Performance Characterization of the nees@UCLA Linear Inertial Shaker System

A series of tests were performed to characterize the performance of the *nees*@UCLA linear inertial shaker system. Sinusoidal and recorded earthquake time histories were used as input motions in both displacement and force control modes. For the sinusoidal inputs, the forcing frequencies and amplitude were varied by considering the stroke, velocity and force capacities of the shaker (see Tables 1 & 2). Input frequencies were varied from 0.5 to 10 Hz, and several amplitudes at a given frequency were tested to evaluate the amplitude dependency. For a given frequency and amplitude, the response for 15 cycles were measured, and RMS error and maximum deviations (maximum and minimum of peak values) were calculated from the measured responses after compensating for the phase lag. The 1994 Northridge earthquake recorded at Arcadia Campus Dr. 009 (USC Station 009) was used for earthquake time history input. The displacement and acceleration record was scaled to correspond to peak values of 11.62 in and 2.68 g, respectively, to match the existing linear shaker performance capacities. The RMS error was computed for earthquake inputs after running same input motion 5 times, and using the following equation:

$$\text{RMS error} = \frac{\sum\sqrt{(\text{command - response})^2}}{\sum\sqrt{\text{command}^2}}$$

Test results are presented in Figures 1-4 and Table 3. In general, the displacement control is much more accurate than the acceleration control. Average RMS errors in displacement control mode varied between 2% ~ 20%, while RMS errors in acceleration control mode ranged from 18%~100%. In acceleration control, results show smaller RMS errors at large amplitude and high frequency range. In displacement control, smaller errors were observed as the amplitude becomes large and the frequency becomes low. RMS errors for the earthquake time history were calculated as 2.7% and 70% in displacement and acceleration control, respectively.

Table 1. Sinusoidal input motions using displacement control

Command		Response		
Frequency (Hz)	**Amplitude (in)**	**Max. Peak Amplitude (in)**	**Min. Peak Amplitude (in)**	**Average RMS Error (%)**
0.5	10	10.28	10.25	2.2%
0.5	13	13.33	13.28	2.2%
1.5	5	5.06	5.04	4.8%
1.5	7	6.89	6.86	8.3%
3	2.2	2.29	2.22	6.2%
5	0.8	0.92	0.88	12.6%
10	0.2	0.23	0.20	19.2%

Table 2. Sinusoidal input motions using force control

Command		Response		
Frequency (Hz)	**Amplitude (g)**	**Max. Peak Amplitude (g)**	**Min. Peak Amplitude (g)**	**Average RMS Error (%)**
0.5	0.25	0.17	0.12	77.4%
0.5	0.35	0.22	0.15	76.4%
1.5	0.02	0.01	0.01	102.1%
1.5	0.05	0.02	0.01	88.9%
1.5	0.1	0.08	0.03	83.9%
1.5	0.2	0.23	0.20	50.9%
1.5	0.5	0.65	0.36	49.7%
1.5	1	0.83	0.67	46.8%
1.5	1.5	1.41	1.17	52.1%
3	0.05	0.02	0.01	93.3%
3	0.1	0.04	0.02	85.5%
3	0.25	0.42	0.22	47.2%
3	0.5	0.75	0.58	35.3%
3	1	1.25	0.99	23.8%
3	2	2.23	2.17	34.3%
5	2	2.59	2.52	23.5%
10	2	2.80	2.75	18.7%

Table 3. Summary of test results

Command		Response		
Frequency (Hz)	**Amplitude (g)**	**Max. Peak Amplitude (g)**	**Min. Peak Amplitude (g)**	**Average RMS Error (%)**
0.5	0.25	0.17	0.12	77.4%
0.5	0.35	0.22	0.15	76.4%
1.5	0.02	0.01	0.01	102.1%
1.5	0.05	0.02	0.01	88.9%
1.5	0.1	0.08	0.03	83.9%
1.5	0.2	0.23	0.20	50.9%
1.5	0.5	0.65	0.36	49.7%
1.5	1	0.83	0.67	46.8%
1.5	1.5	1.41	1.17	52.1%
3	0.05	0.02	0.01	93.3%
3	0.1	0.04	0.02	85.5%
3	0.25	0.42	0.22	47.2%
3	0.5	0.75	0.58	35.3%
3	1	1.25	0.99	23.8%
3	2	2.23	2.17	34.3%
5	2	2.59	2.52	23.5%
10	2	2.80	2.75	18.7%

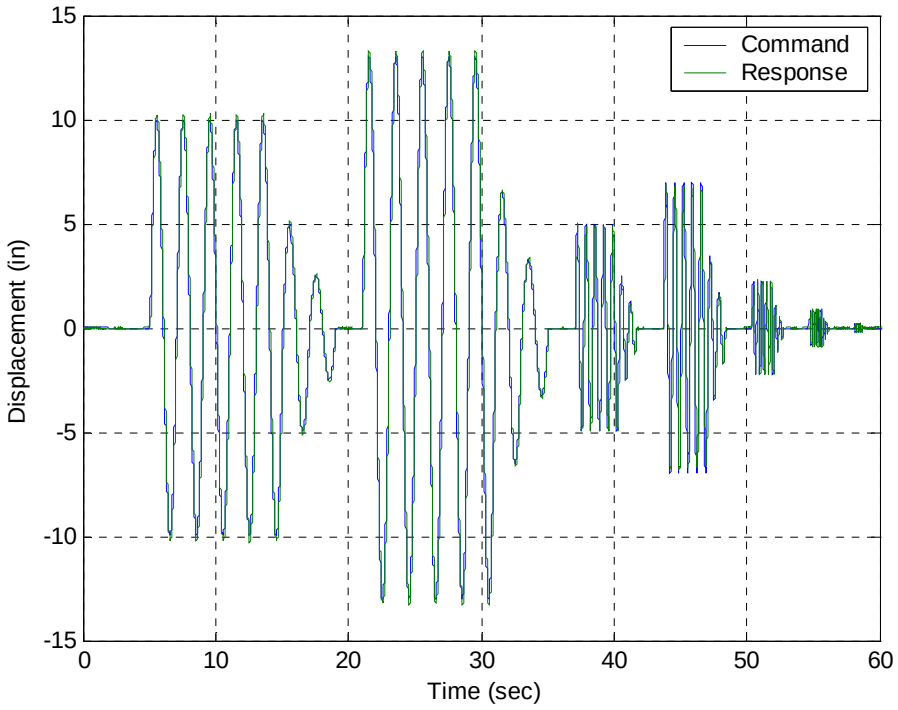
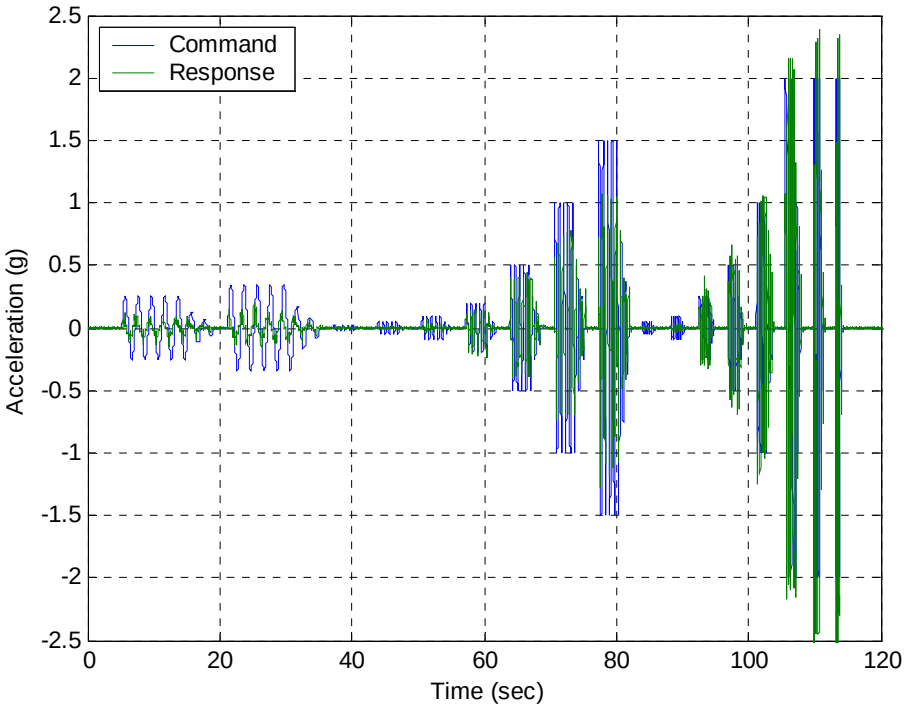
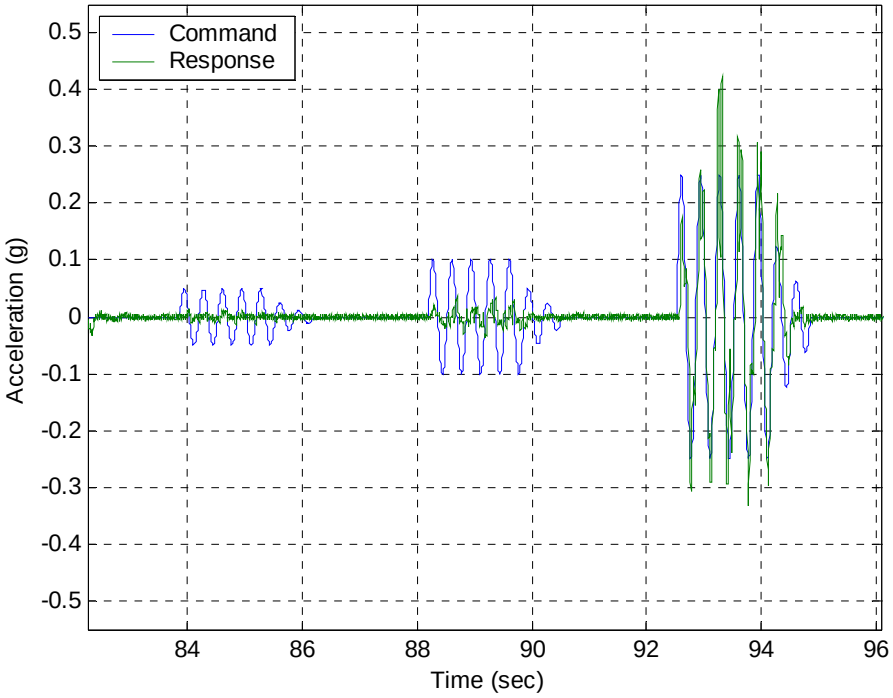


Fig. 1. Displacement control for sinusoidal input



(a)



(b)

Fig. 2. Acceleration control for sinusoidal input

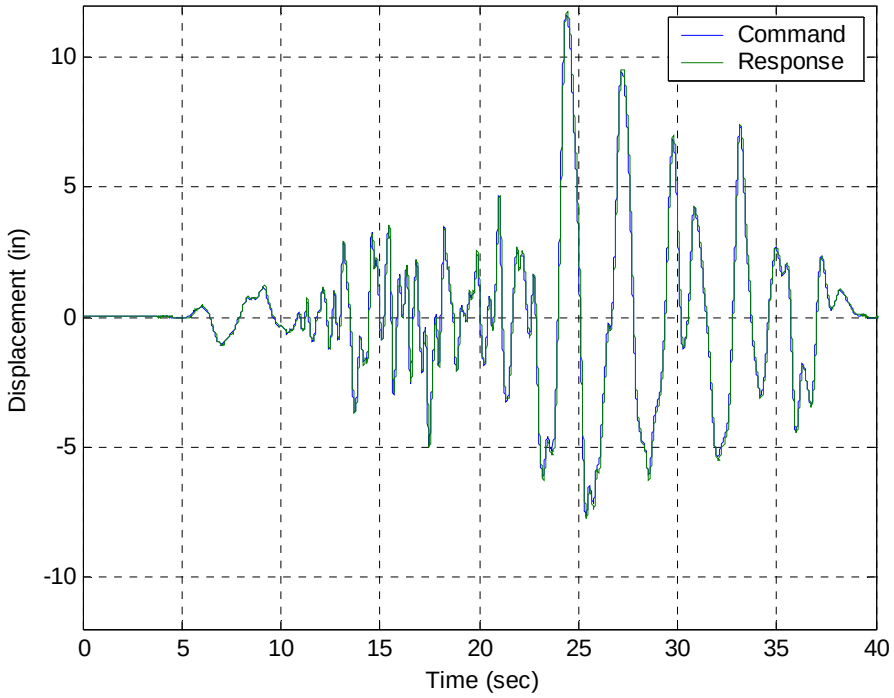


Fig. 3. Displacement control for earthquake record (RMS error = 2.7%)

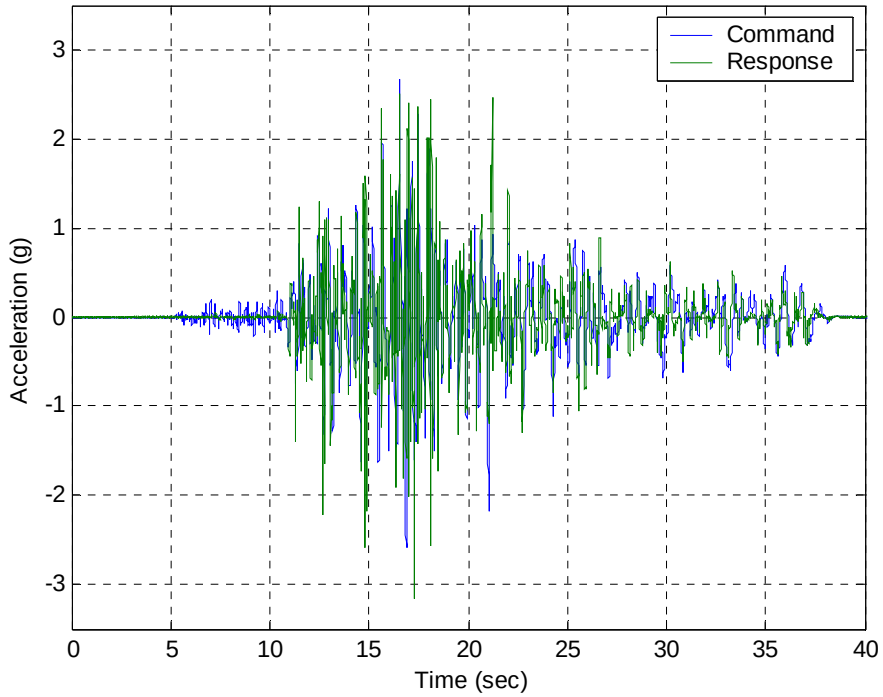


Fig. 4. Acceleration control for earthquake record (RMS error = 70.0 %)