Non-linear Dynamic Analysis of Spur Gear pair with Rotor Bearing Clearances

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Abstract
Gearbox is one of the most widely used mechanical component, known for its motion and power transfer flexibility in almost every industry such as manufacturing, cement, power generation, steel plant, textile and so on. Backlash is always present in gear as it provide clearance to prevent binding of the mating gear, which introduces noise and is one of the major source of non-linearity in gears. Hence study of backlash in gears are important. In this work a three degree of freedom lumped parameter model of spur gear with backlash and static transmission error with bearing clearance is studied. System response is analysed using phase plot, poincare map and FFT. Results shows various non-linear phenomenon like periodic doubling, non-linear jumps, subharmonics response.
Keywords: Dynamic modelling, Backlash, Static transmission error, Non-linear analysis, poincare map

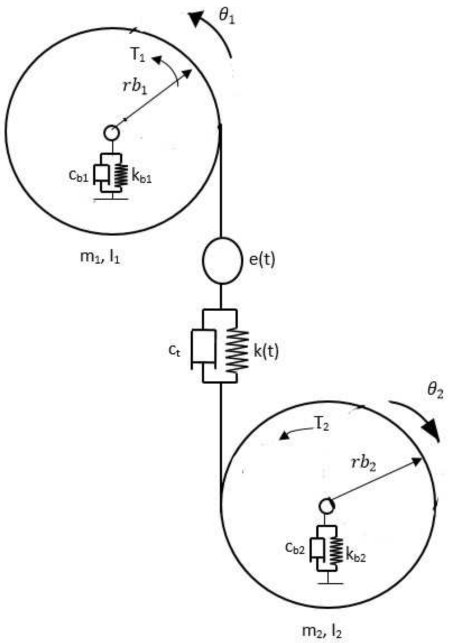


Figure 1: Three degree of freedom spur gear with backlash and transmission error

Equation of motion [1]

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 1 & 1 \end{bmatrix} \begin{Bmatrix} \ddot{y}_1 \\ \ddot{y}_2 \\ \ddot{x} \end{Bmatrix} + 2 \begin{bmatrix} \zeta_{11} & 0 & \zeta_{13} \\ 0 & \zeta_{22} & -\zeta_{23} \\ 0 & 0 & \zeta_{33} \end{bmatrix} \begin{Bmatrix} \dot{y}_1 \\ \dot{y}_2 \\ \dot{x} \end{Bmatrix} + \begin{bmatrix} k_{11} & 0 & k_{13} \\ 0 & k_{22} & -k_{23} \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} f_{b1}(y_1) \\ f_{b2}(y_2) \\ f_g(x) \end{Bmatrix} = \{F(t)\} \tag{1}$$

$$\zeta_{11} = c_{b1}/2m_{g1}\omega_n \qquad \zeta_{13} = c_h/2m_{g1}\omega_n$$

$$\zeta_{23} = c_h/2m_{g2}\omega_n \qquad \zeta_{33} = c_h/2m_{c1}\omega_n$$

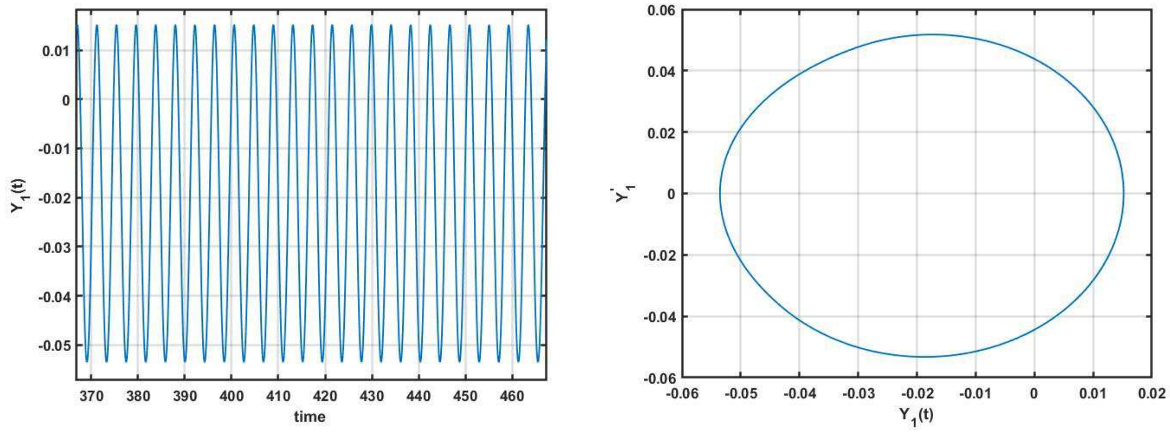
Bearing displacement function [2]

$$f_{bi}(y_i) = \begin{cases} y_i - b_i & y_i > b_i \\ 0 & |y_i| \le b_i \\ y_i + b_i & y_i < -b_i \end{cases}$$

Backlash function [2]

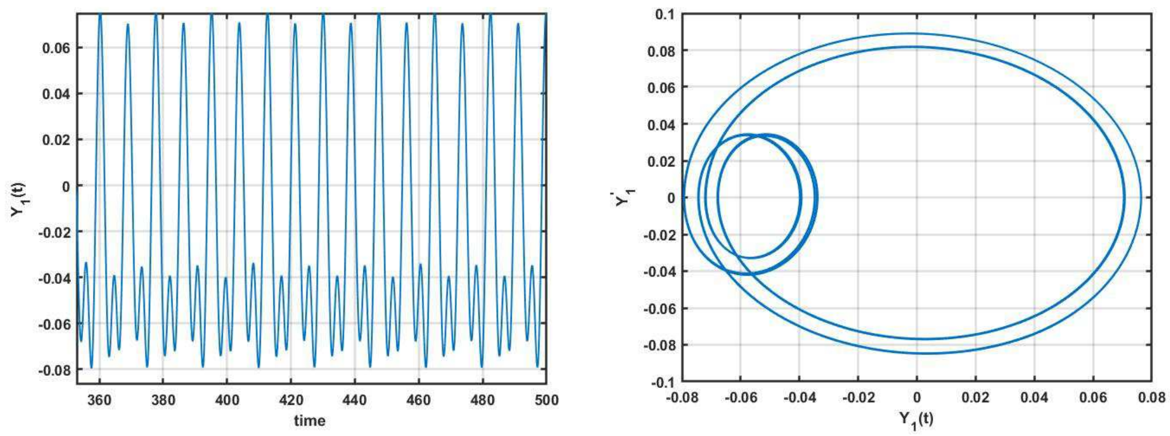
$$f_g(x) = \begin{cases} x - b_g & x > b_g \\ 0 & |x| \le b_g \\ x + b_g & x < -b_g \end{cases}$$

Results



(a) Time response (b) Phase plot

Figure 2: $F_m = 0.05$, F_{ah}= 0, $\zeta_{33} = 0.05$, $\zeta_{13} = \zeta_{23} = 0.0125$, $\zeta_{11} = \zeta_{22} = 0.01$, period-one,$\Omega_h = 1.5$



(a) Time response (b) Phase plot

Figure 3: $F_m = 0.05$, F_{ah}= 0, $\zeta_{33} = 0.05$, $\zeta_{13} = \zeta_{23} = 0.0125$, $\zeta_{11} = \zeta_{22} = 0.01$, period-four,$\Omega_h = 1.44$

Figure 1 shows the proposed system model. From Figure 2 and Figure 3, it is observed that there is a periodic solution for value of $\Omega_h = 1.5$ and period four solution for value of $\Omega_h = 1.44$, respectively. If the value of Ω_h decreases further then the solutions shows period-doubling route to chaos.

References

[1] Kahraman, A. and Singh, R., 1991. Non-linear dynamics of a geared rotor-bearing system with multiple clearances. Journal of sound and vibration, 144(3), pp.469-506.

[2] Yang, Y., Xia, W., Han, J., Song, Y., Wang, J. and Dai, Y., 2019. Vibration analysis for tooth crack detection in a spur gear system with clearance nonlinearity. International Journal of Mechanical Sciences, 157, pp.648-661.