Tutorial for Response Spectrum Analysis using CAEPIPE

The following are the Steps for performing the Response Spectrum Analysis using CAEPIPE.

General

- The Response Spectrum is a plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified dynamic loading applied on all possible single degree-of-freedom systems. The abscissa of the spectrum is the natural frequency (or period) of the system, and the ordinate is the maximum response.

  In general, response spectra for a seismic event are prepared by calculating the maximum response to a specified ground motion excitation of single degree-of-freedom systems with various amounts of damping. Numerical integration with short time steps is used to calculate the response of each single degree-of-freedom system. The step-by-step process is continued until the total earthquake record is completed, the results of which becomes the response of that system to that excitation. Change the parameters of the system to change its natural frequency, repeat the process for the same excitation and record the new maximum response. This process is repeated until all frequencies of interest have been covered and the results plotted. Typically the El Centro, California earthquake of 1940 is used for this purpose. Attached ("ElCentro.txt") is an ASCII file that contains spectrum from El Centro, California earthquake of 1940. [*First line in this file is the name of the spectrum. Second line defines the "Units" for Abscissa (X-axis) and Ordinate (Y-axis) axes, separated by a space. Starting from the 3rd line, the first column is Abscissa and the second column is Ordinate. For further details on this ASCII file, refer to the "Spectrums" subsection under "Misc." section of Menus in the CAEPIPE User's Manual.*]

- Response Spectrum thus prepared as explained above is then input/imported into CAEPIPE Stress model for analysis through CAEPIPE Layout window > Misc > Spectrums.

- Once the inputting of different spectrums are done, input the Spectrum load applicable for the current analysis through Layout window > Spectrum.

- Save the model and perform analysis using CAEPIPE.

- Spectrum load specified will be applied simultaneously at all supports during the "uniform response spectrum" analysis, following which CAEPIPE will compute the modal and directional responses (to this uniform excitation), which are further combined as per the combination method selected.

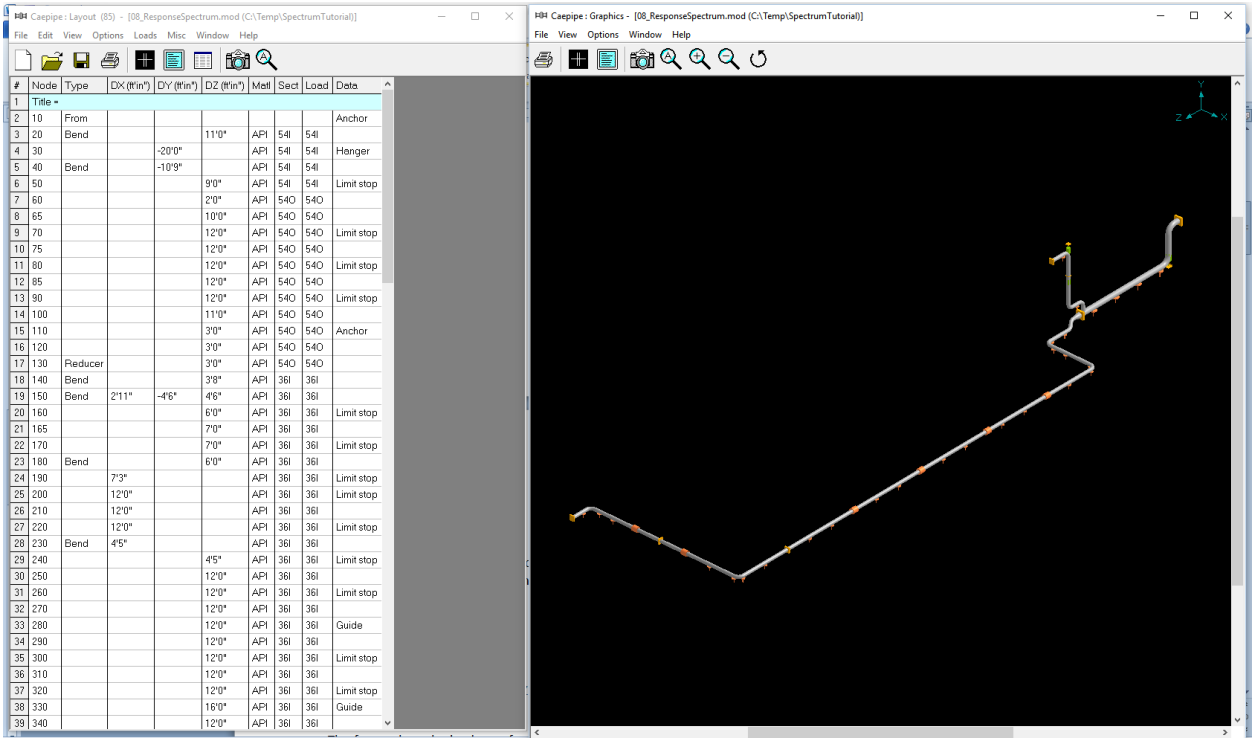
- Since the response spectra give only maximum response, only the maximum values for each mode are calculated and then superimposed (modal combination) to give total response. A conservative upper bound for the total response may be obtained by adding the absolute values of the maximum modal components (absolute sum). However this is excessively conservative and a more probable value of the maximum response is the square root of the sum of squares (SRSS) of the modal maxima.

- Ensure the CAEPIPE results meet project specific analysis requirements. If not, make changes to piping layout and/or changes to support types and their locations and then reanalyze the model until the analysis requirements are met.

Tutorial

Step 1:

Attached is a sample CAEPIPE model with Response Spectrum. The piping layout shown below (extracted from the attached model) is for a water supply line that has the following layout and properties. The Analysis Code is specified as B31.9 for this sample model.



Caepipe : Layout (85) - [08_ResponseSpectrum.mod (C:\Temp\SpectrumTutorial)]

File Edit View Options Loads Misc Window Help

#	Node	Type	DX (ft'in")	DY (ft'in")	DZ (ft'in")	Matl	Sect	Load	Data
1	Title =								
2	10	From							Anchor
3	20	Bend			11'0"	API	54I	54I	
4	30			-20'0"		API	54I	54I	Hanger
5	40	Bend		-10'9"		API	54I	54I	
6	50				9'0"	API	54I	54I	Limit stop
7	60				2'0"	API	54O	54O	
8	65				10'0"	API	54O	54O	
9	70				12'0"	API	54O	54O	Limit stop
10	75				12'0"	API	54O	54O	
11	80				12'0"	API	54O	54O	Limit stop
12	85				12'0"	API	54O	54O	
13	90				12'0"	API	54O	54O	Limit stop
14	100				11'0"	API	54O	54O	
15	110				3'0"	API	54O	54O	Anchor
16	120				3'0"	API	54O	54O	
17	130	Reducer			3'0"	API	54O	54O	
18	140	Bend			3'8"	API	36I	36I	
19	150	Bend	2'11"	-4'6"	4'6"	API	36I	36I	
20	160				6'0"	API	36I	36I	Limit stop
21	165				7'0"	API	36I	36I	
22	170				7'0"	API	36I	36I	Limit stop
23	180	Bend			6'0"	API	36I	36I	
24	190		7'3"			API	36I	36I	Limit stop
25	200		12'0"			API	36I	36I	Limit stop
26	210		12'0"			API	36I	36I	
27	220		12'0"			API	36I	36I	Limit stop
28	230	Bend	4'5"			API	36I	36I	
29	240				4'5"	API	36I	36I	Limit stop
30	250				12'0"	API	36I	36I	
31	260				12'0"	API	36I	36I	Limit stop
32	270				12'0"	API	36I	36I	
33	280				12'0"	API	36I	36I	Guide
34	290				12'0"	API	36I	36I	
35	300				12'0"	API	36I	36I	Limit stop
36	310				12'0"	API	36I	36I	
37	320				12'0"	API	36I	36I	Limit stop
38	330				16'0"	API	36I	36I	Guide
39	340				12'0"	API	36I	36I	

Caepipe : Graphics - [08_ResponseSpectrum.mod (C:\Temp\SpectrumTutorial)]

File View Options Window Help

Caepipe : Materials (2) - [08_ResponseSpectrum.mod (C:\Temp\SpectrumTutorial)]

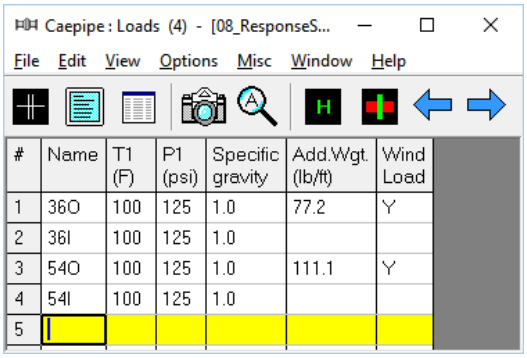
File Edit View Options Misc Window Help

#	Name	Description	Type	Density (lb/in3)	Nu	Joint factor	#	Temp (F)	E (psi)	Alpha (in/in/F)	Allowable (psi)
1	A53	A53 Grade B	CS	0.283	0.3	1.00	1	-325	31.4E+6	5.00E-6	20000
2	API	API 5L Grade B	CS	0.283	0.3	1.00	2	-200	30.8E+6	5.35E-6	20000
3							3	-100	30.2E+6	5.65E-6	20000
							4	70	29.5E+6	6.07E-6	20000
							5	200	28.8E+6	6.38E-6	20000

Caepipe : Pipe Sections (4) - [08_ResponseSpectrum.mod (C:\Temp\SpectrumTutorial)]

File Edit View Options Misc Window Help

#	Name	Nom Dia	Sch	OD (inch)	Thk (inch)	Cor.Al (inch)	M.Tol (%)	Ins.Dens (lb/ft3)	Ins.Thk (inch)	Lin.Dens (lb/ft3)	Lin.Thk (inch)	Soil
1	36I	36"	STD	36	0.375	0.075		13	2			
2	36O	36"	STD	36	0.375	0.075		13	2.5			
3	54O	Non Std		54	0.375	0.075		13	2.5			
4	54I	Non Std		54	0.375	0.075		13	2			
5												



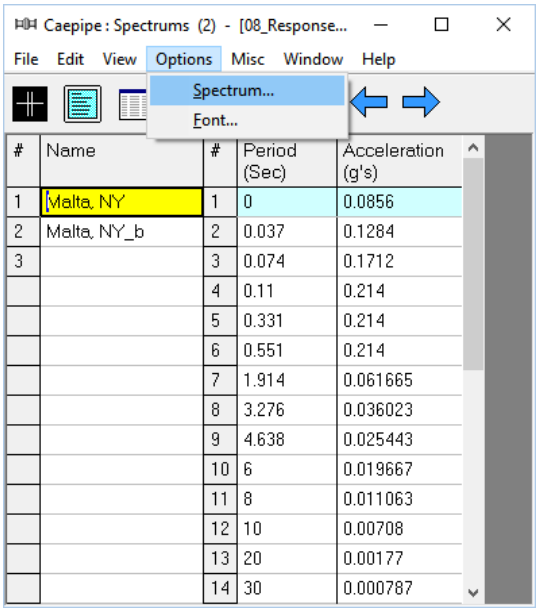
#	Name	T1 (F)	P1 (psi)	Specific gravity	Add.Wgt. (lb/ft)	Wind Load
1	36O	100	125	1.0	77.2	Y
2	36I	100	125	1.0		
3	54O	100	125	1.0	111.1	Y
4	54I	100	125	1.0		
5						

Step 2:

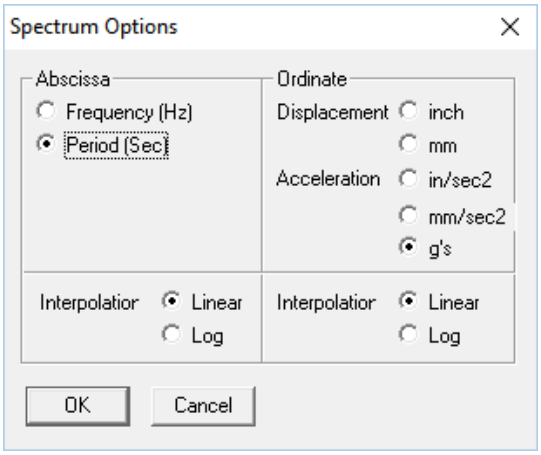
Input Spectrums into CAEPIPE. This can be done in three ways:

1. Input spectrums directly into the model.
2. Create a spectrum library and load spectrums from it.
3. Input spectrums from a text file.

When the first two methods are used, the units for the X- and the Y-axes as well as the interpolation method are set through the menu Options > Spectrum.



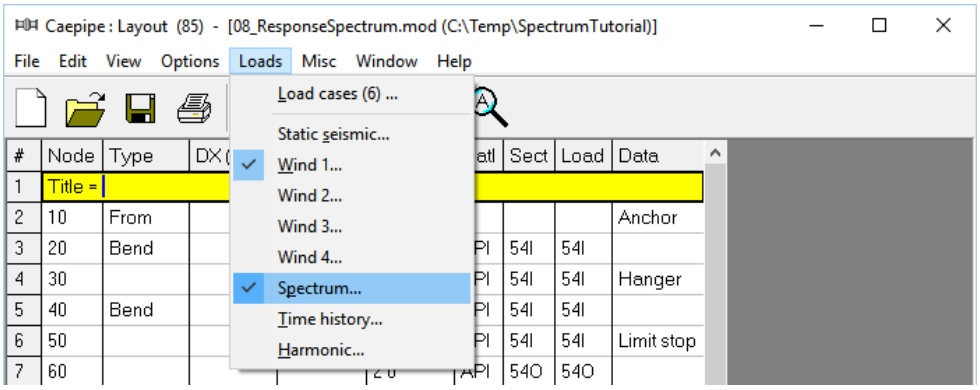
#	Name	#	Period (Sec)	Acceleration (g's)
1	Malta, NY	1	0	0.0856
2	Malta, NY_b	2	0.037	0.1284
3		3	0.074	0.1712
		4	0.11	0.214
		5	0.331	0.214
		6	0.551	0.214
		7	1.914	0.061665
		8	3.276	0.036023
		9	4.638	0.025443
		10	6	0.019667
		11	8	0.011063
		12	10	0.00708
		13	20	0.00177
		14	30	0.000787

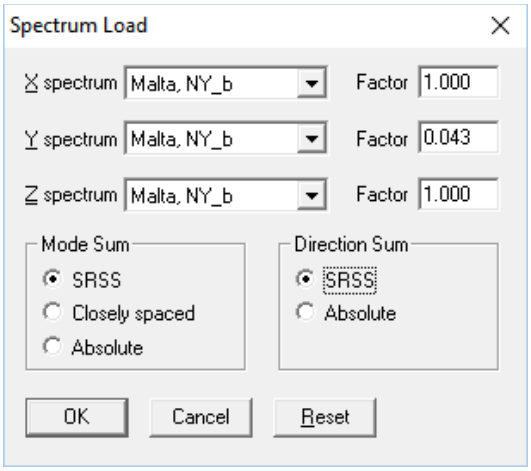


For the sample layout described above, spectrum was input directly into CAEPIPE model manually. In case you wish to read in the supplied "ElCentro.txt" spectrum file into the CAEPIPE model, select "Read Spectrum" from the File menu in the Layout window.

Step 3:

Once the inputting of different spectrums are done, input the Spectrum load itself for analysis through Layout window > Spectrum.





X, Y and Z spectrums

Select a spectrum from the drop-down combo box, which should have been input in the spectrum table for each direction.

Factor

The multiplying (scale) factor for the spectrum is input here. The same spectrum may be multiplied by different (Scale) factors to apply spectrum loads for different dynamic events.

Mode Sum

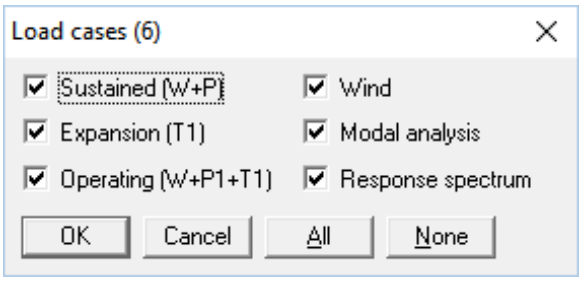
Pick one of three choices, “SRSS” (square root of sum of squares), “Closely spaced” or “Absolute”.

Direction Sum

Pick one of two choices, “SRSS” (square root of sum of squares) or “Absolute”.

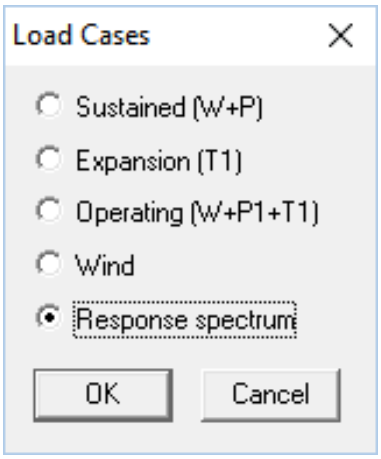
Step 4:

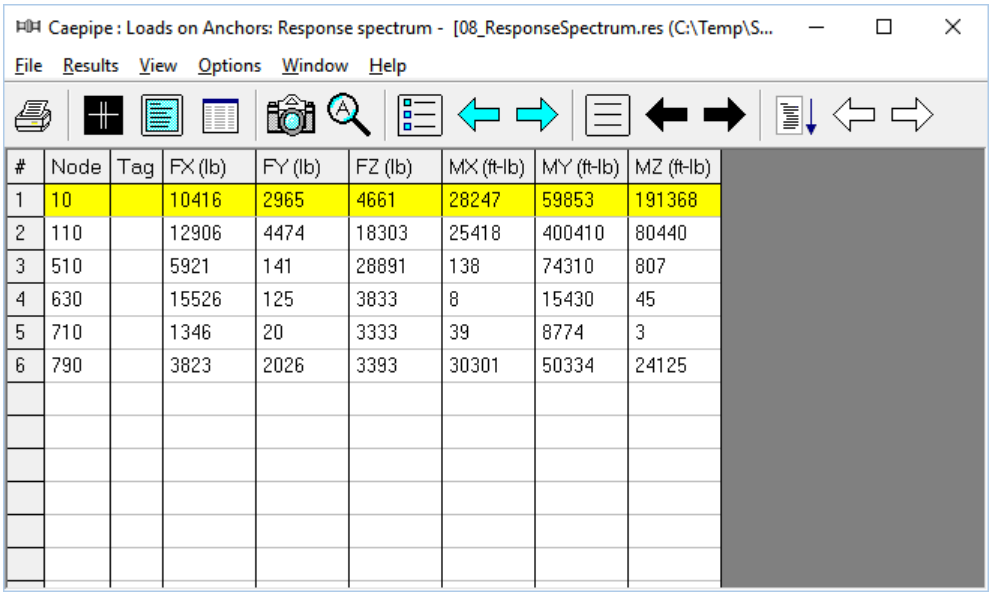
Include “Response spectrum” analysis load case through Layout window > Load cases. Save the model and perform the analysis through Layout window > File > Analyze. CAEPIPE will apply these loads to compute the response of the piping system by performing a Response Spectrum analysis along with other load cases defined in the piping system.



Step 5:

Upon successful analysis, CAEPIPE will now show a “Load case” with name “Response spectrum” under “Support Loads”, “Displacements”, “Element forces” and “Support load summary” results.





#	Node	Tag	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)
1	10		10416	2965	4661	28247	59853	191368
2	110		12906	4474	18303	25418	400410	80440
3	510		5921	141	28891	138	74310	807
4	630		15526	125	3833	8	15430	45
5	710		1346	20	3333	39	8774	3
6	790		3823	2026	3393	30301	50334	24125

Caepipe : Displacements: Response spectrum - [08_ResponseSpectrum.res (C:\Temp\Spec...

File Results View Options Window Help

#	Node	Displacements (global) X (inch)	Y (inch)	Z (inch)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0001
2	20A	0.003	0.001	0.000	0.0012	0.0020	0.0132
3	20B	0.235	0.015	0.014	0.0027	0.1256	0.2231
4	30	0.877	0.015	0.017	0.0017	0.1146	0.2332
5	40A	1.073	0.015	0.016	0.0021	0.1113	0.2324
6	40B	1.375	0.001	0.006	0.0025	0.0532	0.1013
7	50	1.351	0.000	0.006	0.0020	0.0558	0.0987
8	60	1.328	0.001	0.006	0.0015	0.0583	0.0964
9	65	1.195	0.002	0.006	0.0001	0.0718	0.0850
10	70	0.996	0.000	0.005	0.0005	0.0875	0.0712
11	75	0.762	0.001	0.004	0.0000	0.0977	0.0574

Caepipe : Pipe forces in local coordinates: Response spectrum - [08_ResponseSpectrum.re...

File Results View Options Window Help

#	Node	fx (lb)	fy (lb)	fz (lb)	mx (ft-lb)	my (ft-lb)	mz (ft-lb)	SIF	SL+SO (psi)
1	10	4180	2964	10310	191368	59853	28247		7906
	20A	4180	2964	10310	191368	16955	16213		7326
2	20A	2711	2883	10150	191368	16955	16213	3.31	11523
	20B	2883	2711	10150	52845	123744	15539	3.31	9440
3	20B	1095	9400	872	52845	15539	123744		6488
	30	1095	9400	872	52845	20023	8867		5344
4	30	1413	7698	1222	52845	20023	8867		5344
	40A	1413	7698	1222	52845	15215	31917		5427
5	40A	2569	2957	6147	52845	31917	15215	3.31	6804
	40B	2957	2569	6147	71283	91806	13842	3.31	9139
6	40B	4004	2721	4373	71283	91806	13842		6366
	50	4004	2721	4373	71283	100776	19342		6736
7	50	4404	840	3815	71283	100776	19342		6736

Caepipe : Support load summary for anchor at node 10 - [08_ResponseSpectrum.res (C:\Temp\Spec...

File Results View Options Window Help

Load combination	FX (lb)	FY (lb)	FZ (lb)	MX (ft-lb)	MY (ft-lb)	MZ (ft-lb)	Displacements (global) X (inch)	Y (inch)	Z (inch)
Sustained	0	-9872	-144	36276	0	0	0.000	0.000	0.000
Operating1	0	39149	-13404	-301287	2	4	0.000	0.000	0.000
Sustained+Wind	0	-9858	-150	36176	0	0	0.000	0.000	0.000
Operating1+Wind	0	39163	-13410	-301387	2	4	0.000	0.000	0.000
Sustained+Response	10416	-6907	4517	64523	59853	191368	0.000	0.000	0.000
Sustained-Response	-10416	-12837	-4804	8028	-59853	-191368	0.000	0.000	0.000
Operating1+Response	10416	42114	-8743	-273040	59856	191372	0.000	0.000	0.000
Operating1-Response	-10416	36184	-18064	-329535	-59851	-191364	0.000	0.000	0.000
Maximum	10416	42114	4517	64523	59856	191372	0.000	0.000	0.000
Minimum	-10416	-12837	-18064	-329535	-59853	-191368	0.000	0.000	0.000
Allowables	0	0	0	0	0	0	0.000	0.000	0.000