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Experimental Investigation for Fault Diagnosis of a Single Stage Worm Gearbox Using Response Surface Methodology

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ABSTRACT: Gearbox transmission system is a fundamental factor in the industrial applications. If gearbox stops working due to different faults, it may break normal machine operation and cause a production loss. This research paper focused on fault analysis of combination of worm wheel and bearing by using root mean square (RMS) and response surface method (RSM). Three fault conditions namely on outer and inner race of worm wheel bearing and on worm wheel tooth of worm gearbox are considered. These faults and load were considered as an important independent factor to understand their effects on RMS response of worm gearbox. Worm gearbox experimental setup is manufacture for laboratory experimentation and RSM for analysis. Twenty seven experimental trials were conducted for three level of parameters based on design of experiment (DOE). Vibration based response measured in frequency domain and RMS parameter extracted for the fault analysis. Box-Behnken design RSM is implemented to investigate independent parameters effect on output parameter i.e. RMS. The results showed that effects of faulty inner race bearing is more on worm wheel as compared to faulty outer race bearing and fault parameter influence RMS than load parameter.

KEYWORDS: Design of experiment, Production loss, Response Surface Method, Worm wheel Bearing, Worm wheel.

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I. INTRODUCTION

Fault analysis in intricate engineering systems depends on data acquisition through experiments, signal processing methods to analyse the data for feature extraction and mapping the extracted features to assess the state of the machine. (Patil *et al*, 2023) evaluate the effect of load, rotor defect, and speed on vibration based RMS response by using noncontact type of sensor and response surface methodology (RSM). Result shows that rotor speed and rotor defect seriousness influence RMS response more than load. For reliability determination and efficiency of machine and machine components, appropriate fault analysis of machine and machine components by using vibration monitoring is crucial (Ammar *et al*, 2022). Experiment data analysis provides valid research and provides useful relevance. It is necessary to make use of the correct experimental setup and statistical method to improve experiment data analysis. Condition monitoring of gearbox of all automobiles, conveyors, escalators, press, mining, rolling mills, blending machine, machine tools, aircraft, turbines, etc. are important because most of the time gear boxes fail due to fault present in gears or bearings (Dhamande and Chaudhari, 2018). In industrial applications such as conveyors, escalators, press, mining, rolling mills, blending etc. worm gearboxes are key element. In the case of the worm gearbox, as the material of the worm wheel is softer than that of the worm screw, the worm wheel gear is vulnerable to failure through various modes like pitting, wearing out, or tooth breakage during the sliding process (Waqar and Demetgul, 2016). In fault analysis, vibration signatures are measured by using data acquisition and sensors. Extracted vibration signals are analysed in the time domain, frequency domain, time-frequency domain (Attoui *et al*, 2017). Statistical feature parameters such as mean, median, root mean square (RMS), standard deviation, peak-to-peak, kurtosis, crest factor are used for vibration signal analysis. In past research, RMS is plays vital role in analysing the relationship between faults and vibration amplitude (Umutlu *et al*, 2020). In the literature, experimental investigations were observed using design of experiment (DOE) and vibration responses are analysed by RSM for fault detection in bearing (Mishra and Jalan, 2021). The DOEs methods such as factorial design, response surface method (RSM), Placket-Burmann design (PBD) and Taguchi techniques was used (Jankovic *et al*, 2021). To extract vibration signal accurate sensor mounting plays a vital role in fault diagnosis of the rotating machine. The RSM effectively examine statistical parameter i.e the RMS for sensor placement on a rotating machine (Vanraj *et al*, 2017; Goyal *et al*, 2019). Ahmad *et al*, (2020) analysed ultrasound-assisted extraction health by Box–Behnken RSM and the study of its antioxidant potential. The result shows that RSM statistical model with the experimental data is reliable, adequate, and precise. Three-level full factorial design (Box–Behnken design) and central composite design (CCD) in concurrence with RSM has effectively been used for fault

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