

# EM 406 Vibrations

## Laboratory 3 - System Identification using Frequency Response

In this lab we will perform system ID using frequency response data.

### Objectives

1. Learn about fminsearch and tfestimate (mini-lecture)
2. System identification using data from week 2
  - a. Peak pick to find  $\zeta$  and  $\omega_n$  using the FRF obtained from the 70 second swept sin data.
  - b. Parameter ID (find  $\zeta$  and  $\omega_n$ ) using fminsearch using FRF obtained one frequency at a time.
  - c. Parameter ID (find  $\zeta$  and  $\omega_n$ ) using fminsearch using FRF obtained from 35 second swept sin
  - d. Parameter ID (find  $\zeta$  and  $\omega_n$ ) using fminsearch using FRF obtained from 70 second swept sin
  - e. Analyze the band-limited random data to the cart and examine the various inputs to tfestimate.

### Analysis:

#### **Task 1: Peak Pick method of system identification**

In experimental modal analysis the process of obtaining the system parameters  $\omega_n$  and  $\zeta$  is called “curve fitting”. One quick and dirty way of estimating  $\omega_n$  and  $\zeta$  is called “peak picking.” If the magnitude plot looks like the curve shown in Figure 1, that is has small damping, then the damping ratio can be estimated from the half-power points as shown in Eq. 10.66 in the text. For convenience this equation is shown in Eq. 1.

$$\zeta \approx \frac{\omega_b - \omega_a}{2\omega_n} \quad (1)$$

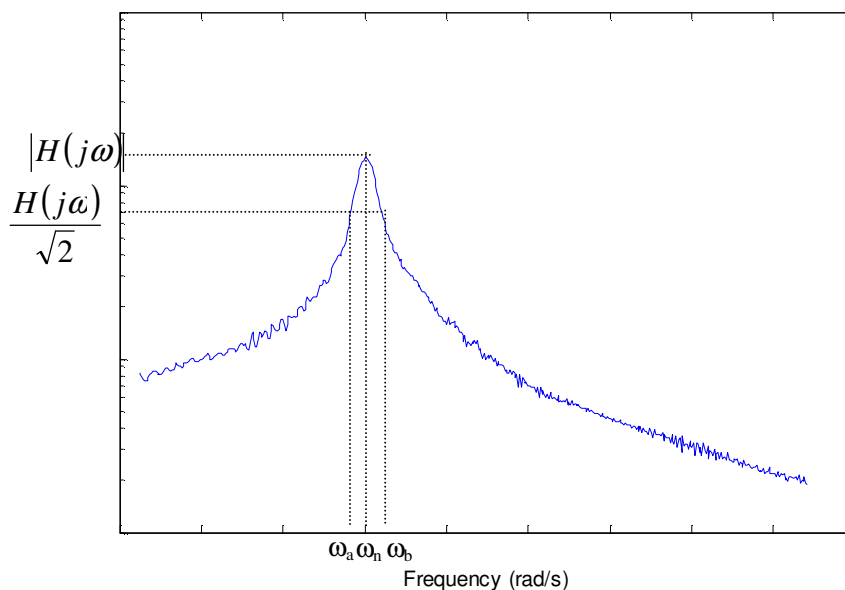


Figure 1 – Typical FRF

Using the FRF generated last week for the 70 second swept sin test use the peak picking method and estimate  $\omega_n$  and  $\zeta$ . Fill in the appropriate row in the table provided on the worksheet. Attach a figure showing the 1/2 power points and show your calculations.

**For all the remaining plots please use a semilogy plot, that is, a log scale for the y axis.**

**Task 2: Identify system parameters using fminsearch from FRF obtained one point at a time**

The frequency response plot you generated last week is the magnitude and phase of the transfer function evaluated at  $j\omega$  as shown in Eq. 2

$$|H(j\omega)| = \frac{1/k}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} \quad (2)$$

Since we don't actually know the input force (we only know what we put in the Simulink model) we will have an unknown constant related to the force. Therefore, Eq. 2 can be written as

$$|H(j\omega)| = \frac{K}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}} \quad (3)$$

In this task we will identify  $K$ ,  $\omega_n$  and  $\zeta$  in two ways: 1) Minimize the cost function J using the magnitude, 2) minimize J using the magnitude in dB.

Using the m-file you implemented in the prelab, complete the rows in the table provided in the worksheet.

**Task 3: Identify system parameters using fminsearch from FRF obtained using 35-s swept sin test.**

Use the FRF (35 second swept sin) generated in last week (only use up to 7.0 Hz) and use fminsearch again to identify  $K$ ,  $\omega_n$  and  $\zeta$ . The easiest way to do this is to create new variables with the necessary data such as `freq = F(1:?)` and `mag = abs(Txy(1:?))` where ? is the index number corresponding to 7 Hz. Fill in the row in the table provided in the worksheet.

**Task 4: Identify system parameters using fminsearch from FRF obtained using 70-s swept sin test.**

Use the FRF (70 second swept sin) generated in last week (only use up to 7.0 Hz) and use fminsearch again to identify  $K$ ,  $\omega_n$  and  $\zeta$ . The easiest way to do this is to create new variables with the necessary data such as `freq = F(1:?)` and `mag = abs(Txy(1:?))` where ? is the index number corresponding to 7 Hz. Fill in the row in the table provided in the worksheet.

**Task 5: Look at the various inputs to tfestimate using a band-limited random**

Last week you used took data using a bandlimited random input. Let's look at the effects of averaging and windowing on the resulting FRF.

**5a)** Determine the FRF using the default command

```
[Txy,F] = tfestimate(f,x)
```

**5b)** Determine the FRF using:

```
[Txy,F] = tfestimate(f,x,hanning(N),0,N,fs)
```

Where  $f$  is the input signal,  $x$  is the output signal,  $N$  is the number of data points and  $fs$  is the sampling frequency =  $1/\Delta t$ .

What is the difference between the results from 5a) and 5b)?

**5c)** Type "help tfestimate" at the command line for more help with this command. This command also allows you to average the data. For example, you can break the signal into blocks of 512 data points and use an overlap of 256 points. The command would look like this:

```
[Txy,F] = tfestimate(f,x,hanning(512),256,512,fs)
```

**5d)** Play with the size of the data block and overlap to get the best looking FRF possible.

**Questions to examine and discuss in your lab discussion:**

- How did your results compare for  $\zeta$  and  $\omega_n$ ? What might explain any differences you observed?
- What is the difference between the FRF determine with averaging on the one with no averaging? How did the FRF from the chirp compare to the one using a random input? How did they compare over a frequency range of 0 – 7 Hz. How did they compare over the entire frequency range?
- What happens if you don't use a Hanning window for the band-limited random test?
- 

**Be sure to save all the m-files from this week, because we will be using them during week 4.**

## Lab #3 Worksheet – System Identification of SDOF systems

Names: \_\_\_\_\_

Date: \_\_\_\_\_

Results:

| Table 1 – Summary system identification results                                      |     |            |         |
|--|-----|------------|---------|
| Task   | $K$ | $\omega_n$ | $\zeta$ |
| Task 1 (from $\frac{1}{2}$ power point using FRF generated from 70-s swept sin data) | NA  |            |         |
| Task 2 (using linear values in amplitude ratio)                                      |     |            |         |
| Task 2 (using amplitude ratio in dB)   |     |            |         |
| Task 3 (using transfer function from 35 swept sin data (0 – 7.0 Hz))                 |     |            |         |
| Task 4 (using transfer function from 70 swept sin data (0 – 7.0 Hz))                 |     |            |         |

**Observations:** Be sure to discuss any observations you made while performing this lab. Be sure to answer any questions asked in the lab handout. Attach additional sheets if necessary.

Please attach any Figures you feel help explain your results (for example you should include your figures for all the tasks and any additional ones you made when examining the effect of changing the parameters in testimate).