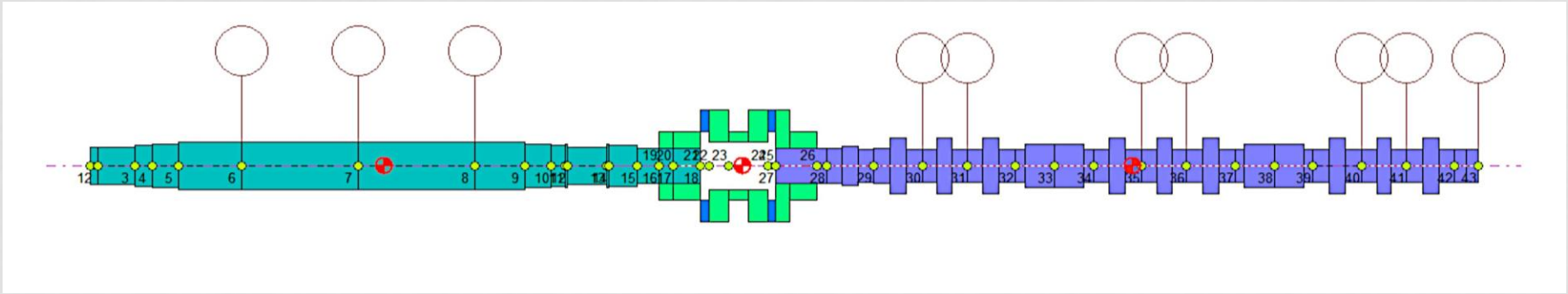
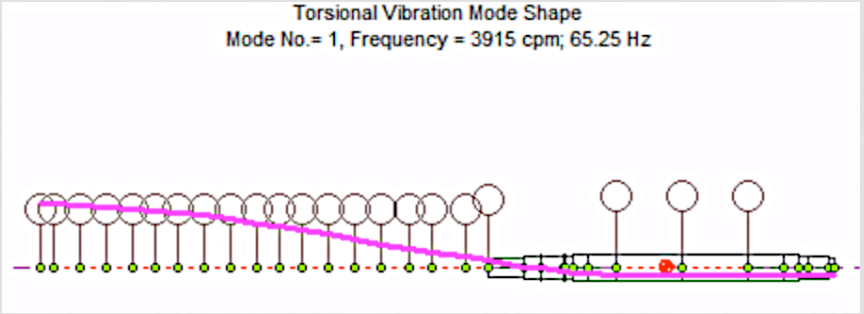
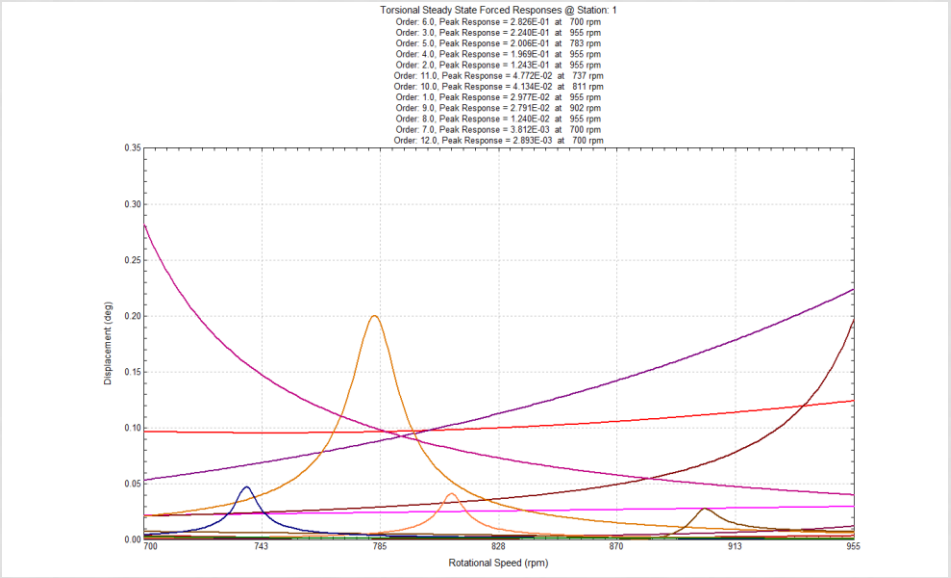
TORSIONAL VIBRATION ANALYSIS

RUGVED NAKADE

TORSIONAL VIBRATION ANALYSIS OF RECIPROCATING COMPRESSOR DRIVETRAINS

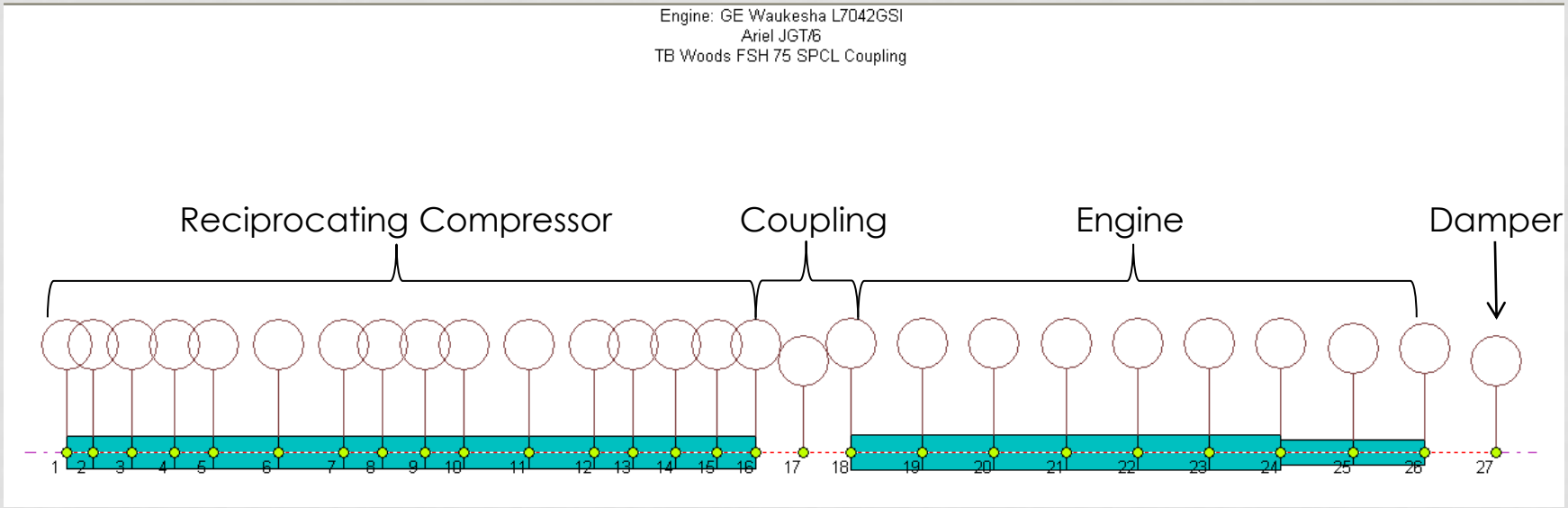






Torsional vibration models of reciprocating machinery drive-trains are modeled using DyRoBeS

ENGINE DRIVEN MODEL



- Mass elastic methodology used for modeling reciprocating machinery drive-trains
- Above example is a mass elastic model of a Waukesha Engine driving an Ariel JGT, 6 Throw compressor via a TB Woods coupling
- Mass elastic information is provided by OEMs

MASS ELASTIC DATA SHEETS FROM OEMS

MASS ELASTIC DATA

Location	Station (in)	Symbol	Inertia (lb·in2)	Internal Flywheel (lb·in2)	Symbol	Stiffness (in-lbs/RAD x 10E6)
Drive Flange Face	0.000	I1	4036.470		K1	385.120
Main #1 CL	6.375	I2	848.960		K2	186.480
Throw #1 CL	13.250	I3	2075.699		K3	180.460
Throw #2 CL	20.375	I4	2073.660		K4	186.480
Main #2 CL	26.875	I5	746.550		K5	178.710
Spreader CL	37.813	I6	569.160		K6	178.710
Main #3 CL	48.750	I7	746.550		K7	186.480
Throw #3 CL	55.250	I8	2405.435		K8	180.460
Throw #4 CL	62.375	I9	2404.926		K9	186.480
Main #4 CL	68.875	I10	746.550		K10	178.710
Spreader CL	79.813	I11	569.160		K11	178.710
Main #5 CL	90.750	I12	746.550		K12	186.480
Throw #5 CL	97.250	I13	2405.435		K13	180.460
Throw #6 CL	104.375	I14	2404.926		K14	186.480
Main #6 CL	110.875	I15	520.370		K15	354.590
Aux Drive End	115.313	I16	246.310			
		Total:	23546.713	0.000		

Crankshaft Material:

Material: ASTM A668 Class M/AISI 4340 (Forged Alloy Steel)
Yield, psi: 110000
Tensile, psi: 135000

GE imagination at work

GE Energy Waukesha gas engines
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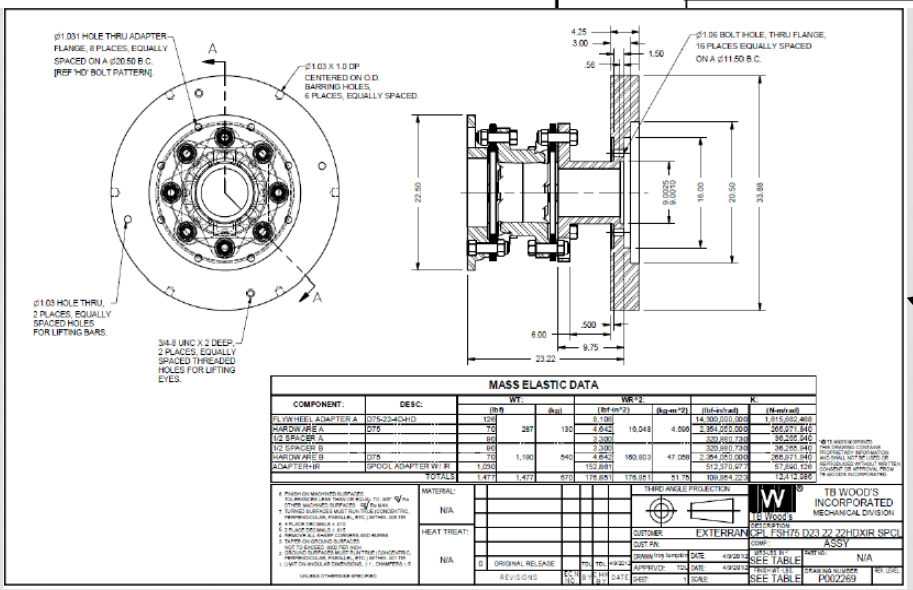
Mass Elastic Diagram
Engine Model: L7042GSI
Engine Order: Star#: L7042GSI-2636470 SO#: 3001600

Mass Name	I Lbf-In-s²	K * 10^6 Lbf-In/rad	Diameter Inch
RING 199331F	53.760	5.000	
HOUSING 199331F	23.908	59.900	4.375
GEAR TRAIN	2.790	111.000	4.500
CRANKTHROW 1	24.075	116.000	6.250
CRANKTHROW 2	24.075	116.000	6.250
CRANKTHROW 3	24.135	108.000	6.250
CRANKTHROW 4	24.135	116.000	6.250
CRANKTHROW 5	24.075	116.000	6.250
CRANKTHROW 6	24.075	143.500	6.250
FLYWHEEL	396.570		

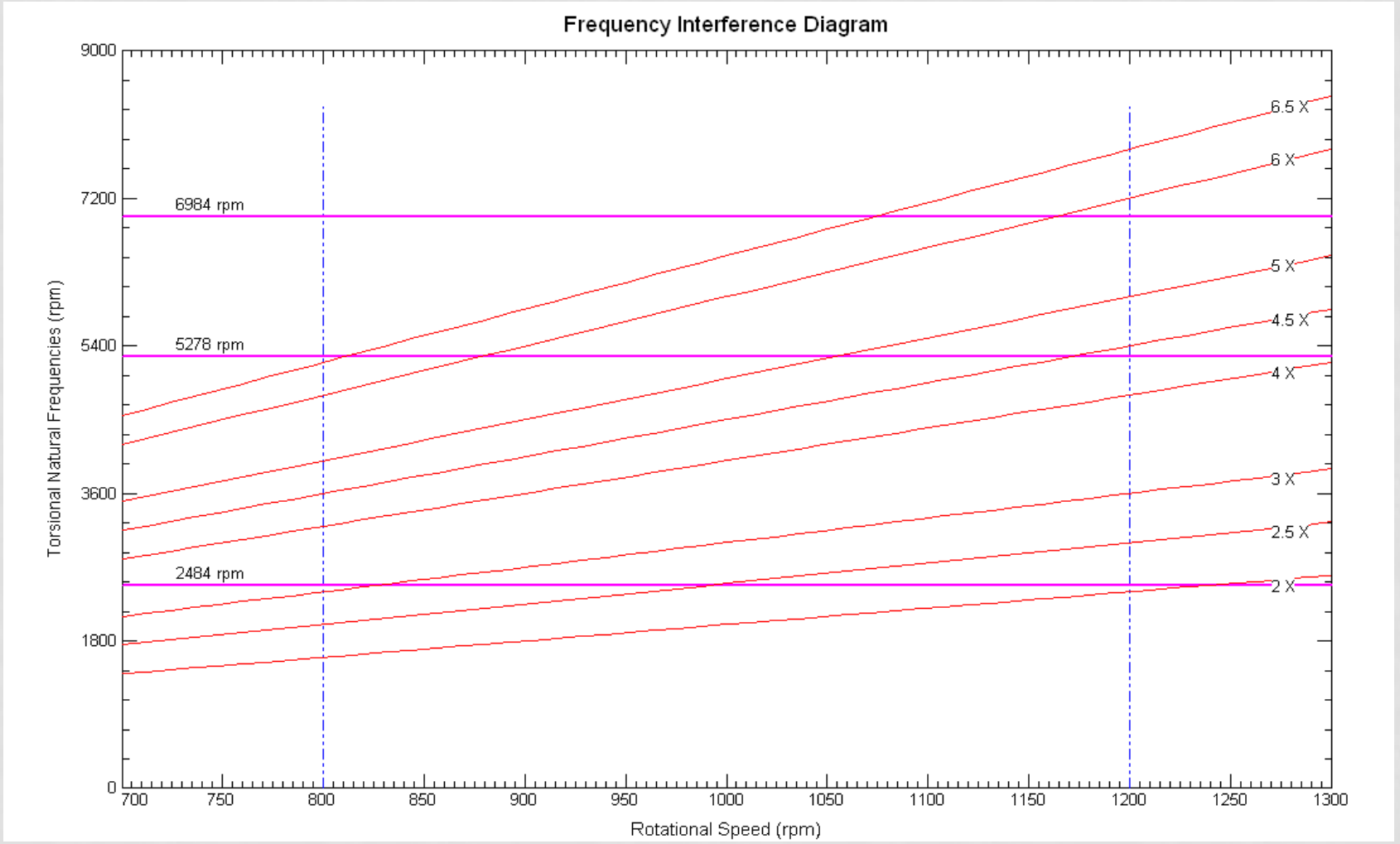
Compressor Data

Engine Data

Coupling Data

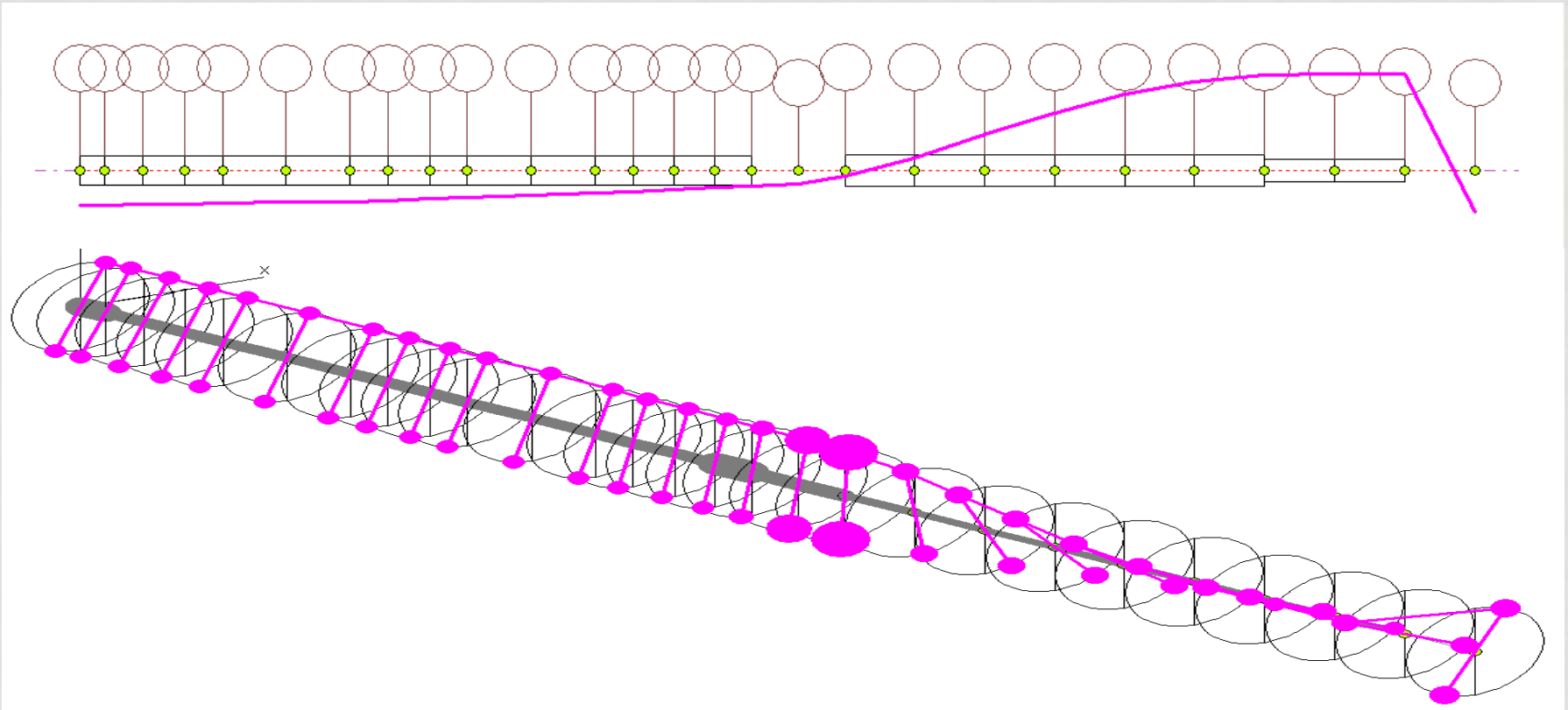


FREQUENCY INTERFERENCE DIAGRAM



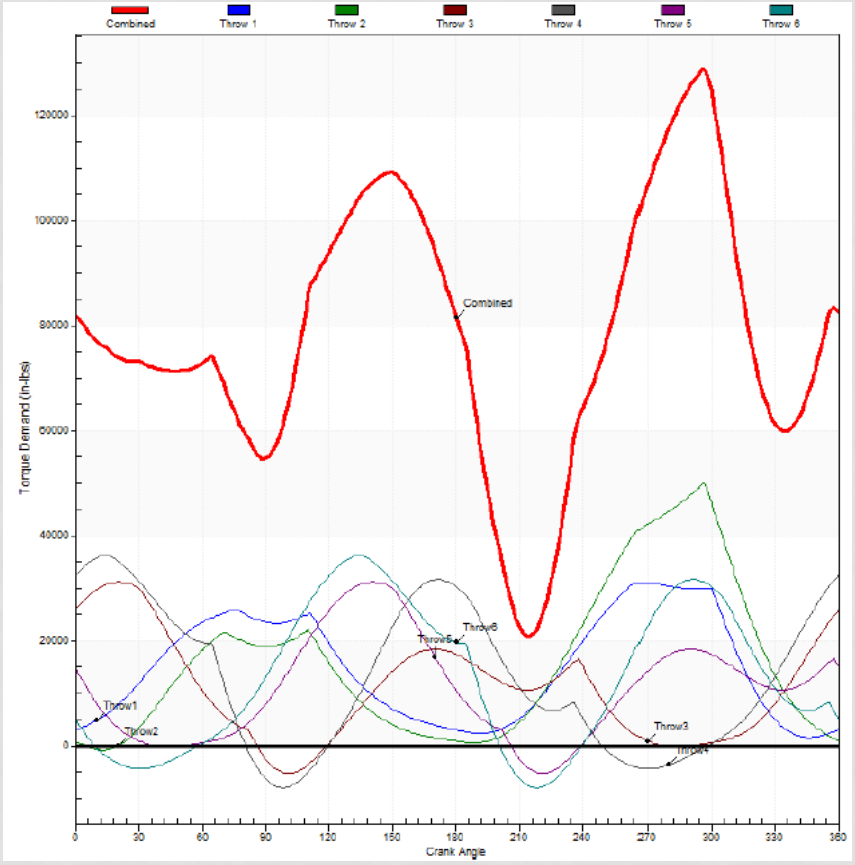
MODE SHAPES

Torsional Natural Frequency: 89.87 Hz



- Ability to calculate and plot mode shapes in either 2-D or 3-D format

STEADY STATE FORCED RESPONSE ANALYSIS



GE imagination at work

GE Energy Waukesha gas engines
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Harmonic Coefficients of Tangential Pressure, PSI
Engine Model: L7042GSI

Order	100 PSI BMEP Cosine Coeff	100 PSI BMEP Sine Coeff	100 PSI BMEP Tn	150 PSI BMEP Cosine Coeff	150 PSI BMEP Sine Coeff	150 PSI BMEP Tn
0.5	35.760	31.340	47.550	47.250	42.630	63.639
1.0	18.210	54.520	57.481	23.450	73.450	77.103
1.5	1.730	48.640	48.671	0.870	65.730	65.736
2.0	-3.290	37.460	37.604	-6.380	49.370	49.781
2.5	-6.690	27.370	28.176	-9.970	35.260	36.642
3.0	-6.780	20.040	21.156	-9.720	25.310	27.112
3.5	-7.720	13.820	15.830	-10.880	17.230	20.378
4.0	-7.050	8.330	10.913	-9.630	10.330	14.123
4.5	-6.050	4.940	7.811	-7.990	5.820	9.885
5.0	-5.200	2.870	5.939	-6.970	2.790	7.508
5.5	-4.830	1.200	4.977	-6.360	0.150	6.362
6.0	-3.790	-0.180	3.794	-5.030	-1.660	5.297
6.5	-2.930	-1.180	3.159	-4.020	-2.420	4.692
7.0	-2.120	-1.790	2.775	-3.080	-2.710	4.102
7.5	-1.620	-2.100	2.652	-2.360	-2.860	3.708
8.0	-1.320	-2.070	2.455	-1.630	-2.640	3.103
8.5	-1.320	-1.980	2.380	-1.140	-2.480	2.729
9.0	-1.220	-1.830	2.199	-0.690	-2.300	2.401
9.5	-1.160	-1.740	2.091	-0.350	-2.150	2.178
10.0	-0.940	-1.650	1.899	-0.160	-1.950	1.957
10.5	-0.630	-1.610	1.729	-0.100	-1.750	1.753
11.0	-0.370	-1.380	1.429	-0.070	-1.550	1.552
11.5	-0.260	-1.160	1.189	-0.110	-1.420	1.424
12.0	-0.140	-0.950	0.960	-0.120	-1.310	1.315

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GE PROPRIETARY INFORMATION
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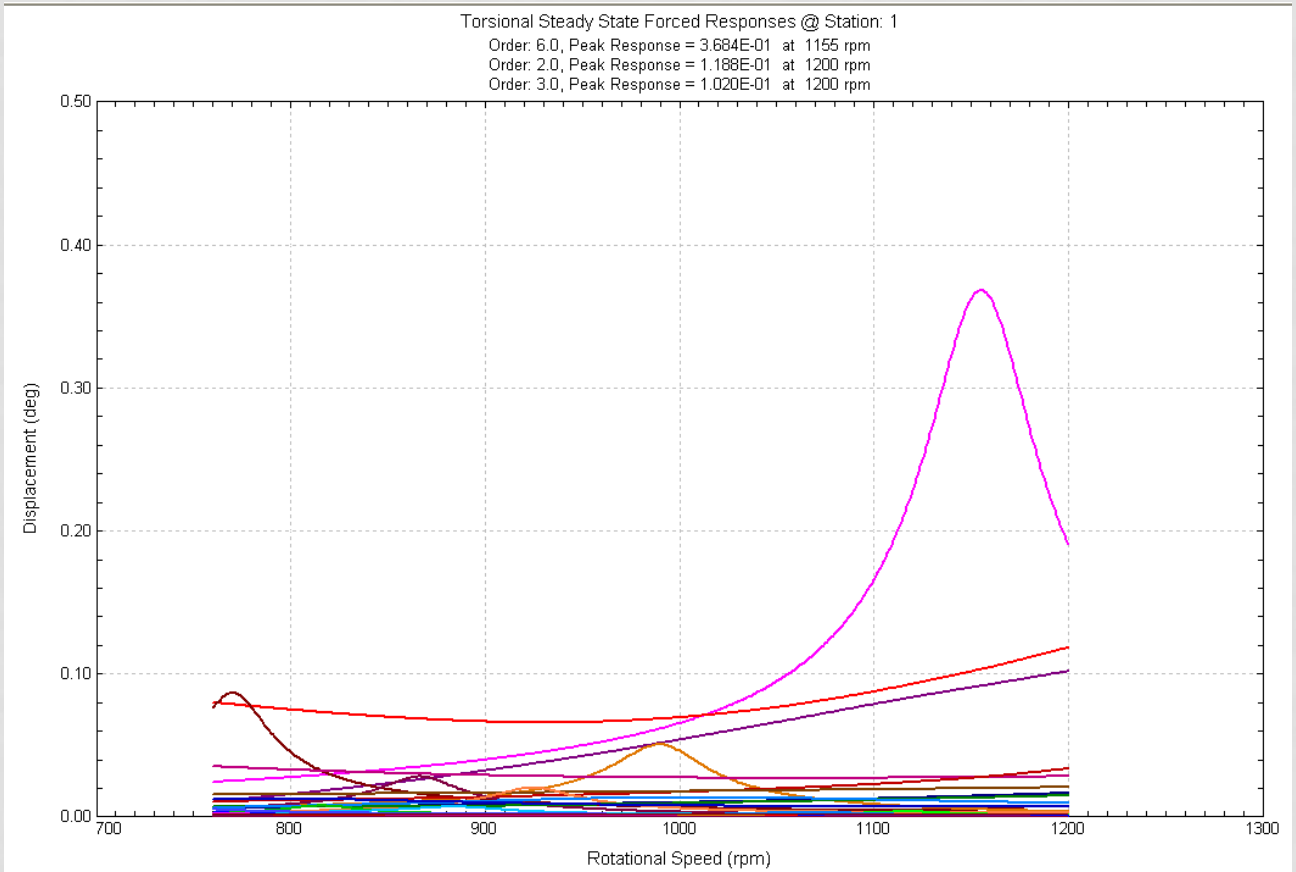
- Ability to input steady state reciprocating torque due to inertia and gas forces
- Above plots show reciprocating torque of compressor and harmonic coefficients of tangential pressure of engines

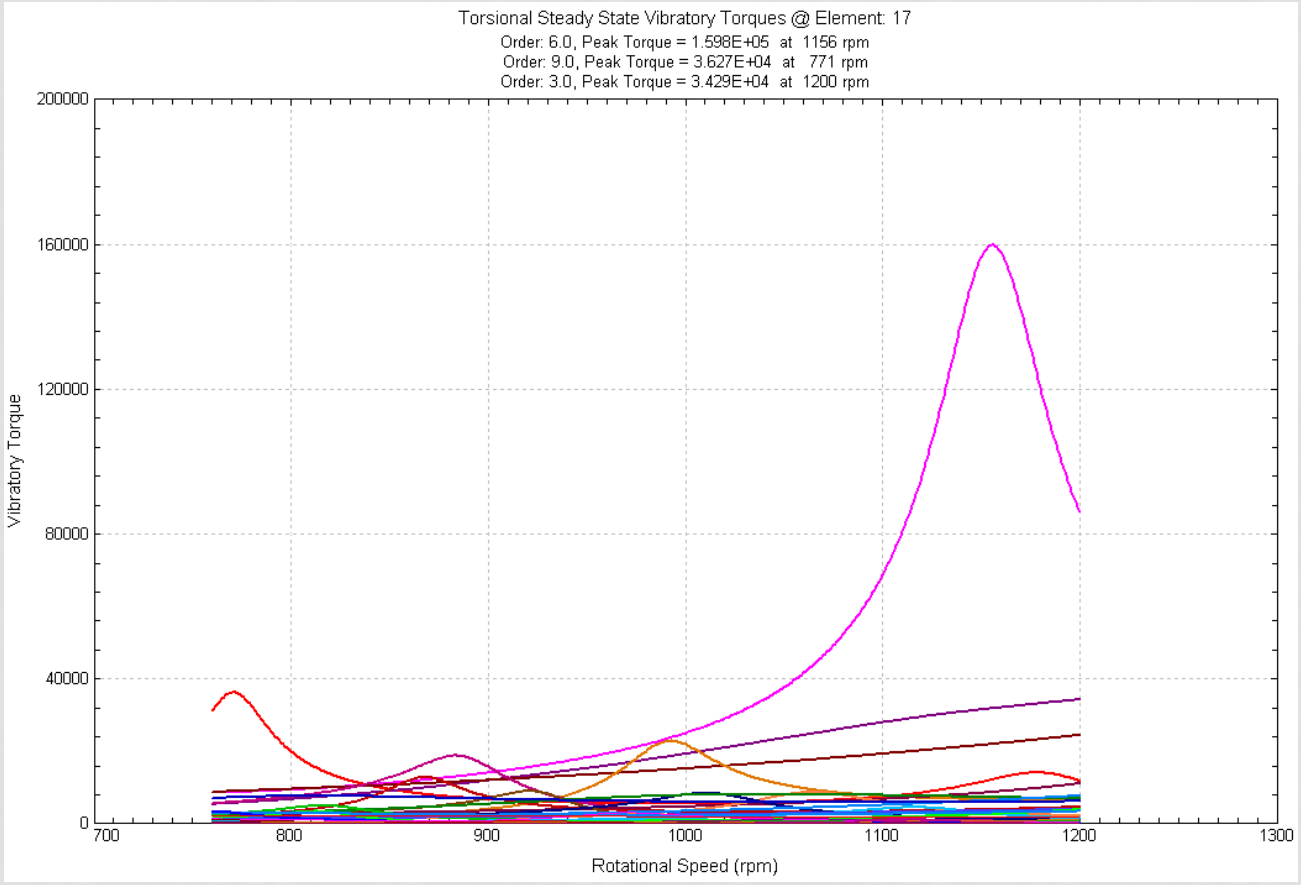
COMPRESSOR AUX END TORSIONAL AMPLITUDE



Order based torsional response (Angular displacement)

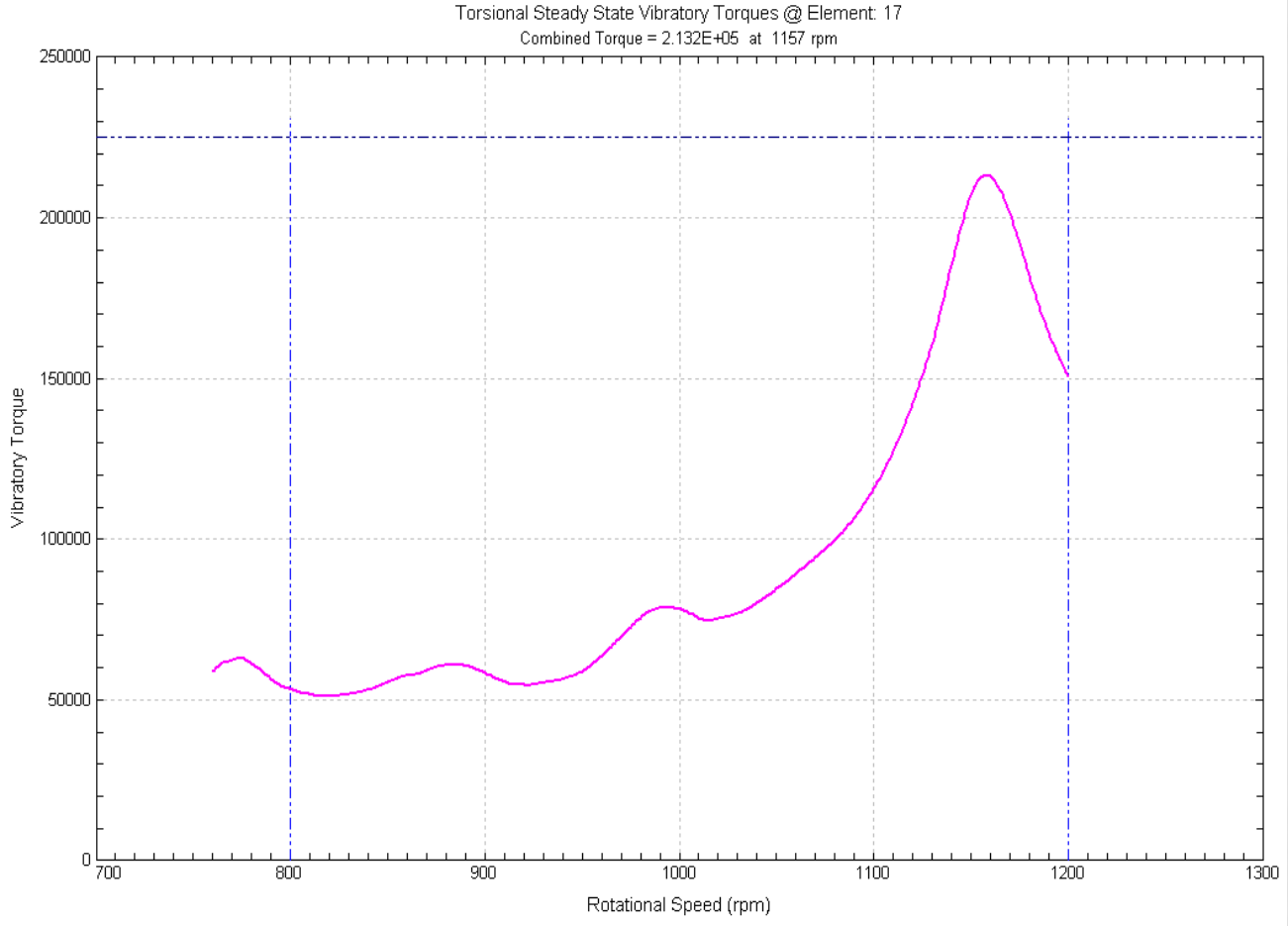
- Order based torsional vibration of the auxiliary end of the compressor
- Typically Ariel provides maximum allowable torsional vibration levels at the auxiliary end
- A lube-oil pump is driven via a gear at aux end of the compressor
- The intent is to prevent lube pump shaft failures

COUPLING VIBRATORY TORQUE



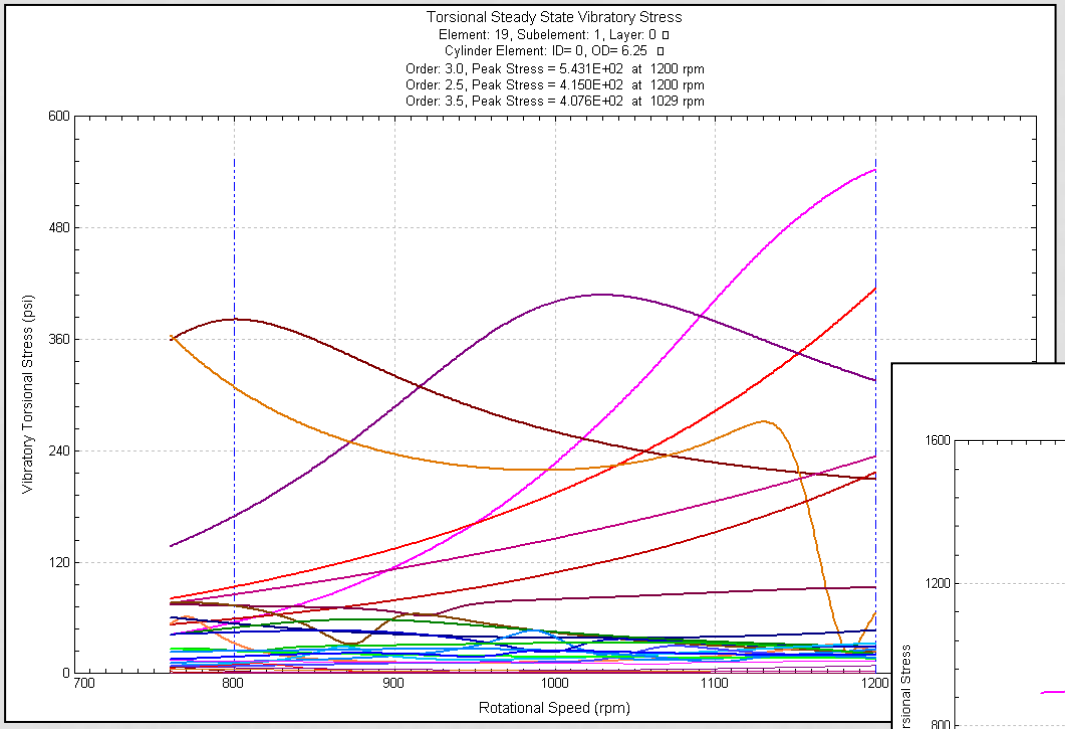
- Ability to calculate vibratory torque across the drive-train
- The plot represents order based vibratory torque generated in coupling
- The vibratory torque generated is compared against maximum allowable by coupling manufacturer

COMBINED ORDER TORQUE IN COUPLING

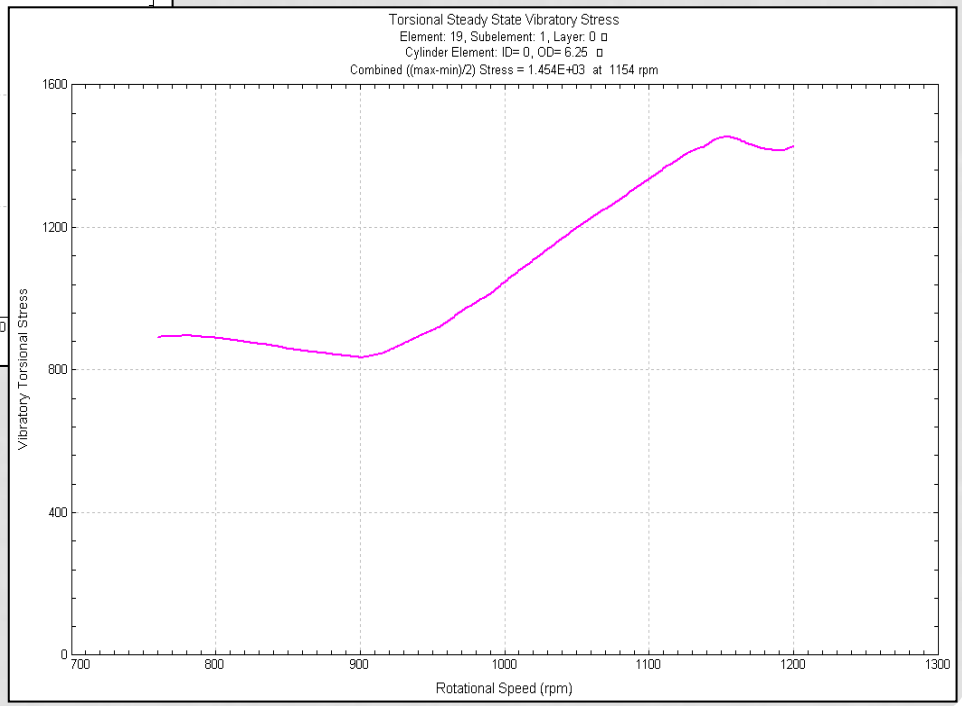


- Ability to also calculate the combined order vibratory torque response across the drive-train
- This is to again compare with maximum allowable by manufacturer

ORDER BASED AND COMBINED ORDER VIBRATORY STRESS

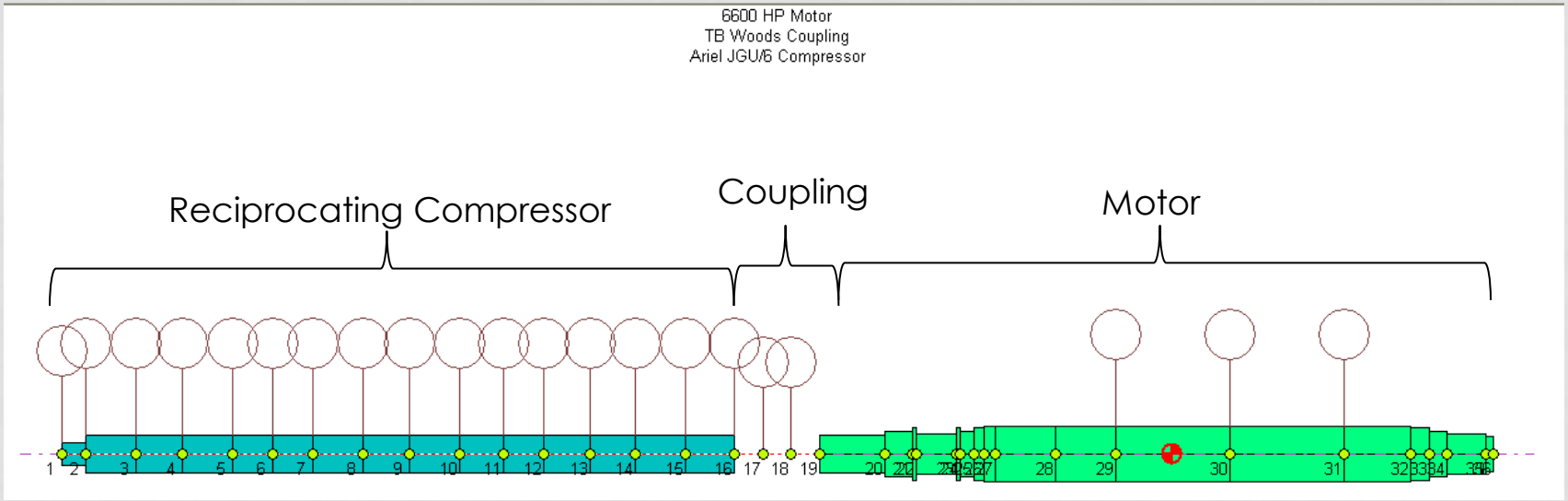


- Ability to calculate order based vibratory stress generated in the drive-train
- The vibratory stress can then be compared against an endurance limit calculation in order to determine failure due to fatigue



- Similarly, a combined order stress can be calculated and evaluated against the endurance limit

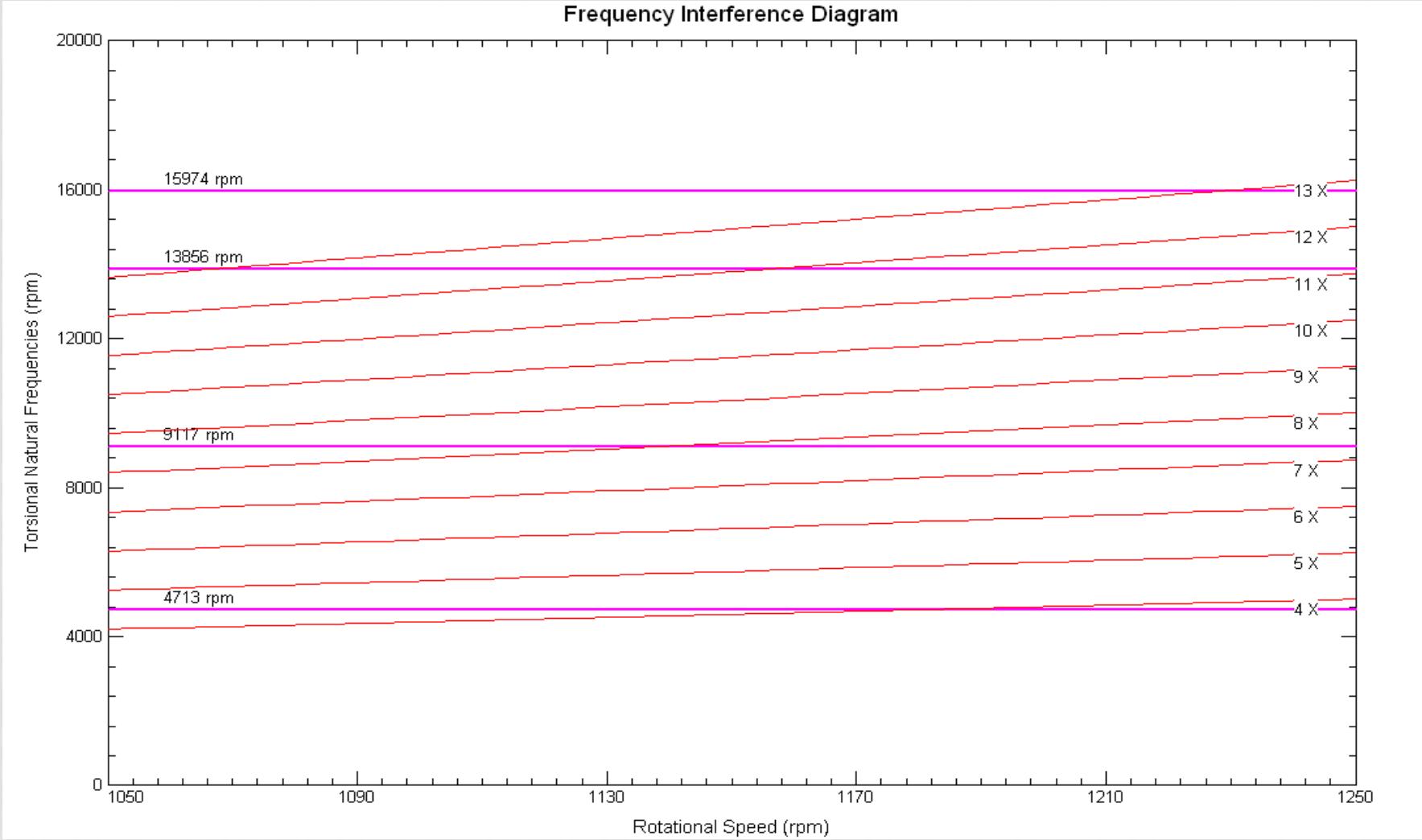
MOTOR DRIVEN MODEL



- Above model shows a reciprocating compressor driven by a fixed speed motor (1200 RPM)

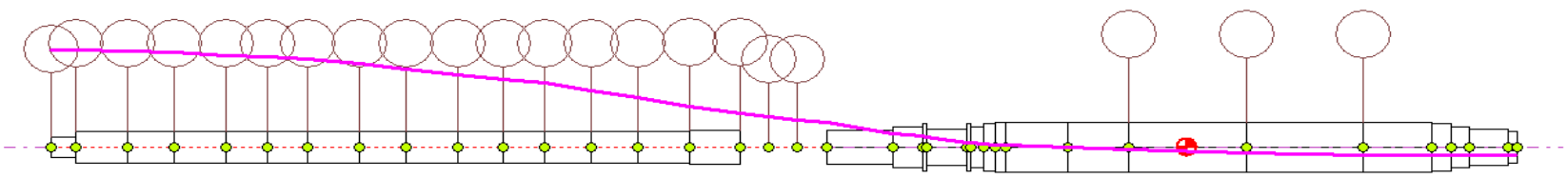
- The model is a hybrid model that models the mass elastic data of the compressor and coupling, but models actual motor shaft geometry to calculate torsional inertia and stiffness

FREQUENCY INTERFERENCE DIAGRAM

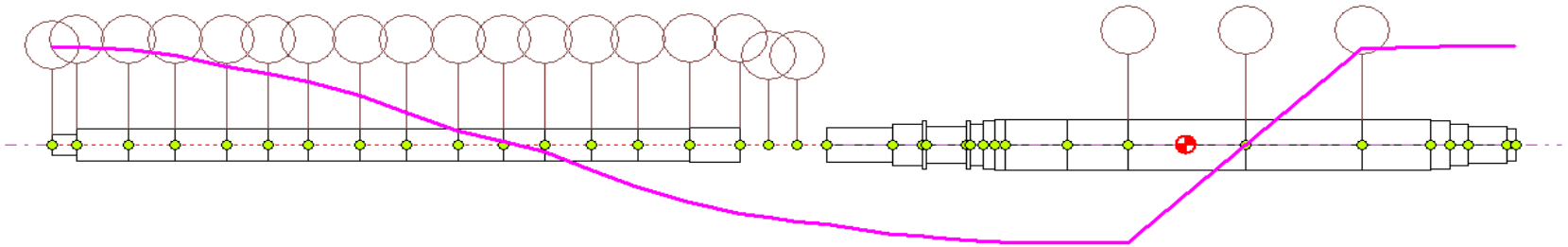


MODE SHAPES

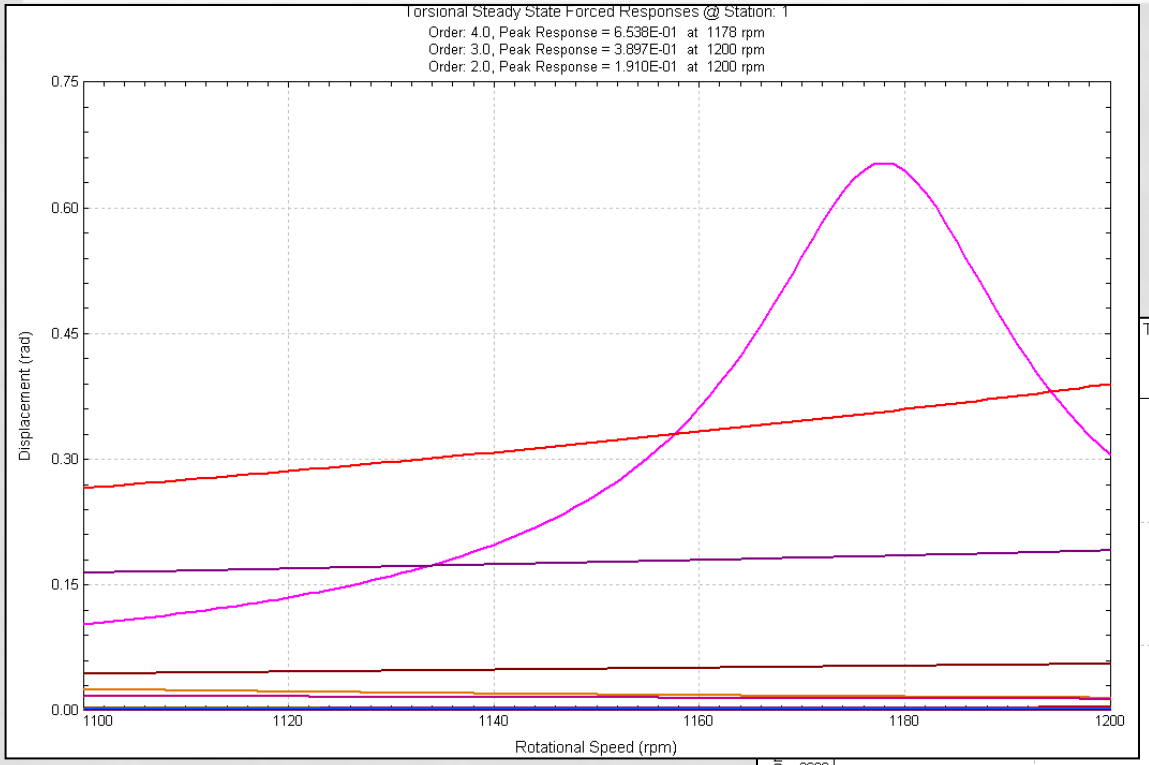
Torsional Vibration Mode Shape
Mode No.= 1, Undamped Frequency = 4713 cpm; 78.54 Hz



Torsional Vibration Mode Shape
Mode No.= 2, Undamped Frequency = 9117 cpm; 151.95 Hz

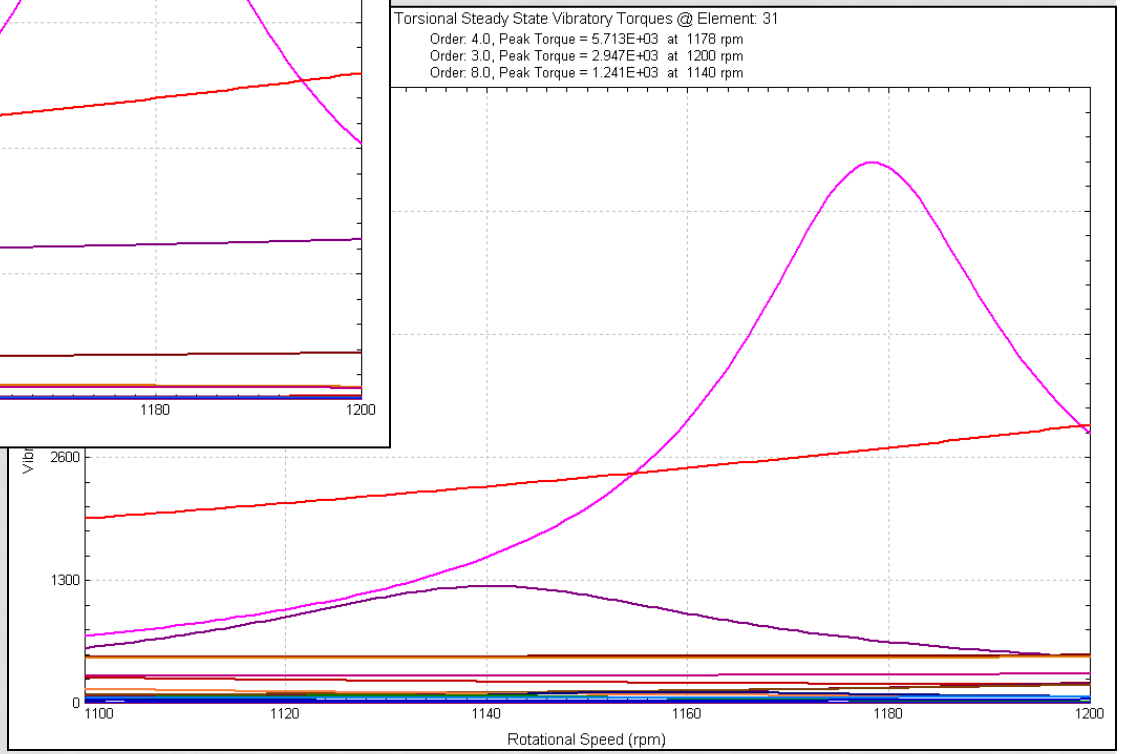


TORSIONAL RESPONSE



Angular displacement

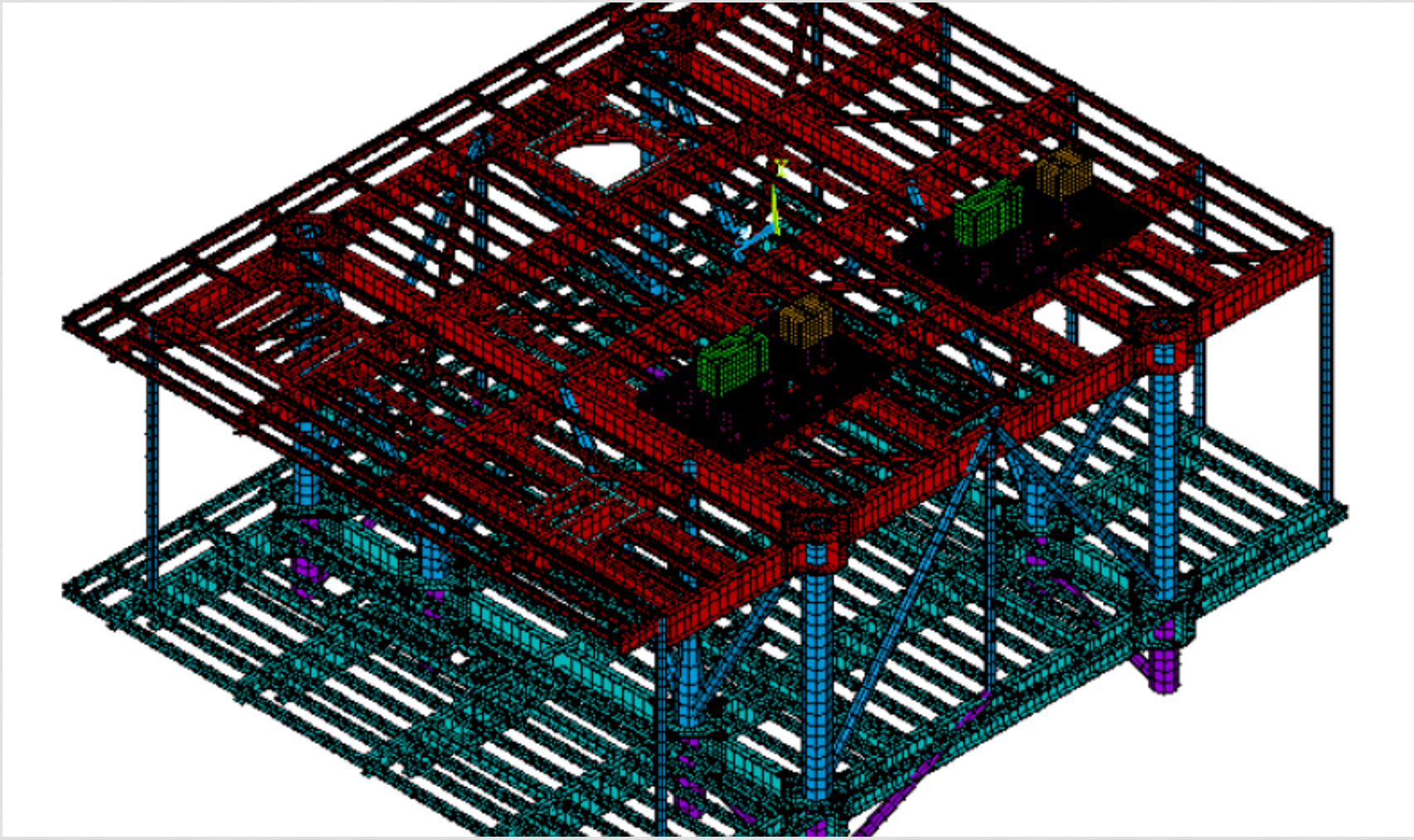
Vibratory torque



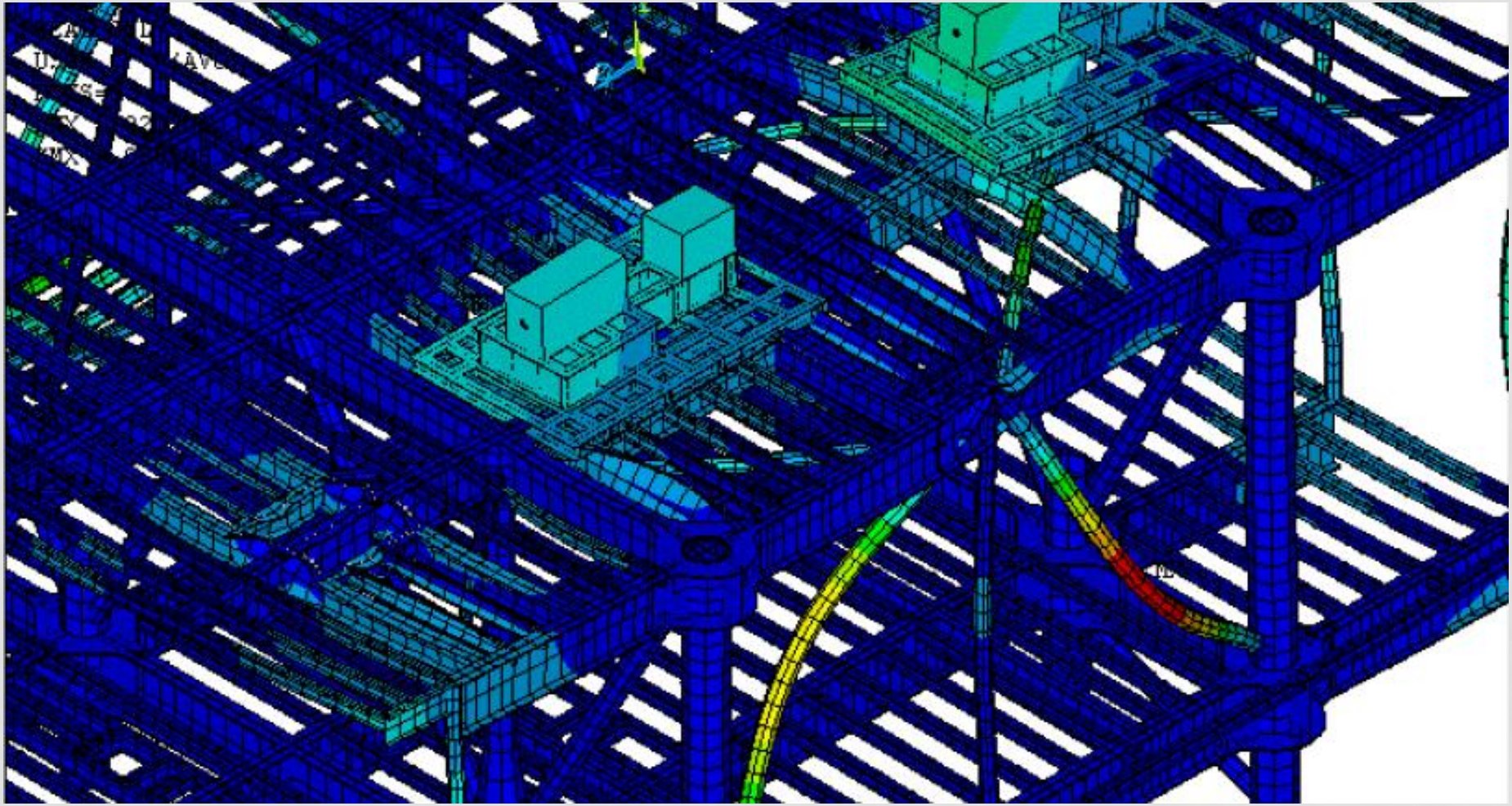
OTHER AREAS OF INTEREST

- Finite element analysis using Ansys and Abaqus
- Comfortable with building Ansys Parametric Design Language (APDL) scripts for vibration and stress analysis
- Operating deflection shape and experimental modal analysis using ME'Scope
- Experience with field vibration data acquisition using Dataphysics tools
- Programming skills using MATLAB
- Python Programming
- C programming
- Keen Research and Development drive
- Entrepreneurial spirit

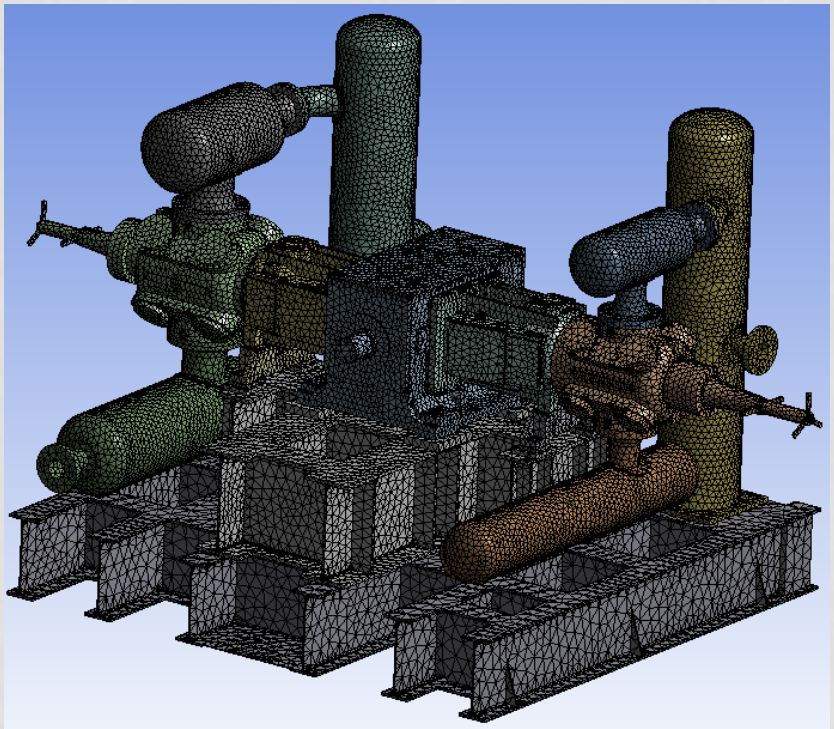
VIBRATION SIMULATIONS AND ANALYSIS OF OFFSHORE PLATFORM

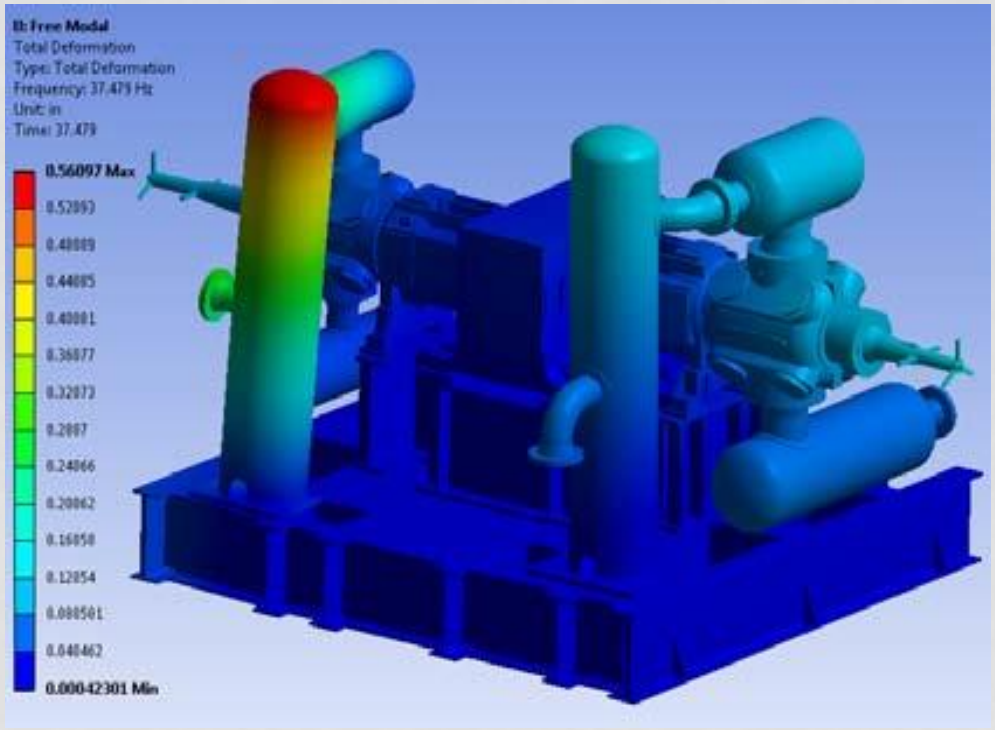


VIBRATION SIMULATIONS AND ANALYSIS OF OFFSHORE PLATFORM



VIBRATION ANALYSIS OF RECIPROCATING COMPRESSOR PACKAGES





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- Rangawala. Reciprocating machinery dynamics
- Norton, Robert. Design of Machinery.