Steady State Analysis Model for the Example in CSI Analysis Reference Manual

Analysis Model - Joint Loads (ECCZ) (As Defined)
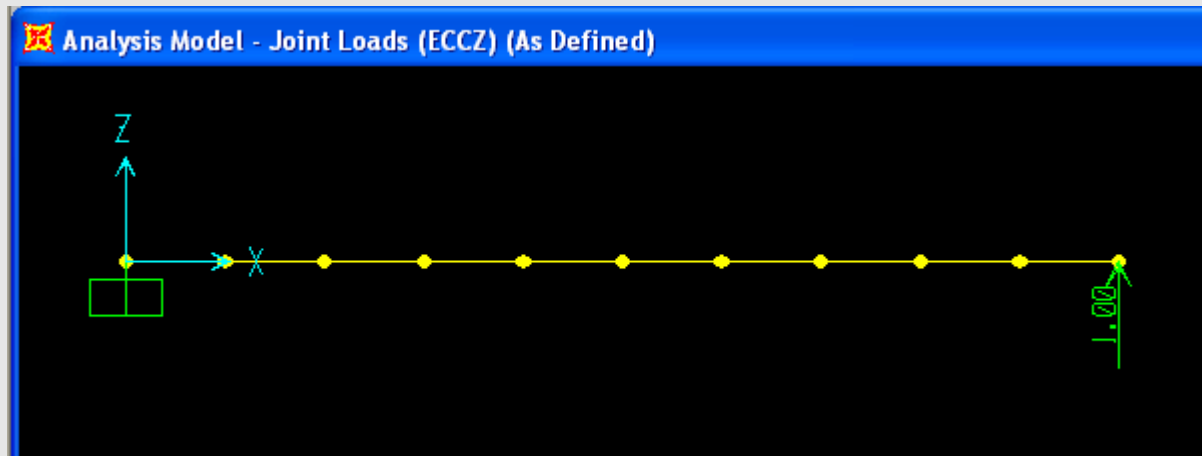
Rotating machinery is loading the tip of cantilever structure as shown in the above screen capture.

The loading properties are as described in CSI Analysis Reference Manual, chapter "Frequency Domain Analyses", section "Steady-State Analysis >Example".

Use the *em* factor of 0.001.

Steady State Time Function

Frequency f entered in Hz units

Steady state function value, calculated as $\omega^2 = (2\pi f)^2$

Steady State Function Definition

SAP2000 v14.2.2 Advanced - model A V14.2.2

Function Name: FSQUARED
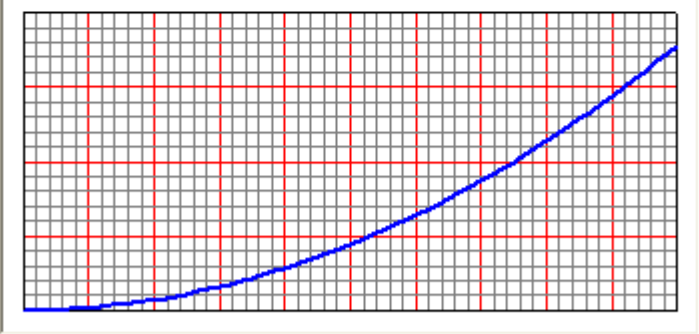
Define Function

Frequency	Value
0.	0.
0.5	9.87
1.	39.48
1.5	88.83
2.	157.91
2.5	246.74
3.	355.31
3.5	483.61
4.	631.65

Add
Modify
Delete

Frequency Units
- ◉ Hz
- ○ RPM

Function Graph

Display Graph   0.0,0.0

OK   Cancel

Definition of the Steady State Load Case

Vertical Displacement of Tip as a Function of Frequency for Phase Angle = 0
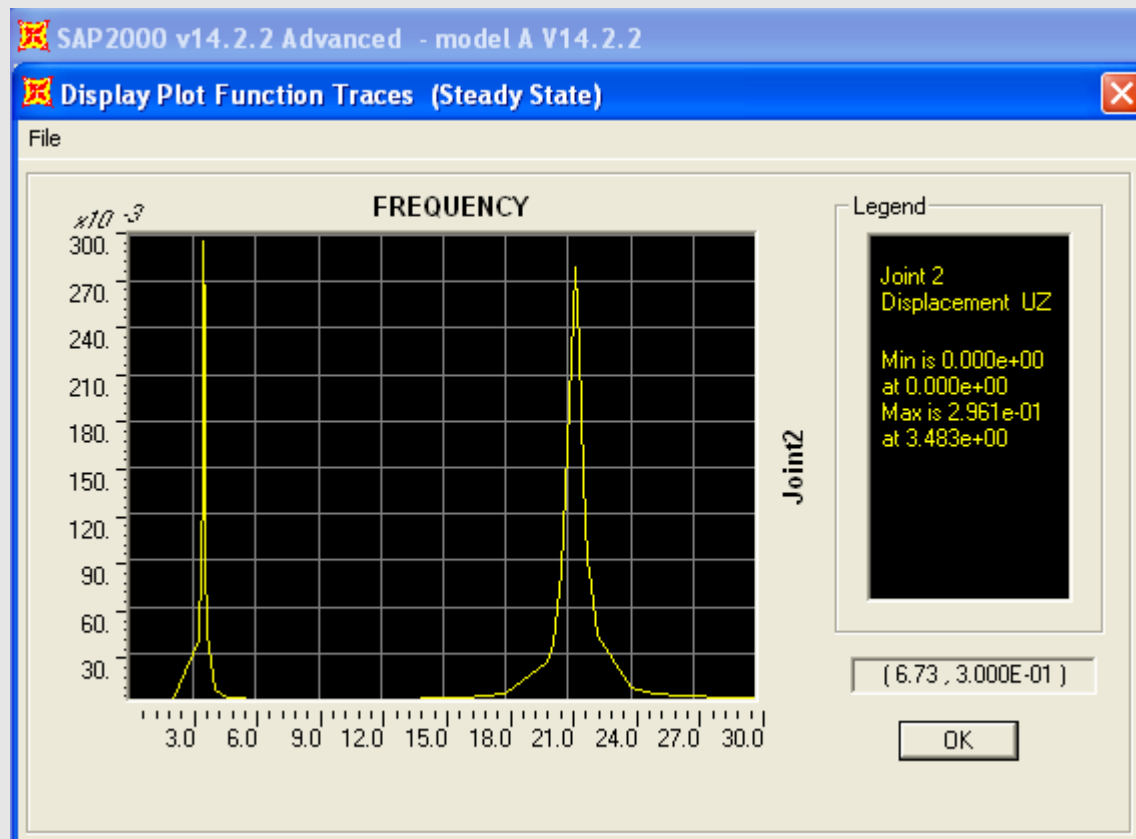
Magnitude of Vertical Tip Displacement as a Function of Frequency
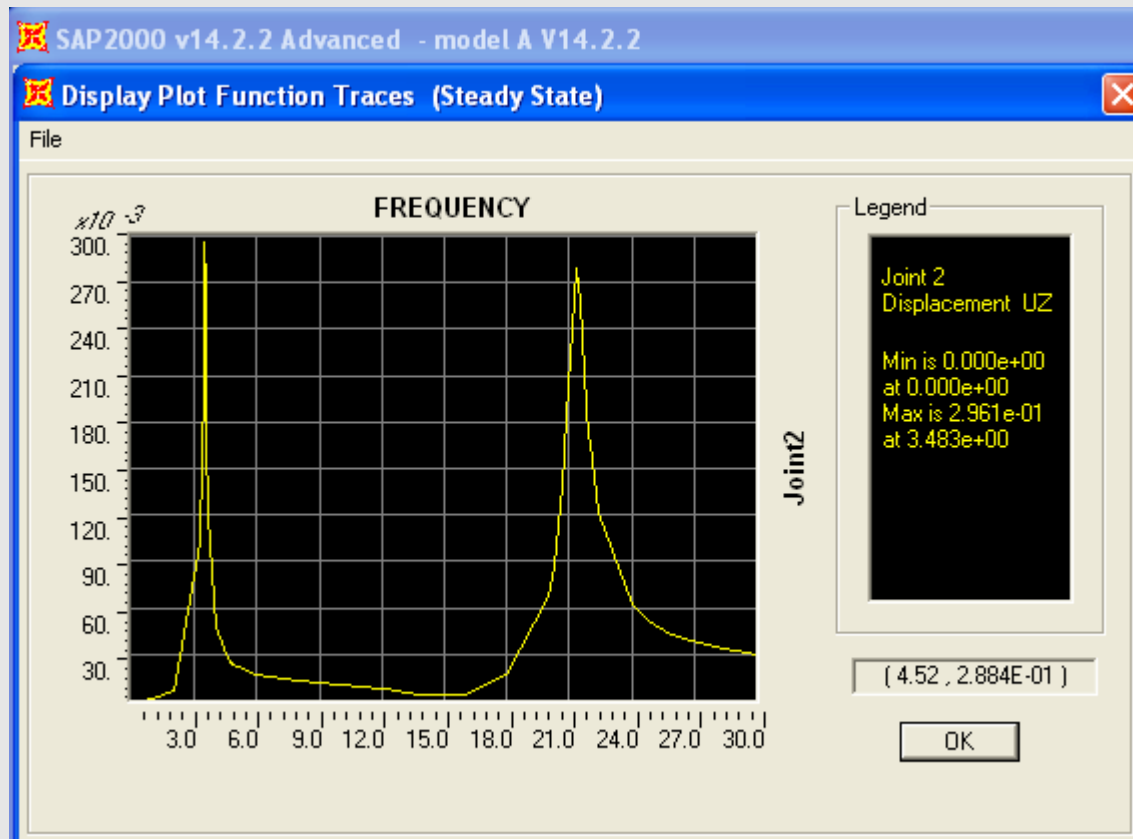
Note that the structure resonates for frequencies of modes 2 and 5 which are vertical modes.

Modal Participating Mass Ratios

Modes 2 and 5 are vertical modes.

Modal Frequencies

OutputCase Text	StepType Text	StepNum Unitless	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	Mode	1	1.27851	0.78216	4.9145	24.152
MODAL	Mode	2	0.287091	3.4832	21.886	478.98
MODAL	Mode	3	0.206424	4.8444	30.438	926.48
MODAL	Mode	4	0.074538	13.416	84.295	7105.6
MODAL	Mode	5	0.04688	21.331	134.03	17963
MODAL	Mode	6	0.038494	25.978	163.22	26642
MODAL	Mode	7	0.023597	42.378	266.27	70899
MODAL	Mode	8	0.017236	58.018	364.54	132890
MODAL	Mode	9	0.016058	62.273	391.27	153090
MODAL	Mode	10	0.011776	84.918	533.56	284680
MODAL	Mode	11	0.009204	108.65	682.66	466020
MODAL	Mode	12	0.009141	109.4	687.36	472470

Frequency for the first vertical mode (ie. mode 2) was used to setup time history analysis to verify the steady state results.

Equivalent Time History Load Cases

- The results of the steady state analysis were verified by time history analyses for loading frequencies of 1 Hz and 3.4832 Hz

Calculate dynamic characteristics for f = 3.4832 Hz

$f = 3.4832 \, Hz$

$\omega = 2\pi f = 21.8856 \, rad/sec$

$\omega^2 = 478.9791 \, rad^2/sec^2$

$T = 1/f = 0.2871$

Loading Characteristics of the "TH-per 1 Hz" Time History Load Case

Note:

(1) Scale factor was set to $em\omega^2 = (0.001)(6.2831)^2 = 0.039478$

(2) Time factor was set to $T = 1/f = 1$

See previous page for calculation of intermediate values.

Loading Characteristics of the "TH-per 3.4822 Hz" Time History Load Case

Note:

(1) Scale factor was set to $em\omega^2 = (0.001)(21.8856)^2 = 0.479$

(2) Time factor was set to $T = 1/f = 0.2871$

See previous page for calculation of intermediate values.

Displacement for f = 1 Hz

Note that the time history displacement shown in the top screen capture matches the steady-state displacement shown in the bottom screen capture.
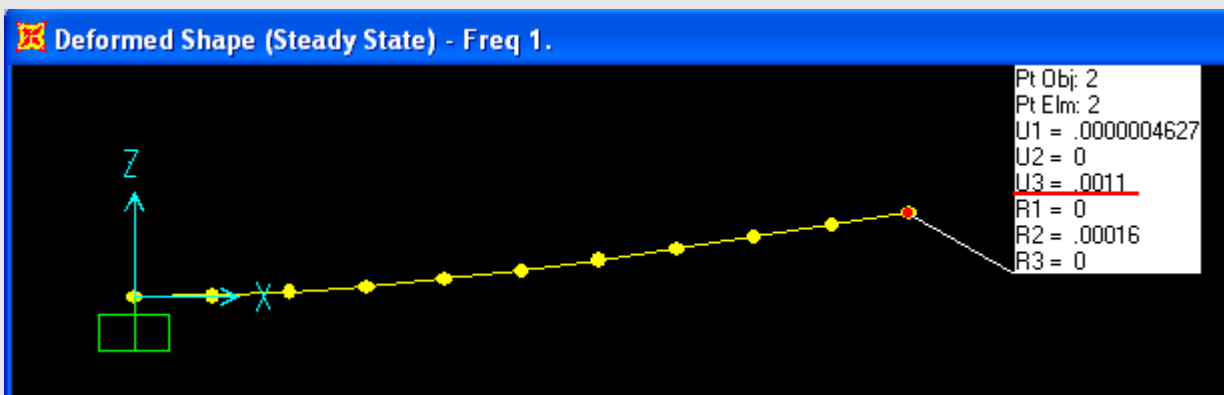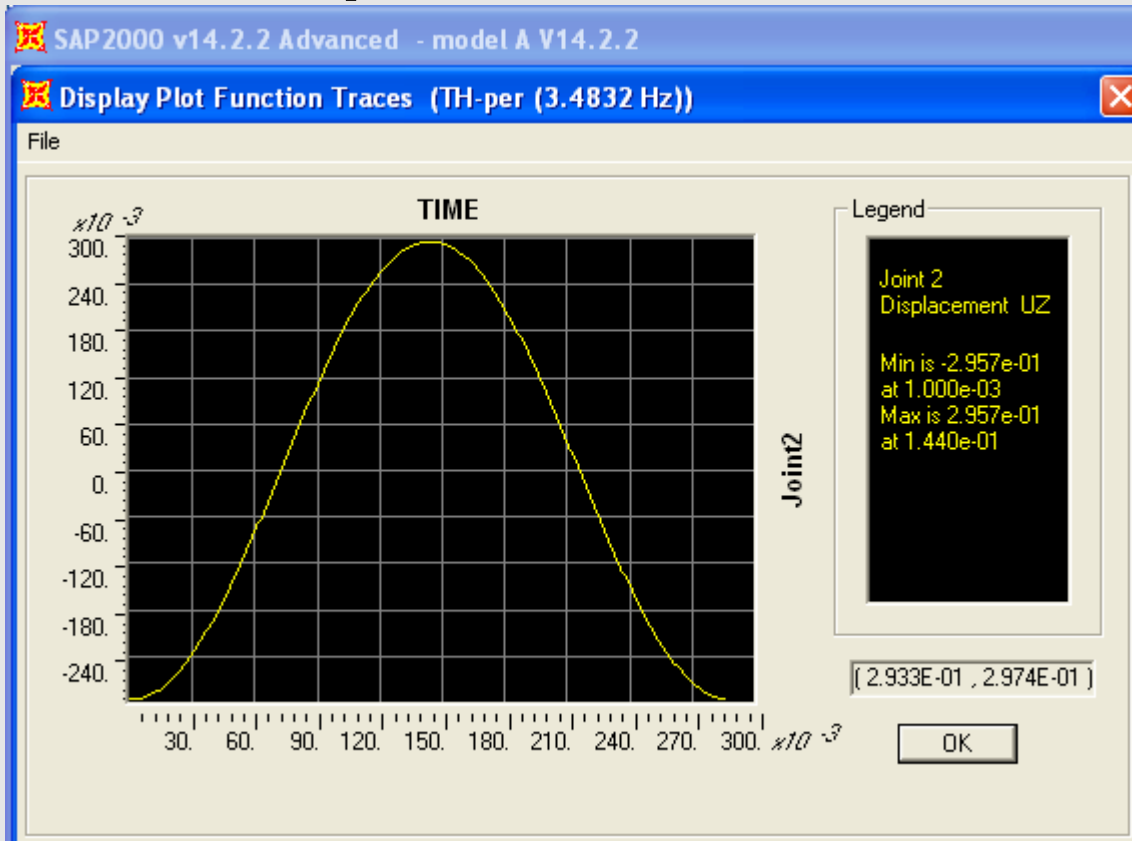
Displacements for f = 3.4832 Hz
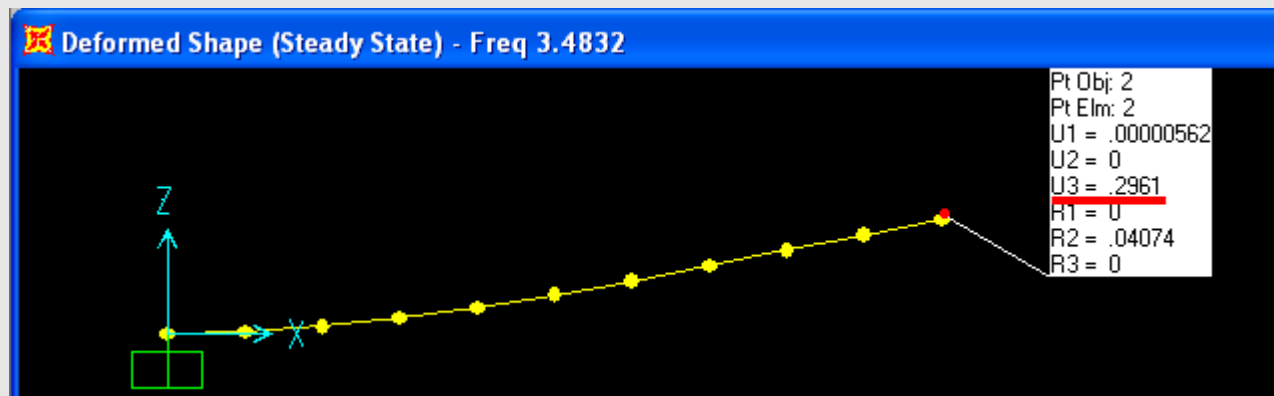

Note that the time history displacement shown in the top screen capture matches the steady-state displacement shown in the bottom screen capture.
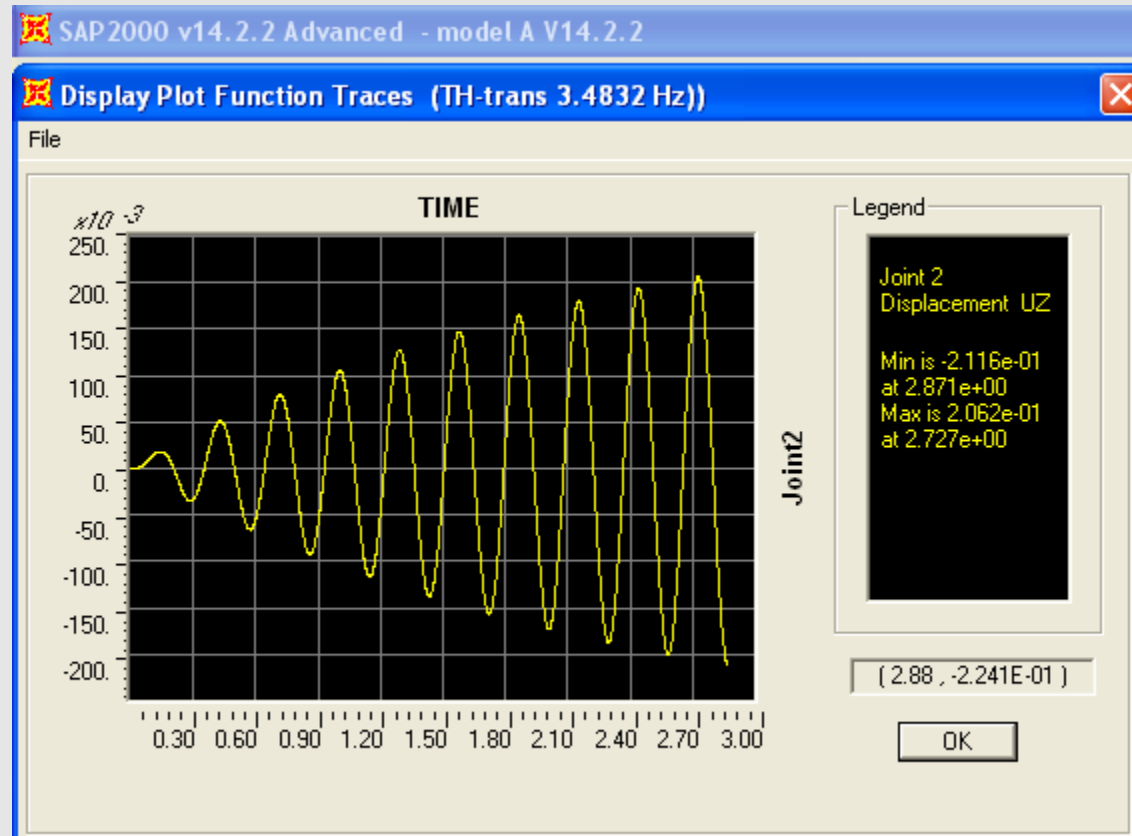
Plot of the same displacement for transient time history analysis

Note the gradual increase in amplitude due to resonance.