zero, after that the signal can be assumed to be noise. Therefore, the proposed transfer function can be used to approximate the plant transfer function.

It can also be seen that the initial value of the system is:

$$\Delta f(0) = \frac{KI_0}{\tau}$$

For 2% settling time criteria:

$$e^{\frac{-t_s}{\tau}} = 0.02 \Rightarrow \tau = \frac{t_s}{3.9120}$$

The four sets of transfer function parameters obtained are:

I_0 (A)	K (Ns/A)	τ (s)	K_c (A/N)
2.0	6.0106	0.0504	0.0084
2.5	4.5642	0.0417	0.0091
3.0	4.2142	0.0475	0.0114
3.3	4.8849	0.0598	0.0123

Table 1: Parameter Values

3 Lag Compensator Design

The transfer function for the lag compensator is given as follows:

$$C(s) = K_c\beta\frac{T_c s + 1}{\beta T_c s + 1}$$

$$K_c > 0, \quad \beta > 1, \quad T_c > 0$$

The corner frequencies are given to be 1 Hz and 5 Hz

$$\frac{1}{T_c} = 5 \times 2\pi \Rightarrow T_c = 0.0318s$$

$$\frac{1}{\beta T_c} = 1 \Rightarrow \beta = 5$$

3.1 Estimation of K_c

To determine K_c we use the formula:

$$attenuation = -20\ log_{10}(K_c)$$

This formula is used because it gets us a value of K_c that pushed the attenuation at high frequency to zero in the Bode plot. The values of K_c are given in Table 1.

3.2 Controller Tuning

$$\frac{Y(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

$$Y(s) = U(s)P(s)$$

$$\Rightarrow \frac{U(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)} \times \frac{1}{P(s)}$$

$$G(s) = C(s)P(s)$$

$$\Rightarrow \frac{U(s)}{R(s)} = \frac{C(s)}{1 + G(s)H(s)}$$

Here, Y(s) is the closed loop system output. R(s) is the reference signal, that is the disturbance signal in this case. U(s) is the controller output. C(s) is the controller transfer function.

The input shown in Figure 3 was used as an input to simulate the system.

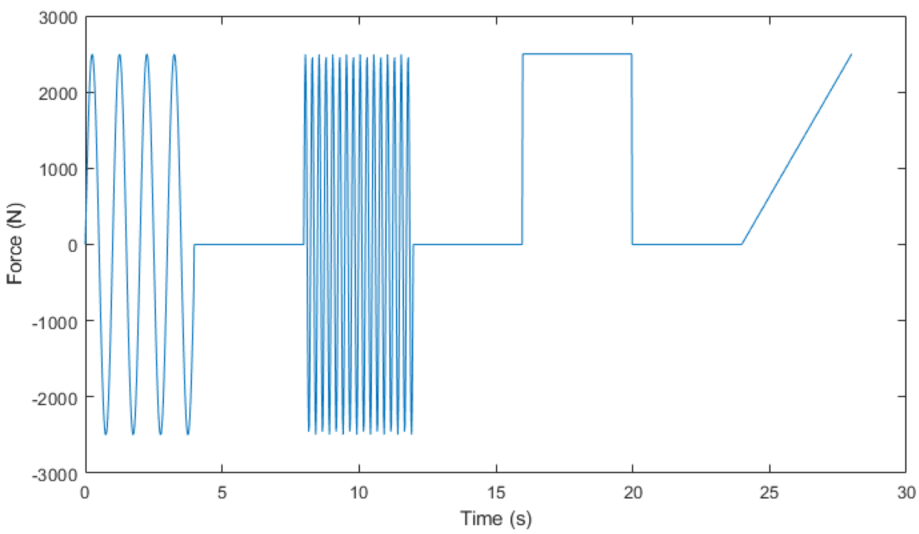

Figure 3: Disturbance Signal

As seen in Figure 4, the output current from the controller is too high. Here, the Kc used is 0.0123 A/N. Therefore the controller gain needs to be adjusted so that the controller output is lower than 2.3 A, which is the required upperbound.

Figure 5, Kc was chosen to be 0.00018 A/N. The maximum controller output was seen to be 2.25 A for all four controllers. Hence, this value is optimal.

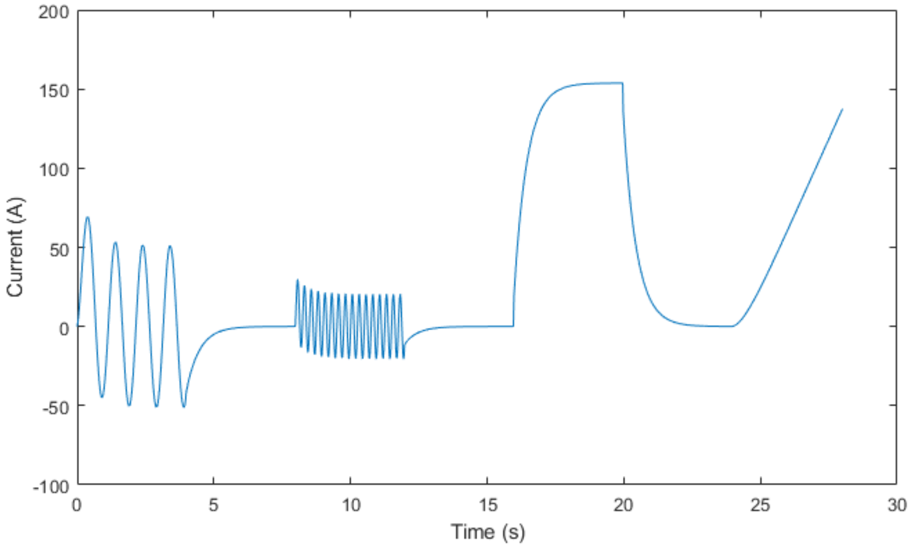

Figure 4: Controller output for untuned controller ($K_c = 0.0123$ A/N)

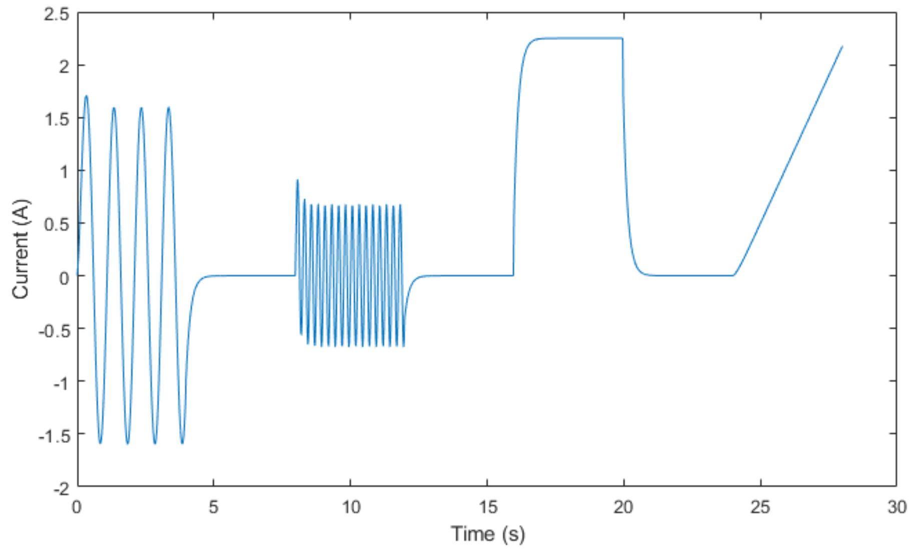

Figure 5: Controller output for tuned controller ($K_c = 0.00018$ A/N)

3.3 Choosing the Best Controller

We have four such controllers, and we have to choose the best one based on some metric. Since, all the controllers satisfied the required performance metrics, the one which attenuates the output for the disturbance signal the most is chosen.

As seen from the Table 2, the controller obtained from the step input of 3.3 A is chosen.

4 Conclusion

The values are chosen for the controller obtained using step input of 3.3 A. The corresponding lag compensator transfer function is as follows:

$$C(s) = 0.0009\,\frac{0.318s + 1}{0.1592s + 1}$$

Figure 6 shows the closed loop system output using the above mentioned lag compensator or the given disturbance signal.

I_0 (A)	Max Output (N)	Attenuation (%)
2.0	63.4809	97.4608
2.5	53.9937	97.8403
3.0	46.4574	98.1417
3.3	46.0565	98.1577

Table 2: Dominant poles for different closed loop transfer functions

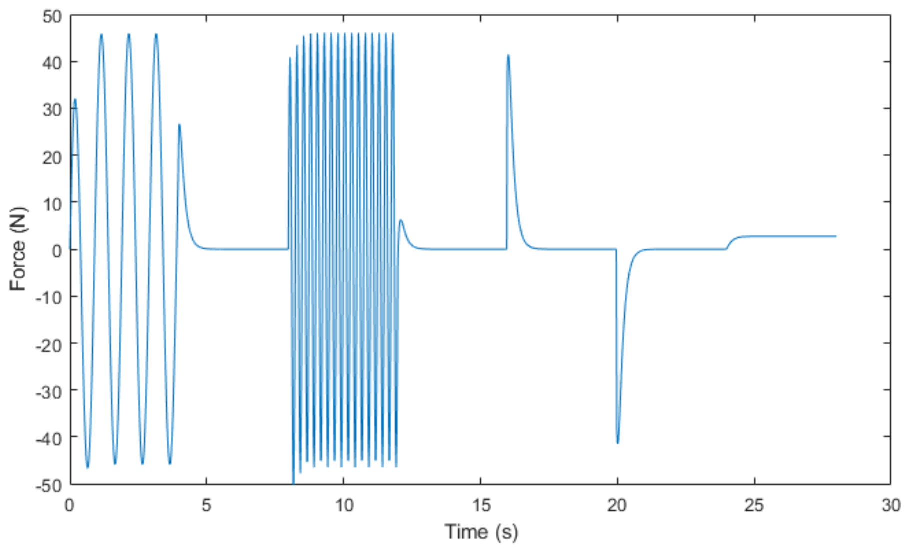

Figure 6: Output of closed loop system