Chapter 2

Data Presentation

Presentation Formats

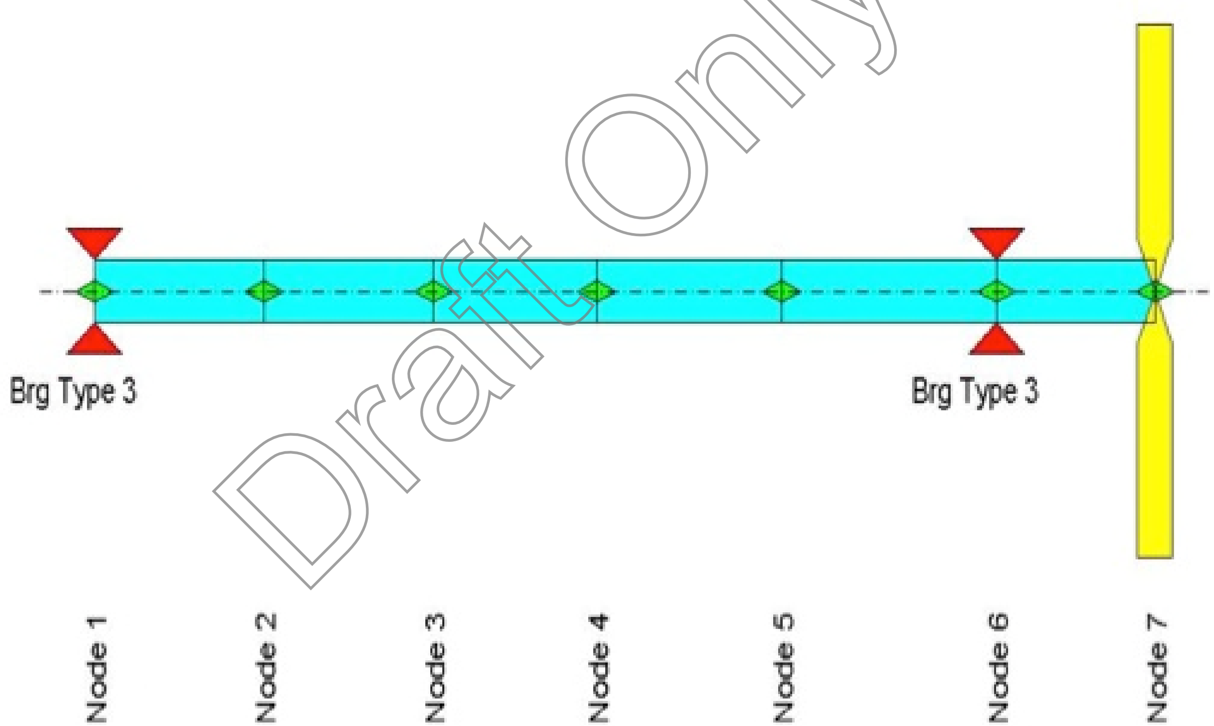
$$\mathbf{Kx} + \mathbf{C}\dot{\mathbf{x}} + +\mathbf{G}\boldsymbol{\Omega}\dot{\mathbf{x}} + \mathbf{M}\ddot{\mathbf{x}} = \mathbf{F}\left(t\right)$$

This may be converted to frequency domain

$$X_k = \sum_{(r=0)}^{(n-1)} x_r e^{(j2\ \ kr/n)} \qquad k = 0,1,2,\ldots\ldots..,n-1$$

$$x_r = \frac{1}{n}\sum_{k}^{n-1} X_k e^{j2\pi kr/n} \qquad r = 0,1,2,\ldots\ldots.,n-1$$

A Fourier pair


Brg Type 3
Brg Type 3
Node 1
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7

Fast Fourier Transform

$$x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(\omega)e^{j\omega t}\,d\omega$$

$$X(\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}\,dt$$

This reduces the number of summations required to $^{n}/_{2}\, log_2 n$.

Variations influencing machines

ambient temperature
water level in the condenser
steam temperature
Steam pressure
variations in power supplied
variations in reactive power
rotor and stator cooling operation
rotor current settings

Analyzing the plot

- To resolve these issues consider the set of data points . The first step is take averages and use these to calculate the variance matrix as

$$\mathbf{A} = \frac{1}{N}\begin{bmatrix} \sum_{i=1}^{i=N}\left(x_i - \bar{x}\right)\left(x_i - \bar{x}\right) & \sum_{i=1}^{i=N}\left(y_i - \bar{y}\right)\left(x_i - \bar{x}\right) \\ \sum_{i=1}^{i=N}\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right) & \sum_{i=1}^{i=N}\left(y_i - \bar{y}\right)\left(y_i - \bar{y}\right) \end{bmatrix}$$

$$\mathbf{A}\Phi = \Lambda\Phi$$

$$\begin{Bmatrix} X_i \\ Y_i \end{Bmatrix} = [\Phi] \begin{Bmatrix} x_i - \bar{x} \\ y_i - \bar{y} \end{Bmatrix}$$

$$\sigma_x^2 = \sum_{i=1}^{i=N} \frac{X_i^2}{N} \qquad \sigma_y^2 = \sum_{i=1}^{i=N} \frac{Y_i^2}{N}$$

Transient Analysis

$$\Delta f = \frac{1}{T}$$

$$\Omega = \Omega_0 e^{-\alpha t}$$

$$\frac{d\Omega}{dt} = -\alpha\Omega$$

In this context it is rather more meaningful to express the sampling interval in terms of the numbers of shaft rotations, *N*, then the decrease in speed during this interval is given by

Optimum Resolution

$$\Delta\Omega \approx -\alpha\Omega T = -\alpha\Omega\frac{2\pi N}{\Omega} = -2\pi\alpha N$$

$$\Delta f = \frac{1}{T} = \frac{\Omega}{2\pi N}$$

$$\Delta f_1 = \frac{\Delta\Omega}{2\pi} = -\alpha N = \Delta f_2 = \frac{\Omega}{2\pi N}$$

$$\therefore N = \sqrt{\frac{\Omega}{2\pi\alpha}}$$

$$\Delta f = \sqrt{\frac{\alpha\Omega}{2\pi}}$$

Rundown Frequency Resolution

Time (secs)		*N* (revs)	(Hz)
10	0.23	15	3.4
50	0.046	33	1.5
100	0.023	47	1.1
500	0.0046	104	0.48
1000	0.0023	147	0.34

System Response

$$c(t) = 1 = \frac{1}{\beta} e^{-\zeta \omega_n t} \sin(\omega_n \beta t + \theta)$$

$$\beta = \sqrt{1 - \zeta^2}$$

$$\theta = \tan^{-1}(\beta / \zeta)$$

ζ is the damping ratio (i.e. the fraction of critical damping).

System Response(2)

$$m\ddot{y} + c\dot{y} + ky = me\omega^2 \cos \omega t$$

$$\ddot{y} + 2\zeta\omega_n \dot{y} + \omega_n^2 y = e\omega^2 \cos \omega t$$

$$y = \frac{me\omega^2 \cos \omega t}{\sqrt{\left(\omega_n^2 - \omega^2\right)^2 + 4\zeta^2\omega^2\omega_n^2}} + e^{-\zeta\omega_n t}\left(A \sin \omega_d t + B \cos \omega_d t\right)$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2}$$

System Response(3)

If we consider now the time required for the response to be within 1% of the steady state value then

$$\zeta\omega_n t = 2\pi\zeta m = \log_e(100)$$

In general

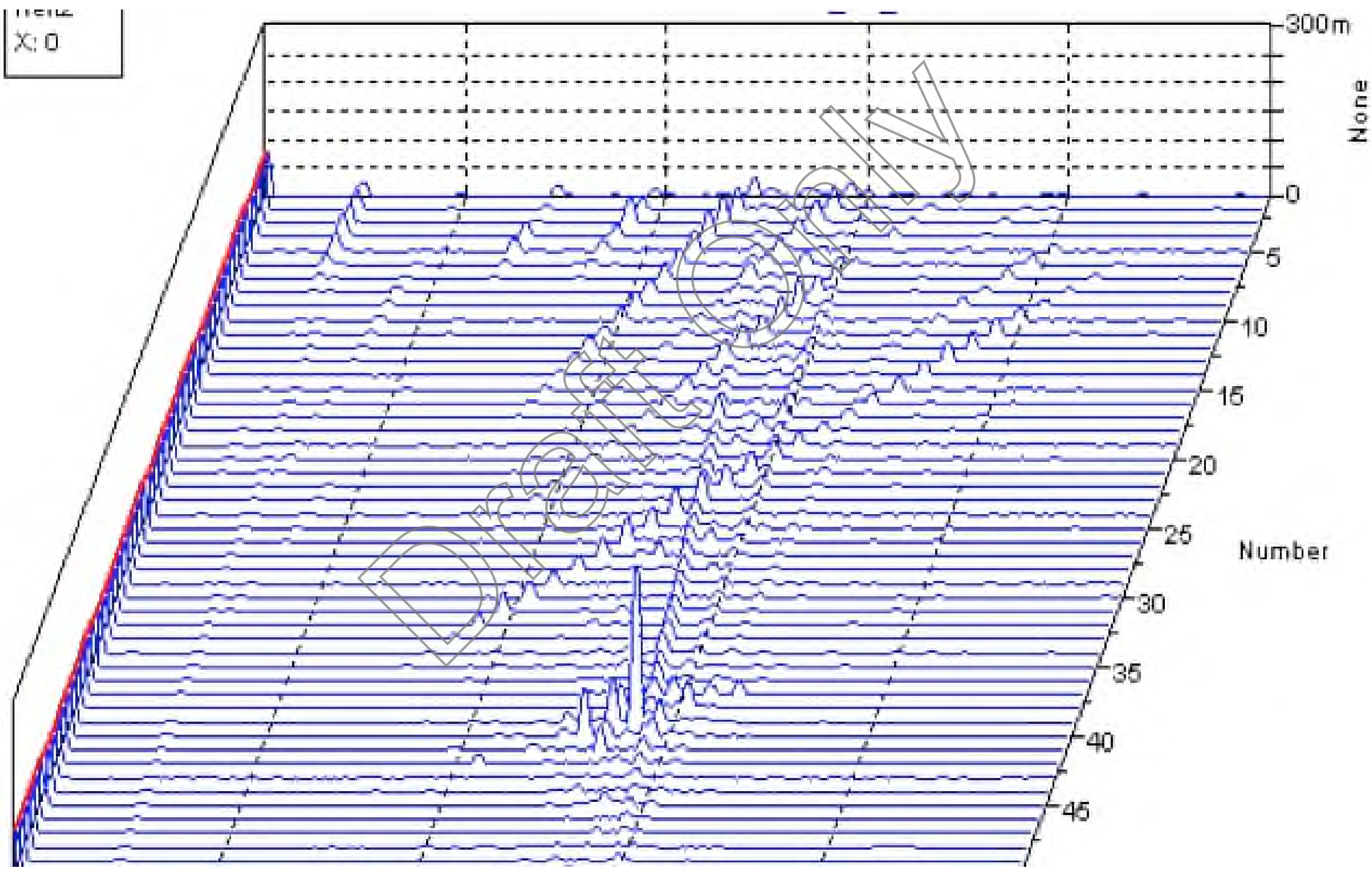
$$h(t-\tau) = \frac{e^{-\zeta\omega_n(t-\tau)}}{m\omega_d}\sin\omega_d(t-\tau) \qquad \text{for } t > \tau$$

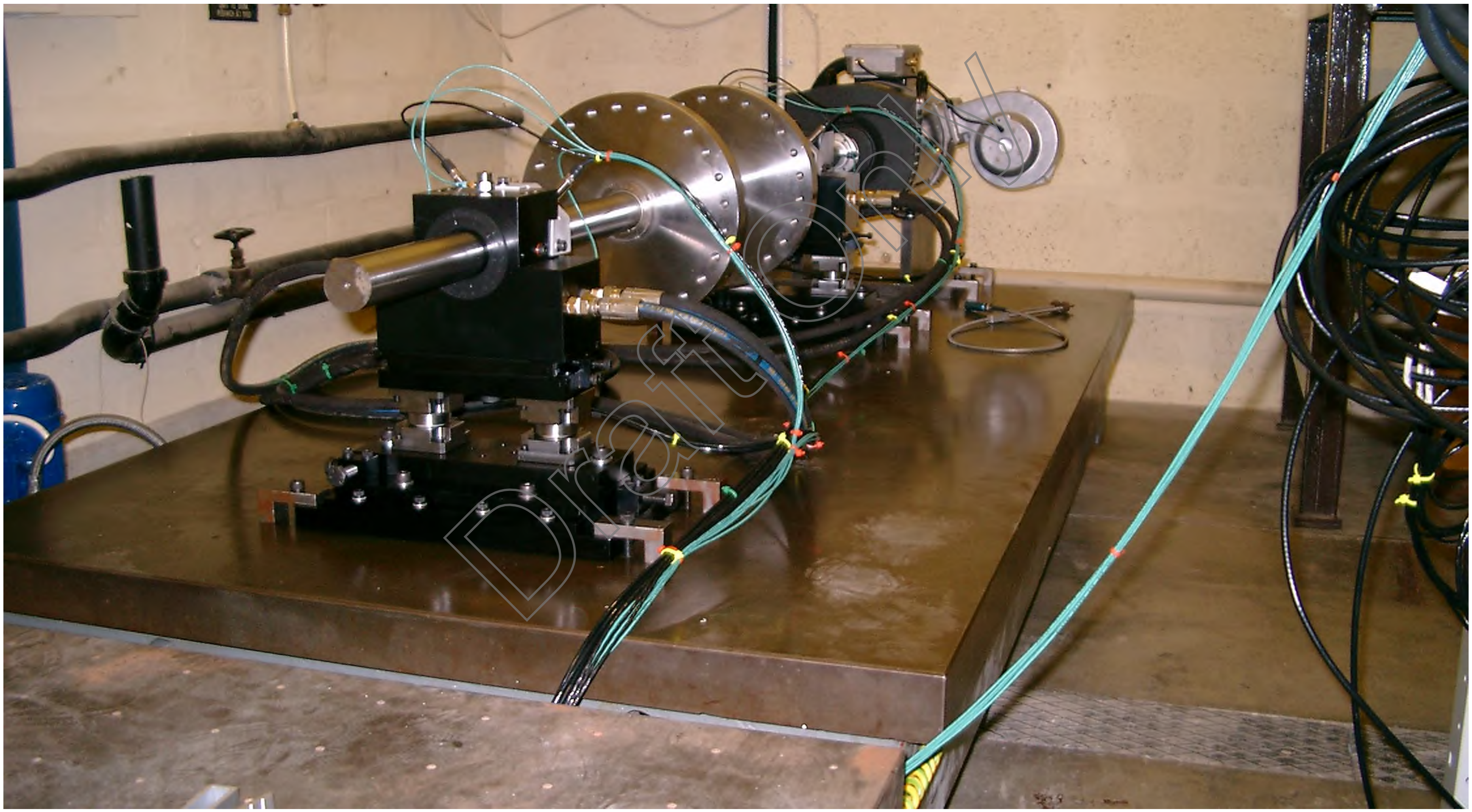
General Response

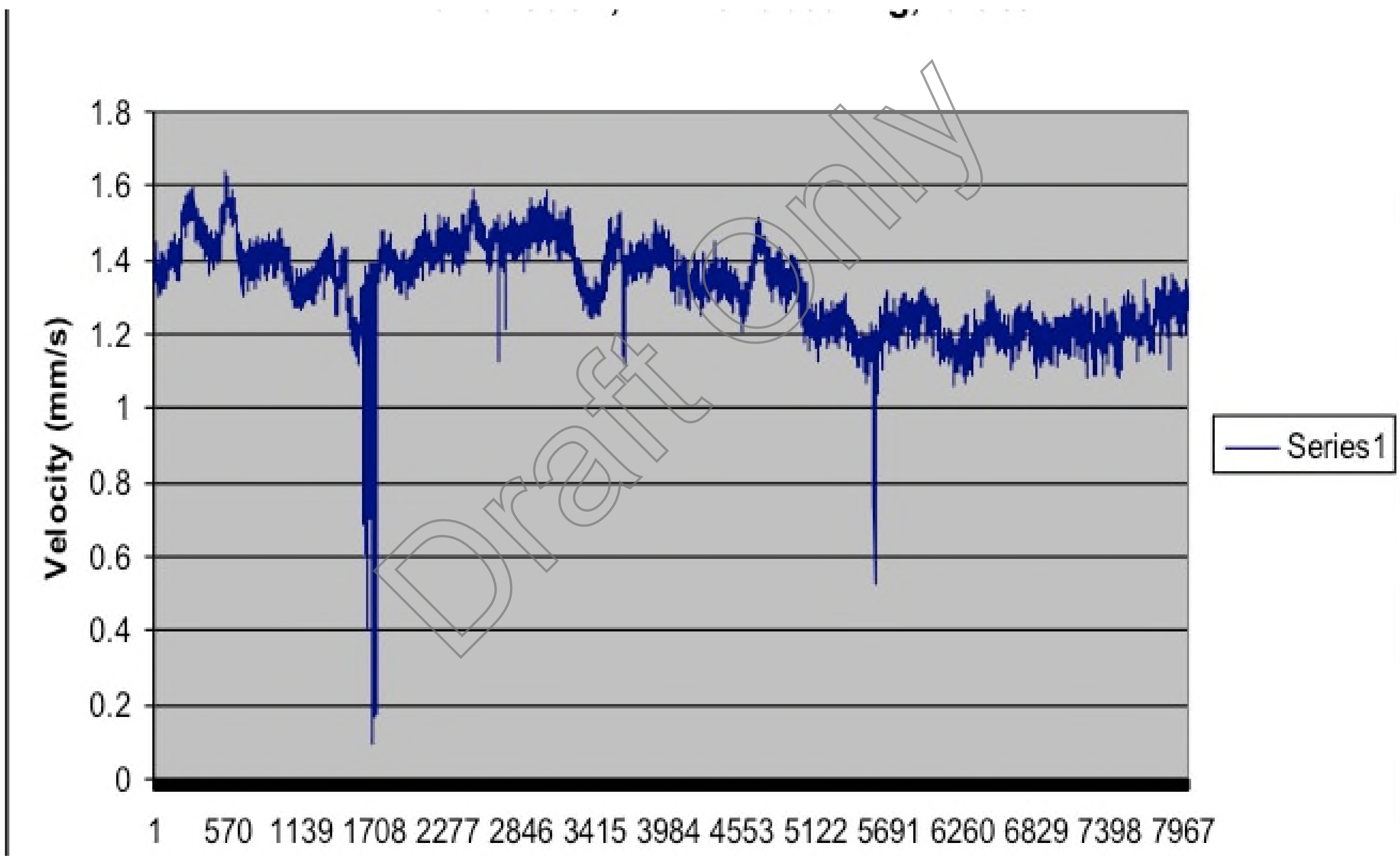
The displacement of the rotor may be written as

$$y(t) = \int_0^t h(t-\tau)\left[e\omega^2 \cos\omega\tau + e\frac{d\omega}{dt}\sin\omega\tau \right] d\tau$$

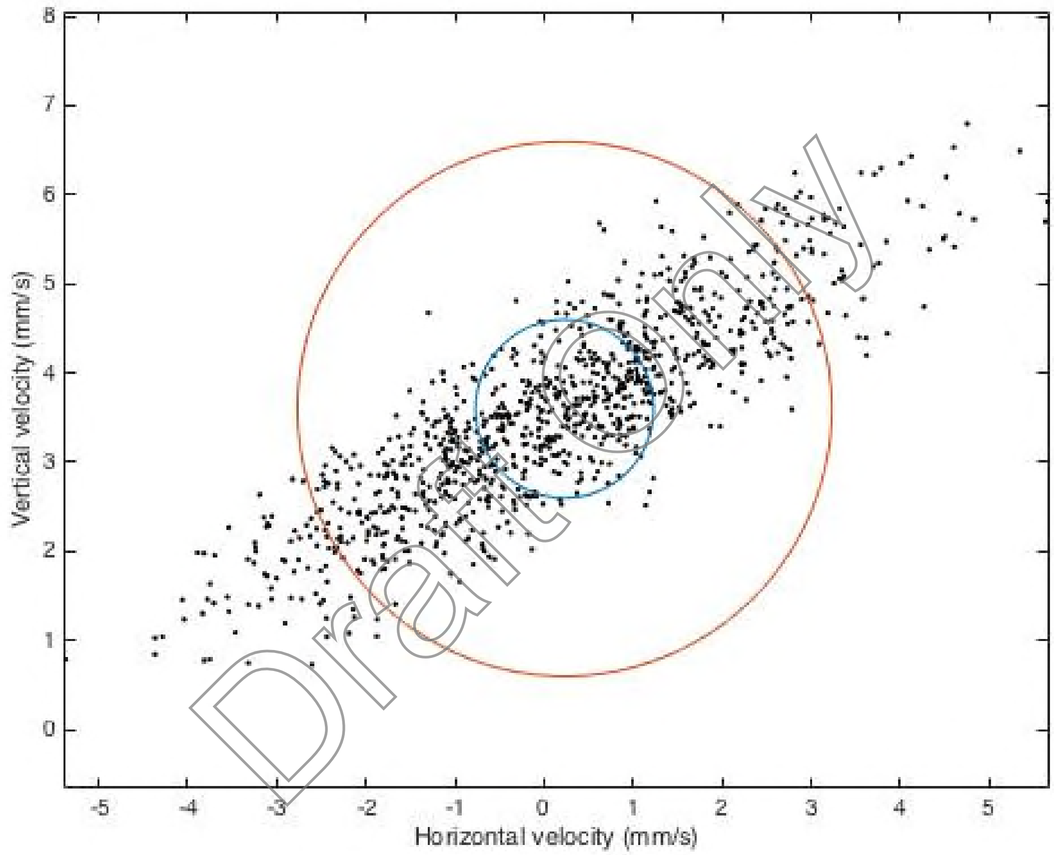
Using the convolution theorem, the Fourier Transform of this equation can be readily formed. Knowing the Fourier Transforms *Y* and *F*, the function *H* is readily calculated.


X: 0
300m
None
0
5
10
15
20
25
30
35
40
45
Number

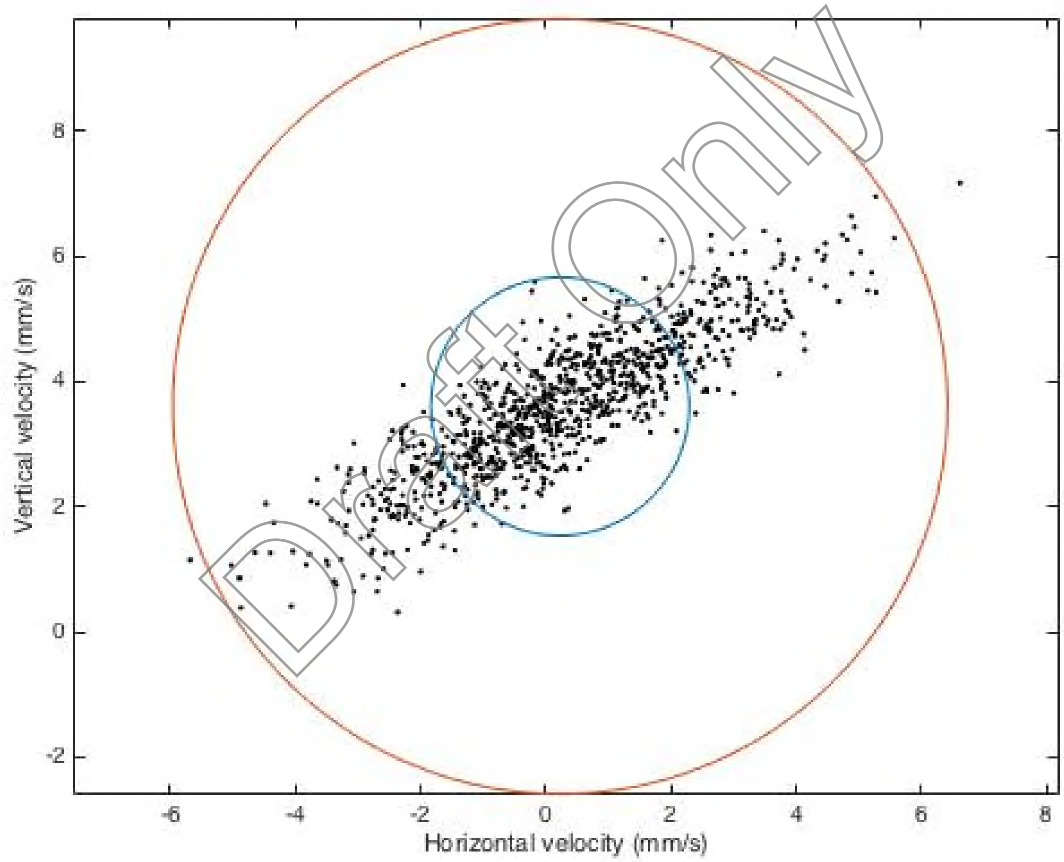



Velocity (mm/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 570 1139 1708 2277 2846 3415 3984 4553 5122 5691 6260 6829 7398 7967
Series1

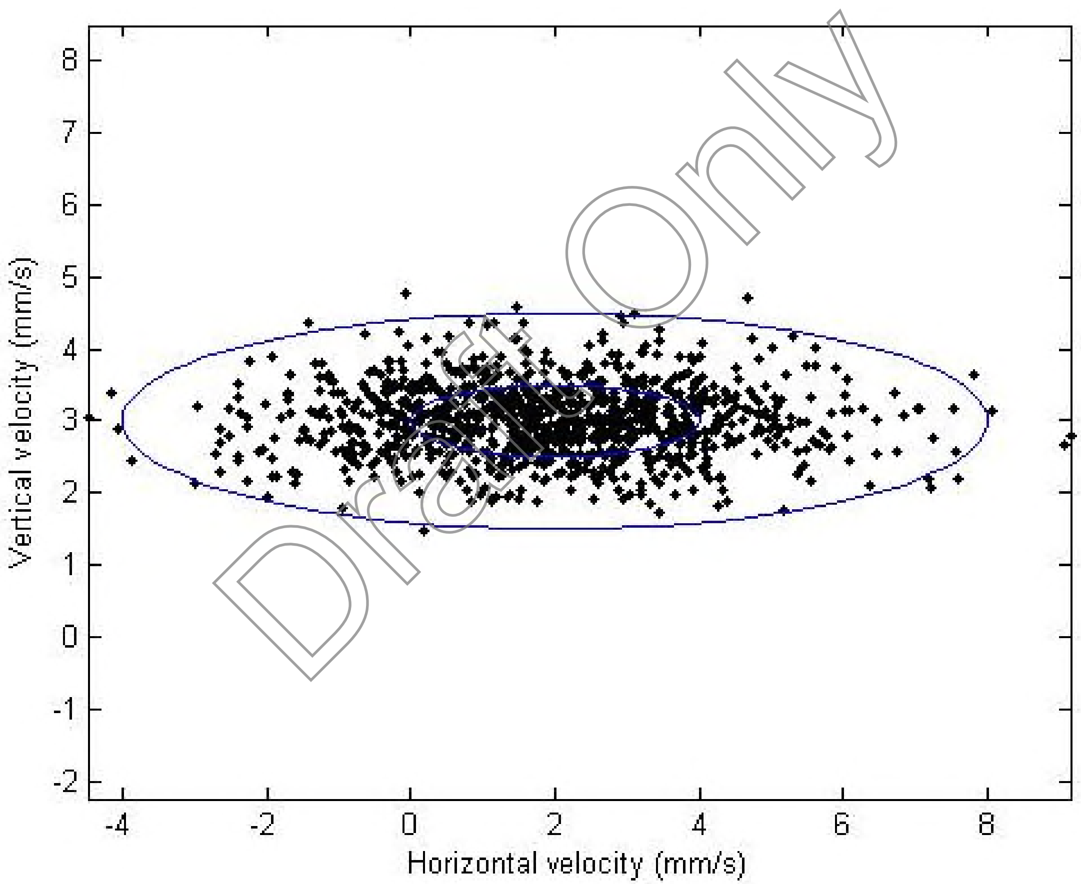
Typical Carpet Plot

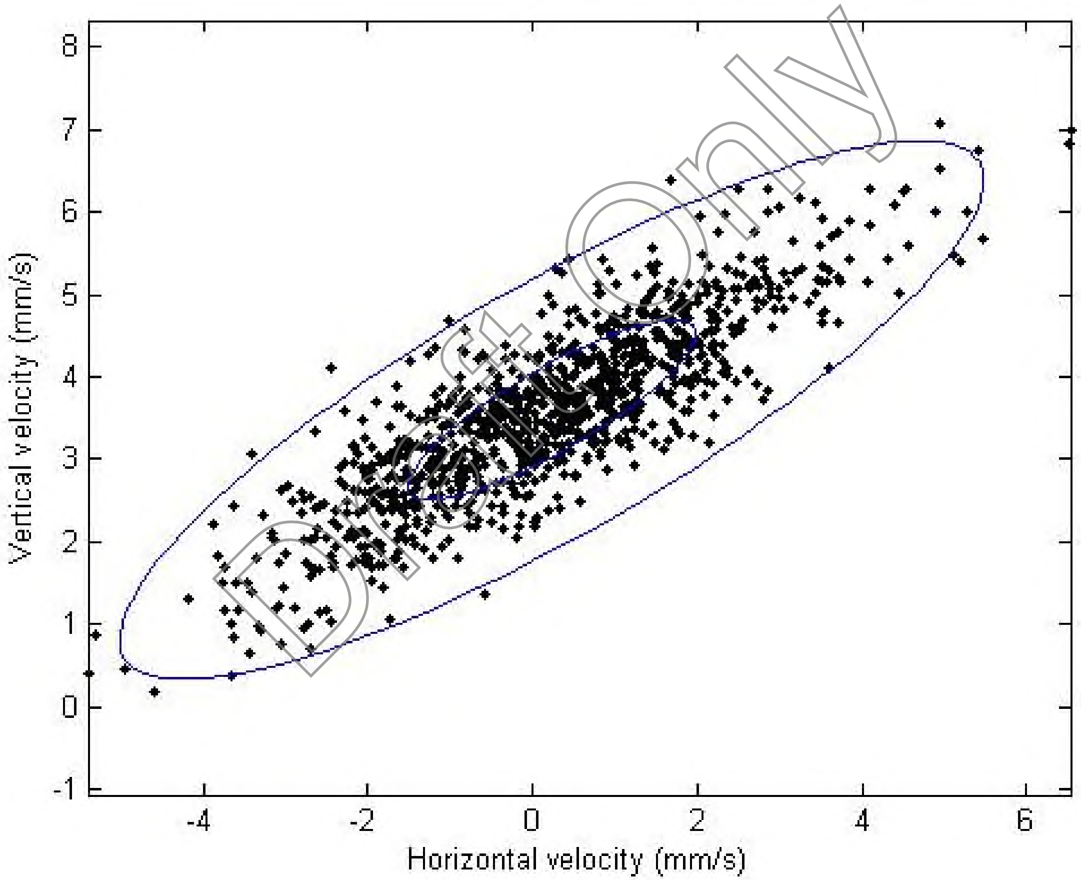


Vertical velocity (mm/s)
Horizontal velocity (mm/s)
8
7
6
5
4
3
2
1
0
-5
-4
-3
-2
-1
0
1
2
3
4
5

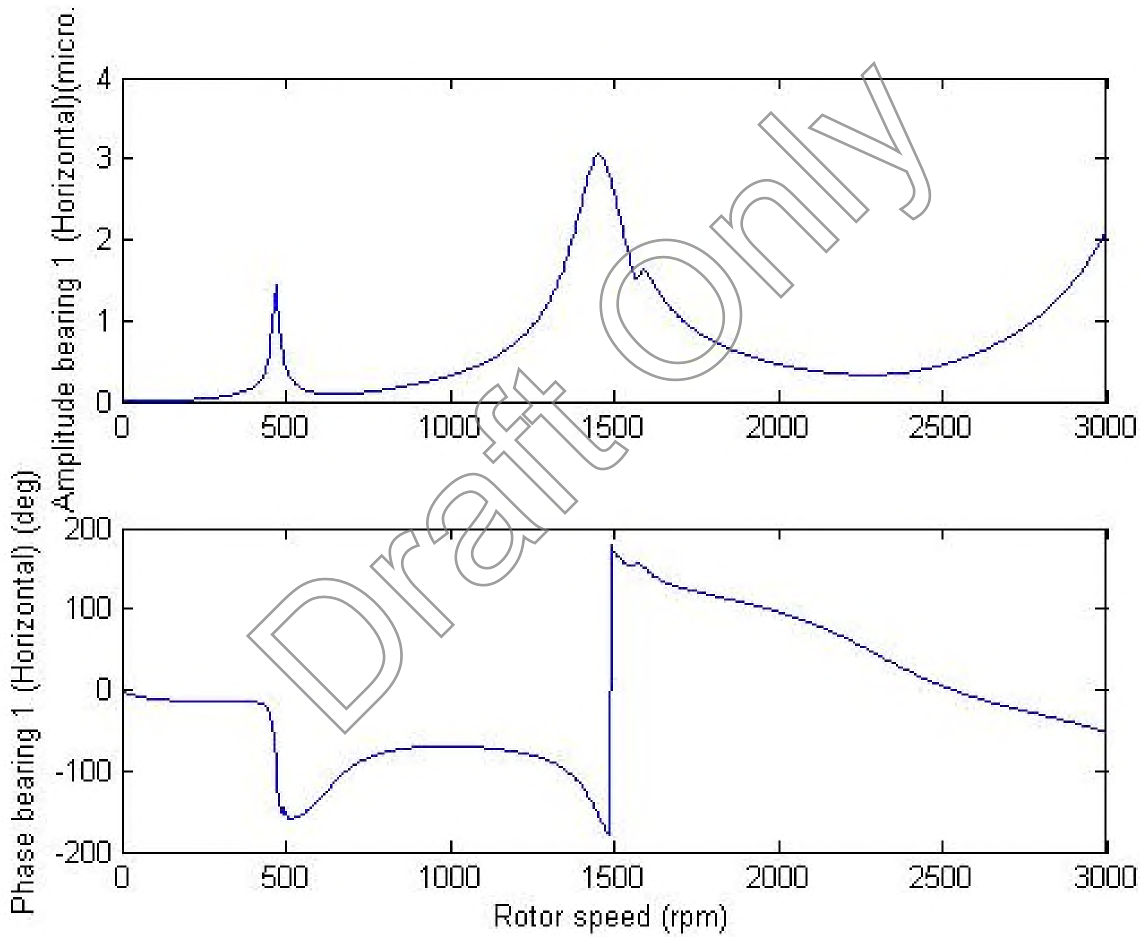

Vertical velocity (mm/s)
Horizontal velocity (mm/s)
-6
-4
-2
0
2
4
6
8
-2
0
2
4
6
8

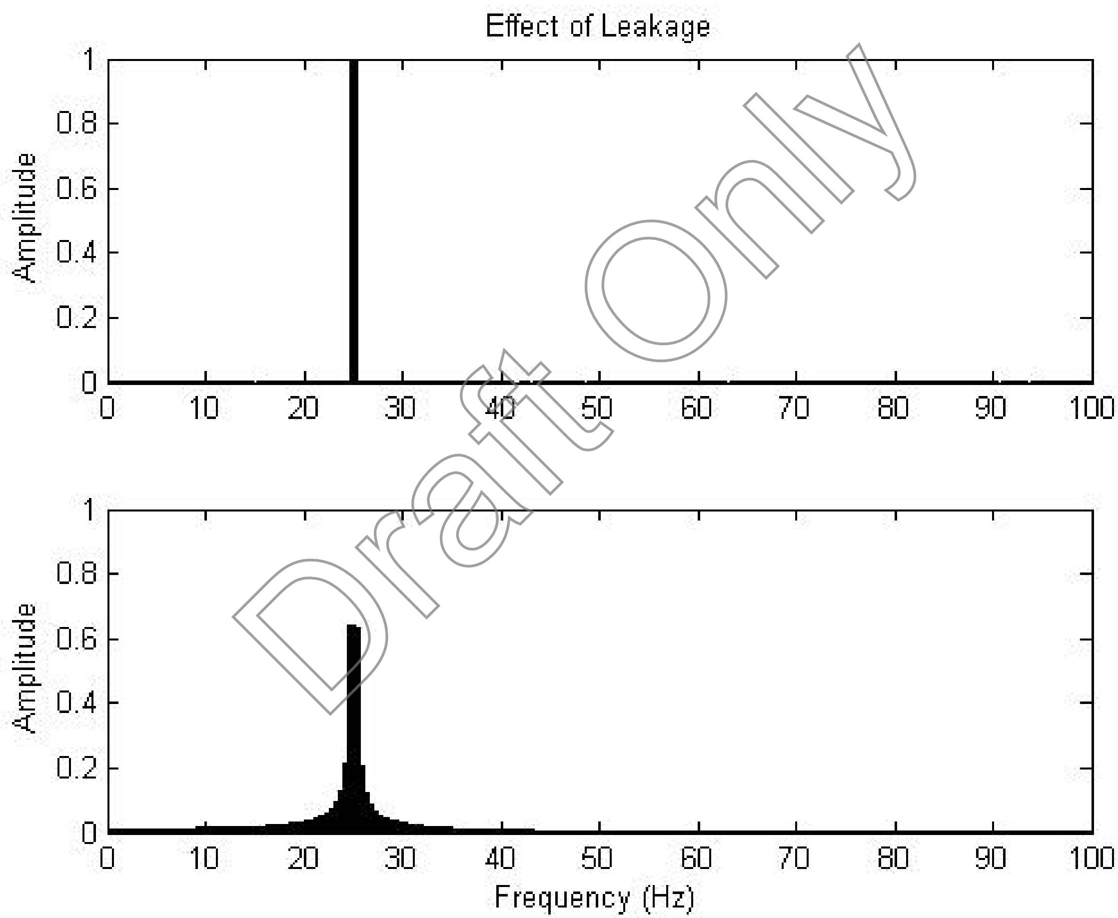
Transformed Plot

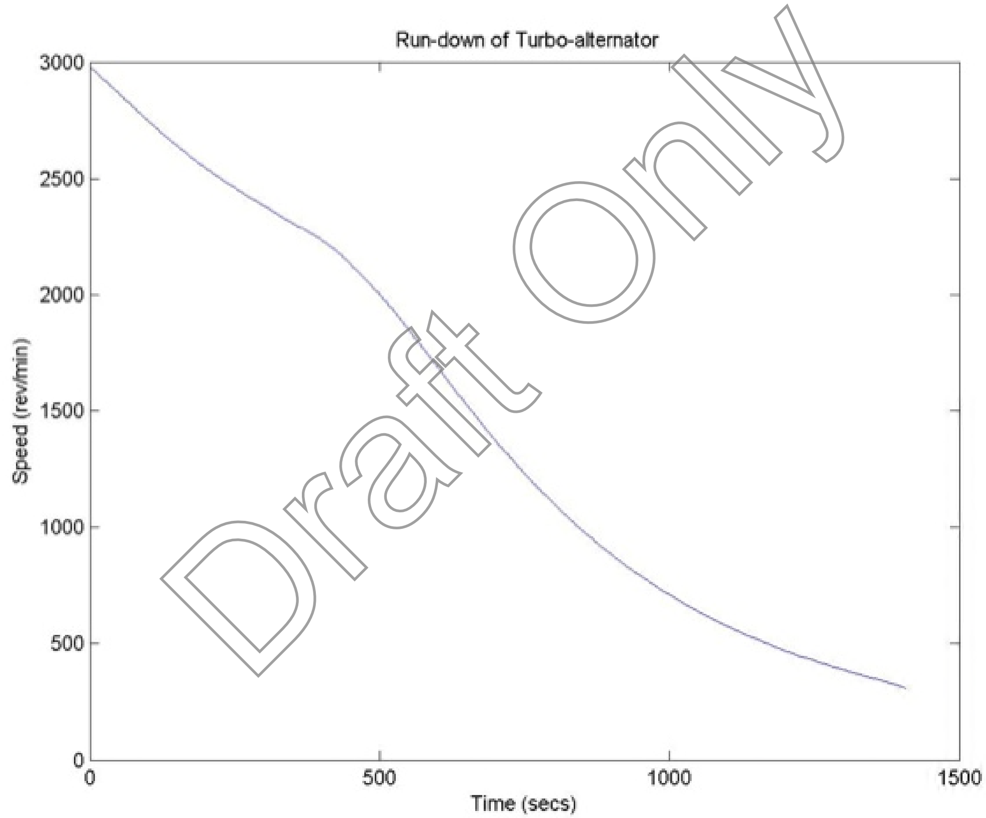




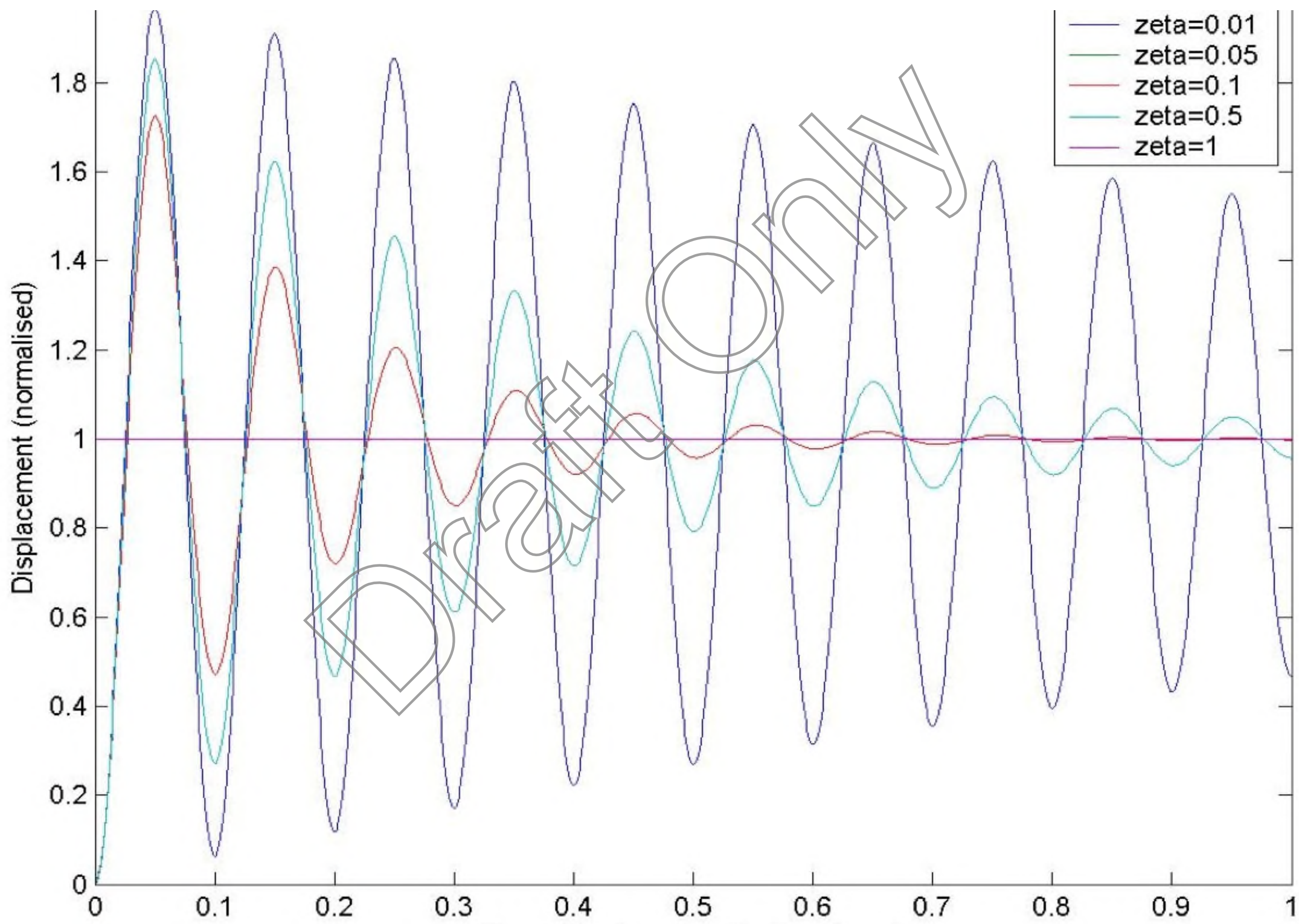
8
7
6
5
4
3
2
1
0
-1
-4
-2
0
2
4
6
Vertical velocity (mm/s)
Horizontal velocity (mm/s)
Draft Only

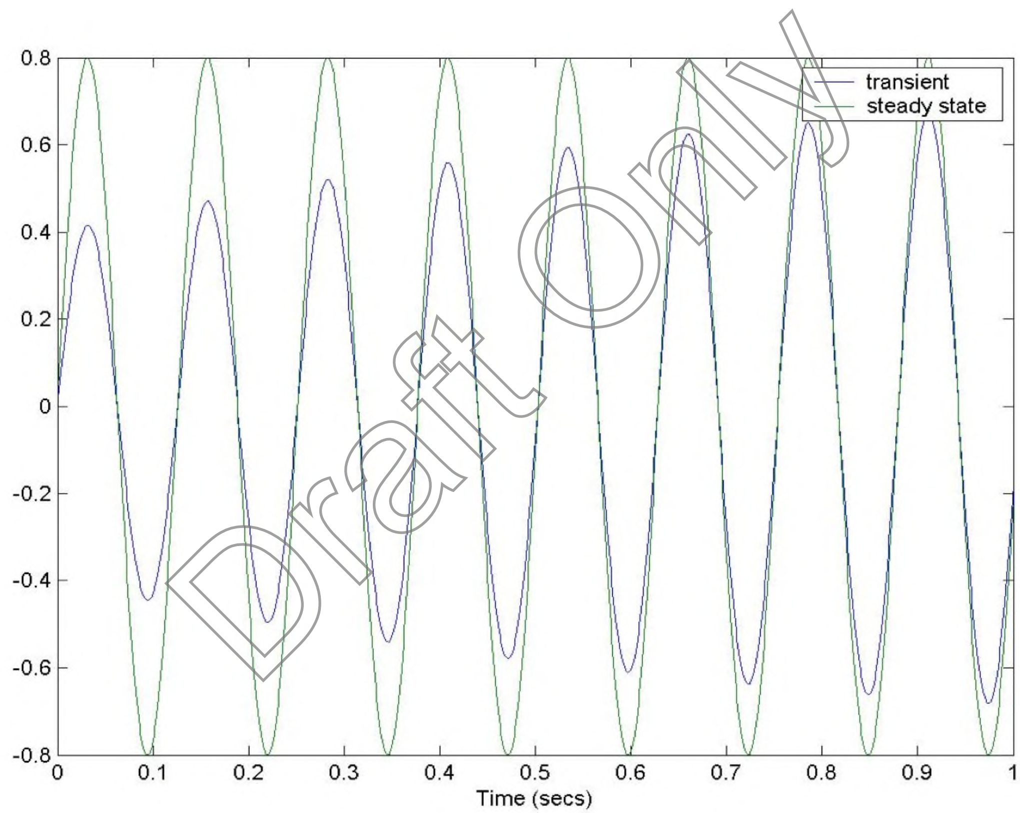

Amplitude bearing 1 (Horizontal)(micro.
4
3
2
1
0
0
500
1000
1500
2000
2500
3000
Phase bearing 1 (Horizontal) (deg)
200
100
0
-100
-200
0
500
1000
1500
2000
2500
3000
Rotor speed (rpm)


Effect of Leakage
Amplitude
Amplitude
Frequency (Hz)
Draft Only


Run-down of Turbo-alternator
Speed (rev/min)
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
Time (secs)

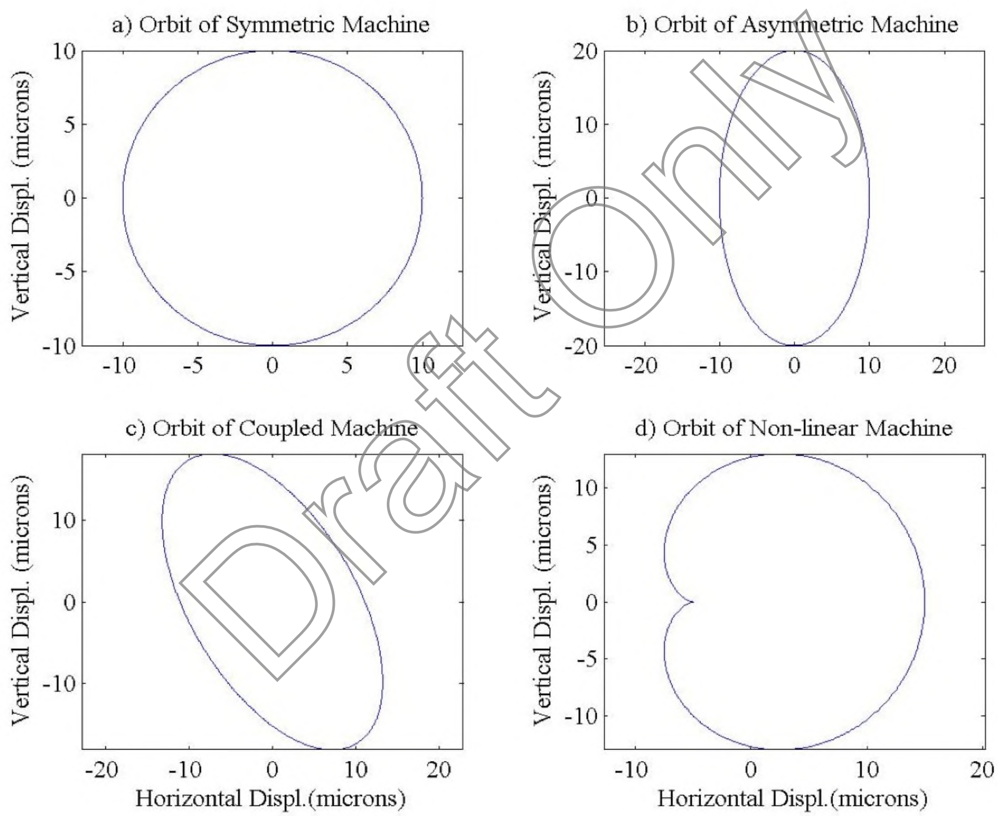
Damped Decay



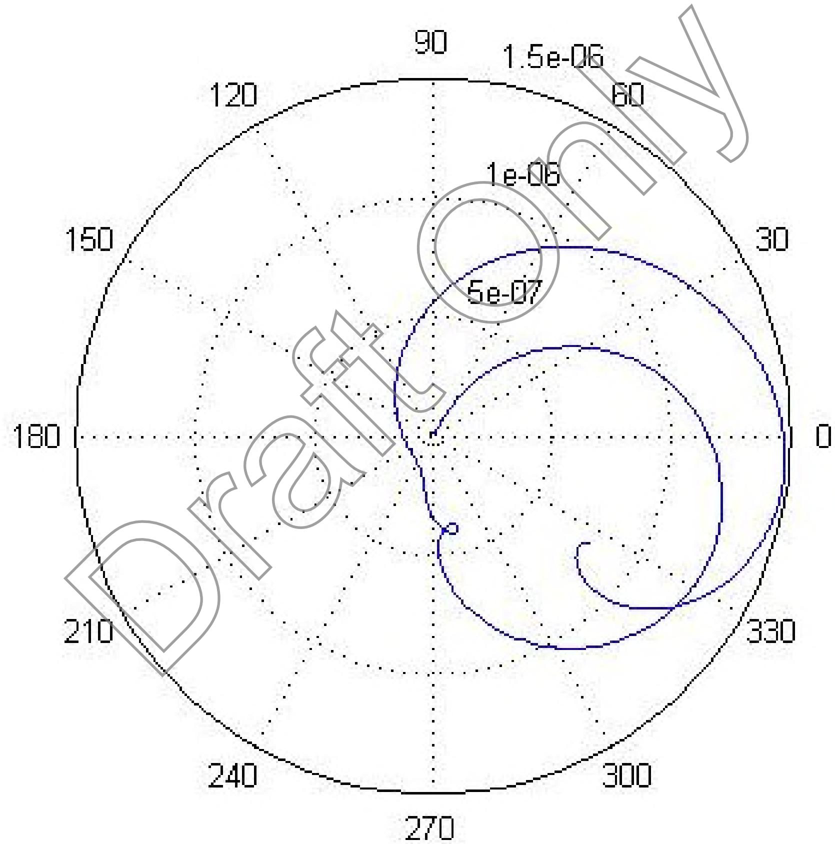


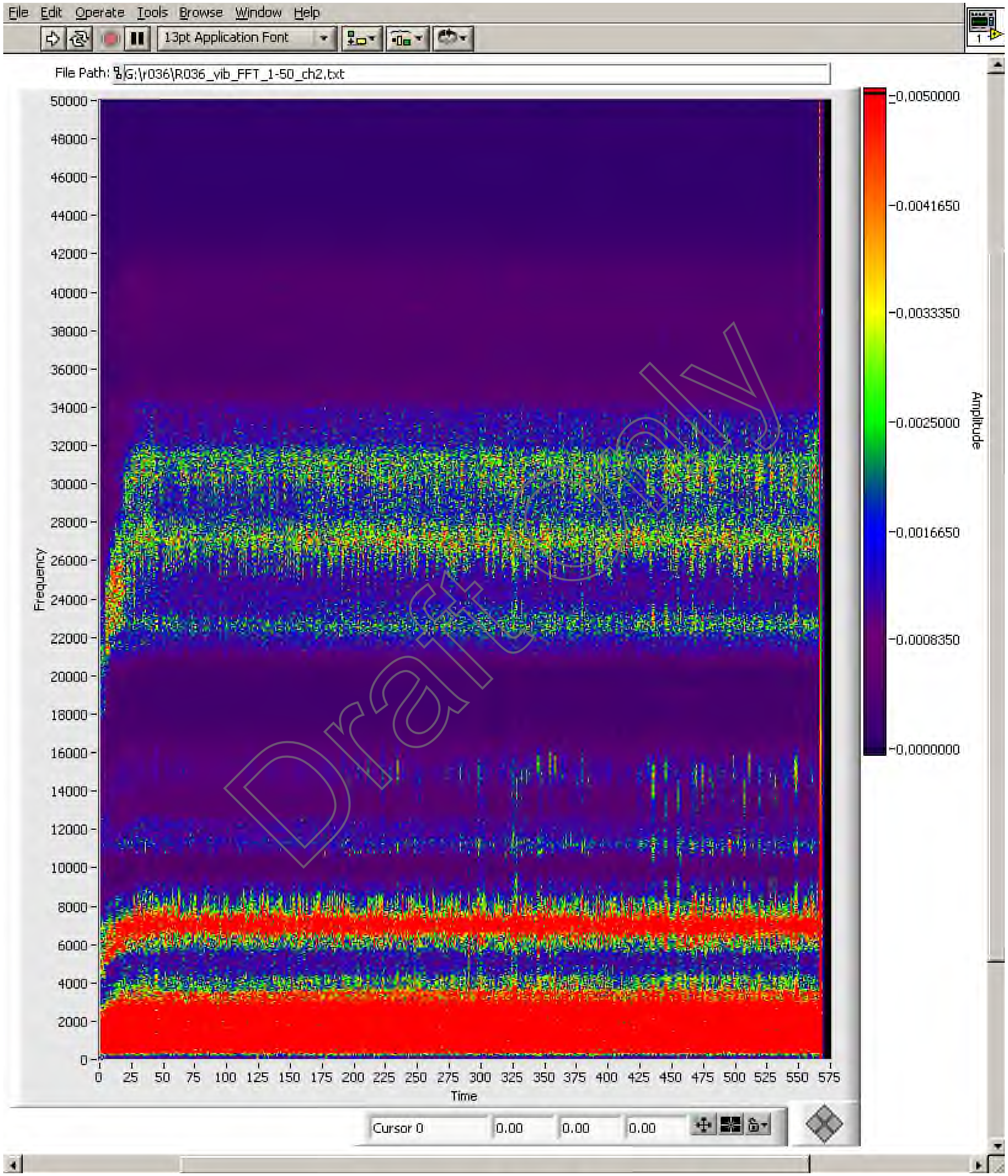
transient
steady state
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (secs)
Draft Only

Orbit Shapes



Polar Plots





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File Path: G:\r036\R036_vib_FFT_1-50_ch2.txt
Frequency
Time
Amplitude
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0,0041650
0,0033350
0,0025000
0,0016650
0,0008350
0,0000000
Cursor 0
0.00
0.00
0.00
Draft Only