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Condition monitoring of spur gear under constant speed operation

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Abstract

Every machine has its vibration signature. Vibration characteristics of a machine changes with the operating conditions (speed, load, fault and etc.). Gears are widely used as power transmission device due to its flexibility to operate at wide range of speed and load. Any faults in the gear can lead to complete failure or even seizure of machine. Therefore, predictive maintenance strategy is adopted where the monitoring of condition of gear is done by analysing the signal (vibration, acoustics, current and etc.) of gear. Modelling of a physical system is economical due to the cost involves in experiments. Moreover, the models are scalable and different types of faults can be introduced into it. In the present study, a gear kinematics based 9-degrees of freedom (DOFs) model is considered to find the response of the gear in healthy as well as in faulty (broken or may be missing tooth) conditions. A higher contact ratio spur gear system is considered for analysis. The model consists of a gear-pinion pair, a loader and a driver. The equations of motion of planer block diagram model of gear-pinion system are solved in Matlab-Simulink environment to study the response of the healthy and faulty gear. This study can be extended for different gear systems to find out the fault symptoms under missing/broken tooth.A detailed review on the modeling of single-stage spur gear with different degrees of freedom are discussed in [1]. Some of the research papers [2-3] discussed the gear system modeling with gear fault condition.

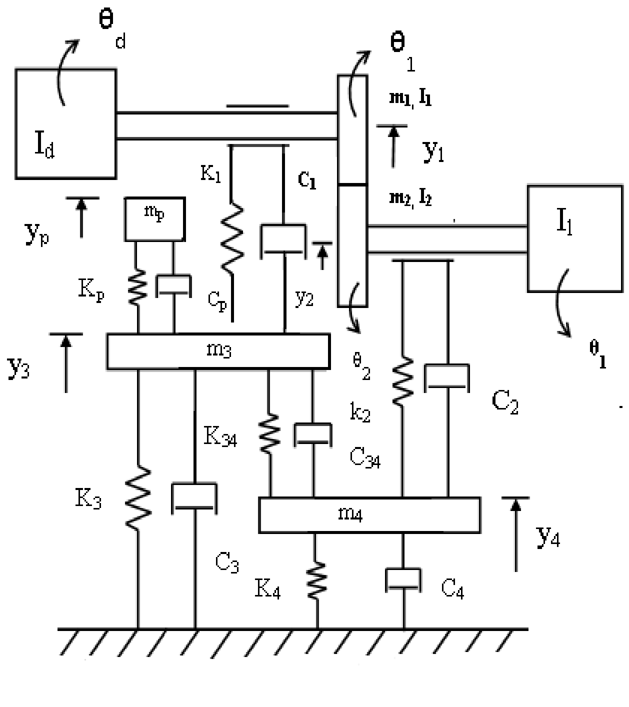

Fig. 1: Model of a gear test rig. [4]

A simplified model of gear test rig is shown in Fig. 1. It consists of a driver and loader which permits rotation (Single degree of freedom system), the gear and pinion can translate in vertical (y1 and y2) and it can rotates about its axis (two degrees of freedom system) and the driver and loader are connected by connecting shafts which is mounted on bearings and foundations which permits translational motion in vertical (y3 and y4) thus a single degree of freedom system and the transducer is placed on a platform that permits translation in vertical (yP) single degree of freedom system.

The governing equations of motion of the mathematical model of the gear system can be written as

$$I_d\ddot{\theta}_d + c_{t1}(\dot{\theta}_d - \dot{\theta}_1) + k_{t1}(\theta_d - \theta_1) = T_d \quad (1)$$

$$I_1\ddot{\theta}_1 + c_{t1}(\dot{\theta}_1 - \dot{\theta}_d) + k_{t1}(\theta_1 - \theta_d) = -WR_1 \quad (2)$$

$$I_2\ddot{\theta}_2 + c_{t2}(\dot{\theta}_2 - \dot{\theta}_l) + k_{t2}(\theta_2 - \theta_l) = WR_2 \quad (3)$$

$$I_l\ddot{\theta}_l + c_{t2}(\dot{\theta}_l - \dot{\theta}_2) + k_{t2}(\theta_l - \theta_2) = -T_l \quad (4)$$

$$m_1\ddot{y}_1 + c_1(\dot{y}_1 - \dot{y}_3) + k_1(y_1 - y_3) = W \quad (5)$$

$$m_2\ddot{y}_2 + c_2(\dot{y}_2 - \dot{y}_4) + k_2(y_2 - y_4) = -W \quad (6)$$

$$m_3\ddot{y}_3 + c_{34}(\dot{y}_3 - \dot{y}_4) + k_{34}(y_3 - y_4) + c_1(\dot{y}_3 - \dot{y}_1) + k_1(y_3 - y_1) + c_p(\dot{y}_3 - \dot{y}_p) + k_p(y_3 - y_p) + c_3\dot{y}_3 + k_3y_3 = 0 \quad (7)$$

$$m_4\ddot{y}_4 + c_{34}(\dot{y}_4 - \dot{y}_3) + k_{34}(y_4 - y_3) + c_2(\dot{y}_4 - \dot{y}_2) + k_4(y_4 - y_2) + c_4\dot{y}_4 + k_4y_4 = 0 \quad (8)$$

$$m_p\ddot{y}_p + c_p(\dot{y}_p - \dot{y}_3) + k_p(y_p - y_3) = 0 \quad (9)$$

where, W is the dynamic meshing force given by

$$W = k_m(\theta_1R_1 - \theta_2R_2 + y_2 - y_1) + c_m(\dot{\theta}_1R_1 - \dot{\theta}_2R_2 + \dot{y}_2 - \dot{y}_1) + c_m\dot{x}_E + k_mx_E \quad (10)$$

The equations of motion are solved in Matlab-Simulink environment using ODE-45 solver to find out the response. Gear fault like missing tooth is modeled for higher contact ratio gear system. The responses are computed for healthy and faulted condition in higher contact ratio gear system. The obtained vibration responses are analyzed in time domain and frequency domain. In both time as well as frequency domain, it is observed that there are peaks of higher magnitudes in faulted condition as compare to healthy condition and it is due to the impulsive dynamic forces induced in fault conditions.

References

[1] Mohammed, O. D., Rantatalo, M., & Aidanpaa J.O. Dynamic modelling of a one-stage spur gear system and vibration-based tooth crack detection analysis. Mechanical Systems and Signal Processing, 54-55, 293–305, 2015.

[2] Haword, I., Jia, S., & Wang J. . The dynamic modeling of a spur gear in mesh including friction and a crack. Mechanical Systems and Signal Processing, 15(5), 831-853, 2001.

[3] Chen, Z., & Shao, Y. Dynamic simulation of spur gear with tooth root crack propagating along tooth width and crack depth. Engineering Failure Analysis 18, 2149–2164, 2011.

[4] Omar F., Moustafa K. & Emam S. Mathematical modeling of gearbox including defects with experimental verification. Journal of Vibration and control, 18 (9), 1310-1321, 2011.