CONDITION MONITORING OF GEARBOX

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Abstract

Gears are one of the most important elements of rotating machineries and plays a key role in many industrial applications. If there is an unexpected failure in the gearbox it may lead to large economic losses. The fault diagnostic of rotating elements has dradwn attention for its role in preventing disastrous accidents and beneficially assuring maintenance. Recently, fault diagnosis has paved its way in the multidisciplinary direction. Vibration analysis has always been a crucial component of preventative maintenance methods. and plays a significant role in assessing the health of the machinery and has supported decisions on machinery maintenance. An early fault identification of the gearbox is feasible by analyzing the vibration signal using various signal processing techniques since the vibration signal of a gearbox contains the signature of the defect in gear. This work aims to address fault diagnosis method based on vibrational analysis on gear box. Here an attempt has been made to use a diagnosis technique that when applied to gearbox highlights faults and these fault detection techniques are based on vibrational analysis approach.

Keywords: Fault Diagnosis, Vibration Analysis, Rotating Machinery

1 Introduction

Recent years have seen a significant increase in the number of inquiries that have focused on mechanical equipment breakdown and damage discovery methods. Any time throughout the rotating ministry, a fault could occur that caused harmful outcomes or product detentions. It's crucial to diagnose any issues as soon as possible to avoid suffering from unforeseen malfunction. In order to identify comparable issues in rotating ministries early and prevent unplanned failure, condition-based maintenance was used to look for them. Machine time-out is minimized via condition covering system. Additionally, by identifying the damaged fundamentals without the need for shutdown or investigation, it is effective and time-saving. The scope of rotating ministry condition monitoring is broad. Numerous studies have been done and queries have been focused on finding failure and damage in mechanical equipment. In order to detect any damage before it occurs, a variety of various methods and procedures are used in these investigations and works on all rotating machinery. The major goals of these methods are to reduce the expense and time associated with machine maintenance and to enhance methods for identifying faults. Although condition monitoring was created many years ago, the field of damage discovery and diagnostics has seen many improvements. Predictive maintenance is widely used on gears since they are important components of machinery with many different uses. A crucial and essential component of fault identification has been signal analysis. For thirty years, vibration analysis has been used for monitoring and judgement in a variety of real-world settings. Vibration signal analysis is used to detect the dynamic properties of machines, to extract fault characteristics when a failure occurs, and to then pinpoint the origin of the fault. A short-lived impulsive signal will be generated while the original deformity, which is comparable to a crack in a gear tooth, is present. The gear meshing factors receive extra amplitude and phase modulation products from the impact. As a result, the tooth-entrapping frequency's sidebands and its harmonics will spread widely.

Due to noise and vibration from other mechanical components, it is challenging to determine the distance and progression of side band families in the frequency range. The most popular technique for identifying gear failures is to analyze a gear system by looking at vibration signals. The frequency domain, time sphere, and time frequency domain are the traditional approaches for processing measurable data. These techniques have been used frequently to identify gear breakdowns. Vibration analysis has been widely developed for gear defect diagnosis and monitoring, and its use in large-scale enterprises is well-established.

2 Literature review

Barshikar Raghavendra Rajendra (1) Researchers are looking for a quick and easy approach to monitor the vibration of a gearbox, which is an essential part of any machinery's power transmission system despite the fact that there are numerous condition monitoring and analysis techniques. The two main causes of vibration in gearboxes are variations in the gearbox's load and gear faults. Additionally, there are occasions when attaching the vibration transducers is difficult due to the gearbox's oscillation, making measuring difficult. The motor current signature analysis may be an effective, cutting-edge, and non-intrusive technique to identify variations in gear load (MCSA). The most recent addition as a non-intrusive and simple to assess condition monitoring approach is motor current signature analysis (MCSA). This system for analysing can be utilized to measure the features of a gearbox that is fully functional and then use the data as a benchmark to measure flaws and defects in other gearboxes.

Mr. Daniela toshkova, et al. (2): The complexity and abundance of artefacts in the gearbox vibration spectrum make it challenging for the eye to detect changes brought on by faults. This study provides a trend able gearbox condition indicator as a solution to this problem. Based on the addition of the sideband levels around the first three harmonics of the gear mesh frequency, the gearbox condition indicator calculates the condition of the gearbox. Using seeded incorrect backlash and a variety of operational scenarios, the suggested gearbox condition indicator's sensitivity to damage is examined.

Mr. Amit Aherwar, et al. (3) Gears are a crucial component in many industrial applications, including machine tools and gearboxes. A sudden failure of the equipment could result in huge financial losses. Because of this, gear fault diagnosis has been the focus of extensive study. Analysis of vibration signals has been used extensively to identify faults in rotating machinery. An early failure identification of the gearbox is feasible by analysing the vibration signal using various signal processing techniques since the vibration signal of a gearbox bears the signature of the defect in the gears. In this work, some recent vibration analysis techniques for gear defect state monitoring are reviewed.

3 METHODOLOGY

The primary step in gear fault diagnosis is selection of gear. The gear that was selected was spur gear and depending upon the application a set up was designed. The application was linear actuator, which is used in machines to lift the switch gear, which acts as a speed reducer. Now in the design process gear specifications are provided, material is selected, shaft dimension are inputted. After the setup is designed, parameters are entered for example load, speed etc. then it is run for 10000, 15000 and 20000 hrs for different set of loads and speed. After this step vibration signal is extracted for different cases. Till here the steps are done using kisssoft software. The next step is to analyze the data which done using statistical analysis method in Minitab using analysis of variance. Different graphs are plotted like main effective plots, residual plots and etc. After obtaining the analysis from the graphs and annova tables the fault diagnosis is performed. The last step is testing and validation.

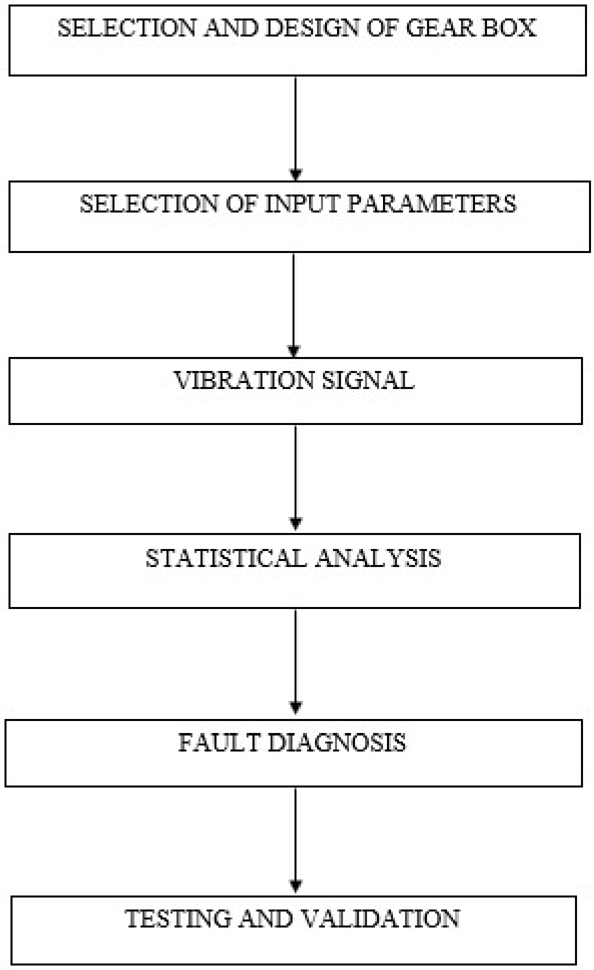

FIGURE 1

Methodology flow chart

3.1 DESIGN PROCESS

3.1.1 *MATERIAL SELECTION*

The choice of material is the initial stage in gearbox design. By thoroughly researching the qualities of the various materials, a material should be chosen. The selection of a material must take into account a number of factors, including strength, weight, durability, cost, and others. Kisssoft gives the user a list of the different materials from which they can choose while designing gears.

TABLE 1

Description of the material

description	GEAR 1	GEAR2
MATERIAL	18 CrNiMo 7-6 CASE CARBONIZED STEEL, CASE HARDERNED ISO 6336- S FIGURE 9/10(MQ) CORE HARDNESS >=29 RC	18 CrNiMo 7-6 CASE CARBONIZED STEEL, CASE HARDERNED ISO 6336- S FIGURE 9/10(MQ) CORE HARDNESS >=29 RC
TYPE OF LUBRICATION	OIL BATH LUBRICATION	OIL BATH LUBRICATION
LUBRICATION	OIL: ISO VG 220	OIL: ISO VG 220

3.1.2 *INPUT PARAMETERS*

TABLE 2

Parameter of gear 1and gear 2.

PARAMETERS	GEAR 1	GEAR 2
TORQUE (Nm)	114.5916	114.5916
SPEED (rpm)	1500	1500
POWER (HP)	24.1386	24.1386
SERVICE LIFE	20000 h	20000 h

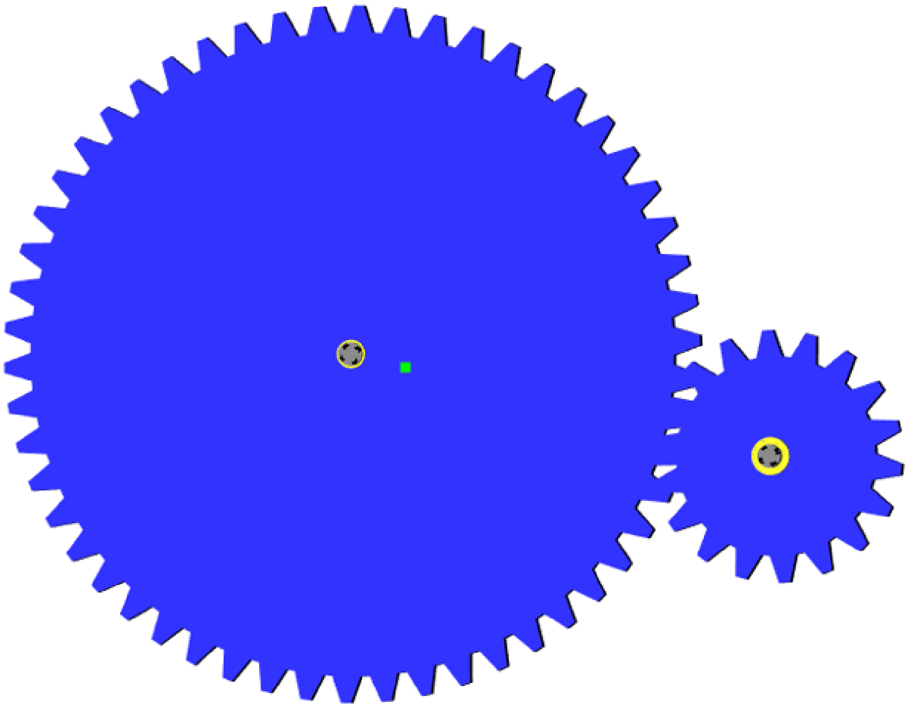

FIGURE 2

Diagram of two meshing gears

3.1.3 *INPUT SHAFT PARAMETERS*

TABLE 3

Shaft parameters

PARAMETERS	VALUE
INITIAL POSITION	0
LENGTH (mm)	80
SPEED (rpm)	1500
SENSE OF ROTATION	Counter clockwise

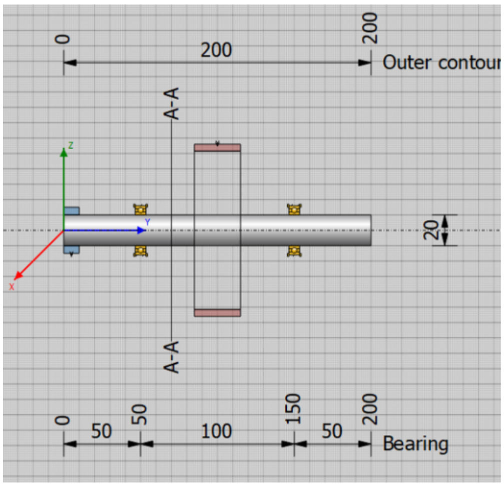

FIGURE 3

Shaft dimension

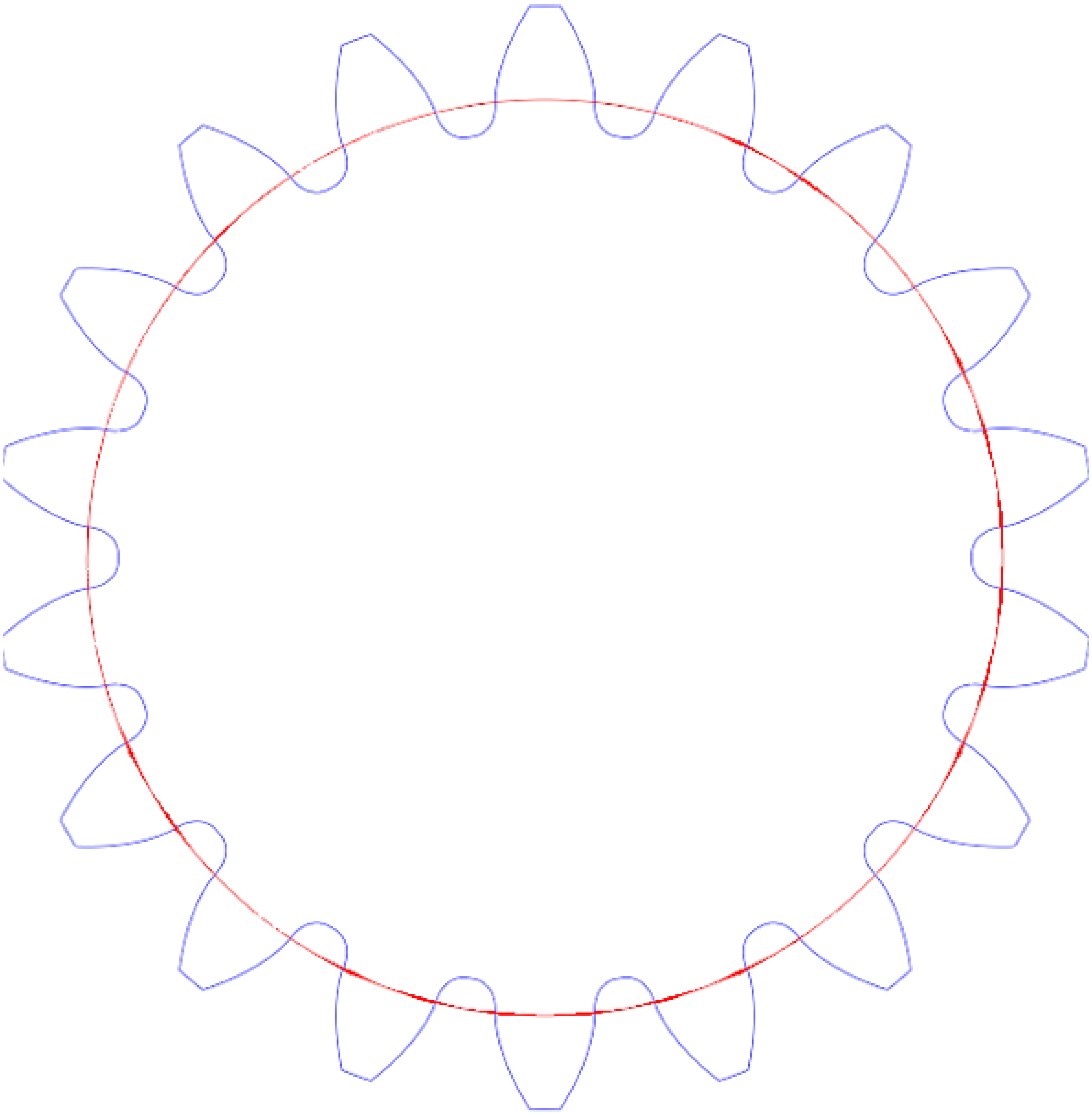

FIGURE 4

Tooth form gear

3.1.4 *PROFILE PARAMETERS*

TABLE 4
Input parameters for gear 1 and gear 2

SPECIFICATION	GEAR 1	GEAR 2
GEAR TYPE	SPUR GEAR	SPUR GEAR
NORMAL MODULE	2mm	2mm
PRESSURE ANGLE	20	20
CENTRE OF DISTANCE	368mm	368mm
TOOTH THICKNESS TOLERANCE	DIN 3967 cd25	DIN 3967 cd25
CALCULATION METHOD	DIN 3990: 1987 METHOD B	DIN 3990: 1987 METHOD B
NUMBER OF Teeth	18	54
TORQUE (Nm)	114.5916	114.5916
SPEED (rpm)	1500	1500
POWER (HP)	24.1386	24.1386
SERVICE LIFE	20000 h	20000 h
ADDENDUM COEFFICIENT	2mm	2mm
DEDENDUM COEFFICIENT	2.5mm	2.5mm
TIP DIAMETER	52mm	52mm
ROOT DIAMETER	43.6432	43.6432
ROOT FROM DIAMETER	45.5860	45.5860
ROOT RADIUS	0.76mm	0.76mm

4 Result and discussion

4.1 Parameters used for experimentationA

TABLE 5
Total experiment number

TOTAL EXPT NO.	GEAR RUNNING HOURS	SPEED (RPM)	LOAD (N)
9	10000,15000,20000	1000,1500,2000	400,450,500

This table shows the numerical values of various parameter (i.e., Gear running hours, speed and load) that have been selected for experimentation that is for gear fault diagnosis. Using the data obtained various graphs are plotted and analyzed.

CASE – 1 (10000 HRS)

TABLE 6

Vibrational data for 10000 hours

				Case-1	
sl no	**Gears-(1x1000) hrs**	**speed-rpm**	**Load-N**	**Amplitude (m)**	**Frequency (Hz)**
1	20	1000	400	0.131	156.000
2	20	1500	450	0.142	168.000
3	20	2000	500	0.176	172.000
4	20	1000	450	0.141	135.000
5	20	1500	500	0.170	147.000
6	20	2000	400	0.183	178.000
7	20	1000	500	0.171	154.000
8	20	1500	400	0.184	176.000
9	20	2000	450	0.198	196.000

This table shows the experimental values of gear wears for different gear running hours, speed and load for different set of experiment conducted. Total 27 experiments were conducted for different gear running hours. The values of different parameters are shown in this table.

4.2 ANALYSIS OF VARIANCE(ANOVA

From this ANOVA table it shows that the p-value of gear running hours and speed is 0.001which very less than 0.1. it shows that the gear running hours speed influence significantly gear wear faults. Also, the speed and gear running hours which has been contributing to gear faults are 52.11% and 42.03% contribution of error is 4.58%.

The major effect plots were examined during the analysis of the data to determine the number of parameters and their contribution. The variation of each individual response with respect to the three parameters was independently displayed using the Minitab software. In the charts, the x-axis represents the parameter values, while the y-axis represents the response value. Finding the gear defects included using the graphs.

TABLE 7

ANOVA table

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.004016	95.42%	0.004016	0.001339	34.71	0.001
Gears-hrs	1	0.001769	42.03%	0.001769	0.001769	45.87	0.001
speed-rpm	1	0.002193	52.11%	0.002193	0.002193	56.87	0.001
Load-N	1	0.000054	1.28%	0.000054	0.000054	1.4	0.29
Error	5	0.000193	4.58%	0.000193	0.000039		
Total	8	0.004209	100.00%				

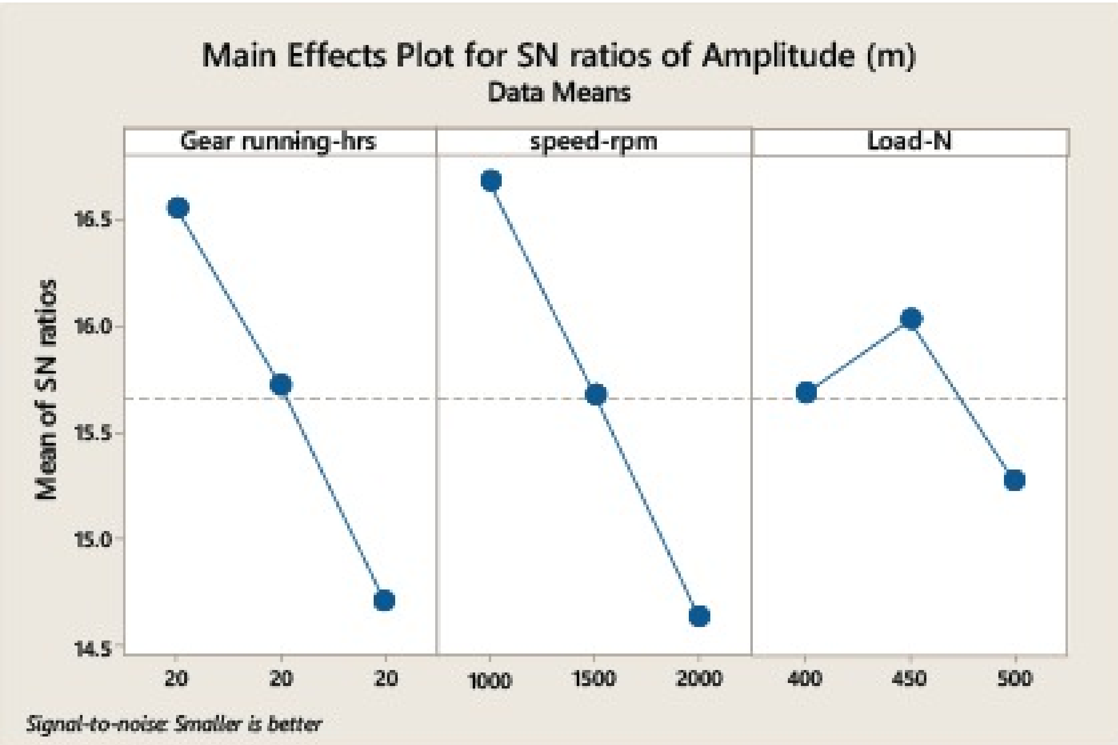

FIGURE 5

Mean of SN ratios vs gear running, speed, load

Figure 4.3.1. Mean of SN ratios vs gear running, speed, load

This figure shows the main effect plots for signal-to-noise ratio of amplitude. The Highest slope tends more significant i.e., gear running hours and speed. The graph shows significant increase in gear faults when gear running hours and speed increase respectively. But for load this not prominent.

The table 8 displays the signal-to-noise ratio for various settings, with smaller being preferable. This response table demonstrates how, for various higher levels, speed dramatically out-

Table 8

Rank Table

Level	Gears-hrs	speed-rpm	Load-N
1	0.1499	0.1475	0.1664
2	0.1647	0.1655	0.16
3	0.1842	0.1858	0.1724
Delta	0.0343	0.0382	0.0123
Rank	2	1	3

performs performance. The rank is given for their contribution to gear errors as speed foremost speed and gear running hours and load following behind.

Table 9

ANOVA table for frequency

Analysis of Variance							
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	2078.3	76.02%	2078.3	692.8	5.28	0.052
Gears-hrs	1	150	5.49%	150	150	1.14	0.334
speed-rpm	1	1700.2	62.19%	1700.2	1700.2	12.97	0.016
Load-N	1	228.2	8.35%	228.2	228.2	1.74	0.244
Error	5	655.7	23.98%	655.7	131.1		
Total	8	2734	100.00%				

From this ANOVA table it shows that the p-value of gear running hours is 0.334 but speed is 0.016 which very less than 0.1. it shows that the speed influence significantly gears wear faults. Also, the speed which has been contributing to gear faults is 62.19% which is the highest among them. Contribution of error is 23.98%.

This figure shows the main effect plots for signal-to-noise ratio of amplitude. The Highest slope tends more significant i.e., speed. The graph shows significant increase in gear faults when speed increase respectively. But for load and gear running hours that is not prominent.

This table displays the signal to noise ratio for various settings, with smaller being preferable. This response table demonstrates how, for various higher levels, speed dramatically outperforms performance. The ranking is based on how much each factor contributes to gear mistakes, with speed being given priority over gear operating hours and load coming in second.

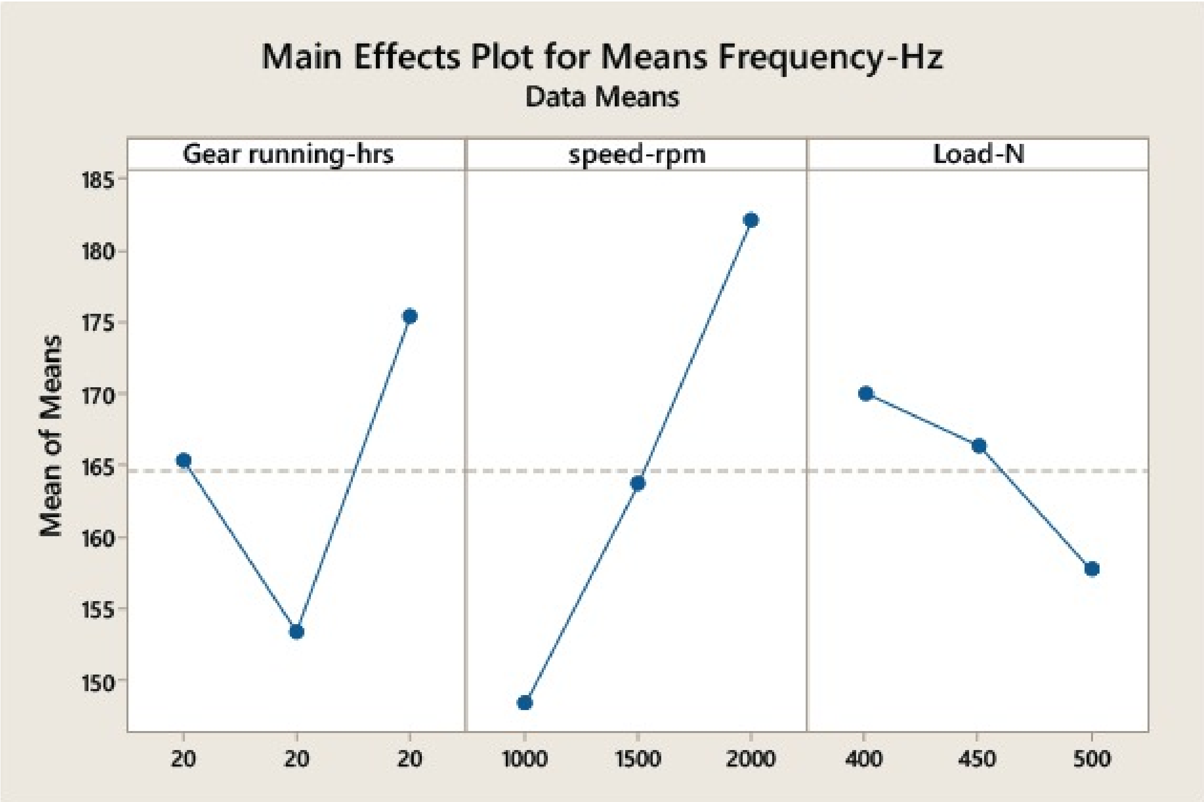

Figure 6

Graphical representation of mean of mean vs parameters

Table 10

Rank table

Level	**Gears-hrs**	**speed-rpm**	**Load-N**
1	165.3	148.3	170
2	153.3	163.7	166.3
3	175.3	182	157.7
Delta	22	33.7	12.3
Rank	2	1	3

5 CONCLUSION

Many of the graphs' analyses yielded dynamic vibrations with values for various errors. After considering this factor, we can say that the entire system was designed to simulate a gearbox failure. These days, this kind of modern system is used for artificial purposes. Before disassembling the entire system, we may determine what type of error the gearbox has by comparing the vibration response of an imperfect gearbox with a certain defect with the response of a fresh gearbox that is an advantage in this kind of artificial system. The benefit of this kind of system is that we can quickly locate the issue without having to open the full thing. As a result, fixing a flawed system using this method will take less time. Experiments were conducted based on DOE using full factorial design L9 orthogonal array.

• Gear errors are influenced by gear running hours, loads, and different speeds and this is confirmed by main effective plot and ANOVA.

• Comparative study shows the contribution of all parameters towards gear faults keeping time constant

• For normal probability plots the system Has been investigated by residual analysis, where in the residual don't fall on the straight line as it confirmed by normal probability plots.

• Regression analysis was done on the data obtained from the experimental runs between gear life span, load, and speed. It was observed that regression equation predicted values with the least errors.

References

[1] Barshikar Raghavendra Rajendra-Condition monitoring of gearbox by using motor current signature analysis.

[2] Daniela Toshkova and Will Moore, Gearbox condition monitoring under variable operational conditions, 2014.

[3] Amit Aherwar and Md Saifullah, Vibration analysis techniques for gearbox diagnostic, 2012.

[4] Abdulrahman S Sait. Chapter 25 a review of gearbox condition Monitoring based on vibration analysis Techniques diagnostics and prognostics. *Springer science and business media llc*, 2011.

[5] M J Raghavendra, C G Ramachandra, T R Srinivas, and Prashanth Pai. Optimization of Surface Roughness in Turning Operation in Machining of TI-6AL-4V (Titanium Grade -5. *IOP Conference Series: Materials Science and Engineering*, 2018.