



Monitoring the Status of the Pride Gear Box Using the *Beta-Kurtosis* of Its Vibrating Signals

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Monitoring the Status of the Pride Gear Box Using the *Beta-Kurtosis* of Its Vibrating Signals

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Abstract

Today, with the growth of industry and the increasing development of industrial machinery, the maintenance of these machines and the evaluation of their operation during the work is of particular importance. In this paper, we have tried to find out all the vibration signals associated with it in the case of a healthy and defective gearbox, and to examine the results by familiarizing them with the methods of receiving and analyzing the transmission of the Pride transmission. Using a laboratory gearbox belonging to this vehicle, all of its vibrational signals should be considered. For this purpose, using the vibration sensor, the data is extracted in different operating modes of the machine. After collecting data of each mode, using the MATLAB program and using the Beta-Kurtosis method, one of the statistical methods suitable for diagnosis of the gears will be extracted and examined by the vibration patterns of the transmission of the pride vehicle.

Keywords: Gearbox, Vibrating rotary machines, Preventive maintenance, Troubleshooting, Beta-Kurtosis



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1- Introduction

In general, vibration monitoring is the most common type of monitoring, especially in rotary machines. In this way, it can be seen from the defects caused by, the gearbox, the inhomogeneity, the idle, the shaft bending, the inappropriate lubrication, and so on. For these investigations, the analog information associated with the machine is collected at the time of operation by the related sensors, and subsequently detected by digital analogue filters for the computer, and finally, the necessary analyzes are performed on them for the final interpretation of the information. After troubleshooting, steps are taken to fix the fault. In the foregoing task, the objective of monitoring the status of the Pride gearbox is the use of Beta-Kurtosis of its vibrational signals through the data received from the installed accelerometers and the specification of this defect with the help of MATLAB software. The general vibration mechanism in machines, motors and in most structures can be modeled and limited to relationships that can be determined by changing the operating conditions or operating conditions. For example, vibrations applied to piston engines can be modeled to combustion forces and mechanical forces such as (piston movement, gears, bearings, fuel spraying equipment and valve mechanisms). These forces are applied to the engine structure and produce vibration responses, which depend on the type of force and the characteristics of the engine structure that forces it. A vibrational signal measured from a machine that can be checked can be very useful in detecting faults by analyzing it in a time and frequency environment. [1] A review of several papers that have been published so far has shown that choosing a time-domain averaging method over large sets of high-noise sources would be an appropriate method [2]. The use of wavelet transformation in recent years, with optimizations, has provided very good results in this regard. Different types of energy methods, which are the basis of many new methods, are useful in many cases [3]. The use of neural network method in the field of troubleshooting of gearboxes and other rotor parts has been very important in recent years [4, 5]. In 2011, Zhang et al., in their paper entitled "A probabilistic approach to troubleshooting the implementation of bearings, have provided a method for troubleshooting important and sensitive members in mechanical systems." Their goal is to identify defects in the least possible time, with due regard to the accuracy of the operation and to ensure its failure rate. In order to apply innovative methods, they have resorted to using the Baisin estimation algorithm. This algorithm combines the system status indicators or indicators that are collected through sensors with some simple model representations of the system, until the deviation or bias between the distributions of these variables is compared to a healthy state (without defects). To this end, it is necessary to define a model that can detect a faulty state in the operating system. As a result, they have introduced a generalized model based on the failure analysis, which, after examining the probability of abnormal conditions, has been able to detect defective states within the intended range of assurance. In order to check the validity of this method, the results of the data of the common bearings in the air transport vehicles and their observation have been used, which confirms the ability of the proposed model [6]. In 2016, Victor and colleagues studied two different methods of non-destructive



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troubleshooting (sound propagation method and acoustic-vibrational combination). The results of this study showed that the use of sound propagation in arc gears is more sensitive to the diagnosis of teeth defects than the combined method of measuring acoustic-vibrational signals. [7] As pointed out in the study's research, in recent decades most of the failures and defects have been studied in isolation and only in rotary machines. But sometimes these failures can only be created simultaneously and overshadowed by the severity of a malfunction, weaker crashes, and their symptoms. The severity of a failure causes some of the weaker failures to be detected, which leads to rework in the repair process and more time and cost, which is discussed in this article.

2- Research method

To test synchronous failure conditions, a laboratory equipment including an electric motor, a pride gearbox, which is also attached to an Excel axle, was designed and installed at the Auto Workshop of the University of Tabriz. The image of this laboratory equipment is shown in Fig. 1. In this research and in the troubleshooting process of the gearbox, our goal is to detect the fault and not to detect the type of fault, so two common types of common faults related to the gears are considered. Various defects such as mass denial, uncooled shafts, teeth cracking during production, or fatigue, scaling, or cavity in the ventricle, tooth failure, tooth erosion in different directions (tooth edges or contact surfaces), The excessive gap between the teeth, the defects caused by the bearings, the exit from the center of the gears and the defects caused by the gear components are common in the gearboxes. Of the cases mentioned, due to the limitation of some types of defects, only two cases have been considered, the failure of the tooth and its abrasion. To create the defects mentioned, the gear is selected for the third (third gear) mode. This choice is due to the fact that increasing the torque applied to the shafts and, consequently, increasing the interdental force, has a direct effect on the increase of the effects and blows caused by the dentures and thus makes it easier to identify the defects in the signal.



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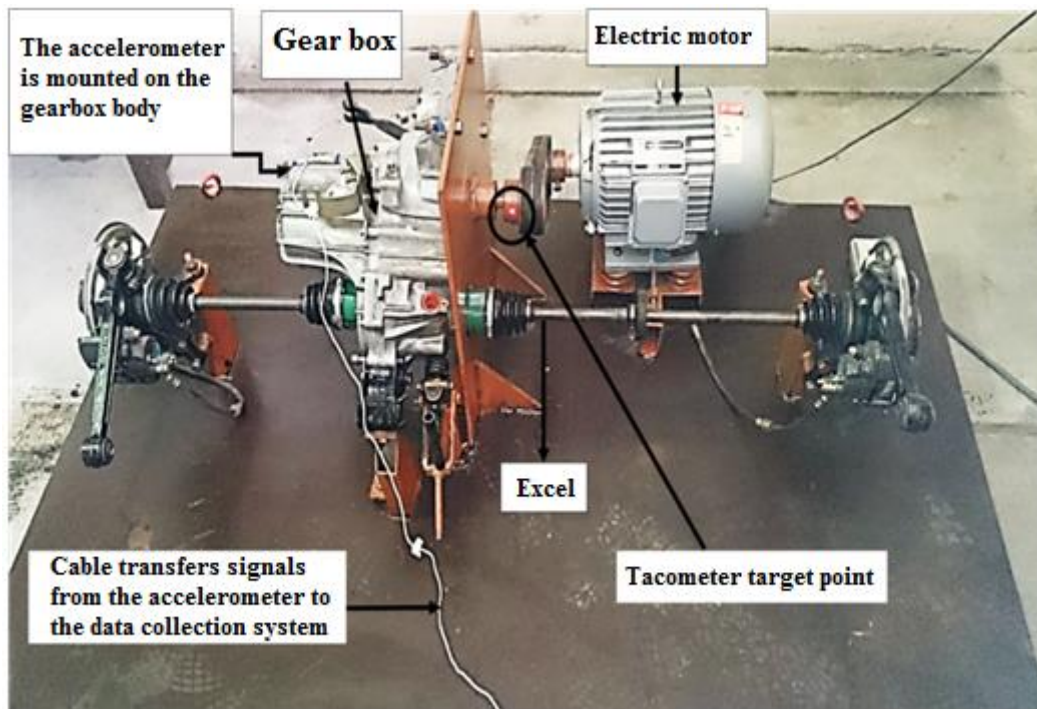


Figure 1: Equipment collection of experimental experiments

Sometimes there is not enough space in the industry for data capture from all parts needed, which makes it impossible to get all of the data points. To accommodate this limitation, only one accelerometer that is close to the breakdown position and mounted on the body of the gear is used. Accelerometer, Model 4507 of Bruel & Kjar, an example of which is shown in Fig. 1. The Fspan device is set to 25.6 kHz for data capture for 60 seconds, and the signals are transmitted by the cable to the data collection system to be stored by Bruel & Kjar Pulse Lab Shop after entering the computer. In general, the signals were collected in two modes of the system. These two states include a healthy state, a failure condition associated with the failure of the end bearing of the input shaft, as indicated in Table (1).

Table 1: Various test modes

Test number	State	Working speed (rpm)	Gear number
1	Healthy state	150	3
2	Damage state of the end bearing of the input shaft	150	3



2-1- Tests and receive signals related to it

- **Getting the signal in a healthy state:**

At this stage, which is called the base state analysis, the vibrating signals of the gearbox are received in a healthy state. With Pulse software, the number of sampling points and sampling time is specified, and the time domain graph of the accelerometer and tachometer signals appear on the screen. The relevant information is stored on the computer for later processing.

- **Receive a signal in an unhealthy state:**

After defect in the gear and the bearings, the vibrating signals are similar to the one before, we re-download and process. An example of the raw vibration signals obtained from the two states listed in Table (1) is given in Fig. 2. As seen in the figure, the failure of the bearing is very close to the sound signal, and only slightly different. In fact, by looking at the raw data of the vibrational signals of the time domain, the distinction between the state of health, the failure of the bearing, the failure mode of the gear and the combined failure mode cannot be stated.

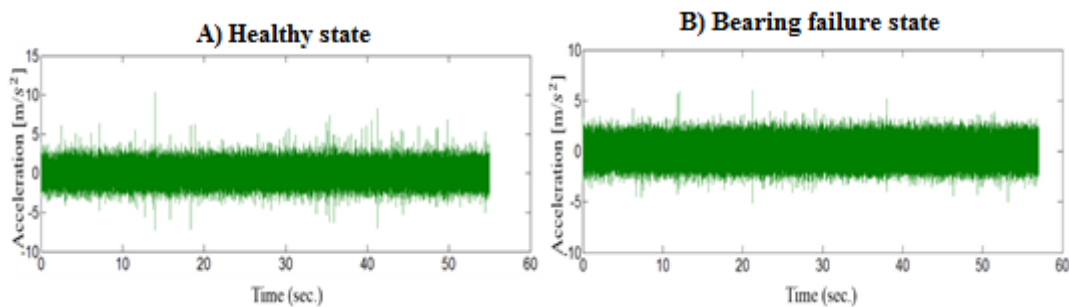


Figure 2: Vibration signals collected from laboratory equipment in two normal conditions and bearing failure

3- Results

In this section, the vibration and gearbox frequencies are presented in two solid state and faulty conditions in the bearings of the gear shaft end in the MATLAB software.



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3-1- *Results for healthy state of gearbox operation*

The first mode of data to the system is completely healthy. The functional characteristics of this system are presented in Table (2).

Table 2: Specifications for a healthy state of gearbox operation

Experiment mode	State	Gearbox speed (rpm)	Gear number
1	Healthy	150	3

After transferring data from the Pulse program to the MATLAB program, we first draw the signal diagram from the data, which shows (3) the state of the signal to the healthy state. This graph represents the measured acceleration signal with unit (m/s^2) versus time (s). For less than 6 seconds, the electric motor does not start at the system, so no data has been recorded at this time.

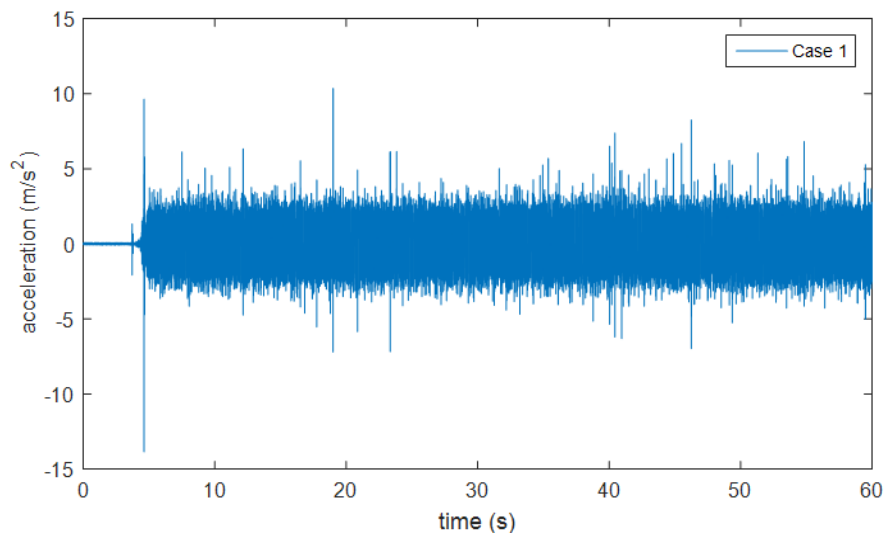


Figure 3: The signal plotted for the healthy state of gearbox operation



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As described in the previous section, during the vectorization of a gauge to record each round of the engine shaft movement. According to the data of this cameraman, the corresponding times correspond to the time of each complete round of the shaft, and by writing the code and algorithm in the MATLAB program, the separation of the signal based on the rounds is done for this mode. The signal shown in Fig. 3 is shown in Fig. 4 for 10 to 20 seconds. Changing the color of the signal over time represents a complete period of shaft. In this form, the data obtained from the remote sensing is also drawn. Matching the changes of the original signal color with the location of pulsed pulsations indicates that the separation of the ranges has been done correctly.

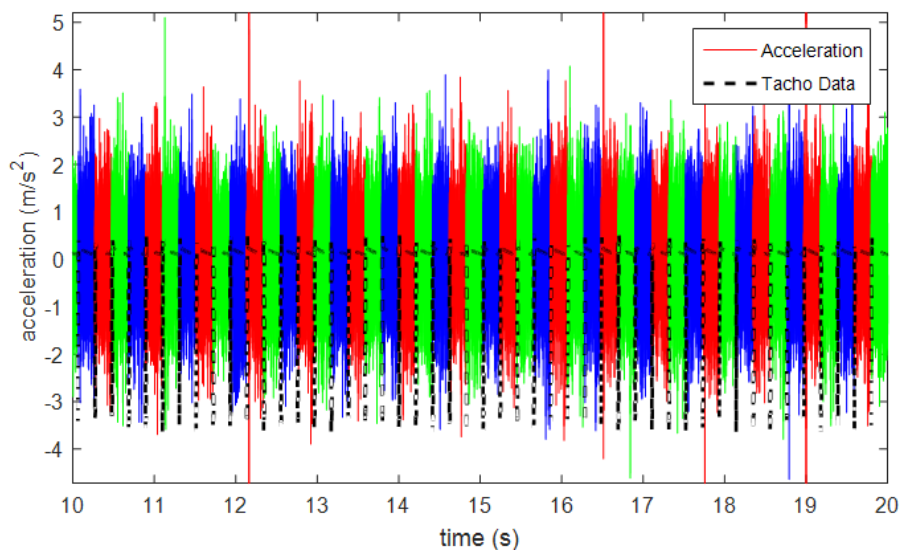


Figure 4: The separation of work cycles using the telemetric signal (tachometer); the change of the original signal color is equal to the change of telephony

By extracting the signal for each round of the system, you can extract the Beta-Kurtosis attribute for each round. First, it is necessary to calculate the parameters α and β and to calculate α and β , the mean values and the time signal variance must be calculated. In this paper, for each short signal, the mean and variance values, and subsequently the values of the parameters α and β , are calculated for each of the rounds above. Finally, the value of the Beta-Kurtosis parameter is obtained. In other words, the Beta-Kurtosis value is a function of a far-off number. In Fig. 5, the values of this parameter are represented by the signal of the first mode.

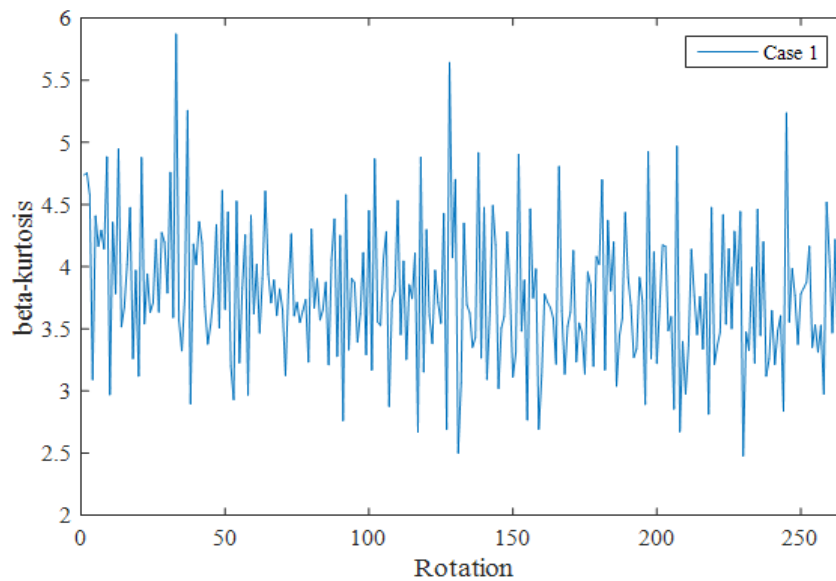


Figure 5: Characteristic Beta-Kurtosis Characteristics for a healthy state of gearbox operation

As shown in Fig. 5, the value of the Beta-Kurtosis parameters is the function of the round, or, in other words, the time function.

3-2- Results for the failure state of the gearbox shaft end

The second type of data is dedicated to the system, with the failure of the bearing of the shaft end. The functional characteristics of this system are presented in Table (3).

Table 3: Test specification for failure state of the end gear shaft gearbox

Experiment mode	State	Gearbox speed (rpm)	Gear number
2	Collapse of the shaft end bearing	150	3

As shown in the previous example, after transferring data from the Pulse program to the MATLAB program, the signal diagram of the data is plotted in Fig. 7, which represents the signal of the failure state of the shaft end bearing. This graph represents the measured acceleration signal with unit (m/s^2) versus time (s). This time, for less than 4 seconds, the electric motor does not start at the system, and so no data has been recorded at this time. For



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complete data analysis and benchmarking based on Beta-Kurtosis coefficients, data from this part of the time has been neglected.

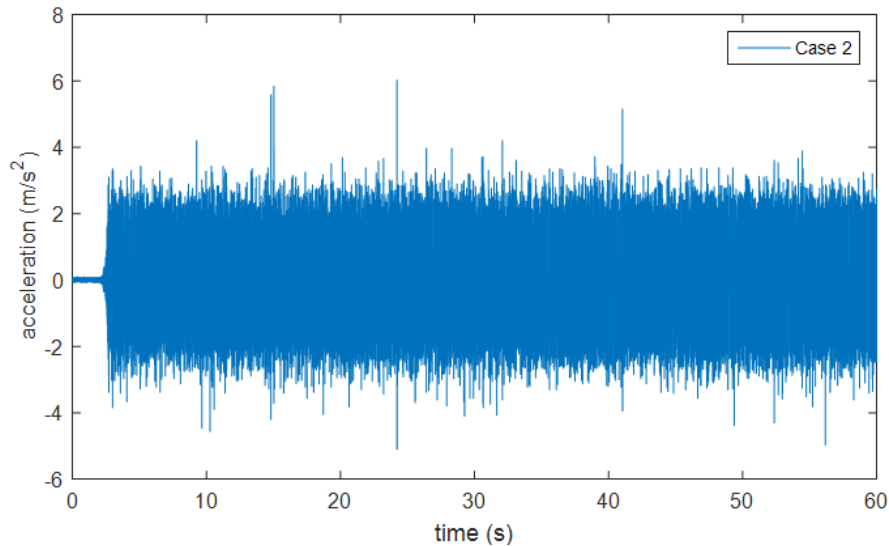


Figure 7: The signal plotted for the operation of the gearbox with a defective bearing at the end of the shaft

According to the sound state, according to the distance data, the corresponding times correspond to the period of each round of the specified shaft and the separation of the signal based on the periods for this mode also has been done. The signal shown in Fig. 7 is shown in Fig. 8 for 10 to 20 seconds. Changing the color of the signal over time represents a complete period of shaft. In this form, the data obtained from the remote sensing is also drawn. Matching the changes of the original signal color with the location of pulsed pulsations indicates that the separation of the ranges has been done correctly.



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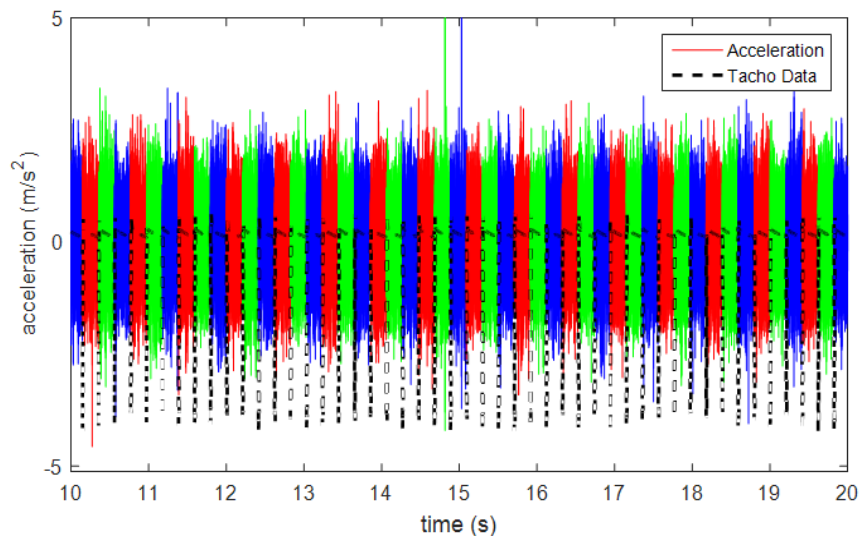


Figure 8: Working-time separation using the telemetric signal (tachometer); Change the color of the original signal equal to the change in working circumference

By extracting the signal for each round of the system, you can extract the Beta-Kurtosis attribute for each round. First, the mean values and the variance of the short-time signals are calculated, and then the parameters α and β are calculated. Finally, the Beta-Kurtosis value is shown as a function of the round number in Fig. 9, which corresponds to the second state signal.

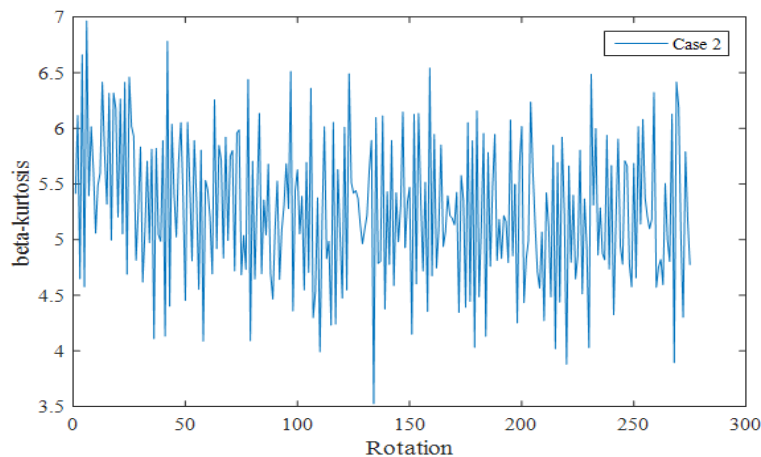


Figure 9: The chart of Beta-Kurtosis characteristic for the operation of a gearbox with a defective bearing at the bottom of the shaft

4- Conclusion

In order to extract and investigate the defects in mechanical parts using statistical methods, the acceleration signals of the piece should be available by special measurements. For this purpose,



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there are various hardware and software systems that are used in this section, and only the systems used in the gearbox tests are given here. In order to record experimental test signals, different hardware systems are used. In order to increase the efficiency of the proposed method, empirical mode decomposition can be used to analyze the signal to subsystems, and then calculate the Beta-Kurtosis benchmark for each sub-signal to better diagnose and diagnose the defect. Several accelerometers are also used to simultaneously record signals from experimental systems from different points of the system, as well as use of three-way accelerometers to record acceleration in different directions.

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