Perspectives of Visualization of Vibration quant data to study effect of particle damping for Gearbox Using Data Analytical Tool: Tableau

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Abstract

One of the crucial mechanical transmission systems used in an industrial setting is the gearbox. In particle damping technique, The impact mass includes number of particles and corresponding dissipation of energy will take up place due to impact, exchange of energy and friction in between gear body and impact mass. Hence Particle impact damping techniques are used to decrease the undesirable vibration in engineering systems such as gear box. Hence this paper's goal is to discuss the impact of particle damping at various ratios on the vibration signals of gears. Also, Its objective is to investigate the vibrations of a single-stage spur gearbox while taking both healthy and faulty situations into account. An experimental test rig is developed for examining the effect of damping in single stage spur gearbox. The study provides lab research that was conducted using an experimental setup for the study of particle damping technique which is applied for minimizing gear vibrations to increased reliability of system. The focus of this research is solely on particle damping and how it affects vibration reduction. This paper attempts to investigate effect of particle damping to find the most sensitive damping combination with considerations by varying the conditions like applied load (0 ,1.5 kg, 2.5 kg), Particle filling rate (10 %,30%,50%,70%,100%), particle size (ball diameter as 3 mm & 5 mm), no. of holes (4 & 6), gear condition (healthy & Faulty) for the gearbox system under consideration. This paper proposes a novel approach of visualizing the vibration data using data visualization toll like Tableau for examine the effect of different parameters like applied load, speed, particle size, number of ger blank hole and particle filling ratio on mechanical system like gearbox.

Keywords: Vibration measurement; Particle Damping, Data Visualization, Vibration reduction.

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1. Introduction:

Gears represent a valuable component of many mechanical devices. The operating life, efficiency, maintainability, and reliability of gear transmission systems are currently being continuously improved. Gearboxes are a class of devices that primarily emits structural noise. Vibration and noise are mostly transmitted via three different channels.: firstly, the solid sound that is carried during the process of meshing and is produced by the gears through the tooth surface track ⟶gear blank hole⟶shaft⟶bearing⟶casing cover of gear box and then it is released to transmits the vibrations of surface to the gearbox's exterior space.In addition to handling the vibration problem caused over by exciting force, the gear transmission system introduces the particle damping approach. The damper is developed by adding particles to the interior space (gear blank hole) to efficiently minimize vibration. At the beginning of the transmission path, there is a lightening hole (gear blank) between the tooth side and the shaft. To produce energy dissipation by particle collisions and frictional contact among the dampers surface and the particle, Particle dampers are placed into the gear blank's lightning hole. [11-13]

Data visualization is the systematic representation of data that includes variables and properties for the informational unit. To provide static and dynamic explanations of the data that meet the needs of the end user, data visualization involves learning the data and developing software-driven mechanisms. Many traditional data visualization techniques are frequently employed. They include tables, histograms, scatterplots, line, bar, pie, area, flow, bubble, and combination charts as well as numerous data series, timelines, Venn diagrams, data flow diagrams, and entity connection diagrams, among others. We can process more complex information and improve memory through visualization. The decision-maker and researcher can develop and fine-tune questions from the data with the use of statistical data exploration..Visualization assists in comprehending and presenting data in traditional research, where an objective inquiry and a follow-up question come before data collection. The abilities needed to investigate and present data material in a more attractive way differ from those needed to analyze it, with the latter requiring greater imagination and creativity. [5,7,9]

Tableau is to visualize and understand their large data sets. Tableau's capabilities are worth the time and effort it takes to learn and will continue to use it to assist evaluation methods such as Decision-Making, in which it provides the advances of blending and simultaneously examining visuals of articles data from different sources. [8]

2. Tableau Platform for data visualizations

2.1 Data preparation:The study uses Tableau to quantitatively explore data through visualization and categorized as descriptive research that uses visualization. The visualization of this gearbox vibration data is showed. The available data was in the form of different FFT readings as files (.csv) and visualization was designed to focus on the geographical dimension and overall reading count and number of experimental combinations used in experimentation for studying the effect of particle damping.

2.2 Data visualization: It is representing data in a graphic form that easily understands the logic behind it. This visual representation can be a form like charts, tables, graphs, lists, maps, or sites. Data analytics is the process of analyzing the types of data sets to gain relevant insights and create interpretation regarding them. For understanding, The representation of relational database with its properties and variables is known as data visualization. It relates the data's connections with visuals. This is significant since makes it easier to look trends, shapes, designs, and patterns on the display.

The purpose of this study is to introduce new techniques and improvements in vibration data visualization using traditional techniques and the addition of more than a few of them for data management, explaining the data visualization, and analyzing expertise development in it using tool like Tableau.

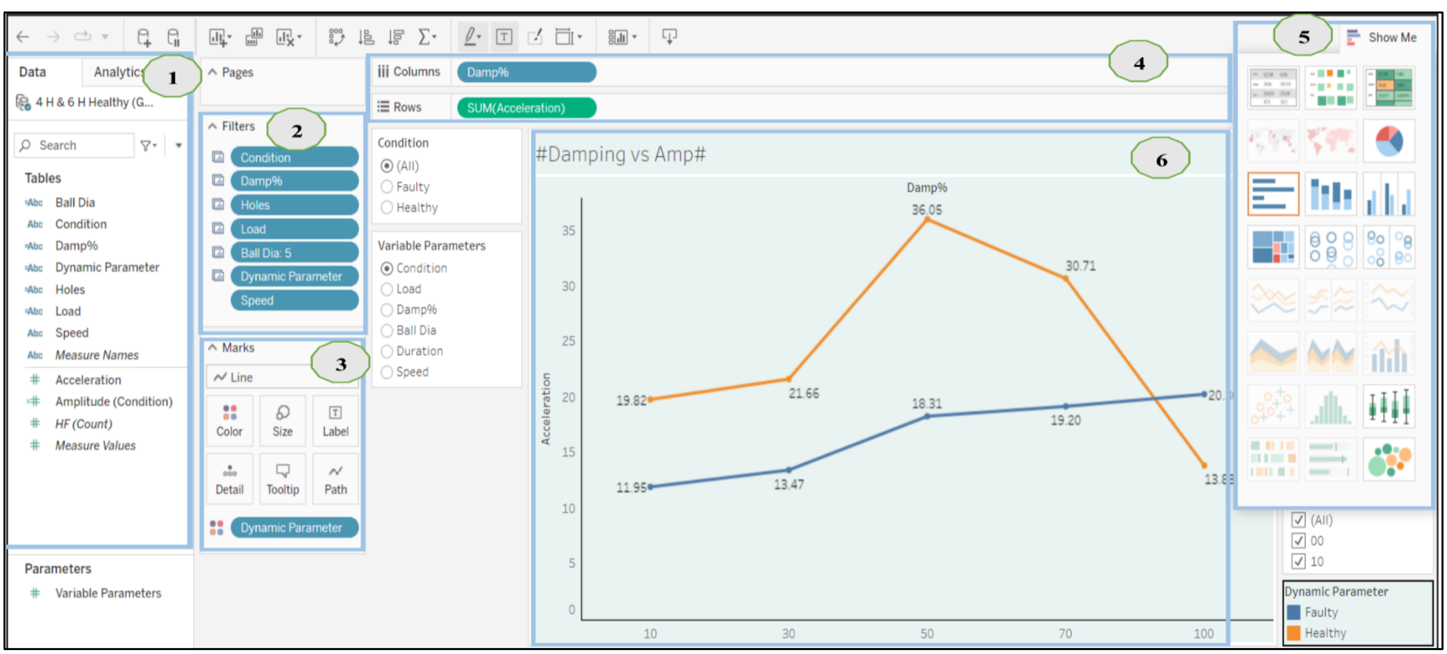


Fig.1Sample Visual descriptionin Tableau

Fig. 1 A sample of the pictorial description in Tableau using the vibrational data.

①
shows the features of the data, and operators can drag features to ④.

④states the column and row features for the aspect of visualization.

The table's column attributes (such as Damping%) and row features (such as Acceleration) are indicated by the columns and rows in end users can select the condition of filter and pictorial map of points in ② and ③, respectively. Also, end users can click in⑤ to choose the type of chart by doing so.

⑥displays to end users the concluding desired visualizations, which is a vibrational conditions line chart.

A unique aspect of the current work is that the genuine scenario is taken into consideration, where the effect of particle damping in healthy and faulty condition of gearbox are studied with help of data visualization tool like Tableau, which is an uncovered area of study. By using Tableau, we can be able to find actual relation of particle damping with respect to different applied load conditions, speed conditions, gear blank (hole) conditions etc. Here, an attempt is made to identify useful aspects from the observed vibration signal at scales matching as the gear mesh frequency (GMF)to analyze particle damping in gears.[21]

3. Experimental Procedure:

3.1 Experimental set up:

The procedure for experimentation work (Fig.2) consists of test rig where it is likely to research the effects of faulty and healthy gear vibration. The approach applied in study (Fig. 3) involves using an experimental setup to assess the vibrations of gear in both healthy and faulty circumstances. The various components in this experimental arrangement like gears, bearings, shafts (input and output), pulleys, dynamometer for varying loads are all connected to each other, transferring the vibrations caused by gear meshing contact between the gear body, the shaft, the bearings, and the gearbox casing. This connection allows the accelerometer sensor to measure the vibration signal at the gearbox casing side near the bearing location. The interaction of all the components produces this signal, which is formed by the rotary motion of the shaft, tooth engagement, bearing movement, casing vibration and sound.

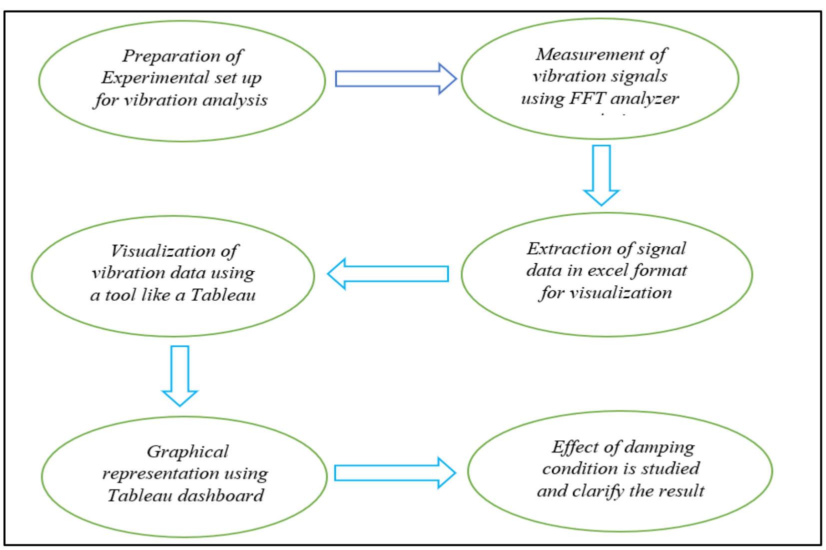


Fig 2. Experimental Procedure

Preparation of experimental set up which consist of different major parts such as motor, gearbox, rope break dynamometer etc. once all connections and alignments from motor to dynamometer are verified then measurement of vibratory signals at different conditions using FFT analyzer are carried out. The extraction of signal data is export from FFT analyzer in .csv file and then it can be used for data visualization for Studying the impact of particle damping on gear vibrations using a tableau.

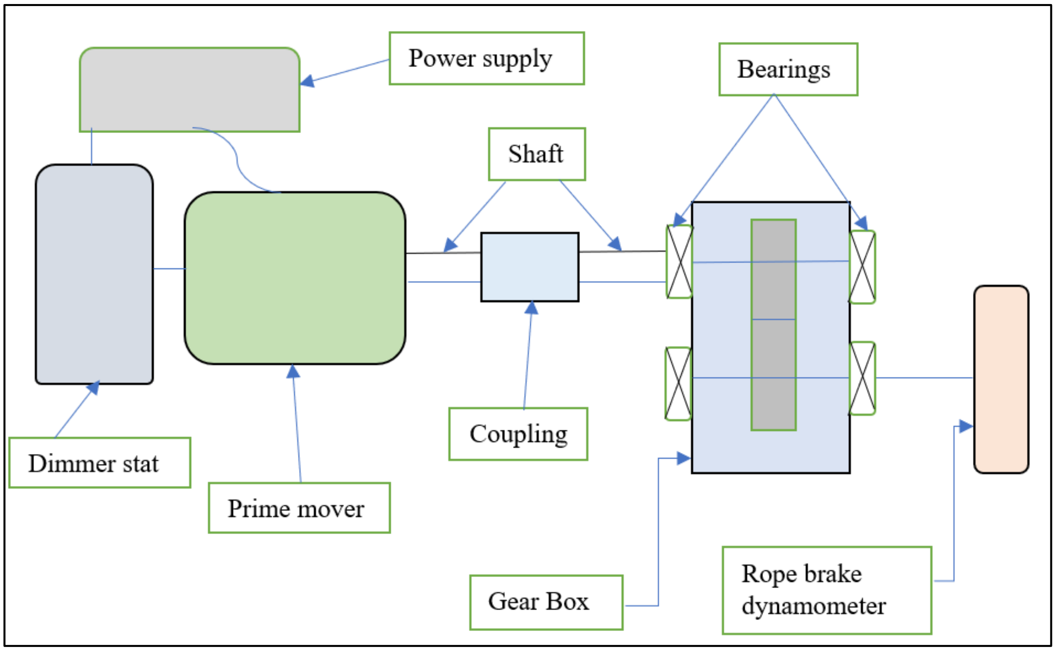


Fig.3. Graphicalblock diagram of experimental setup.

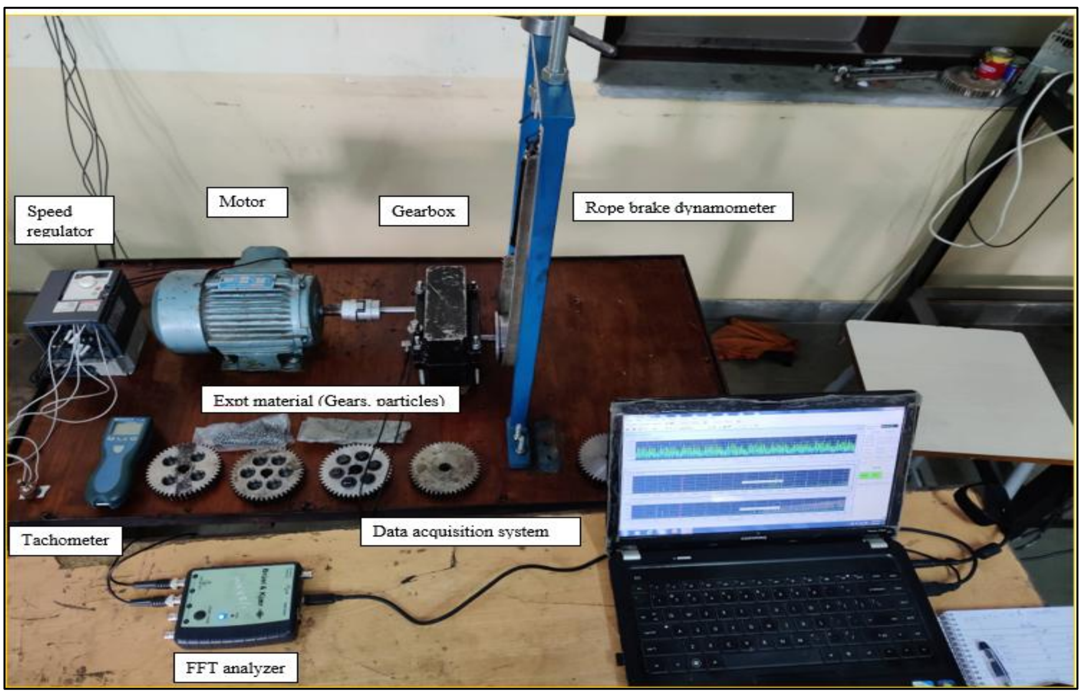


Fig. 4 Pictorial view of actual experimental set up.

3.2 Experimental Methodology: Fig. 4demonstrates the experimental setup for the vibration analysis of particle damping in the single stage spur gear box.The test setup is a single-stage spur gearbox with steel (En8) gears having the specifications as below table,

Table 1 Specification of set up

Sr. No.	Description	Remark
1	module	2.2 mm
2	pressure angle	20 Degree
3	teeth on pinion	23
4	teeth on gear	46
5	face width	22
6	Material	steel (En8)
7	shaft length	175 mm
8	Motor	3 phase 1 HP, 2800 rpm A C motor
9	power Transmitted	0.75 KW
10	Bearings used for input shaft	6201
11	Bearings used for output shaft	6202

After taking into account the interactions between rotational speed and vibration frequencies, the setup's fundamental parameters were defined. Typically, general production concerns are considered. On the gear box casing surface at the bearing location, a single channel accelerometer with a sensitivity of 100 mV/g ($g=9.81 m/s^2$) was installed and using a four-channel FFT analyzer, measure the vibrational characteristics in the radial (vertical) direction, like as velocity and acceleration. The channel 1 was chosen for the capturing signal data from accelerometer, whereas a tachometer was used to monitor the rotational speed.

a)10% Particle Filling Ratio b) 30% Particle Filling Ratio

c) 50% Particle Filling Ratio d) 70% Particle Filling Ratio

Fig. 5. Particle filling ration in gear blank hole.

The Vibration signal data is measured by using the instrument FFT analyzer with an accelerometer. Following combinations of experimental vibration signatures are examined:

(1) Speed ranges from 200 to 800 rpm
(2) Particle damping (filling) ratio varies from null, 10 %, 30 %, 50 %, 70% and 100% (Fig.5)
(3) Load acting on gearbox through rope brake dynameter 0 (NL) to 2.5 kg,
(4) Number of gear blank holes on gear as 4 and 6.
(5) Diameter of particles is 3 mm and 5 mm.

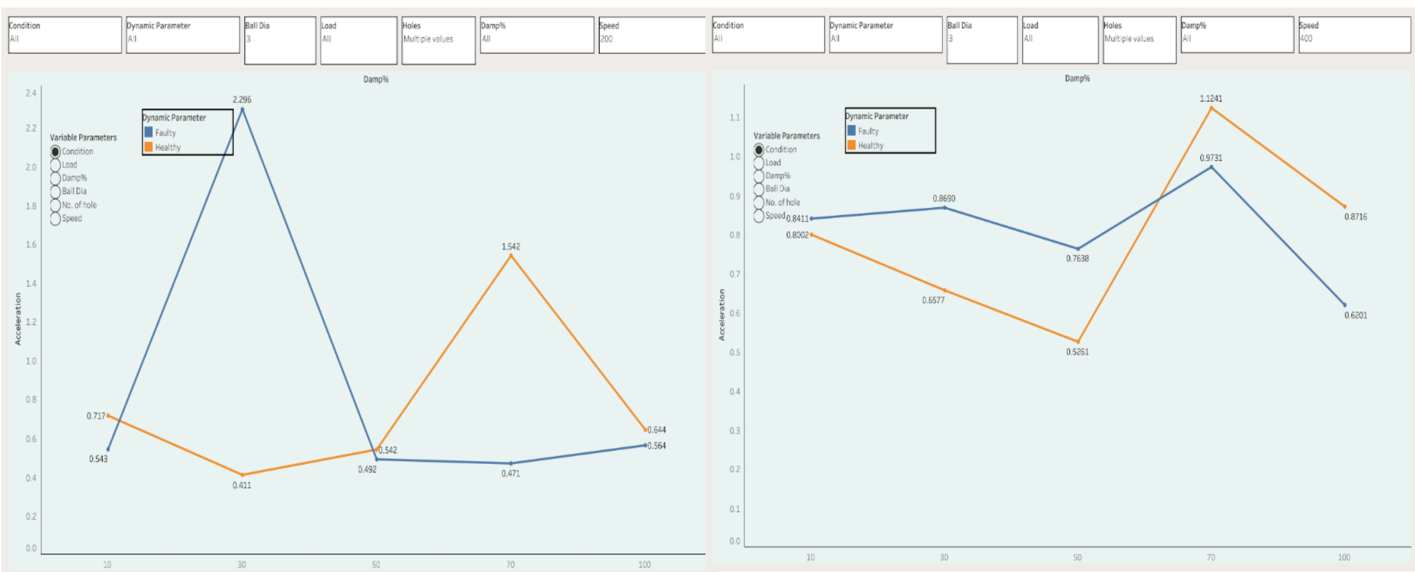
To acquire a proper interpretation of the vibration signatures, all the above conditions are evaluated, and the results are interpreted from the signal analysis.

4. Result and discussion of Vibration data visualization and its interpretation:

As discuss earlier about different combinations for acquiring vibrational signals for gear box experimental set up, the

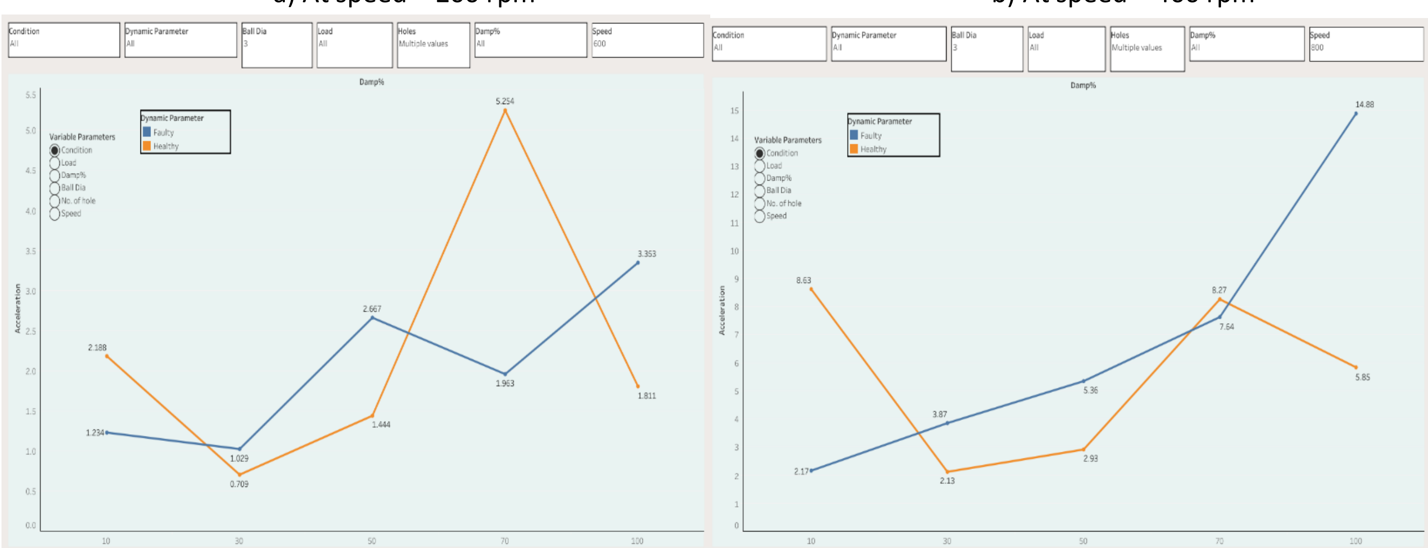
Particle size	No. of Hole	Speed (rpm)	% Particle Damping	Load applied (kg)	Condition
3 mm	4	200 , 400 , 600 ,800	10 % to 100 %	0 to 2.5	Healthy & Faulty

following set of conditions are taken into consideration for visualisation and its insights interpretation.



a) At speed = 200 rpm

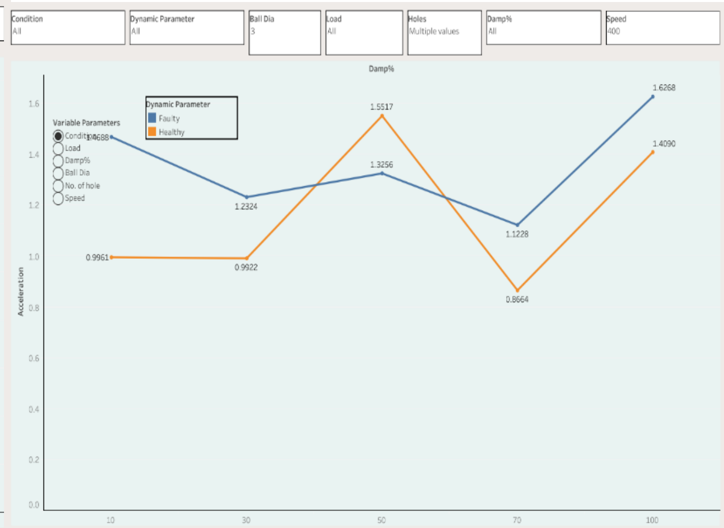
b) At speed = 400 rpm



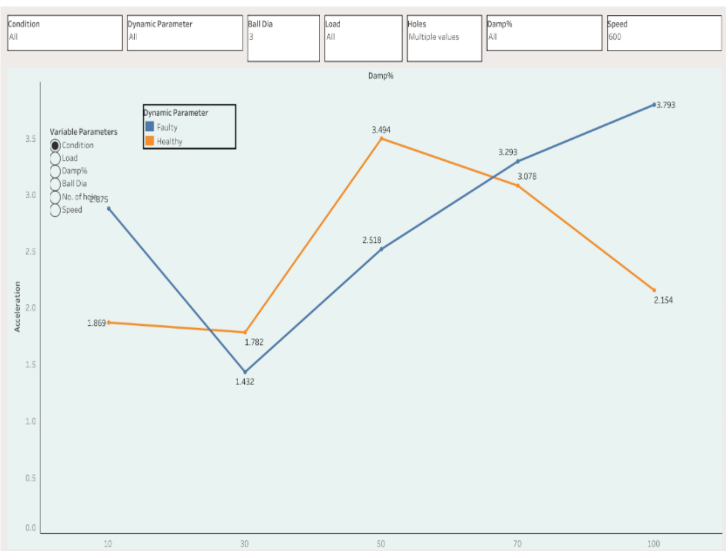
c) At speed = 600 rpm d) At speed = 800 rpm

Particle size	No. of Hole	Speed (rpm)	% Particle Damping	Load applied (kg)	Condition
3 mm	6	200 , 400 , 600 ,800	10 % to 100 %	0 to 2.5	Healthy & Faulty

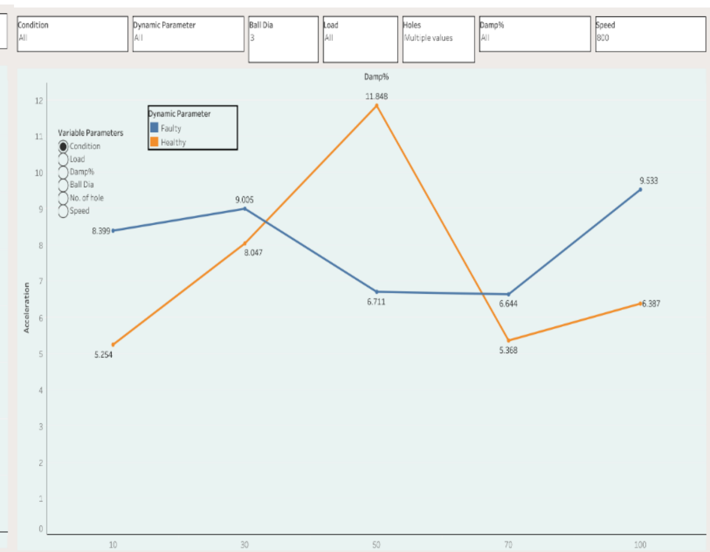
a) At speed = 200 rpm



b) At speed = 400 rpm



c) At speed = 600 rpm

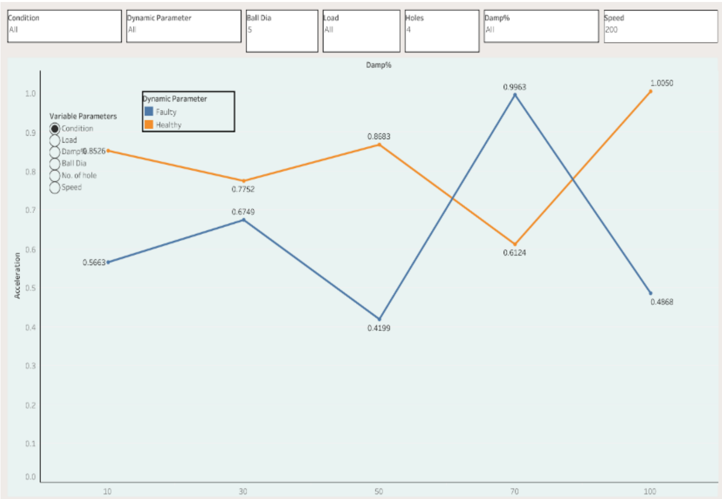


d) At speed = 800 rpm

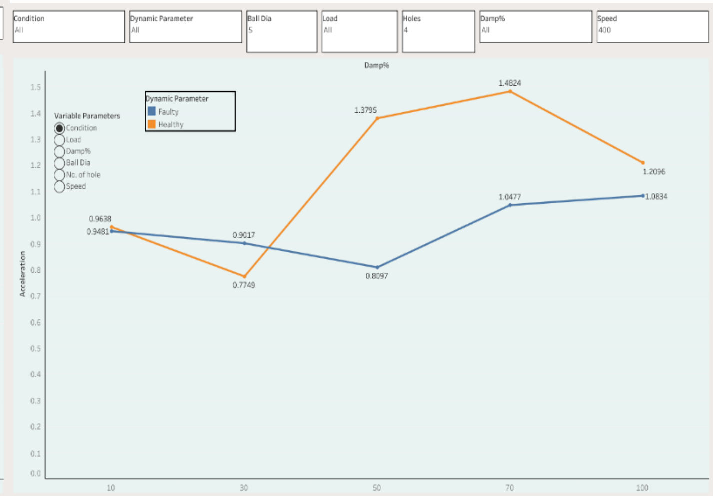
From above plots we can observe the significance of increase in speed from 200 rpm to 800 rpm by keeping particle size as 3 mm with No. of gear blank holes as 4 then the corresponding damping range occurs from 70 % of particle damping. onwards. But as we increase the no. of gear blank holes from 4 to 6 keeping particle size as 5 mm the relative damping range occurs at 30 % to 50 % of particle damping.

Hence, we can conclude that as we increase the gear blank holes from 4 to 6, the damping range of vibrational data shifted from 70 % to 30 % - 50 % of particle damping. So considerable damping observes at higher no. of gear blank hole with respective of speed which ranging from 200 rpm to 800 rpm.

Particle size	No. of Hole	Speed (rpm)	% Particle Damping	Load applied (kg)	Condition
5 mm	4	200 , 400 , 600 ,800	10 % to 100 %	0 to 2.5	Healthy & Faulty

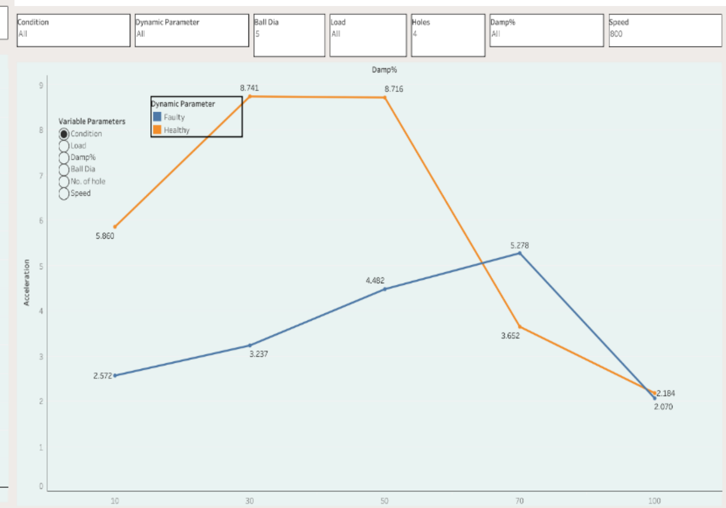


a) At speed = 200 rpm



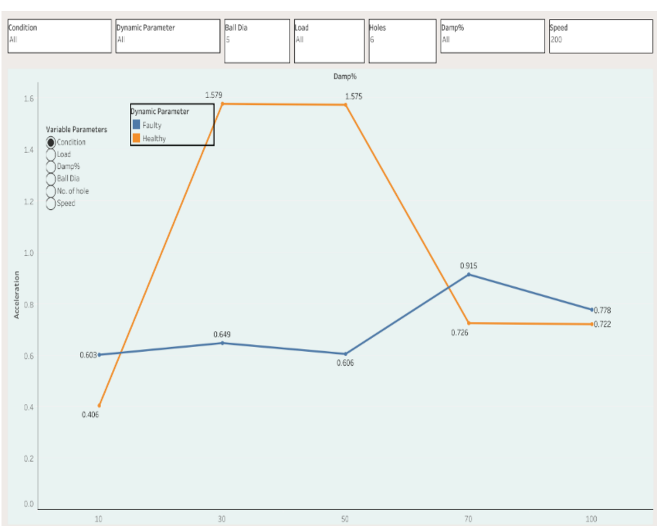
b) At speed = 400 rpm

c) At speed = 600 rpm

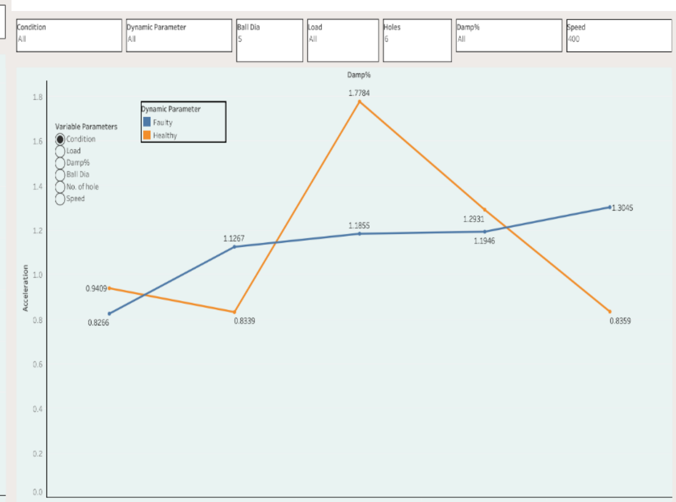


d) At speed = 800 rpm

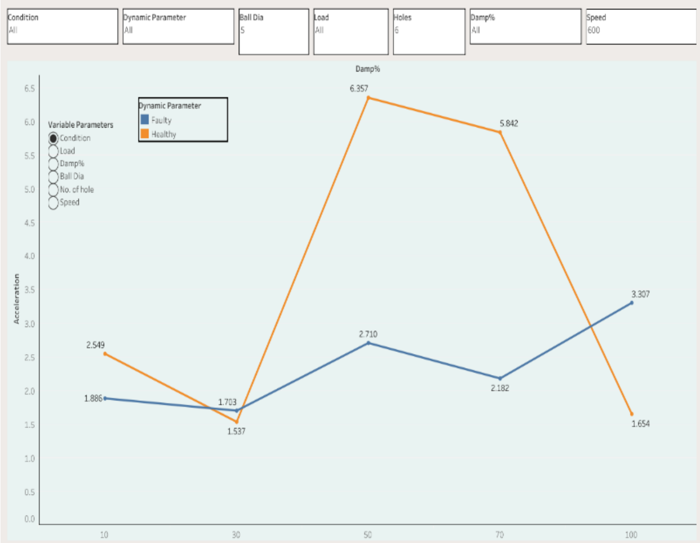
Particle size	No. of Hole	Speed (rpm)	% Particle Damping	Load applied (kg)	Condition
5 mm	6	200 , 400 , 600 ,800	10 % to 100 %	0 to 2.5	Healthy & Faulty



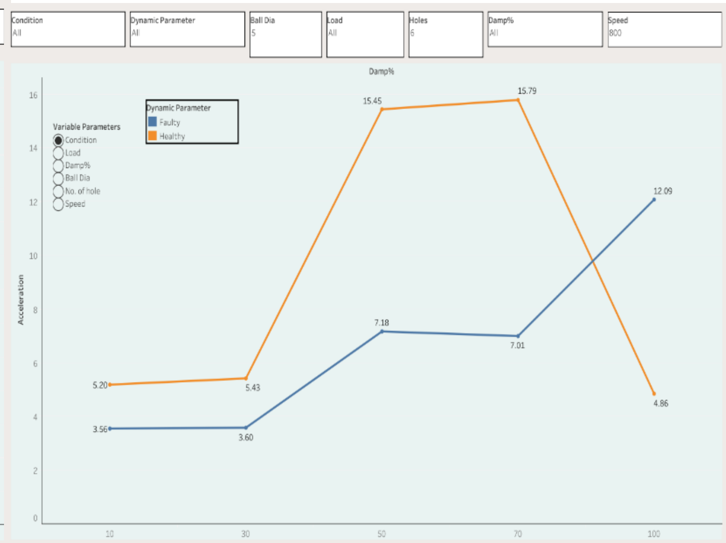
a) At speed = 200 rpm



b) At speed = 400 rpm



c) At speed = 600 rpm



d) At speed = 800 rpm

From above plots we can observe the significance of increase in speed from 200 rpm to 800 rpm by keeping particle size as 5 mm with No. of gear blank holes as 4 then the corresponding damping range occurs from 50 % of particle damping. onwards. But as we increase the no. of gear blank holes from 4 to 6 keeping particle size as 5 mm the relative damping range occurs at 30 % to 50 % of particle damping.

Hence, we can conclude that as we increase the gear blank holes from 4 to 6, the damping range of vibrational data shifted from 50 % to 30 % - 50 % of particle damping. So considerable damping observes at higher no. of gear blank hole with respective of speed which ranging from 200 rpm to 800 rpm.

5. Conclusion:

Following are some conclusions that can be drawn from the above analysis:

- For the current study, Tableau helps with its valuable investigative platform to visualize and compare the vibration data in different conditions like applied load, particle filling (damping) rate, number of holes, particle size, healthy-faulty situation, and possible interpretation from it.
- In this study, particle size and No. of holes plays is a crucial role for getting considerable amount of the damping effect. The dynamic response properties of particles varied under different speed range 200 rpm to 800 rpm and applied load from 0 to 2.5 kg conditions were studied.
- In case of particle size of 3 mm and no. of gear blank holes increase from 4 to 6, noticed the damping range of vibrational data shifted from 70 % to 30 % - 50 % of particle damping.
- In case of particle size of 5 mm and number of gear blank holes increase from 4 to 6, noticed the damping range of vibrational data shifted from 50 % to 30 % - 50 % of particle damping.
- Hence chances of obtaining more damping effect with a greater number of blank holes in gear.

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