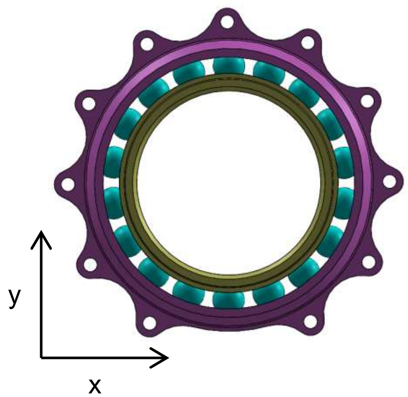
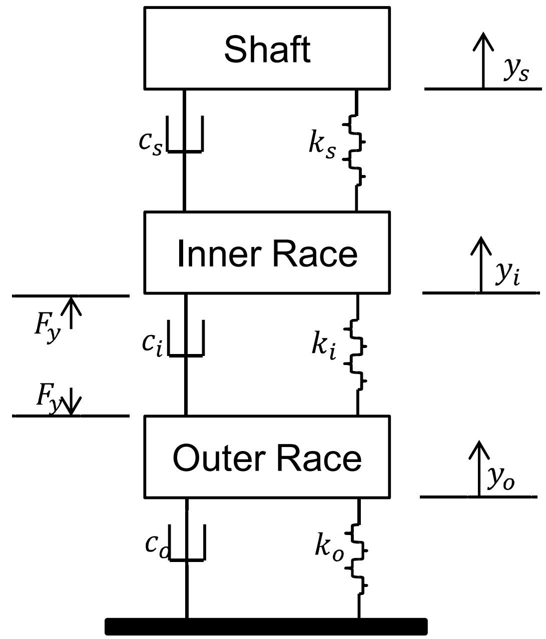
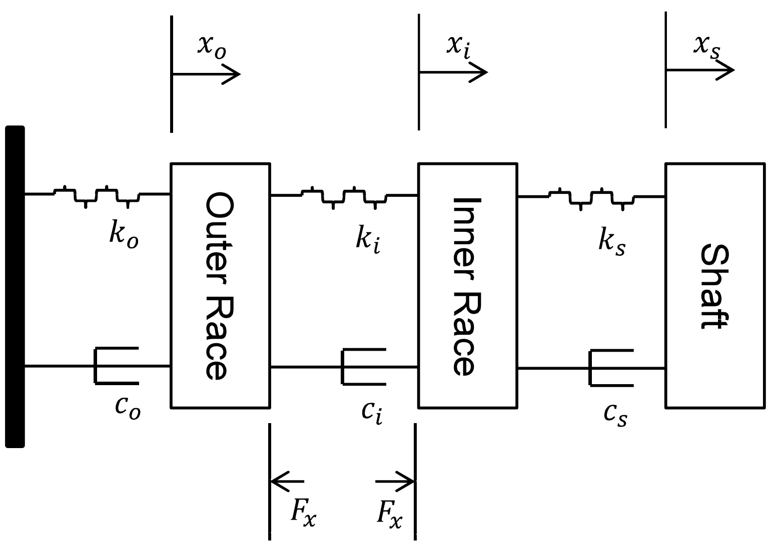
Project : Modelling and Simulation of Roller Element Bearing



Bearing CAD Model





System Representation

Objective:

- To Develop **Mathematical Model** of Roller Element Bearing.
- To Simulate effect of Bearing Force due to Roller Element contact on overall **Vibration of Bearing**.

Methodology:

- Bearing is important component in Rotary machines, therefore any fault in it affects whole machine.
- It is very essential to determine the early faults occurring in bearings.
- Bearing is modeled as spring mass damper system which translates to **Higher Order System of Ordinary Differential Equations.**
- Bearing Force is calculated based on **Hertzian Contact Stress** concept.
- The force is then introduced to model to account for **Forced Vibrations.**

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$Y_1 = y_o, Y_2 = \dot{y}_o, Y_3 = y_i,$
$Y_4 = \dot{y}_i, Y_5 = y_s, Y_6 = \dot{y}_s$

$$\begin{Bmatrix} \dot{Y}_1 \\ \dot{Y}_2 \\ \dot{Y}_3 \\ \dot{Y}_4 \\ \dot{Y}_5 \\ \dot{Y}_6 \end{Bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ \frac{-(k_o + k_i)}{m_o} & \frac{-(c_o + c_i)}{m_o} & \frac{c_i}{m_o} & \frac{k_i}{m_o} & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ \frac{k_i}{m_i} & \frac{c_i}{m_i} & \frac{-(k_i + k_s)}{m_i} & \frac{-(c_i + c_s)}{m_i} & \frac{k_s}{m_i} & \frac{c_s}{m_i} \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & \frac{k_s}{m_s} & \frac{c_s}{m_s} & \frac{-k_s}{m_s} & \frac{-c_s}{m_s} \end{bmatrix} \begin{Bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ Y_5 \\ Y_6 \end{Bmatrix} + \begin{Bmatrix} 0 \\ \frac{-(F_y + W_o)}{m_o} \\ 0 \\ \frac{-(F_y + W_i)}{m_i} \\ 0 \\ \frac{-(W_s)}{m_s} \end{Bmatrix}$$

$X_1 = x_o, X_2 = \dot{x}_o, X_3 = x_i,$
$X_4 = \dot{x}_i, X_5 = x_s, X_6 = \dot{x}_s$

$$\begin{Bmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \dot{X}_3 \\ \dot{X}_4 \\ \dot{X}_5 \\ \dot{X}_6 \end{Bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ \frac{-(k_o + k_i)}{m_o} & \frac{-(c_o + c_i)}{m_o} & \frac{c_i}{m_o} & \frac{k_i}{m_o} & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ \frac{k_i}{m_i} & \frac{c_i}{m_i} & \frac{-(k_i + k_s)}{m_i} & \frac{-(c_i + c_s)}{m_i} & \frac{k_s}{m_i} & \frac{c_s}{m_i} \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & \frac{k_s}{m_s} & \frac{c_s}{m_s} & \frac{-k_s}{m_s} & \frac{-c_s}{m_s} \end{bmatrix} \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \end{Bmatrix} + \begin{Bmatrix} 0 \\ \frac{-(F_X)}{m_o} \\ 0 \\ \frac{-(F_X)}{m_i} \\ 0 \\ 0 \end{Bmatrix}$$

Linearized Differential Equation for Numerical Computation

Methodology:

- X's and Y's are the displacements of respective elements.
- ODE is solved to obtain **Displacement, Velocity** and **Acceleration.**

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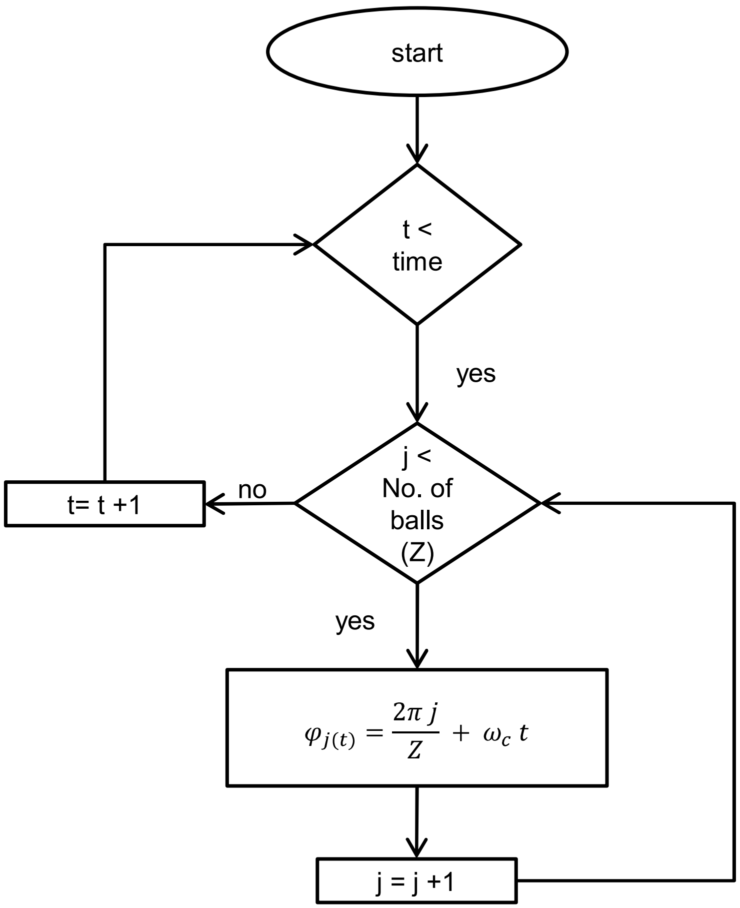
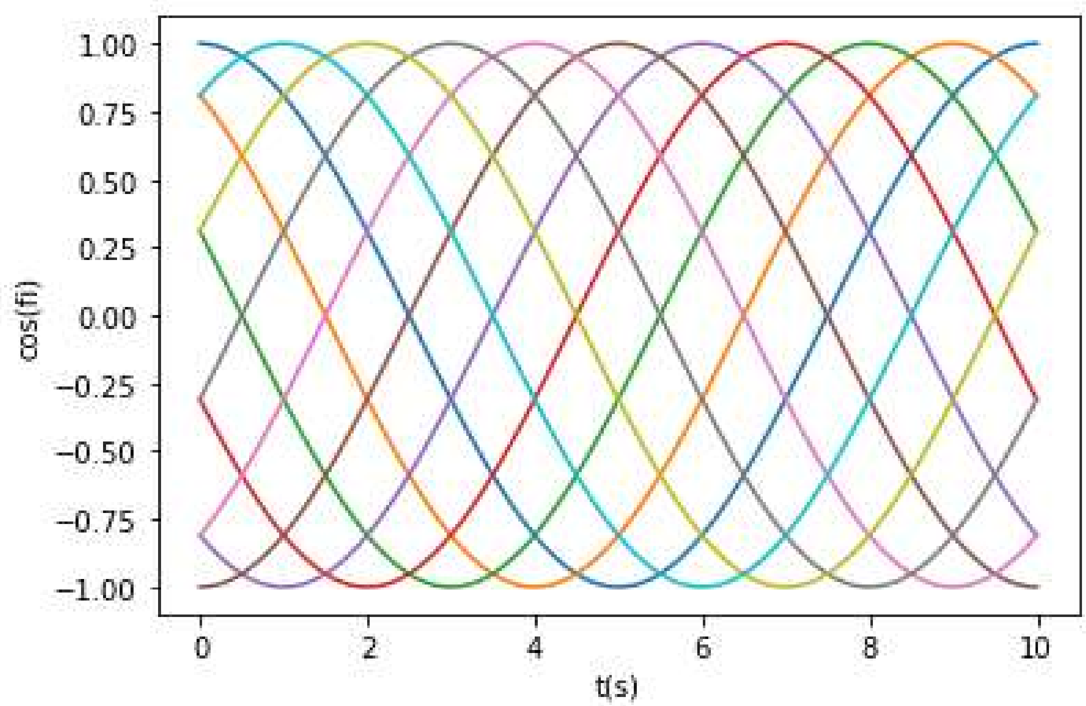
Ball Position Algorithm



Ball Position Plots



Z = 10, Every Curve Indicate different **Ball.**

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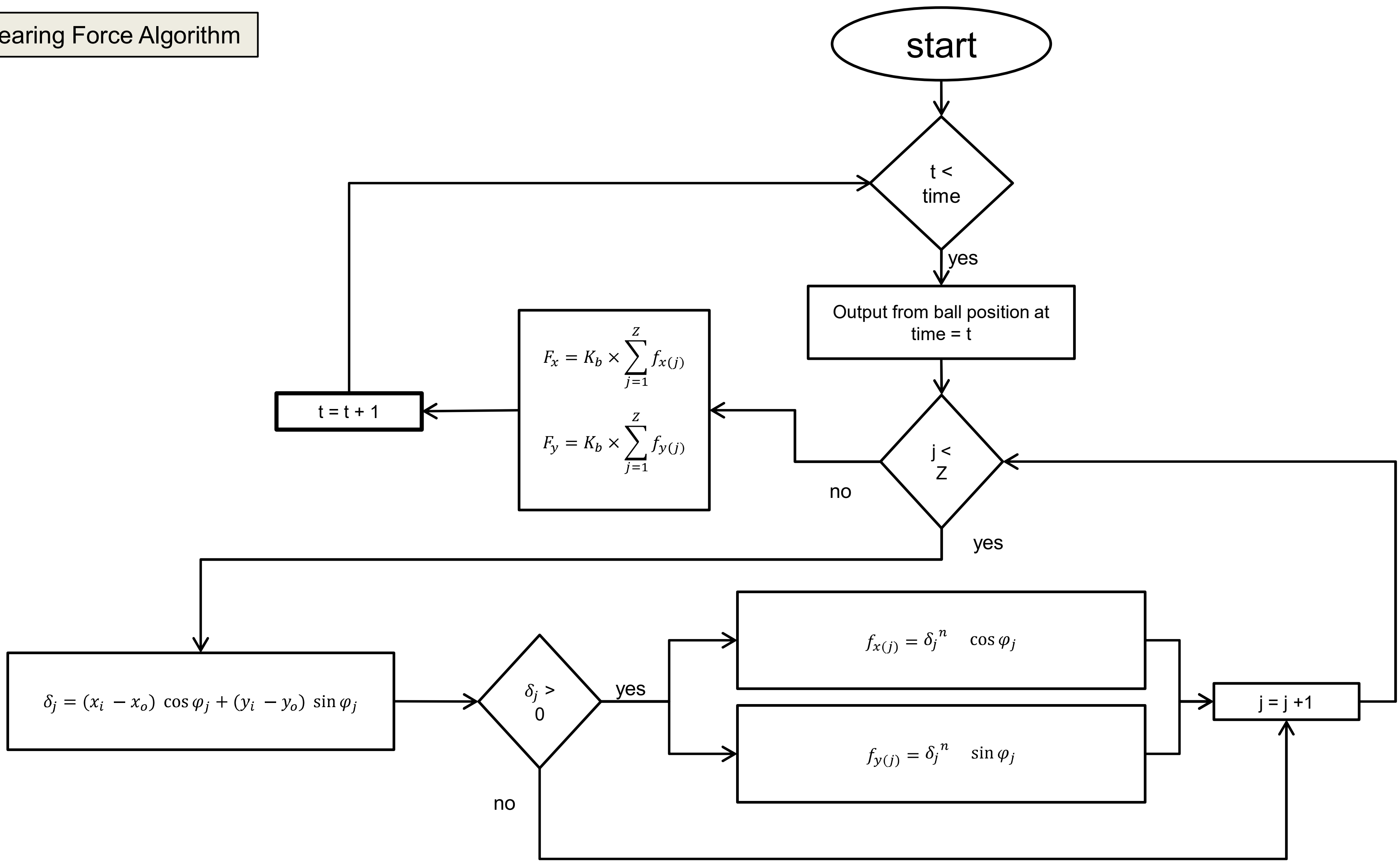
Bearing Force Algorithm



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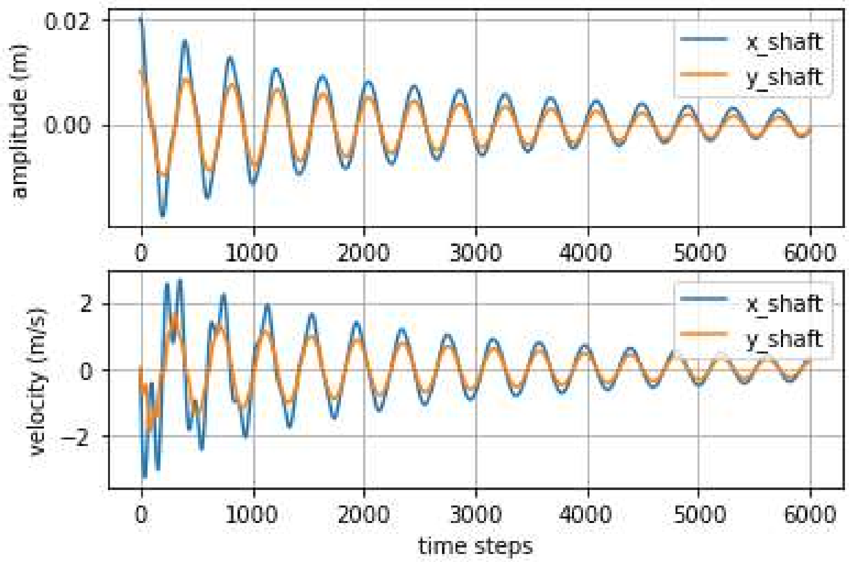
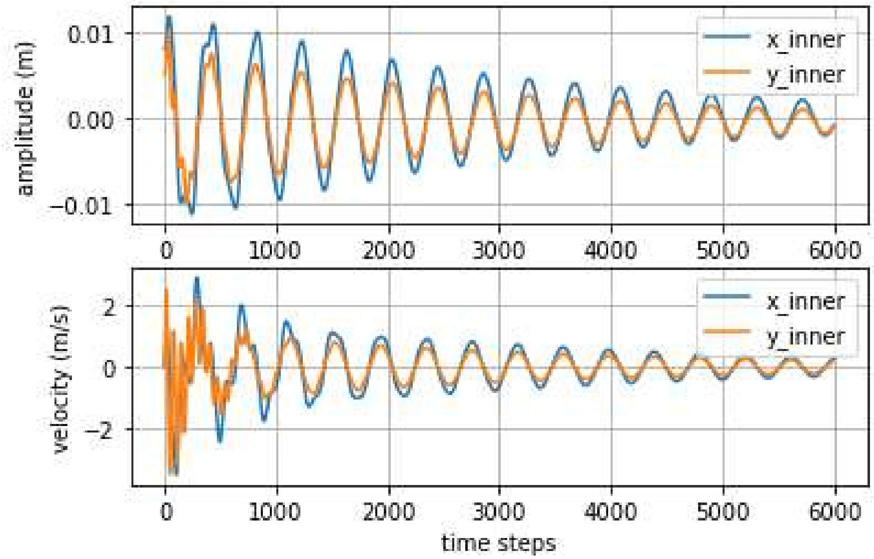
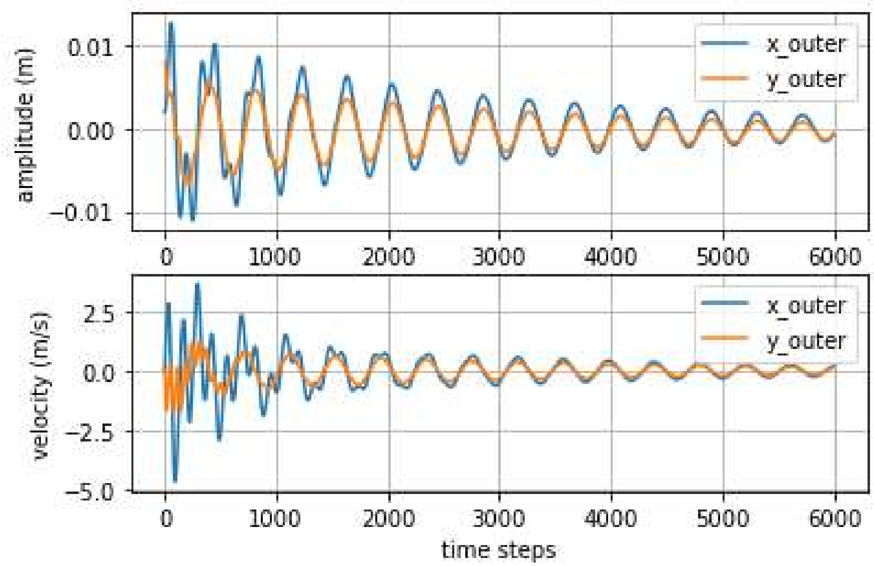
Displacement. Velocity Plots



Shaft Vibration



Inner Race Vibration



Outer Race Vibration

Scope:

- Model Refinement, Experimental verification of results.
- Predictive Defect Response Analysis, by introducing defects (i.e. inner, outer race or ball defects) in form of mathematical equation.
- Study of how bearing responds to defects to understand and improve applications in critical areas (i.e. Aerospace, Automotive etc)