Vibration Monitoring for Defect Diagnosis on a Machine Tool: A Comprehensive Case Study

Mouleeswaran Senthilkumar, Moorthy Vikram and Bhaskaran Pradeep
Department of Production Engineering, PSG College of Technology, Coimbatore 641 004, India

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Vibration monitoring and analysis of machine tools are carried out in industry to reduce maintenance cost and downtime. In this case study, the application of vibration monitoring and analysis was carried out on a lathe. The characteristic frequencies of tapered roller bearings, gear mesh frequencies, and belt drive frequencies were found to locate the source of vibration. Multi-harmonics of fundamental defect frequencies were observed. From the real-time observation, experimental prediction of defects has been found to be correct and accurate. This case study shows that vibration analysis plays a vital role in monitoring the condition of the machine tool.

NOMENCLATURE

N_b	Number of rollers
n	Revolutions per minute
D	Outer diameter, mm
d	Inner diameter, mm
T	Width, mm
C	Dynamic load rating, kN
C_o	Static load rating, kN
P_u	Fatigue load limit, kN
m	Mass, kg
Z	Number of gear teeth
N	Gear speed, rpm
F_{gm}	Gear meshing frequency, Hz
F_b	Belt drive frequency, Hz
d_p	Pulley diameter, mm
N_p	Pulley speed, rpm
l_b	Belt length, mm

1. INTRODUCTION

Vibration analysis is a measurement tool used to identify, predict, and prevent failures in machine tools. It involves the trending and analysis of machinery performance parameters to detect and identify problems before failure and extensive damage can occur. If problems can be detected early when the defects are minor and do not affect performance, and the nature of the problem can be identified while the machine runs, then repair time can be kept to a minimum, resulting in reduced machinery downtime. Therefore, vibration analysis is a technique that is employed to track machine operating conditions and trend deteriorations so as to reduce maintenance costs as well as downtime.[1] The vibration analysis technique consists mainly of vibration measurement and its interpretation. The vibration measurement is done by picking up signals from machines by means of vibration measurements. The signals are then processed using an FFT analyser to obtain the frequency spectrum. The results are mainly interpreted by relating the measured frequencies with their relevant causes such as unbalance, misalignment, bearing defects and resonance, etc. A case study on vibration-based maintenance in paper mills has been presented to improve accuracy and effectiveness.[2]

There are many case studies on vibration monitoring and analysis of rotating machineries. Vibrations associated with rolling element bearings, especially ball bearings have been discussed extensively,[3] while applied statistical moments to bearings defect detection.[4] Two case studies present on the defect diagnosis of rolling element bearings.[5,6] Another case study has analysed the vibration of a centrifugal pump and investigated the spike energy of bearings in order to find out the source of the vibration.[7] In vibration analysis, an artificial neural network has also been employed to monitor and diagnose rolling element bearings.[8] In vibration diagnosis, it is found that not only rolling elements but other sources of vibration exist as well. Vibration analysis of a motor-flexible coupling-rotor system subjected to misalignment and unbalance has been studied extensively.[9,10] Characteristics of the torsional vibrations of an unbalanced shaft were also analysed in another study.[11]

This case study analyses the vibration produced in a lathe during the real operation at different machining conditions. The study has been made to identify defects in three major sources of vibration, namely, rolling element bearings, gears, and belt drives.

2. EXPERIMENTAL SETUP AND VIBRATION MEASUREMENT

Experiments on PSG 141 lathes have been conducted using the accelerometer, and these experiments have discovered the vibrations that formed. The technical details of the lathe and the experimental conditions are as follows:

Machine tool :	PSG 141 lathe
Machine speed (rpm) :	38 60 71 90 115 140 200 250 228 360 450 580 740 800 1150 1600
Power :	Std. motor for main drive 1.1/2.2 kW (For 16 speeds) 1440/2880 rpm, 415 V, 3 phase, 50 Hz, AC