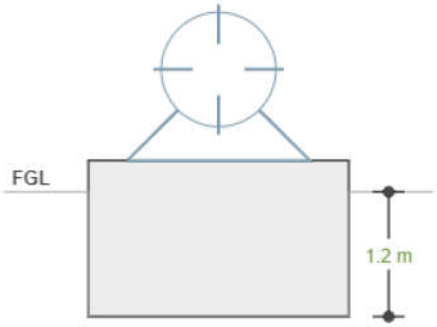
1.0 INPUT

1.1 Foundation

Depth of foundation	D_f	= **1.2** m
Embedment Depth	D_{em}	= **0** %



1.2 Dynamic Criteria

Lower Frequency Limit	F_{LOW}	= **0.8**
Higher Frequency Limit	F_{HIGH}	= **1.2**
Permissible Amplitude	A_p	= **20** µm
Permissible Velocity	V_p	= **2** mm/s
Min. Fdn. / Machine Mass Ratio	MR	= **3**
Base Eccentricity Limit	E_{cc}	= **5** %
Degree Step	θ	= **45** deg

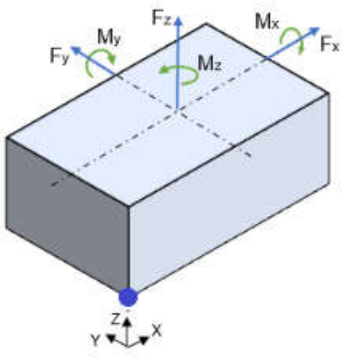
1.3 Maximum Damping Ratio

(ACI 351.3R-18 Clause 5.4.2)

Motion in Vertical (Z Direction)	D_{zmax}	= **0.25**
Motion in Horizontal (X & Y Dir.)	D_{xymax}	= **0.2**
Rotational Motion (Mx)	D_{rxmax}	= **0.1**
Rotational Motion (My)	D_{rymax}	= **0.1**
Rotational Motion (Mz)	D_{rzmax}	= **0.15**

1.4 Properties

Allowable Net Bearing Pressure	SBC	= **150** kN/m²
Dynamic Shear Modulus	G_s	= **124000** kN/m²
Density of Concrete	γ_{conc}	= **24** kN/m³
Density of Soil	γ_{soil}	= **18** kN/m³
Ground Water Table depth	H_{wt}	= **0.5** m
Coefficient of Friction	µ	= **0.35**
Poisson's Ratio	ν	= **0.5**



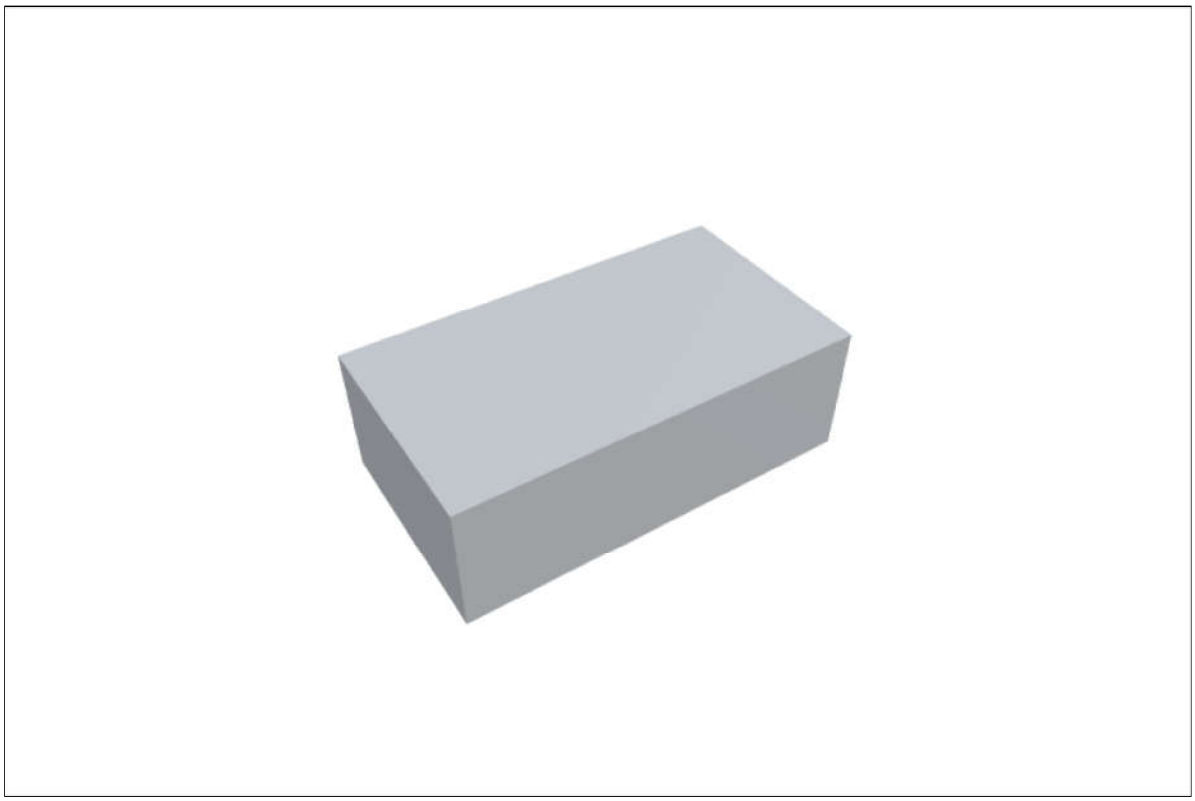
Sign Convention (Input)

1.5 Factor of Safety

F.O.S against Sliding	γ_{Slide}	= **1.5**
F.O.S against Overturning	γ_{Over}	= **1.5**

1.6 Base Block Details

No.	Location of Base Block (m)		Dimensions of Base Block (m)		
	In X Dir.	In Y Dir.	L_{xb}	L_{yb}	L_{zb}
Block 1	0	0	4.5	2.5	1.5



1.7 Machine Components

Component Desc.	Weight (kN)	Mass Moment of Inertia (kg.m²)			Centre of gravity (m)		
	Wm	Jmx	Jmy	Jmz	Xm	Ym	Zm
Pump	10	0.0	0.0	0.0	3	2	2

1.8 Machine Speed

No.	Speed - 1 (RPM)	Speed - 2 (RPM)
Machine 1	1000	750
Machine 2	1500	500

1.9 Dynamic Loading Points

Point	Coordinates of Points (m)		
	In X Dir.	In Y Dir.	In Z Dir.
DP 1	1	2	1.5
DP 2	0	1	1.5

1.10 Dynamic Loads

No.	Loading Point	Forces (kN) / Phase Angle (deg)			Moments (kN.m) / Phase Angle (deg)			Machine Speed (RPM)
		Fx	Fy	Fz	Mx	My	Mz	
DL 1	DP1	20.000 (90°)	15.000 (90°)	10.000 (0°)	16.000 (0°)	20.000 (90°)	28.000 (0°)	MN1-1000

1.11 Amplitude and Velocity Points

Points	Coordinates of Points (m)		
	In X Dir.	In Y Dir.	In Z Dir.
AP 1	1	2	3
AP 2	0.5	0.5	1
AP 3	2	1.5	0.5

1.12 Non Dynamic Load Cases

No.	Description	Type
LC1	Dead	Dead
LC2	Live	Live
LC3	Wind-X	Wind
LC4	Seismic-X	Seismic

1.13 Non Dynamic Loading Points

Point	Coordinates of Points (m)		
	In X Dir.	In Y Dir.	In Z Dir.
NDP 1	2	1	1.5

1.14 Non Dynamic Loads

1.14.1 Non Dynamic Loads on NDP1

Load Case	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN.m)	M_y (kN.m)	M_z (kN.m)
LC1	0.0	7.5	0.0	15.0	0.0	20.0
LC2	0.0	10.0	0.0	0.0	2.0	15.0
LC3	10.0	5.0	15.0	10.0	1.0	0.0
LC4	15.0	0.0	25.0	25.0	0.0	30.0

1.15 Serviceability Load Combinations

No	Combination
SLS1	Dead + 0.9Live
SLS2	Dead + 0.9{Wind-X}
SLS3	Dead + 0.9{Seismic-X} + Dynamic
SLS4	Dead + Live
SLS5	Dead + {Wind-X}
SLS6	Dead + {Seismic-X} + 0.9Dynamic

1.16 Allowable Bearing and Stability Factors

Comb.	SBC Inc. / Dec. (%)	Overturning	Sliding
SLS1	0	1.5	1.5
SLS2	10	1.5	1.5
SLS3	0	1.5	1.5
SLS4	0	1.5	1.5
SLS5	0	1.5	1.5

1.16 Allowable Bearing and Stability Factors

Comb.	SBC Inc. / Dec. (%)	Overturning	Sliding
SLS6	0	1.5	1.5

2.0 OUTPUT

2.1 Dimension and Weight - Base Blocks

Weight of Base Block $W_b = L_{xb} * L_{yb} * L_{zb} * \gamma_{conc}$

Base Block No.	Dimensions of Base Block (m)			Location of Base Block (m)		CG. of Base Block (m)			Base Area (m^2)	Weight of Base (kN)
	Lxb	Lyb	Lzb	In X Dir.	In Y Dir.	Xf	Yf	Zf	Ab	Wb
Block 1	4.5	2.5	1.5	0	0	2.25	1.25	-0.75	11.250	405

CG. of Base in X Direction $x_{base} = \frac{\Sigma (A_b * X_f)}{\Sigma A_b}$ x_{base} = **2.25** m

CG. of Base in Y Direction $y_{base} = \frac{\Sigma (A_b * Y_f)}{\Sigma A_b}$ y_{base} = **1.25** m

2.2 Weight and Inertia Properties of Machine Parts

Component Desc.	Weight (kN)	Mass Moment of Inertia ($kg.m^2$)			Centre of gravity of Machine (m)		
	Wm	Jmx	Jmy	Jmz	Xm	Ym	Zm
Pump	10	0.0	0.0	0.0	3	2	-2

2.3 Center of Gravity of Machine and Foundation System

X - Direction $x_c = \Sigma \frac{(W_b * X_f + W_m * X_m)}{(\Sigma W_B + \Sigma W_m)}$ x_c = **2.268** m

Y - Direction $y_c = \Sigma \frac{(W_b * Y_f + W_m * Y_m)}{(\Sigma W_b + \Sigma W_m)}$ y_c = **1.268** m

Z - Direction $z_c = \Sigma \frac{(w_b * Z_f + W_m * Z_m)}{(\Sigma W_b + \Sigma W_m)}$ z_c = **-0.78** m

2.4 Foundation and Machine Mass Ratio

Total Weight of Base Blocks W_b = **405** kN

Total Weight of Machine W_m = **10** kN

Ratio $MR_{actual} = \frac{W_b}{W_m}$ MR_{actual} = **40.5**

2.5 Foundation Base Eccentricity

Maximum Dimension in X Direction X - Dim = **4.50** m

Maximum Dimension in Y Direction Y - Dim = **2.50** m

In X Direction $e_x = \frac{x_{base} \sim x_c}{\text{X - Dim}} * 100$ e_x = **0.40** %

In Y Direction $e_y = \frac{y_{base} \sim y_c}{\text{Y - Dim}} * 100$ e_y = **0.72** %

2.6 Mass Moment of Inertia of Foundation and Machine

2.6.1 Formula for Foundation

About X $$J_x = \sum_{i=1}^{n} \left[\frac{W_{bi}}{g} * \left((Y_{fi} - y_c)^2 + (Z_{fi} - z_c)^2 + \frac{L_{ybi}^{\ 2} + L_{zbi}^{\ 2}}{12} \right) \right]$$

About Y $$J_y = \sum_{i=1}^{n} \left[\frac{W_{bi}}{g} * \left((X_{fi} - x_c)^2 + (Z_{fi} - z_c)^2 + \frac{L_{xbi}^{\ 2} + L_{zbi}^{\ 2}}{12} \right) \right]$$

About Z $$J_z = \sum_{i=1}^{n} \left[\frac{W_{bi}}{g} * \left((X_{fi} - x_c)^2 + (Y_{fi} - y_c)^2 + \frac{L_{xbi}^{\ 2} + L_{ybi}^{\ 2}}{12} \right) \right]$$

2.6.2 Formula for Machine Components

About X $$J_x = \sum_{i=1}^{n} \left[\frac{W_{mi}}{g} * ((Y_{mi} - y_c)^2 + (Z_{mi} - z_c)^2) \right] + J_{mx}$$

About Y $$J_y = \sum_{i=1}^{n} \left[\frac{W_{mi}}{g} * ((X_{mi} - x_c)^2 + (Z_{mi} - z_c)^2) \right] + J_{my}$$

About Z $$J_z = \sum_{i=1}^{n} \left[\frac{W_{mi}}{g} * ((X_{mi} - x_c)^2 + (Y_{mi} - y_c)^2) \right] + J_{mz}$$

2.6.3 Calculated Values about common CG.

Description	X - Direction (kg.m²) Jx	Y - Direction (kg.m²) Jy	Z - Direction (kg.m²) Jz
Base	29303	77482.9	91224.6
Machine	2063.7	2063.7	1092.5
Total	**31366.4**	**79546.2**	**92316.7**

2.7 Natural Frequencies and Resonances

2.7.1 Geometrical Parameters

(Dynamic Parameters using Richard - Lysmer model)

Base Area		Area = **11.25** m²
Longest Dimension of Foundation		L_{found} = **4.5** m
Equivalent Breadth	B_{found} = Area / L_{found}	B_{found} = **2.5** m
Total Weight of Machine and Foundation System	$W_t = W_b + W_m$	W_t = **415** kN
Total Mass of Machine and Foundation System	$M_t = W_t / g$	M_t = **42.32** kN-mass
Moment of Inertia about X Direction		I_x = **5.86** m⁴
Moment of Inertia about Y Direction		I_y = **18.98** m⁴

2.7.2 Equivalent Circular Radius for Rectangular Base

In Vertical (Z - Direction)	$r_z = \sqrt{B_{found} * L_{found} / \pi}$	r_z = **1.892** m
In Horizontal (X or Y - Direction)	$r_{xy} = \sqrt{B_{found} * L_{found} / \pi}$	r_{xy} = **1.892** m
Rotation (about Y axis)	$r_{rx} = \sqrt[4]{4 * I_y / \pi}$	r_{rx} = **2.217** m
Rotation (about X axis)	$r_{ry} = \sqrt[4]{4 * I_x / \pi}$	r_{ry} = **1.653** m
Yawing (about Z axis)	$r_{rz} = \sqrt[4]{2 * (I_x + I_y) / \pi}$	r_{rz} = **1.994** m

2.7.3 Embedment Coefficients

Embedment Depth	$h = D_{em} * D_f$	h = **0** m
In Vertical (Z - Direction)	$\eta_z = 1 + 0.6 * (1 - \nu) * \left(\frac{h}{r_z}\right)$	η_z = **1**
In Horizontal (X or Y - Direction)	$\eta_{xy} = 1 + 0.55 * (2 - \nu) * \left(\frac{h}{r_{xy}}\right)$	η_{xy} = **1**
Rotation (about Y axis)	$\eta_{rx} = 1 + 1.2 * (1 - \nu) * \left(\frac{h}{r_{rx}}\right) + 0.2 * (2 - \nu) * \left(\frac{h}{r_{rx}}\right)^3$	η_{rx} = **1**
Rotation (about X axis)	$\eta_{ry} = 1 + 1.2 * (1 - \nu) * \left(\frac{h}{r_{ry}}\right) + 0.2 * (2 - \nu) * \left(\frac{h}{r_{ry}}\right)^3$	η_{ry} = **1**

2.7.4 Mass Ratio

In Vertical (Z - Direction)	$B_z = \frac{1 - \nu}{4} * \frac{M_t * g}{\gamma_{soil} * r_z^3}$	B_z = **0.425**
In Horizontal (X or Y - Direction)	$B_{xy} = \frac{7 - 8 * \nu}{32 * (1 - \nu)} * \frac{M_t * g}{\gamma_{soil} * r_{xy}^3}$	B_{xy} = **0.638**
Rotation (about Y axis)	$B_{rx} = \frac{3 * (1 - \nu)}{8} * \frac{J_y}{\gamma_{soil} * r_{rx}^5}$	B_{rx} = **0.152**
Rotation (about X axis)	$B_{ry} = \frac{3 * (1 - \nu)}{8} * \frac{J_x}{\gamma_{soil} * r_{ry}^5}$	B_{ry} = **0.26**
Yawing (about Z axis)	$B_{rz} = \frac{J_z}{\gamma_{soil} * r_{rz}^5}$	B_{rz} = **1.595**

2.7.5 Damping Ratio Embedment Factor

In Vertical (Z - Direction)	$\alpha_z = \frac{1 + 1.9 * (1 - \nu) * h}{r_z * \sqrt{\eta_z}}$	α_z = **1**
In Horizontal (X or Y - Direction)	$\alpha_{xy} = \frac{1 + 1.9 * (1 - \nu) * h}{r_{xy} * \sqrt{\eta_{xy}}}$	α_{xy} = **1**
Rotation (about Y axis)	$\alpha_{rx} = \frac{1 + 0.7 * (1 - \nu) * \left(\frac{h}{r_{rx}}\right) + 0.6 * (2 - \nu) * \left(\frac{h}{r_{rx}}\right)^3}{\sqrt{\eta_{rx}}}$	α_{rx} = **1**

Rotation (about X axis)

$$\alpha_{ry} = \frac{1 + 0.7 * (1 - v) * \left(\frac{h}{r_{ry}}\right) + 0.6 * (2 - v) * \left(\frac{h}{r_{ry}}\right)^3}{\sqrt{\eta_{ry}}}$$

α_{ry} = **1**

2.7.6 Damping Ratio

In Vertical (Z - Direction)

$$D_z = min\left(\frac{0.425 * \alpha_z}{\sqrt{B_z}}, D_{zmax}\right)$$

D_z = **0.25**

In Horizontal (X or Y - Direction)

$$D_{xy} = min\left(\frac{0.288 * \alpha_{xy}}{\sqrt{B_{xy}}}, D_{xymax}\right)$$

D_{xy} = **0.2**

Rotation (about Y axis)

$$D_{rx} = min\left(\frac{0.15 * \alpha_{rx}}{(1 + \eta_{rx} * B_{rx}) * \sqrt{\eta_{rx} * B_{rx}}}, D_{rxmax}\right)$$

D_{rx} = **0.1**

Rotation (about X axis)

$$D_{ry} = min\left(\frac{0.15 * \alpha_{ry}}{(1 + \eta_{ry} * B_{ry}) * \sqrt{\eta_{ry} * B_{ry}}}, D_{rymax}\right)$$

D_{ry} = **0.1**

Yawing (about Z axis)

$$D_{rz} = min\left(\frac{0.5}{1 + 2 * B_{rz}}, D_{rzmax}\right)$$

D_{rz} = **0.119**

Z - Direction

2.7.7 Coefficient based on Breadth to Length Ratio

Motion along Z axis β_z = **2.19**

Motion along X axis β_x = **1**

Motion along Y axis β_y = **0.968**

Rotation about Y axis β_{rx} = **0.453**

Rotation about X axis β_{ry} = **0.589**

2.7.8 Equivalent Spring Constant for Rigid Rectangular Foundation

In Vertical (Z - Direction)

$$k_z = \frac{G_s}{1 - v} * \beta_z * \sqrt{B_{found} * L_{found}} * \eta_z$$

k_z = **1821.68 X 10^3** kN/m

In Horizontal (X or Y - Direction)

$$k_x = 2 * (1 + v) * G_s * \beta_x * \sqrt{B_{found} * L_{found}} * \eta_{xy}$$

k_x = **1247.73 X 10^3** kN/m

Rotation (about Y axis)

$$k_{rx} = \frac{G_s}{1 - v} * \beta_{rx} * L_{found} * B_{found}^2 * \eta_{rx}$$

k_{rx} = **3.16 X 10^6** kN.m/rad

Rotation (about X axis)

$$k_{ry} = \frac{G_s}{1 - v} * \beta_{ry} * B_{found} * L_{found}^2 * \eta_{ry}$$

k_{ry} = **7.39 X 10^6** kN.m/rad

Yawing (about Z axis)

$$k_{rz} = \frac{16 * G_s * r_{rz}^3}{3}$$

k_{rz} = **5.24 X 10^6** kN.m/rad

2.7.9 Damping Constant for Rigid Rectangular Foundation

In Vertical (Z - Direction)

$$C_z = 2 * D_z * \sqrt{k_z * M_t}$$

C_z = **4389.97** kN/(m/s)

In Horizontal (X - Direction)

$$C_x = 2 * D_{xy} * \sqrt{k_x * M_t}$$

C_x = **2906.53** kN/(m/s)

In Horizontal (Y - Direction)

$$C_y = 2 * D_{xy} * \sqrt{k_y * M_t}$$

C_y = **2859.65** kN/(m/s)

Rotation (about Y axis)	$C_{rx} = 2 * D_{rx} * \sqrt{k_{rx} * J_y}$	C_{rx} = **3170.75** kN.m/(rad/s)
Rotation (about X axis)	$C_{ry} = 2 * D_{ry} * \sqrt{k_{ry} * J_x}$	C_{ry} = **3046** kN.m/(rad/s)
Yawing (about Z axis)	$C_{rz} = 2 * D_{rz} * \sqrt{k_{rz} * J_z}$	C_{rz} = **5252.48** kN.m/(rad/s)

2.7.10 Undamped Natural Frequencies

In Vertical (Z - Direction)	$f_z = \sqrt{\frac{k_z}{M_t}}$	f_z = **207.482** rad/s
In Horizontal (X - Direction)	$f_x = \sqrt{\frac{k_x}{M_t}}$	f_x = **171.713** rad/s
In Horizontal (Y - Direction)	$f_y = \sqrt{\frac{k_y}{M_t}}$	f_y = **168.943** rad/s
Rotation (about Y axis)	$f_{rx} = \sqrt{\frac{k_{rx} + M_t * z_c}{J_y + M_t * z_c^2}}$	f_{rx} = **173.223** rad/s
Rotation (about X axis)	$f_{ry} = \sqrt{\frac{k_{ry} + M_t * z_c}{J_x + M_t * z_c^2}}$	f_{ry} = **359.808** rad/s
Yawing (about Z axis)	$f_{rz} = \sqrt{\frac{k_{rz}}{J_z}}$	f_{rz} = **238.358** rad/s

2.7.11 Undamped Coupled Natural Frequencies

X - Direction	$\alpha_x = \frac{J_x}{J_x + W_t * z_c^2}$	α_x = **0.549**
Y - Direction	$\alpha_y = \frac{J_y}{J_y + W_t * z_c^2}$	α_y = **0.755**
Horizontal (Fx) and My	$f_{1rx} = \sqrt{\frac{f_{rx}^2 + f_x^2 + \sqrt{(f_{rx}^2 + f_x^2)^2 - 4 * \alpha_y * f_{rx}^2 * f_x^2}}{2 * \alpha_y}}$	f_{1rx} = **242.593** rad/s
	$f_{2rx} = \sqrt{\frac{f_{rx}^2 + f_x^2 - \sqrt{(f_{rx}^2 + f_x^2)^2 - 4 * \alpha_y * f_{rx}^2 * f_x^2}}{2 * \alpha_y}}$	f_{2rx} = **141.07** rad/s
Horizontal (Fy) and Mx	$f_{1ry} = \sqrt{\frac{f_{ry}^2 + f_y^2 + \sqrt{(f_{ry}^2 + f_y^2)^2 - 4 * \alpha_x * f_{ry}^2 * f_y^2}}{2 * \alpha_x}}$	f_{1ry} = **511.912** rad/s
	$f_{2ry} = \sqrt{\frac{f_{ry}^2 + f_y^2 - \sqrt{(f_{ry}^2 + f_y^2)^2 - 4 * \alpha_x * f_{ry}^2 * f_y^2}}{2 * \alpha_x}}$	f_{2ry} = **160.242** rad/s

2.7.12 Resonance - Machine Speed vs Natural Frequency

✻ Resonance check for Speed - **1000 RPM**

- Undamped Uncoupled Modes

Vertical Mode	F_z	= **1.98**
Horizontal Mode (X Dir.)	F_x	= **1.64**
Horizontal Mode (Y Dir.)	F_y	= **1.61**
Twisting / Yawing	M_z	= **2.28**
Rocking or Pitching	M_x	= **1.65**
Rocking or Pitching	M_y	= **3.44**
Allowable Frequency Ratio		**0.8 - 1.2**

- Undamped Coupled Modes

Horizontal (Fx) and My - F1rx	F_{1rx}	= **2.32**
Horizontal (Fx) and My - F2rx	F_{2rx}	= **1.35**
Horizontal (Fy) and Mx - F1ry	F_{1ry}	= **4.89**
Horizontal (Fy) and Mx - F2ry	F_{2ry}	= **1.53**
Allowable Frequency Ratio		**0.8 - 1.2**

✻ Resonance check for Speed - **750 RPM**

- Undamped Uncoupled Modes

Vertical Mode	F_z	= **2.64**
Horizontal Mode (X Dir.)	F_x	= **2.19**
Horizontal Mode (Y Dir.)	F_y	= **2.15**
Twisting / Yawing	M_z	= **3.03**
Rocking or Pitching	M_x	= **2.21**
Rocking or Pitching	M_y	= **4.58**
Allowable Frequency Ratio		**0.8 - 1.2**

- Undamped Coupled Modes

Horizontal (Fx) and My - F1rx	F_{1rx}	= **3.09**
Horizontal (Fx) and My - F2rx	F_{2rx}	= **1.8**
Horizontal (Fy) and Mx - F1ry	F_{1ry}	= **6.52**
Horizontal (Fy) and Mx - F2ry	F_{2ry}	= **2.04**
Allowable Frequency Ratio		**0.8 - 1.2**

✻ Resonance check for Speed - **1500 RPM**

- Undamped Uncoupled Modes

Vertical Mode	F_z	= **1.32**
Horizontal Mode (X Dir.)	F_x	= **1.09**
Horizontal Mode (Y Dir.)	F_y	= **1.08**
Twisting / Yawing	M_z	= **1.52**
Rocking or Pitching	M_x	= **1.1**
Rocking or Pitching	M_y	= **2.29**
Allowable Frequency Ratio		**0.8 - 1.2**

- Undamped Coupled Modes

Horizontal (Fx) and My - F1rx	F_{1rx}	= **1.54**
Horizontal (Fx) and My - F2rx	F_{2rx}	= **0.9**
Horizontal (Fy) and Mx - F1ry	F_{1ry}	= **3.26**
Horizontal (Fy) and Mx - F2ry	F_{2ry}	= **1.02**
Allowable Frequency Ratio		**0.8 - 1.2**

✻ Resonance check for Speed - **500 RPM**

- Undamped Uncoupled Modes

Vertical Mode	F_z	= **3.96**
Horizontal Mode (X Dir.)	F_x	= **3.28**
Horizontal Mode (Y Dir.)	F_y	= **3.23**
Twisting / Yawing	M_z	= **4.55**

Rocking or Pitching M_x = **3.31**

Rocking or Pitching M_y = **6.87**

Allowable Frequency Ratio **0.8 - 1.2**

- Undamped Coupled Modes

Horizontal (Fx) and My - F1rx F_{1rx} = **4.63**

Horizontal (Fx) and My - F2rx F_{2rx} = **2.69**

Horizontal (Fy) and Mx - F1ry F_{1ry} = **9.78**

Horizontal (Fy) and Mx - F2ry F_{2ry} = **3.06**

Allowable Frequency Ratio **0.8 - 1.2**

2.8 Time History Analysis

2.8.1 Time History Analysis - Load Groups

	Loading Point	Forces (kN)			Moments (kN.m)			Machine Speed (RPM) Phase Angle (deg)
		Fx	Fy	Fz	Mx	My	Mz	
DL1	DP1	20	15	-10	16	20	-28	MN1-1000-0

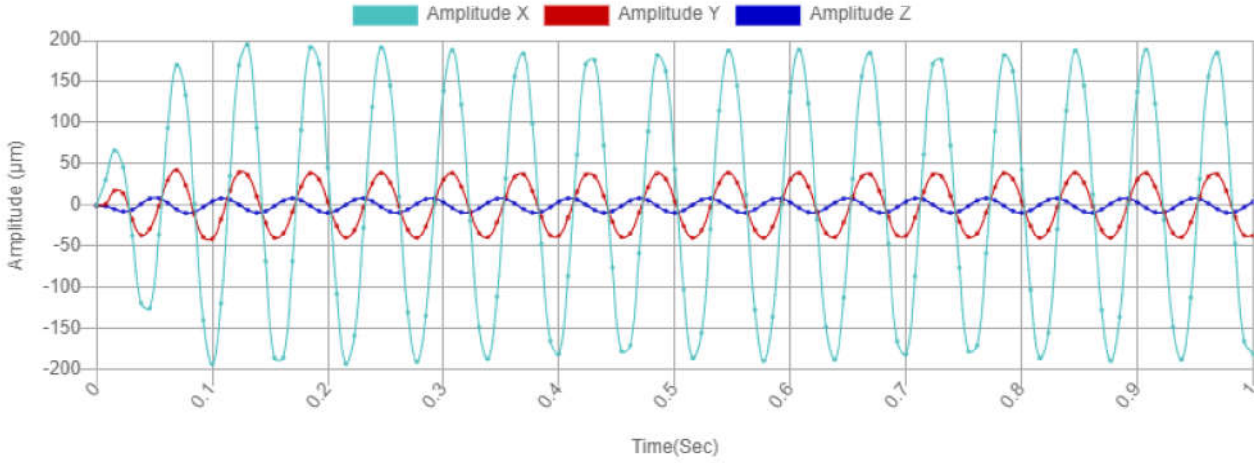
2.8.2 Calculation of Amplitude and Velocity

	Amplitude - Zero to peak (µm)				Velocity (mm/s)			
	X	Y	Z	Resultant	X	Y	Z	Resultant
Point -1	194.977	42.624	8.941	198.473	21.115	4.608	0.999	21.517
Point -2	106.093	37.222	8.941	109.106	11.391	4.009	0.999	11.757
Point -3	80.372	29.685	8.941	84.666	8.651	3.265	0.999	9.145

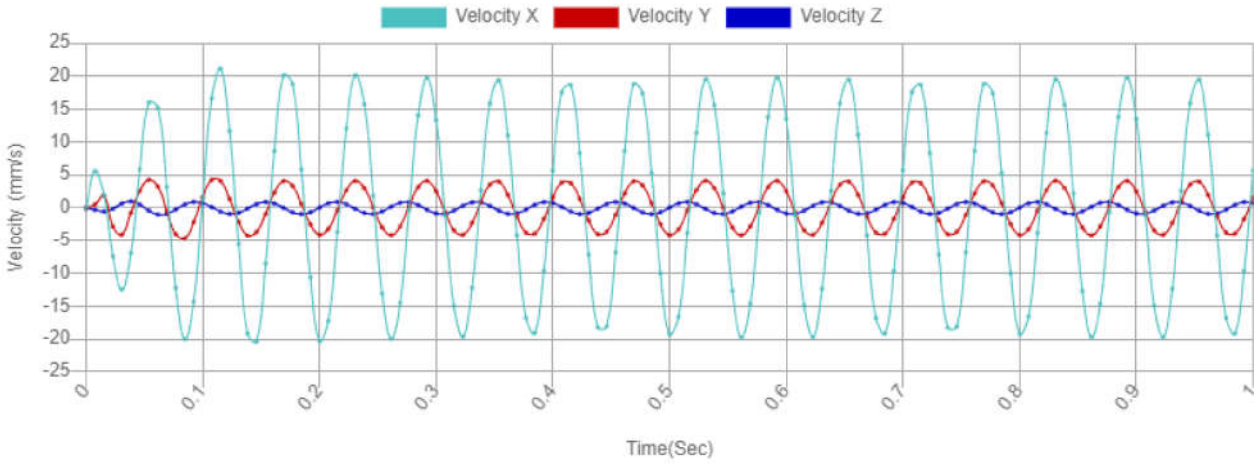
2.9 Graphs showing Total Amplitude and Velocity

(Graphs drawn for the Critical Load Group)

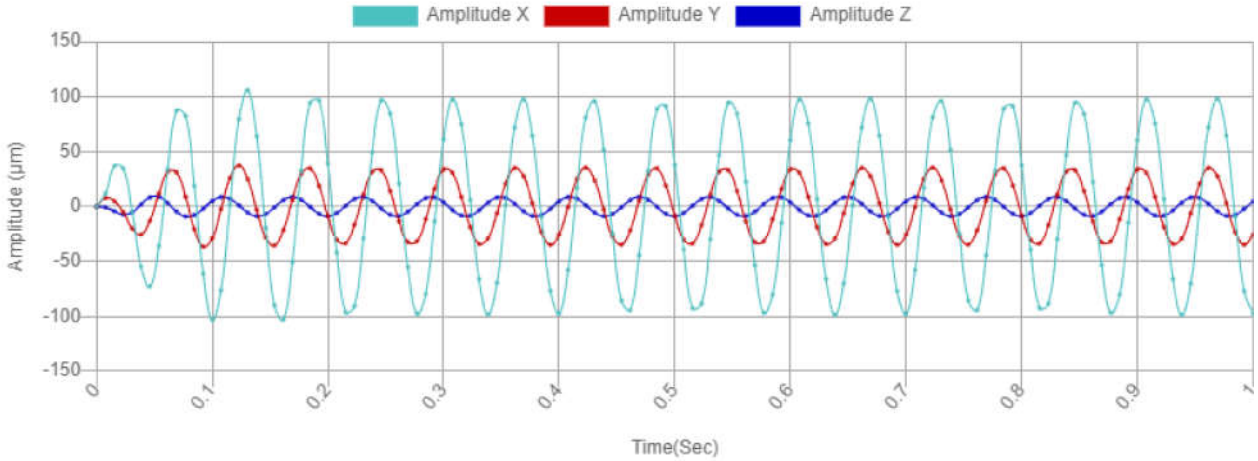
◯ Point 1 - Amplitude (Group 1)



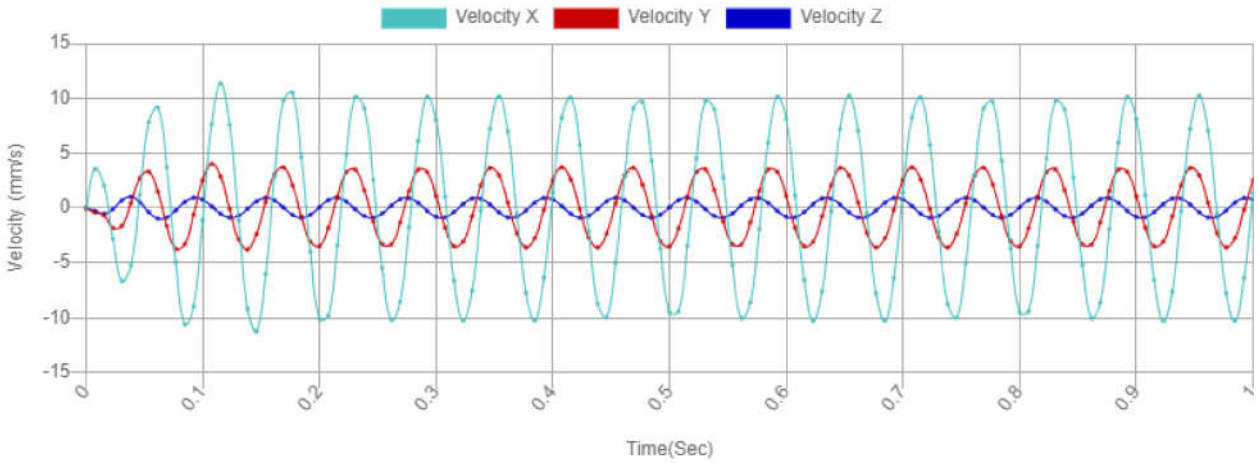
◯ Point 1 - Velocity (Group 1)



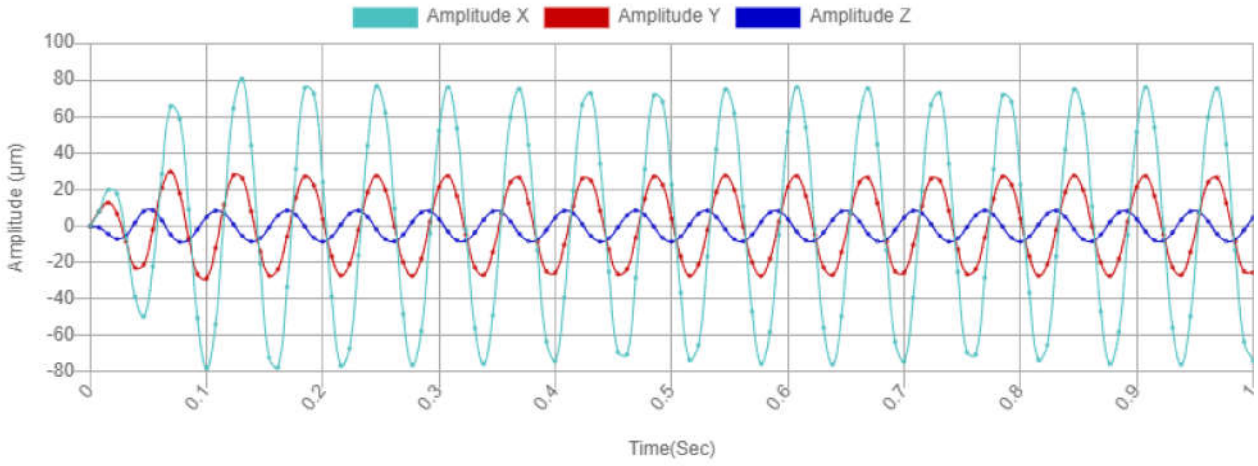
◯ Point 2 - Amplitude (Group 1)



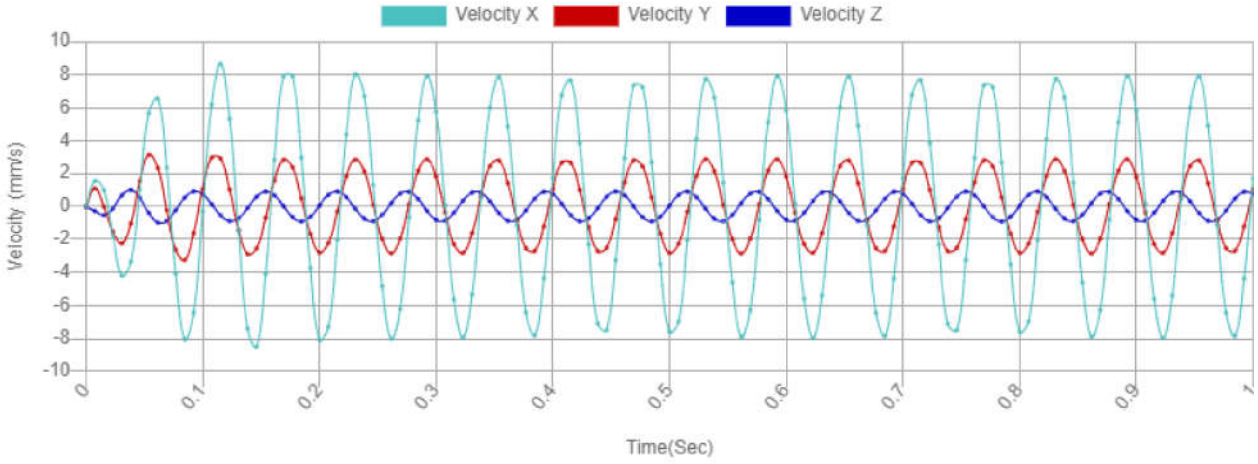
◯ Point 2 - Velocity (Group 1)



◯ Point 3 - Amplitude (Group 1)



◯ Point 3 - Velocity (Group 1)



2.10 Static Analysis

2.10.1 Dynamic Load Groups

Dynamic load groups are generated for orthogonal phases (0°, 90°, 180°, and 270°) with combinations of one or more rotating machines.

	Loading Point	Forces (kN)			Moments (kN.m)			Machine Speed (RPM) - Phase Angle (deg)
		Fx	Fy	Fz	Mx	My	Mz	
== Group 1								
DL1	DP1	0	0	-10	16	0	-28	MN1-1000-0
== Group 2								
DL1	DP1	20	15	0	0	20	0	MN1-1000-90
== Group 3								
DL1	DP1	0	0	10	-16	0	28	MN1-1000-180
== Group 4								
DL1	DP1	-20	-15	0	0	-20	0	MN1-1000-270

2.10.2 Transmissibility Factors

Machine Speed in radians / s $S_{rs} = \frac{2 * \pi * Speed}{60}$ rad / s

Ratio of Machine Speed to Natural Frequencies $r_x = \frac{S_{rs}}{f_x},\ r_y = \frac{S_{rs}}{f_y},\ r_z = \frac{S_{rs}}{f_z},\ r_{rx} = \frac{S_{rs}}{f_{rx}},\ r_{ry} = \frac{S_{rs}}{f_{ry}},\ r_{rz} = \frac{S_{rs}}{f_{rz}}$

Transmissibility factors in X, Y and Z

Force

$$F_x = \frac{\sqrt{1 + (2 * D_{xy} * r_x)^2}}{\sqrt{(1 - r_x^2)^2 + (2 * D_{xy} * r_x)^2}}$$

$$F_y = \frac{\sqrt{1 + (2 * D_{xy} * r_y)^2}}{\sqrt{(1 - r_y^2)^2 + (2 * D_{xy} * r_y)^2}}$$

$$F_z = \frac{\sqrt{1 + (2 * D_z * r_z)^2}}{\sqrt{(1 - r_z^2)^2 + (2 * D_z * r_z)^2}}$$

Moment

$$M_x = \frac{\sqrt{1 + (2 * D_{ry} * r_{rx})^2}}{\sqrt{(1 - r_{rx}^2)^2 + (2 * D_{ry} * r_{rx})^2}}$$

$$M_y = \frac{\sqrt{1 + (2 * D_{rx} * r_{ry})^2}}{\sqrt{(1 - r_{ry}^2)^2 + (2 * D_{rx} * r_{ry})^2}}$$

$$M_z = \frac{\sqrt{1 + (2 * D_{rz} * r_{rz})^2}}{\sqrt{(1 - r_{rz}^2)^2 + (2 * D_{rz} * r_{rz})^2}}$$

Speed (RPM)	Transmissibility Factor					
	Fx	Fy	Fz	Mx	My	Mz
1000	1.53	1.55	1.31	1.09	1.56	1.24
750	1.25	1.26	1.16	1.05	1.26	1.12
1500	2.66	2.7	1.87	1.23	4	1.72
500	1.1	1.1	1.07	1.02	1.1	1.05

2.10.3 Transmitted Dynamic Loads to Foundation

	Force (kN)			Moment (kN.m)		
	Fx	Fy	Fz	Mx	My	Mz
Group 1	0	0	-13.1	27.3	16.4	-34.6
Group 2	30.6	23.3	0	-34.9	77	52
Group 3	0	0	13.1	-27.3	-16.4	34.6
Group 4	-30.6	-23.3	0	34.9	-77	-52

2.10.4 Total Foundation Loads

Soil Overburden Weight = **0** kN

Buoyancy due to ground water table = **77.23** kN

SLS combination loads due to Non - Dynamic load cases + dynamic load case groups:

Load Comb	Force (kN)			Moment (kN.m)		
	Fx	Fy	Fz	Mx	My	Mz
SLS 1	0.00	16.50	415.00	-17.25	9.30	-29.38
SLS 2	9.00	12.00	401.50	-4.88	25.28	-19.25
SLS 3 - 1	13.50	7.50	379.39	40.43	49.76	-83.10
SLS 3 - 2	44.05	30.78	392.50	-21.80	110.39	3.52
SLS 3 - 3	13.50	7.50	405.61	-14.18	16.99	-13.90
SLS 3 - 4	-17.05	-15.78	392.50	48.05	-43.64	-100.52
SLS 4	0.00	17.50	415.00	-18.75	9.50	-30.62
SLS 5	10.00	12.50	400.00	-5.00	27.25	-19.38
SLS 6 - 1	15.00	7.50	378.20	39.58	51.00	-83.01
SLS 6 - 2	42.50	28.45	390.00	-16.43	105.57	-5.06
SLS 6 - 3	15.00	7.50	401.80	-9.58	21.50	-20.74
SLS 6 - 4	-12.50	-13.45	390.00	46.43	-33.07	-98.69

2.10.5 Check for Soil Bearing Capacity

Comb.	Fz (kN)	Mx (kN.m)	My (kN.m)	Pmax (kN/m²)	Pmin (kN/m²)	Pallow (kN/m²)
SLS 1	415	-17.25	9.3	41.67	25.24	171.6
SLS 2	401.5	-4.88	25.28	39.72	24.79	186.6
SLS 3 - 1	379.39	40.43	49.76	48.25	12.34	171.6
SLS 3 - 2	392.5	-21.8	110.39	52.62	10.29	171.6
SLS 3 - 3	405.61	-14.18	16.99	41.09	24.15	171.6
SLS 3 - 4	392.5	48.05	-43.64	50.31	12.6	171.6
SLS 4	415	-18.75	9.5	42.01	24.9	171.6
SLS 5	400	-5	27.25	39.85	24.39	171.6
SLS 6 - 1	378.2	39.58	51	48.1	12.27	171.6
SLS 6 - 2	390	-16.43	105.57	50.68	11.79	171.6
SLS 6 - 3	401.8	-9.58	21.5	40.31	24.26	171.6
SLS 6 - 4	390	46.43	-33.07	48.49	13.98	171.6

2.10.6 Check for Sliding

Comb.	Resistance (kN)	Resultant shear (kN)	F.O.S. Sliding	
			Actual	Allowable
SLS 1	118.22	16.5	7.16	1.5
SLS 2	113.49	15	7.57	1.5
SLS 3 - 1	105.76	15.44	6.85	1.5
SLS 3 - 2	110.34	53.74	2.05	1.5
SLS 3 - 3	114.93	15.44	7.44	1.5
SLS 3 - 4	110.34	23.23	4.75	1.5
SLS 4	118.22	17.5	6.76	1.5
SLS 5	112.97	16.01	7.06	1.5
SLS 6 - 1	105.34	16.77	6.28	1.5
SLS 6 - 2	109.47	51.14	2.14	1.5
SLS 6 - 3	113.6	16.77	6.77	1.5
SLS 6 - 4	109.47	18.36	5.96	1.5

2.10.7 Check for Overturning

Comb.	Resisting (kN.m)		Overturning (kN.m)		F.O.S. Overturning		
	Moment X	Moment Y	Moment X	Moment Y	Actual X	Actual Y	Allowable
SLS 1	414.7	752.5	9.8	1.8	42.53	100	1.5
SLS 2	416.2	718.7	6	14.4	69.37	49.91	1.5
SLS 3 - 1	381	650.4	43.7	20.2	8.71	32.12	1.5
SLS 3 - 2	381	696.2	8.7	97.3	43.94	7.16	1.5
SLS 3 - 3	433.4	742.1	8.8	20.2	49.39	36.65	1.5
SLS 3 - 4	407.2	722.5	61.2	56.8	6.66	12.73	1.5
SLS 4	414.7	752.5	11.2	2	36.86	100	1.5
SLS 5	414.7	715	6.2	16	66.35	44.69	1.5
SLS 6 - 1	381.1	648.7	44.5	22.5	8.57	28.83	1.5
SLS 6 - 2	377.2	690	2.7	91.8	100	7.51	1.5
SLS 6 - 3	428.3	731.3	13	22.5	32.89	32.5	1.5
SLS 6 - 4	404.7	717.5	60.2	46.8	6.73	15.33	1.5

3.0 SUMMARY

3.1 Preliminary Checks

Condition	Actual	Allowable	Status
Hor. Eccentricity X (%)	0.40	≤ 5.00	Pass
Hor. Eccentricity Y (%)	0.72	≤ 5.00	Pass
Mass Ratio	40.50	≥ 3.00	Pass

3.2 Stability Checks (SLS)

Condition	Combination	Actual	Allowable	Status
F.O.S. Overturning X	SLS 3 - 4	6.657	1.500	Pass
F.O.S. Overturning Y	SLS 3 - 2	7.158	1.500	Pass
Resultant Sliding	SLS 1 - 1	7.165	1.500	Pass
Max. Bearing Pr. (kN/m²)	SLS 3 - 2	52.62	171.60	Pass
Min. Bearing Pr. (kN/m²)	SLS 3 - 2	10.29	0.00	Pass

3.3 Resonance check

Mode	Foundation Natural Freq. (RPM)	Nearest Machine Speed	Actual Freq. Ratio	Status
• Undamped Uncoupled Frequency				
Horizontal Mode (Fx)	1640	1500	1.09	Fail
Horizontal Mode (Fy)	1613	1500	1.08	Fail
Vertical Mode (Fz)	1981	1500	1.32	Pass
Rocking or Pitching (Mx)	1654	1500	1.1	Fail
Rocking or Pitching (My)	3436	1500	2.29	Pass
Twisting / Yawing (Mz)	2276	1500	1.52	Pass
• Undamped Coupled Frequency				
Horizontal (Fx) and My - F1rx	2317	1500	1.54	Pass
Horizontal (Fx) and My - F2rx	1347	1500	0.9	Fail
Horizontal (Fy) and Mx - F1ry	4888	1500	3.26	Pass
Horizontal (Fy) and Mx - F2ry	1530	1500	1.02	Fail

3.4 Amplitude Checks

Point	Amplitude - Zero to Peak (µm)				Allowable Amplitude (µm)	Status
	Actual X	Actual Y	Actual Z	Resultant		
AP1	194.977	42.624	8.941	198.473	20.000	Fail
AP2	106.093	37.222	8.941	109.106	20.000	Fail
AP3	80.372	29.685	8.941	84.666	20.000	Fail

3.5 Velocity Checks

Point	Velocity (mm/s)				Allowable Velocity (mm/s)	Status
	Actual X	Actual Y	Actual Z	Resultant		
AP1	21.115	4.608	0.999	21.517	2.000	Fail
AP2	11.391	4.009	0.999	11.757	2.000	Fail

3.5 Velocity Checks

Point	Velocity (mm/s)				Allowable Velocity (mm/s)	Status
	Actual X	Actual Y	Actual Z	Resultant		
AP3	8.651	3.265	0.999	9.145	2.000	Fail