Palestine Polytechnic University
College of Engineering

Vibration Test Bench For Bearing Data Set Collection

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Submitted to the College of Engineering
in partial fulfillment of the requirements for the
Bachelor degree in Automotive Engineering.

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Palestine Polytechnic University

Collage of Engineering

Mechanical Engineering Department

Hebron – Palestine

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22.1.19

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January 2019

Dedication:

To our Families … For their support

To our Teachers … For help us until the

end   To our Friends … Who give us positive

sentiment

To oppressed people throughout the world and their struggle for social justice and egalitarianism

To our great Palestine

To our supervisor Eng . Jalal Alsalayme

Acknowledgment:

We would like to express our gratitude for everyone who helps us during the graduation project, starting with endless thanks for our supervisor Eng. Jalal Alsalaymeh who didn’t keep any effort in encouraging our to do a great job, providing us with valuable information and advices to be better each time.

Thanks for the continuous support and kind communication which great effect regarding to feel interesting about what we are working on.

Finally, Thanks for the beneficial lectures provided.

Abstract:

A wheel bearing is a set of steel balls held together by a metal ring called a race, they help wheels spin fast with as little friction as possible. Then bearing diagnosis is important because the faults that occur due to damage of bearing can’t be known until after they occur. The problems resulting from the damage of bearing are large and sometimes lead to an accident, and the failure of the vehicle.

We collect a set of bearing with different conditions (healthy bearing, distorted bearing bearing without Balls, ...). We then installed the loader on a rotary device and measured the acceleration vibration of the accelerometer and turned the voltage change to a signal display device.

As a result of this project, we created a table of problems that are expected to occur in the bearing with specific reference to each problem.

بيليا العجل هي عبارة عن مجموعة من الكرات الفولاذية يتم تثبيتها معاً بحلقة معدنية ، وهي تساعد العجلات على الدوران بسرعة مع أقل قدر ممكن من الاحتكاك.،و تشخيص البيليا مهم لأنه لا يمكن معرفة الأخطاء التي تحدث بسبب تلف البيليا إلا بعد حدوثها. إن المشاكل الناتجة عن ضرر البيليا كبيرة وأحيانا تؤدي إلى حادث .

قمنا بتجميع مجموعة من البيل في ظروف مختلفة (بيليا جيدة ، بيليا تحتاج الى تشحيم ، بيليا دون كرات ، ...). ثم قمنا بتثبيت المحمل على جهاز دوار ونقوم بقياس اهتزاز الدوران المحمل بمقياس التسارع وتحويل هذا التغير في الجهد إلى جهاز لعرض الإشارة.

ونتيجة لهذا المشروع ، أنشأنا جدولاً بالمشاكل التي من المتوقع حدوثها في الناقل مع إشارة محددة لكل مشكلة.

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Chapter 1: Introduction

This chapter deals with a general introduction of the project and then talks about the problem definition, why this topic is chosen, how the project is implemented, and the expected costs of this project. We will also talk about the outputs of this project and the time distribution of each section.

1.1Introduction

Bearing Exposed to several problems that cause malfunction in the work of a bearing, for example, Excessive Load, overheating false brinelling, true brinelling and normal fatigue failure …..

In this project we did diagnose the case of bearing to find out whether these bearing are exposed to one of these problems or not.

We limit ourselves to a specific type of bearing; the rotating bearing that found in the Automobiles wheel.

What Is a Wheel Bearing?

A wheel bearing is a set of steel balls held together by a metal ring called a race, as shown in Fig1,2.

They help wheels spin fast with as little friction as possible. They are used on all kinds of vehicles, from bicycles to aircraft and cars. On a car, a wheel bearing rides on a metal axle shaft and fits tightly inside the hub, which is a hollow chunk of metal at the center of the wheel. The hub holds the lug bolts that you use to bolt the tire onto the wheel. The wheel bearing is pressed into the hub from the back.

Figure 1: Bearing

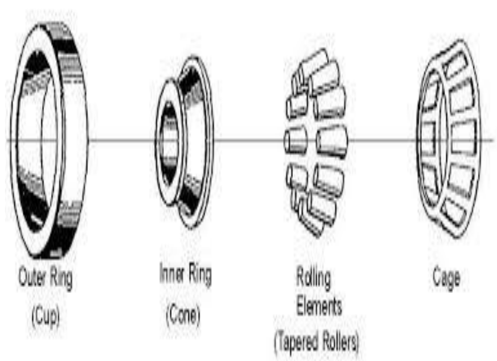


Figure2: Parts of bearing

1.2 Problem definition

Bearings can fail prematurely and unexpectedly even with planning and maintenance, selects bearing for each application in conjunction with a manufacturer's designed life expectancy based on a fatigued spall failure. For a number of reasons, few bearings reach their full designed life expectancy. The principle causes of damage and premature bearing failure is inadequate /improper lubrication, contamination ,overload, and improper handling and installation. These difficulties affect all bearing type.

Unexpected bearing failure the companies force to pay for repairing and replacing the bearing and adjacent component which may also sustain damage, such as housing and shaft. Bearing failure reduces a plant's operating efficiency. Increase down time drives cost of operations up and in the worst cases, may injure workers.

1.3 Motivation

This field had been chosen work on it because the faults that occur due to damage of bearing cannot be known until after they occur. The problems resulting from the damage of bearing are large and sometimes lead to an accident, and the failure of the vehicle, and the cost of repairing the damage caused by the damage of bearing is high, and through this project we reduce the risk of damage and reduce costs, by diagnosing the failure before the problems multiply.

Since it cannot detect the defect only after the occurrence so we studied the vibrations caused by the bearing to know the condition of bearing before there is impact on the vehicle or at the beginning of the effect so that the impact does not cause significant damage.

1.4 Output

Table that contains the problems that are expected to occur in the bearing with a specific reference to each problem.

1.5 Methodology

In this project, we collected a set of bearing with different conditions

1- Healthy bearing,
2- Defect bearing (for example: bearing without Balls).

Then we rotate each bearing and convert the vibration to a specific signal and put each signal with the bearing case in a particular table, so designers can design a device to diagnose the state of stress and compare it to the table we have done.

1.6 Budget

In the following, a table contains project costs

Table 1. 1Budget

Tool &device	No.	Piece price(NIS)	Price (NIS)
Motor	1	600	600
Arduino	2	40	80
Stabilizers	2	0	0
Stabilizers with bearing	1	50	50
Shaft	1	200	200
Bearing	5	50	250
Computer	1	3000	3000
Sensor	1	50	50
Total			4220

1.7 Action plan

The following is the time distribution of the project work for the current and previous semester.

a- First Semester :

Table١ .2 First Semester

Task\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Identifying the project idea																
Writing project name and abstract																
Proposal																
Literature review																
Bearing failure cause																
Design project																
Reference and finishing																

b– Second Semester :

Table 1٢ . Second Semester

Task\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Review and adjust the project introduction																
Purchase and supply of project supplies																
Processing of test branch																
Processing of measurement device																
Bearing diagnosis and writing the table																
Writing and documentati on																
finalize the project																

Chapter 2: Literature Review

This chapter talk about previous studies which presents the methods used by researchers in this topic, which can benefit from their experiences and research done to complete our project.

Introduction:

.Devendiran and Manivannan in International Journal of Applied Engineering Research, showed that all machines with moving parts give rise to sound and vibration and each machine has a specific vibration signature related to the construction and the state of the machine by used two methods to bearing diagnosis, Bearing Condition Monitoring Using Signal Processing Techniques and Bearing Condition Monitoring Using Artificial Intelligent Diagnostics Techniques[1].

Jianqiang, Chenand Nan Chao in the energies magazine, showed that the accurate method can accurately diagnose fault with high accuracy rate and lower diagnostic error rate compared to previous methods. Thus, the method of diagnosing the proposed errors can accurately and effectively determine the errors of the metro motor bearings by using the smart error diagnosis method used. Based on the improved D-S evidence theory (Dempster-Shafer), this method comprehensively analyzes vibration and temperature signals to diagnose carrying errors. In order to verify the feasibility and effectiveness of the proposed method, this theory was designed as a device and a test platform was developed. Bogie bearings were tested with errors that occur on the outer ring, inner ring and rolling elements on this platform. The diagnostic accuracy rate of the proposed fusion algorithm reached 91%, and the diagnostic error rate was only 2%[2].

For the rolling bearing diagnosis and how to identify the fault feature effectively ZHANG at all, In the Proceedings of the 2007 International Conference on Wavelet Analysis and Pattern Recognition, showed that through analyzing the simulation signal of outer race fault, the base functions for the discrete wavelet transform are optimized. The analysis results on the simulated signal of bearing fault have shown that the demy base function can be more effective in the fault recognition than other wavelet functions. the reason for this is that its model is very similar to the high frequency damping Oscillation vibration, which is the typical shock fault feature of rolling bearings. Though it is very difficult to capture the shock fault characteristic due to the impact of the background noise, the signal and noise can be divided successfully through wavelet decomposition using proper wavelet base function. Furthermore, the deeper analysis such as spectrum and envelope demodulation on the decomposition signal after discretion wave latrines form can obtain good incipient diagnosis[3].

Shimjutsumi at all , in article of topic" Use of Wavelet Transform and Fuzzy System Theory to Distinguish Wear Particles in Lubricating Oil for Bearing Diagnosis" They did work Ferro graphic analysis in order to detect wear particles in lubricating oil automatically, because the customary approach takes a great deal of time. Has been proposed a new method to detect wear particles in lubricating oil in order to diagnose bearings, by means of local spatial frequency analysis using the wavelet transform. The Gabor function and cylindrical Gabor function are used as the mother functions of the wavelet transform. The Gabor function is effective in detecting particles which distribute along the lines of magnetic force on the ferrogram slide. The cylindrical Gabor function can detect circular particles. To discriminate the particles, we apply fuzzy system theory to the image transformed by two Gabor functions and show the effectiveness of this method[4].

Nambhard using vibration and bearing temperature measurement. They did a simplified Fault Diagnosis (FD) method that uses just a single vibration and a single temperature sensor on each bearing. Initial trials on an experimental rotating rig indicate that supplementing vibration data with temperature measurements gave improved FD when compared with FD using vibration data alone. And in other methods, Len Gelman, Tejas H. Patel, and Brian Murray [5]. And Allan Thomson in "Rolling Bearing Diagnosis Based on the Higher Order Spectra" Bearing defect diagnosis is traditionally done by using the demodulation/enveloping technology. Diagnosis is mostly based on the spectrum of the squared envelope signal. In literature, the use of the Higher Order Spectra (HOS) has shown to have a tremendous potential for vibration based diagnostics. In this experiment they implemented and experimentally validated the higher order spectra based on the envelope analysis for the diagnosis of ball bearing defects. The implemented technology employs the spectral kurtosis to obtain a frequency band for the demodulation and the third order normalized spectra, i.e. the bicoherence for diagnosis of bearing fault. The high effectiveness of the diagnostics of the implemented technology has been experimentally revealed and compared with that of well known demodulation/enveloping technology [6].

Wojnar, the tests were carried out on cone rolling bearings of rear, non-driven wheels of a Seat Ibiza car – year of production 1993. Stand tests were carried out with the car lifted on a workshop lift. A car wheel balancer was used to velocity up one of the wheels. This allowed acceleration of the wheel up to the rotation velocity which corresponded to the car's velocity of maximum ca.150 km/h. The acceleration values of axial vibration of the bearing pivot were measured. Also, synchronous reference signals corresponding to the wheel revolutions were recorded. The vibration signal and the signal from the system of averaging synchronization were sampled with the frequency of 25,600 Hz and recorded on a computer hard disk. The car wheel, whose rolling bearings were diagnosed, was balanced on a standard balancer. The recorded vibration signal was analyzed within ten intervals with a width corresponding to 25 revolutions of the wheel[7]. .

Morhain, in Journal of Engineering Tribology , some investigations regarding of Bearing diagnostic defect and acoustical emission, The investigation reported in this experiment was centered on the application of standard Acoustic Emissions (AE) characteristic parameters on a radial loaded bearing. An experimental test-rig was modified such that defects could be seeded onto the inner and outer races of a test bearing. As the test-rig was adapted for this purpose it offered high background acoustic emission noise providing a realistic test for fault diagnosis. In addition to a review of current diagnostic methods for applying AE to bearing diagnosis, the results of this investigation validated the use of r.m.s, amplitude, energy and AE counts for diagnosis. Furthermore, this study determined the most appropriate threshold level for AE count diagnosis, the first known attempt [8].

Chapter 3: Bearing failure and diagnosis

3.1 Introduction bearing failure and diagnosis

Bearing failure

Bearing Performance is directly related to Plant Reliability and Maintenance Costs, We look after the equipment reliability , This chapter talk about why bearings fail and it provides the knowledge to understanding and recognize the different types of failure modes.

Bearing diagnosis

Many bearings fail prematurely in service because of contamination, poor lubrication, temperature extremes, poor fitting/fits, unbalance and misalignment. All these factors lead to an increase in bearing vibration and condition monitoring has been used for many years to detect degrading bearings before they catastrophically fail (with the associated costs with significant damage to other parts of the machine).

3.2 Bearing failure causes:

When a bearing is fail, it is important to determine the exact cause so appropriate adjustments can be made. Examination of the failure mode often reveals the true cause of failure. This procedure is complicated by the fact that one failure mode may initiate another. For example, corrosion in a ball race leaves rust-an abrasive-which can cause wear, resulting in loss of preload or an increase in radial clearance. The wear debris can, in a grease-lubricated bearing, impede lubrication. Resulting in lubrication failure and subsequent overheating. This guide will assist in properly identifying and analyzing 12 primary causes of bearing failure.. Flaws, in most cases, are readily apparent. In some cases, the imperfections may be virtually invisible to the naked eye.

Bearing failed due to many causes such as :

1-ExcessiveLoad

Figure 3: Excessive Load

Excessive loads usually cause premature fatigue. Tight fit brinelling and improper preloading can also bring about early fatigue failure, this type of failure looks the same as normal fatigue, although heavy ball paths, evidence of overheating and a more widespread spalling (fatigue area) are usually evident with shortened life. The solution is to reduce the load or redesign using a bearing with greater capacity[9], As Fig.3

2-Overheating:

Figure4 Bearing failure because overheating

Symptoms are discoloration of the rings, balls, and cages from gold to blue Temperatures in excess of 400 can anneal the ring and ball materials. The resulting loss in hardness reduces the bearing capacity causing early failure. Extreme cases rings will be deformed. The temperature rise can also degrade lubricant. Common culprits are heavy electrical heat loads, inadequate heat paths, and insufficient cooling or lubrication when loads and speeds are excessive. Thermal or overload controls, paths, and supplemental cooling are effective cures[9], As Fig4.

3-False Brinelling:

Figure5:Bearing failure because false brinell

False brinelling- elliptical wear marks in an axial direction at each ball with a bright finish and sharp demarcation. Often surrounded by a ring of brown vibration. A small relative motion between balls and raceway occurs in non-rotating ball bearings that are a subject external vibration. Bearing that isn't an oil film cannot be formed to prevent raceway wear. Wear debris oxidizes and accelerates the wear process. from external vibration ,and using greases containing anti wear additives such disulfide when bearings only oscillate reverse rapidly as in actuate or motors[9], As Fig5.

4-True Brinelling:

Figure6:Bearing failure because true brinelling .

Brinelling occurs when loads exceed the elastic limit of the ring material. Brinell marks show as indentations in the raceways which increase bearing vibration (noise). Severe brinell marks can cause premature fatigue failure. Any static overload or severe impact can cause brinelling. Examples include: using hammers to remove or install bearings, dropping or striking assembled equipment, and pressing a bearing onto a shaft by applying force to the outer ring. Install bearings by applying force only to the ring being press- fitted, i.e., do not push the outer ring to force the inner ring on to a shaft ,[9] As Fig6.

5-Normal Fatigue Failure:

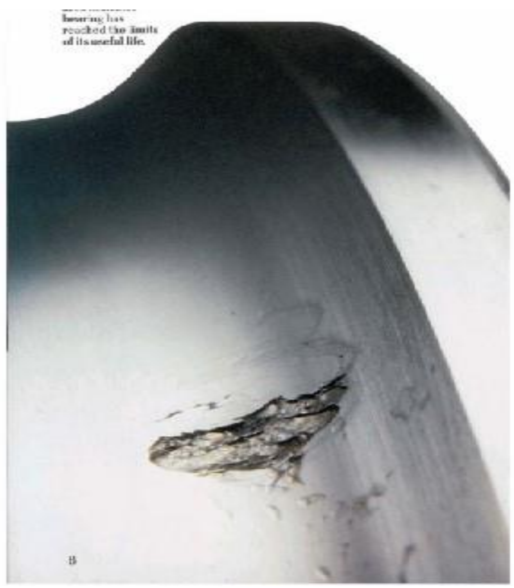


Figure7: Bearing failure because normal fatigue failure

Fatigue failure-usually referred to as spalling- is the fracture of the running surfaces and subsequent removal of small discrete particles of material. Spalling can occur on the inner ring, outer ring, or balls. This type of failure is progressive and once initiated will spread as a result It always be accompanied by a marked increase in vibration, indicating an abnormality. The remedy is to replace the bearing or consider redesigning to use bearing having a greater calculated fatigue life,[9]As Fig7.

6-Reverse Loading:

Figure8: Bearing failure because reverse loading

Angular contact bearings are designed to accept an axial load in one direction only. When loaded in the opposite direction, the elliptical contact area on the outer ring is truncated by the low shoulder on that side of the outer ring. The result is excessive stress and an increase in temperature, followed by increased vibration and early failure. Failure mode is very similar to that of heavy interference (tight) fits. The balls will show grooved wear band caused by the ball riding over the outer edge of the raceway Corrective action is to simply install the bearing correctly. Angular contact bearings must be installed with the resultant thrust on the wide face-which is marked "thrust"-of the outer ring and the opposite face of the inner ring,[9] As Fig8.

7-Contamination:

Figure9: Bearing failure because contamination

Contamination is one of the leading causes of bearing failure. Contamination symptoms are bearing raceways and balls resulting in high vibration and wear. Contaminants include airborne dust, dirt or any abrasive sub- stance that finds its way into the bearing. Principal sources are dirty tools, contaminated work areas. Dirty hands and foreign matter in lubricants or cleaning solutions. Clean work areas, tools, fixtures and hands help reduce contamination failures, Keep grinding operations away from bearing assembly areas and keep bearings in their original packaging until you are ready to install them. Seals are critical damaged or inoperative seals cannot protect bearings from contamination,[9] As Fig9.

8-Lubricant Failure:

Figure10: Bearing failure because lubricant failure

Discolored (blue/brown) ball tracks and balls are symptoms lubricant failure. Excessive wear of balls, ring, and cages will result in overheating and subsequent catastrophic failure. Ball bearings depend on the continuous presence of a very thin-millionths of an inch-film of lubricant between balls and races, cage, bearing rings. And balls. Failures are typically caused by restricted lubricant flow excessive temperatures that degrade the lubricant's properties Barden engineers can advise users on the most suitable lubricant Refer lubricant section of Barden G-10 catalog for more information, Also, any steps taken to correct improper fit, control preload better, and cool the shafts and housings will reduce bearing temperatures and improve lubricant life,[9] As Fig10.

9-Corrosion:

Figure11: Bearing failure because corrosion

Red/brown areas on balls, race- ways, cages, or bands of ball bearings are symptoms of corrosion. This condition results from exposing bearings to corrosive fluids or a corrosive atmosphere. The usual result is increased vibration followed by wear, with subsequent increase in radial clearance or loss of preload. In extreme cases, corrosion can initiate early fatigue failures. Correct by diverting corrosive fluids away from bearing areas and use integrally sealed bearings when- ever possible. If the environment is particularly hostile. The use of external seals in addition to integral seals should be considered the use of stainless steel bearings is also helpful,[9] As Fig11.

10-Misalignment:

Figure12: Bearing failure because misalignment

Misalignment can be detected on the raceway of the non rotating ring by a ball wear path that is not parallel to the raceway edges. Misalignment exceeds 0.001 in Min you can expect an abnormal temperature rise in the bearing and/or housing and heavy wear in the cage ball-pockets. The most prevalent causes of misalignment are: bent shafts, burrs or dirt on shaft or housing shoulders. Shaft threads that are not square with shaft seats, and locking nuts with faces that are not square to the thread axis. The maximum allowable misalignment varies greatly with different applications, decreasing, for example, with speed. Appropriate corrective action includes: inspecting shafts and housings for run out of shoulders and bearing seats; use of single point-turned or ground threads only on hardened shafts and ground threads only on hardened shafts; and using precision grade locknuts,[9] As Fig12.

11-Loose fite:

Figure13: Bearing failure because loose fits

Loose fits can cause relative motion between mating parts. If the relative motion between mating parts is slight but continuous fretting occurs. Fretting is the generation of fine metal particles which oxidize. leaving a distinctive brown color. This material is abrasive and will aggravate the looseness. If the looseness is enough to allow considerable movement of the inner or outer ring, the mountain surfaces (bores, outer diameters, faces) will wear and heat (see photo), causing noise and run out problems Consult Barden C-10 catalog or Barden Engineering for fit recommendation,[9] As Fig13.

12-Tight Fits:

Figure*14:* Bearing failure because tight fits

A heavy ball wear path in the bottom of the raceway around the entire circumference of the inner ring and outer ring indicates a tight fit. Where interference fits exceed the radial clearance at operating temperature, the balls will become excessively loaded. This will result in a rapid temperature rise accompanied by high torque. Continued operation can lead to rapid wear and fatigue. Corrective action includes a decrease in total interference- better matching of bearings to shafts and housings-taking into consideration the differences in materials and operating temperatures. Increased radial clearance will also increase bearing life under the above conditions,[9] As Fig14.

3.3 Bearing Diagnosis

The bearing exposed many defect that is possible to disable the machine and therefore we must know that the bearing approached to damage and we can know that by study the stats of bearing by several method to identify of the defect, in the literature the methods are categorized as following:

1- Vibration method
2- Acoustic method

Vibration and acoustic method:

It is the mostly used method and several techniques have been applied. but the causes vibration and noise?

1-Varying compliance: the number of rolling elements and their position in the load zone change with bearing rotation giving rise to a periodical variation

2-Distributed defect: include surface roughness waviness misaligned races and off size rolling element.

3-Localized defect: include cracks, pits and spall

In this project we will specialize in vibration analysis.

chapter 4 :Design

4.1 Introduction:

In this chapter, we will discuss the design of the devices which are used in the reading process, and through which we can identify the problem. We designed two devices; the first device is designed to work in conditions similar to the working conditions in its original location. The second device is designed to measure the vibration of bearing and displays its signal .

4.2 Devices:

1: Measurement device

This device measures the vibration by using a sensor (Accelerometer sensor)which is installed at the bearing, and then the bearing vibration is converted to a signal drawn on the Mat Lab program by the piece of programming (Arduino)

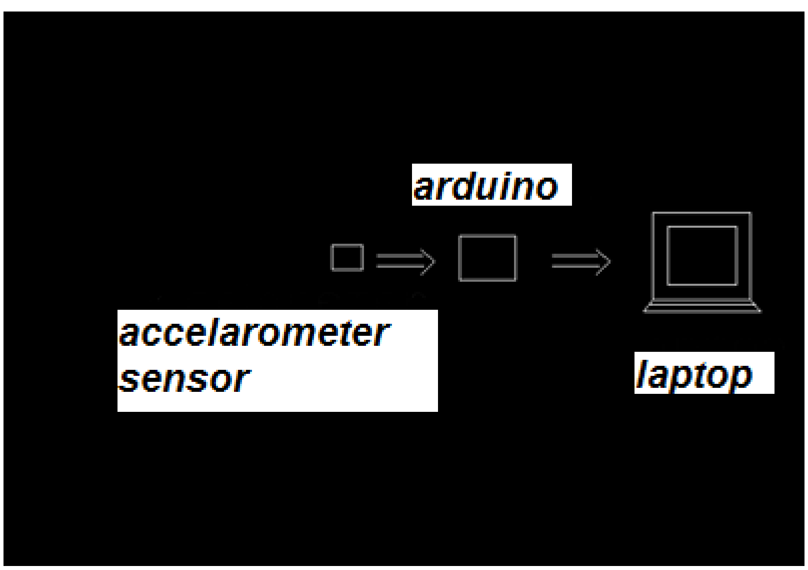


Figure15:Measurement device

2:Testing Machine

This device works to move the bearing in certain conditions so that we can measure the vibration resulting from the bearing

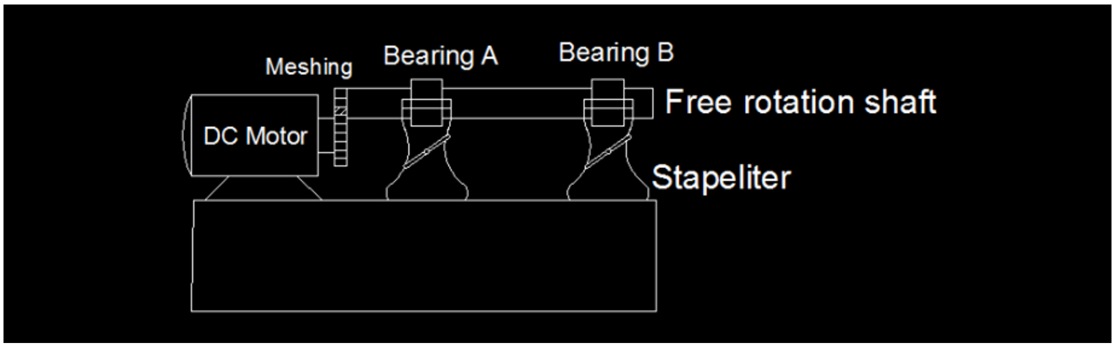


Figure 16:Testing Machine

Testing machine components:

mechanical components

1-shaft and bearings

Calculate factor of safety against fatigue failure use mod-Goodman theory.

$$(\sigma a/Se)+(\sigma m/Sut)=1/nf \qquad \text{equation 1}$$

Where:
nf: factor of safety against fatigue failure.
σm: mid rang steady component of stress.
σa: amplitude of alternating component of stress.
Se: Endurance limit.
Sut: ultimate strength of material.
Shaft material ASTM 30 Steel (Sut=30KPSI =213.42 MPa)

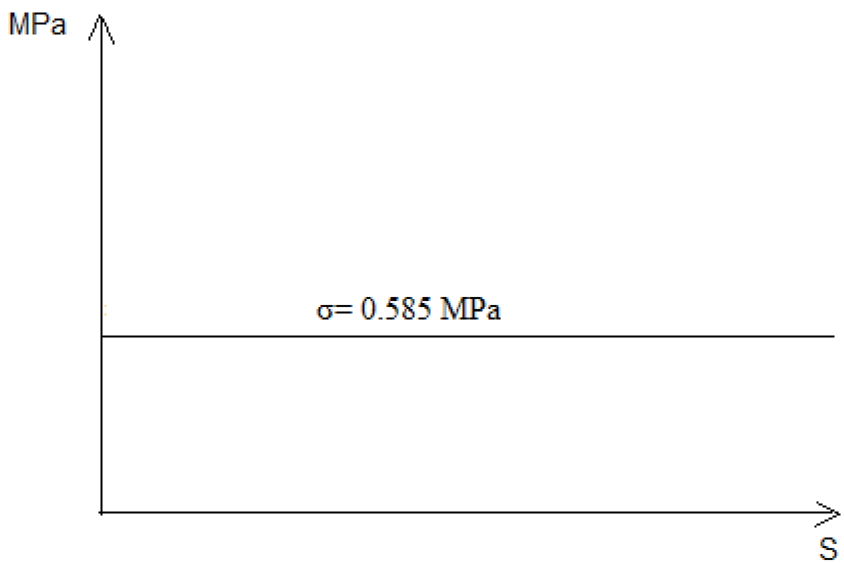
$$Se=Ka*Kb*Kc*Kd*Ke*Kf*0.5*Sut \qquad \text{equation.2}$$

Where:
Se: Endurance limit.
Ka: surface condition modification factor.

Kb: size modification factor.
Kc: load modification factor.
Kt : temperature modification factor .
Ke: reliability factor.
Kf: miscellaneous –effects modification factor.

Ka=a*Sut^ b (a, b) equation. 3

surface finish factor (a, b) for machine finish (4.51, -0.265)
Ka = 4.51*(213.42)^-0.265
Ka = 1.089, Kb = 1, for axial load Kc = 0.59,for torsion load Kt = 1, no temperature change
Ke =0.753,with reliability =99.9%, Kf =1.1 from table.
Se = 1.089*1*0.59*1*0.753*1.1*213.42*0.5
Se =56.8 MPa
d=5cm
σ = T*d/J
J = (3.14* d^4) /32



(σ max, σ, σ min) = (0.585, 0 ,0)
σmo = ((σmax+σmin))/2 = (0.585)/2 = 0.293 MPa
σao = ((σmax-σmin))/2 = (0.585)/2 = 0.293 MPa
nf = 125

nf = 125 because no load in the shaft .

We used shaft According to the diameter of bearing:

The standard Diameter of the Shaft which is available in the market is 40mm.

Then, we turnery the edge of the shaft to a diameter of 34.9 mm in order to the diameter of the second type which is 35 mm.

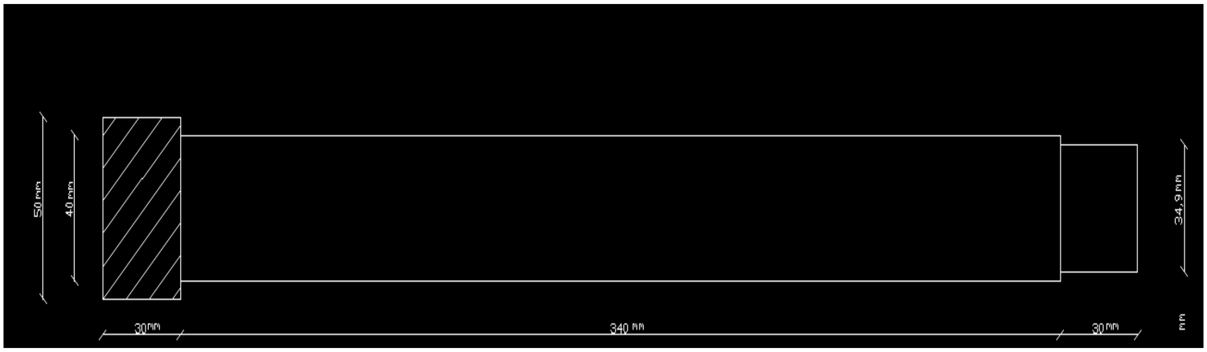


Figure17: Free rotational shaft

In our project we used roller bearing, Firstly, we installed two good bearings, and by measuring the vibration on bearing, we put the resulting signal in the table related to the case of this bearing, then, we replaced one of the installed bearing with one   has a specific problem. Also, we measured the vibration on bearing, and put the resulting signal in a table related to the case of this bearing, this process was repeated to the rest of the bearing which were obtained from this type.

2- Stabilizers:

First stabilizer:

Figure18:First stabilizer

We used a vise for stabilizer at the side of tested bearing. We installed the bearing on the axle at the edge of shaft and installed it by a stabilizer which is placed on a solid body is not affected by vibrations, by using this type of stabilizer, so we are able to change the bearing and install it easily.

Second stabilizer

Figure 19: Second stabilizer

We used this type of stabilizer to install and rotate the Shaft smoothly
Moreover, this type of stabilizer contains the healthy bearing
The Shaft is rotated in free rotational velocity ,and its meshing with AC Motor.

Measuring device component:

We designed a device that diagnoses the case of bearing, in which, we used the accelerometer sensor to measure the bearing vibration and then draw this vibration signal on the arduino program..

Electric component

1-Motor

Figure20:ACmotor

The our selected motor which is containing the following information:
HP = 1 Num. = 49C80684
V = 220 Giri = 1380
Hz = 50 Cos f = 0.89
IP = 54 CI. = 5
Assuming that the maximum speed of the car can be reached 300 km/h ,
The diameter of wheel = 60 cm (0.6 m)
Rotational speed of wheel = (300*1000)/(2*3.14*0.6*60)
= 1326.3 RPM (revolution per minute)
The rotational speed of the selected motor is equal 1400 RPM.

power = torque * angular velocity
1 HP = T * 1400 RPM ** 1 HP = 746 W
746 W = T * (1400 * 2* 3.14)/60
T = 746 / 146.533
Torque = 5 .09 N.M

angular velocity of motor(W1) = 1400 RPM

diameter of gear for motor (D1)= 3.8 mm
diameter of gear for shaft(D2) = 5 mm

to calculate angular velocity of the shaft (W2) =>
W2/W1 = D1/D2
W2 = (D1*W1)/D2
W2= (3.8 * 1400)/5
W2 = 1064 RPM

2-sensor:

We used an accelerometer sensor MPU- 6050 to measured the vibration of rotational bearing in three axis .

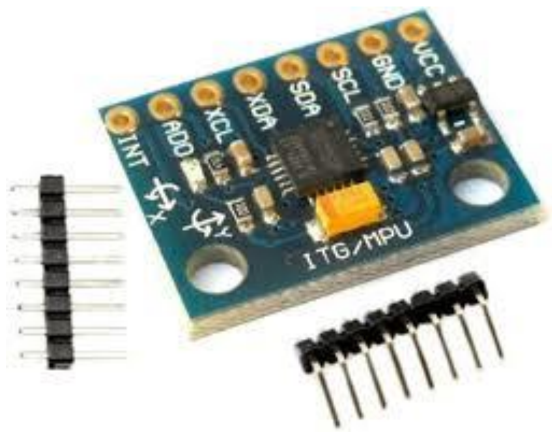


Figure21: Accelerometer MPU-6050

Sensor Datasheet :

The full data sheet of accelerometer sensor is provided in appendix A .

The MPU-6050 sensor module contains an accelerometer and a gyro in a single chip. It is very accurate, as it contains 16-bits analog to digital conversion hardware for each channel .Therefore it captures the x, y, and z channel at the same time. The sensor uses the I2C-bus to interface with the Arduino.

Application:

- Motion-enabled game and application framework
- Location based services, points of interest
- Handset and portable gaming
- Motion-based game controllers
- Wearable sensors for health, fitness and sports Toys

Features:

- Use the chip: MPU-6050.
- Power supply: 3-5v (internal low dropout regulator)
- Communication modes: standard IIC communications protocol.
- Chip built-in 16bit AD converter, 16-bit data output.
- Immersion Gold PCB machine welding process to ensure quality.
- Tri-Axis angular rate sensor (gyro) with a sensitivity up to 131 LSBs/dps and a full scale
- range of ±250, ±500, ±1000, and ±2000dps Tri-Axis accelerometer with a programmable full scale range of ±2g, ±4g, ±8g and ±16g .

Pin Assignment:

The following diagram shows how to the sensor connection with the Arduino programming segment .

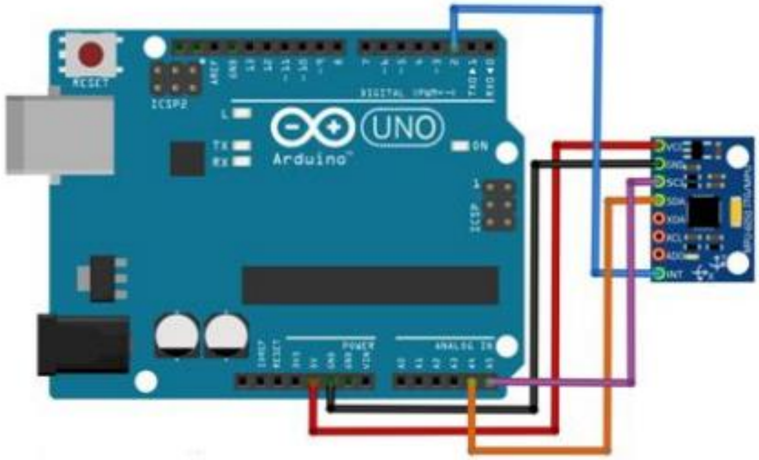


Figure24: Pin Assignment

2-Arduino And Laptop:

We used Arduino UNO Because it is available in the market at a great price and good and because it has a lot of support on the Internet.

Figure25:Arduino And Laptop

Chapter 5: Output And Result

In this chapter we will display the vibration signal for healthy bearing from literature review, and then, we will make a comparison between the vibration signal of the healthy bearing that resulting from our project with the same signal from the previous project, in order to display some faults of bearing with vibration signal and to make a comparison between each indication caused by a defect in the bearing with the resulting signal from the healthy bearing and diagnosis.

In the beginning, we performed the diagnosis on the healthy bearing, and then, we changed the bearing and take the signals. Finally, we re-installed the correct bearing and take its signal to make sure that the unhealthy bearing did not affect the device, wherever, all signals were taken at the same angular speed and the same frequency of the motor.

Through this previous project (the proposed fault diagnosis method can accurately and effectively identify the faults of metro vehicle bogie bearings by used intelligent fault diagnosis method. Based on improved D-S (Dempster-Shafer) evidence theory)[2], the researchers diagnosed bearing by measuring the vibrations using accelerometer sensor(MPU5060) synthesizer and the correct bearing signal in this project was as in the following figure:

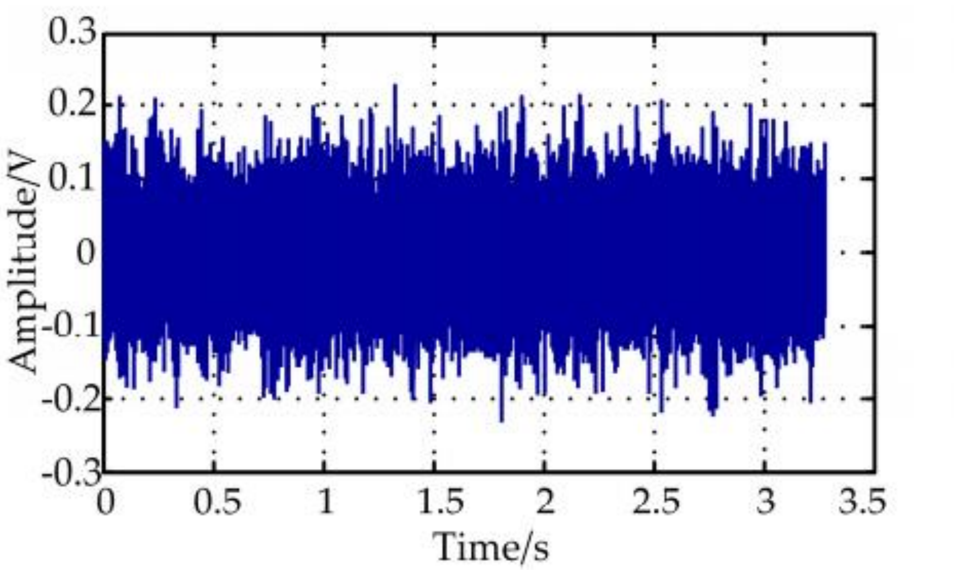


Figure 26:Correct signal

In this project we will use the mentioned above results as a reference to our produced signals.

The following are the signals resulting from the vibration of bearing with each case of bearing, for which this signal was produced .

1. **Healthy bearing with lubrication:**

Figure 27:Healthy bearing with lubrication

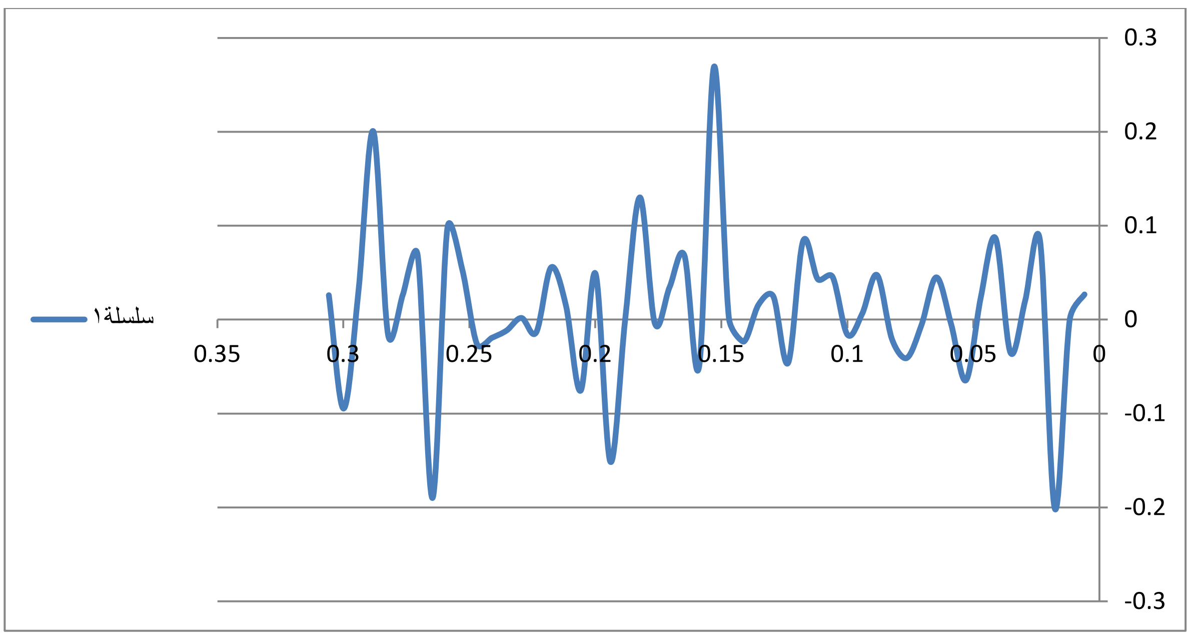


Figure 28: The waveform of the healthy bearing vibration signal.

Through picture26, we notice that peak - peak amplitude of the signal resulting from the healthy bearing rotation almost equal 0.15V to -0.15V, in comparison with the signal from the figure 27, we noticed that the signal amplitude is about 0.15V and may reach as much as 0.2V.

Through this signal we trust on project result that , so we can depend on this signal and compare it with other signals to diagnose the condition of bearing.

2. Defected Bearing:

a- Healthy bearing without lubrication:

Figure 29: Healthy bearing without lubrication

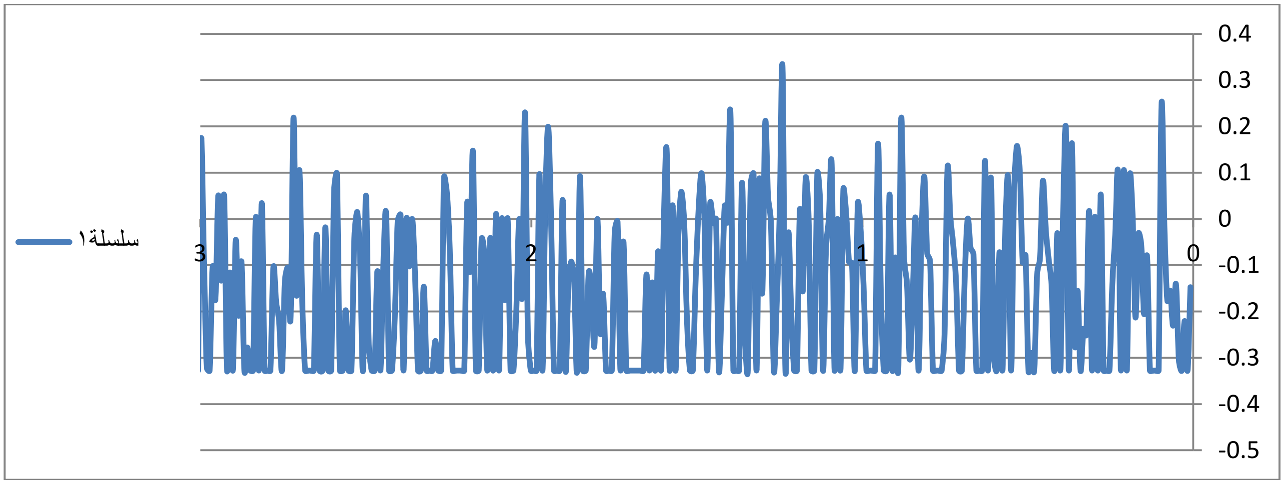


Figure 30: The waveform of the healthy bearing without lubrication vibration signal.

Through this signal we noticed that the vibration is increased by the increasing of friction. Moreover, the amplitude increase and reach almost to 0.3 V(from -0.1V to 0.2V) and then it goes down, we also noticed that this process is constantly repeated .

b- Bearing with dirty lubrication:

Figure 31: Bearing with dirt lubrication

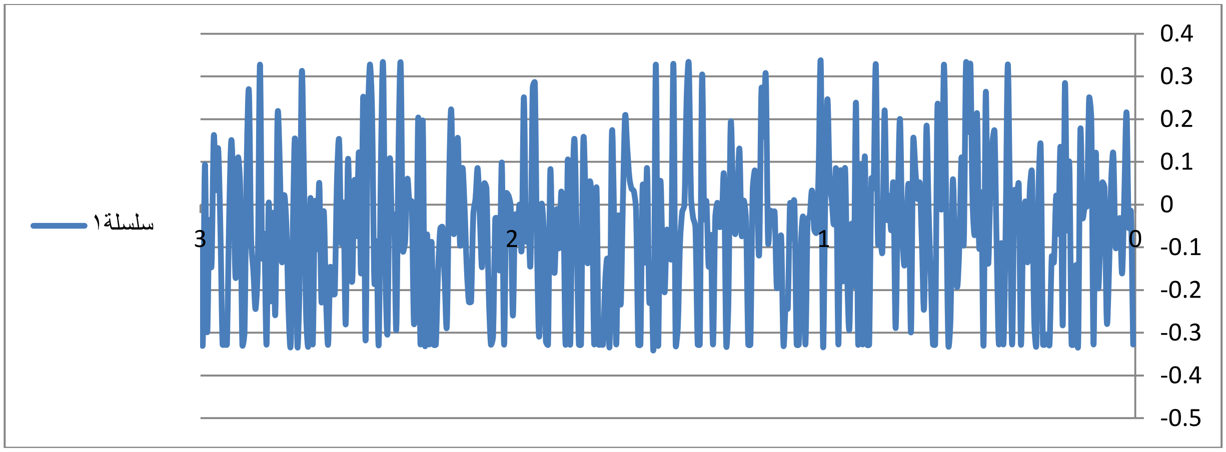


Figure 32.: The waveform of bearing with dirt lubrication vibration signal.

Through this signal we noticed that the vibration is increased dramatically and the amplitude reach almost up to 0.4 V(from -0.1V to 0.3V) and then it goes down to reach almost 0.1V, we also noted that this process is constantly repeated .

c- Bearing without one roller:

Figure 33: Bearing without one roller

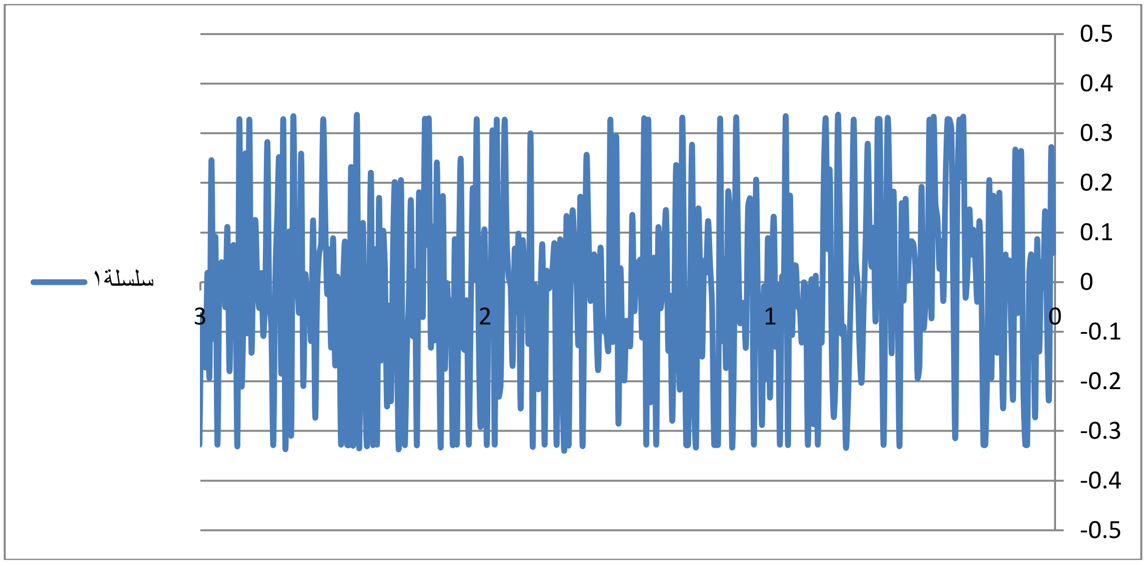


Figure 34: The waveform of bearing without one roller vibration signal.

Through this signal we noticed that the vibration Increases dramatically in order to it is irregular circulating, resulting from the loss of one of the roller. Also we show that the amplitude is permanently up to 0.4V (from-0.1V to 0.3V) and then it goes down in a short period of time to reach almost 0.1V, then will goes up dramatically.

d- Bearing inner race failure:

Figure 35: Bearing inner race failure

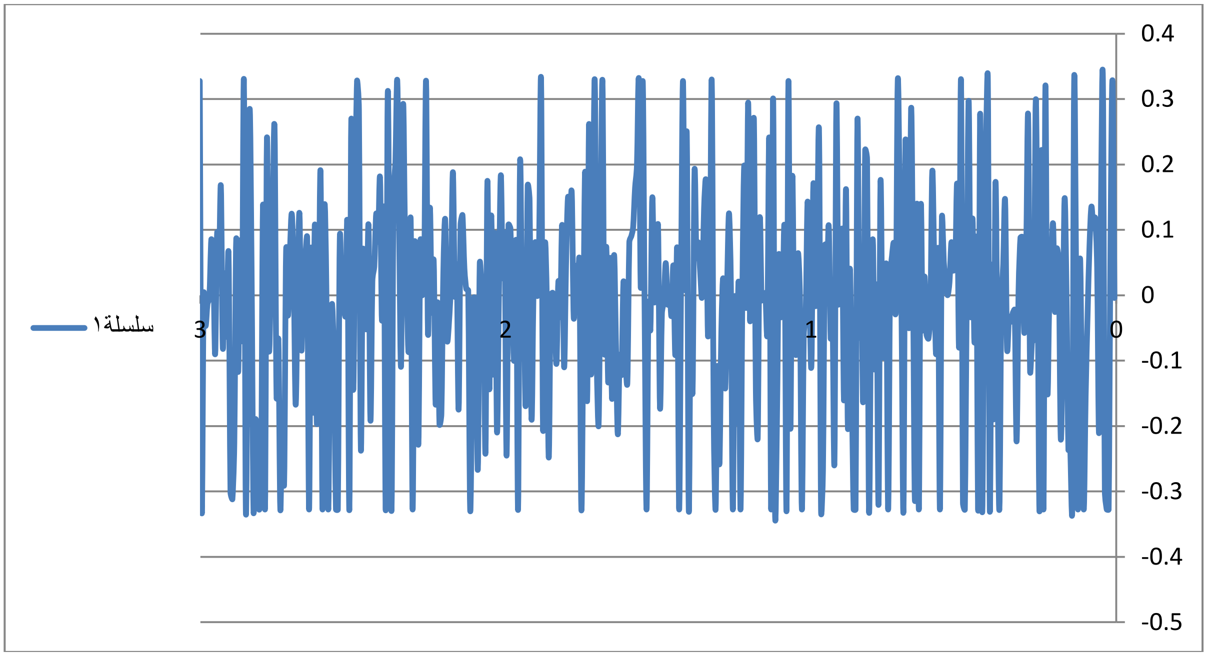
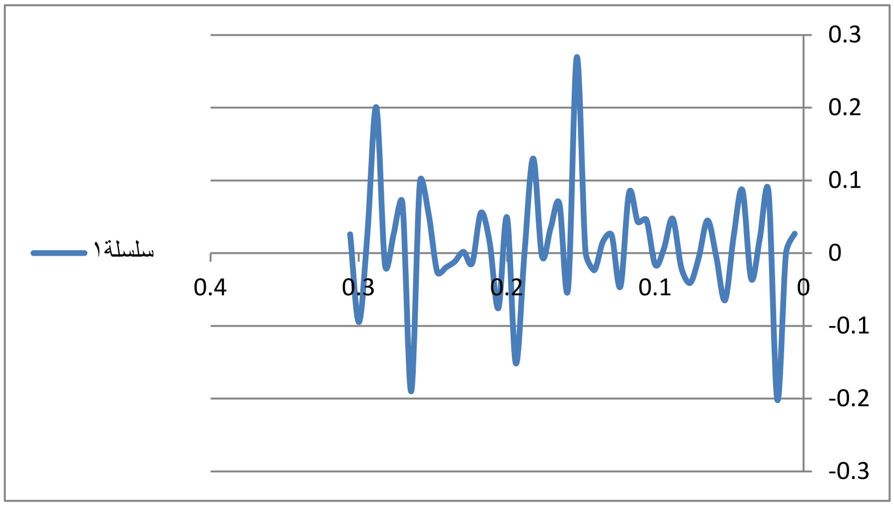
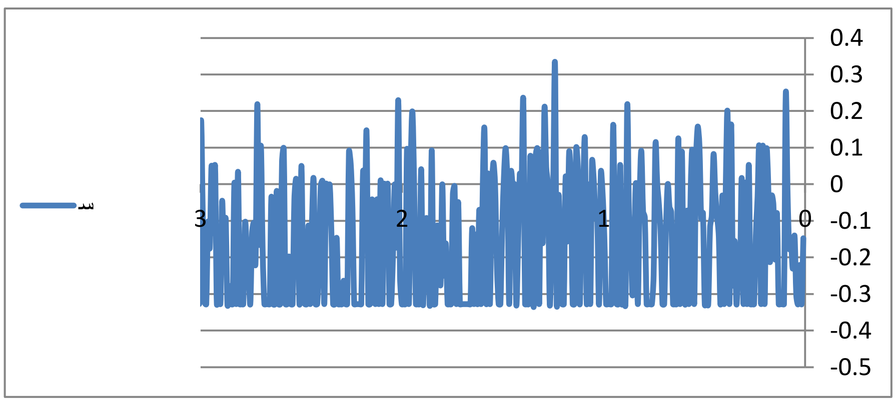
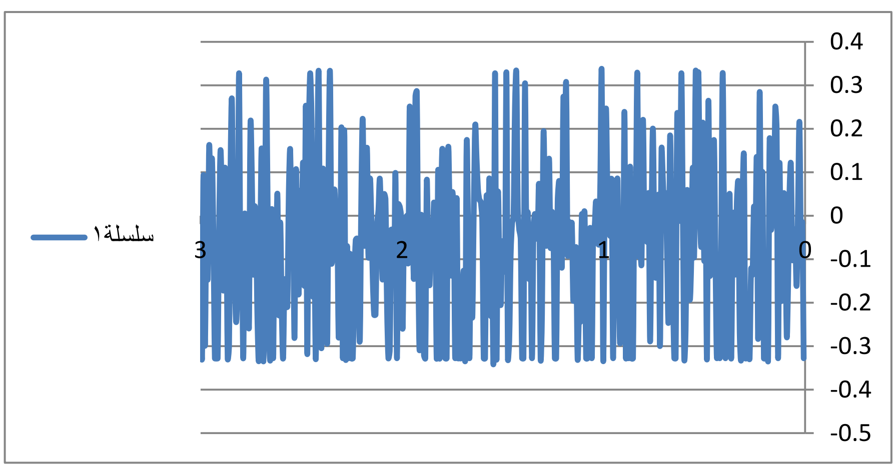
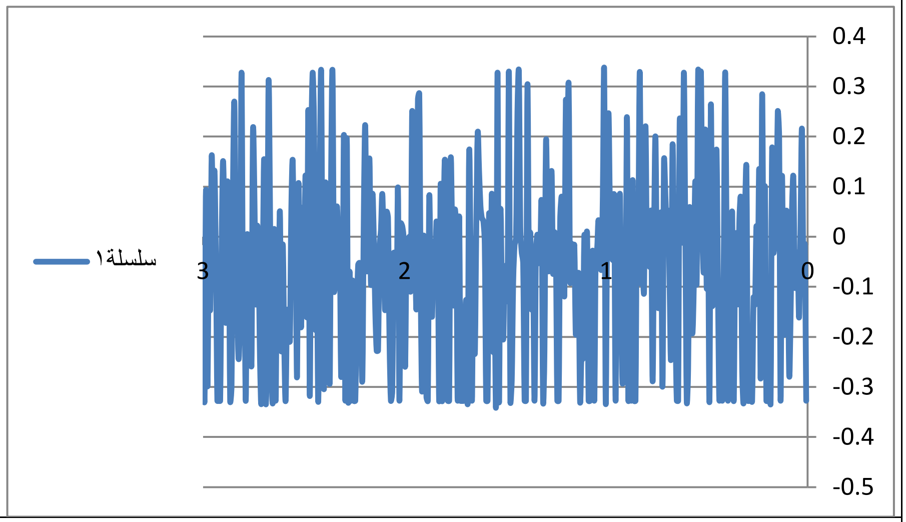
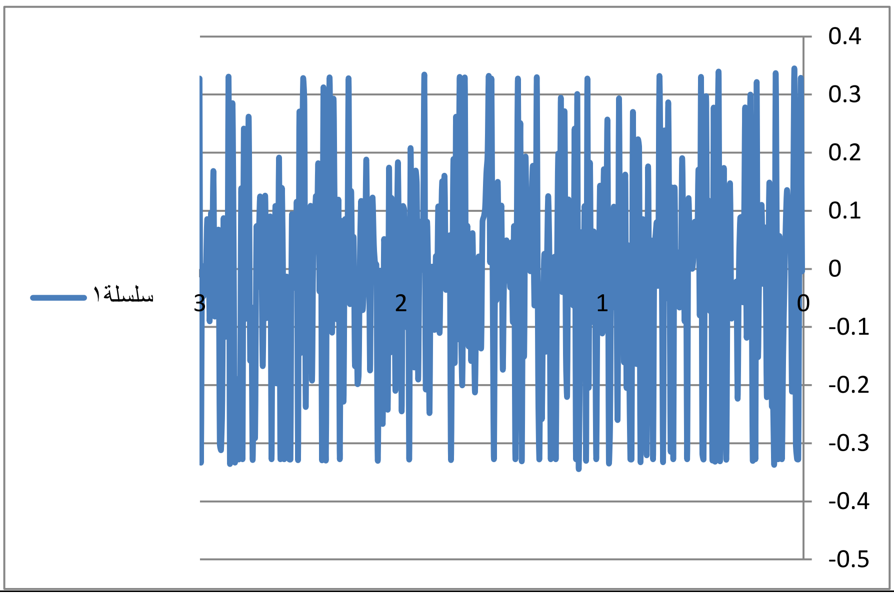


Figure 36: The waveform of bearing inner race failure vibration signal.

Through this signal we noticed that the waveform of this bearing is almost the same as the waveform of bearing without one roller because of it is irregular circulating which is resulting from defected bearing inner race.

table of signals of bearing vibration :
All signals were taken at a constant speed of 1000 rpm.

Healthy bearing with lubrication	
Healthy bearing without lubrication	
Bearing with dirty lubrication	

Bearing without one roller	
Bearing inner race failure	

Conclusion:

The method of diagnosing the condition of bearing is very important, and the problems that get to bearing is one of the most important problems in the car This project makes diagnosing the case of bearing easy before the problem occurs, as there is no way to diagnose the condition of bearing before the fault, so we done this project to solve this problem.

The project was carried out by measuring vibration at bearing. This vibration is converted by aurdino to the signal shown in Excel program. The bookmark was displayed on the computer and put in a table with the name of the problem. So that designers can then design the load vibration measuring device and compare it with the signals we stored and show its name.

Finally, the project will help increase safety in the car and reduce the costs of repairs caused by the disrupted of bearing.

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9.**BARDEN**. BEARING FAILURE CAUSES AND CURES.

Appendix A:

Accelerometer Specifications:

VDD = 2.375V-3.46V, VLOGIC (MPU-6050 only) = 1.8V±5% or VDD, T_A = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
ACCELEROMETER SENSITIVITY						
Full-Scale Range	AFS_SEL=0		±2		*g*	
	AFS_SEL=1		±4		*g*	
	AFS_SEL=2		±8		*g*	
	AFS_SEL=3		±16		*g*	
ADC Word Length	Output in two's complement format		16		bits	
Sensitivity Scale Factor	AFS_SEL=0		16,384		LSB/*g*	
	AFS_SEL=1		8,192		LSB/*g*	
	AFS_SEL=2		4,096		LSB/*g*	
	AFS_SEL=3		2,048		LSB/*g*	
Initial Calibration Tolerance			±3		%	
Sensitivity Change vs. Temperature	AFS_SEL=0, -40°C to +85°C		±0.02		%/°C	
Nonlinearity	Best Fit Straight Line		0.5		%	
Cross-Axis Sensitivity			±2		%	
ZERO-G OUTPUT						
Initial Calibration Tolerance	X and Y axes		±50		m*g*	1
	Z axis		±80		m*g*	
Zero-G Level Change vs. Temperature	X and Y axes, 0°C to +70°C		±35			
	Z axis, 0°C to +70°C		±60		m*g*	
SELF TEST RESPONSE						
Relative	Change from factory trim	-14		14	%	2
NOISE PERFORMANCE						
Power Spectral Density	@10Hz, AFS_SEL=0 & ODR=1kHz		400		μ*g*/√Hz	
LOW PASS FILTER RESPONSE						
	Programmable Range	5		260	Hz	
OUTPUT DATA RATE						
	Programmable Range	4		1,000	Hz	
INTELLIGENCE FUNCTION INCREMENT			32		m*g*/LSB	

Figure22:Accelerometer Specification data sheet

Gyroscope Specifications:

VDD = 2.375V-3.46V, VLOGIC (MPU-6050 only) = 1.8V±5% or VDD, T_A = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
GYROSCOPE SENSITIVITY						
Full-Scale Range	FS_SEL=0		±250		°/s	
	FS_SEL=1		±500		°/s	
	FS_SEL=2		±1000		°/s	
	FS_SEL=3		±2000		°/s	
Gyroscope ADC Word Length			16		bits	
Sensitivity Scale Factor	FS_SEL=0		131		LSB/(°/s)	
	FS_SEL=1		65.5		LSB/(°/s)	
	FS_SEL=2		32.8		LSB/(°/s)	
	FS_SEL=3		16.4		LSB/(°/s)	
Sensitivity Scale Factor Tolerance	25°C	-3		+3	%	
Sensitivity Scale Factor Variation Over Temperature			±2		%	
Nonlinearity	Best fit straight line; 25°C		0.2		%	
Cross-Axis Sensitivity			±2		%	
GYROSCOPE ZERO-RATE OUTPUT (ZRO)						
Initial ZRO Tolerance	25°C		±20		°/s	
ZRO Variation Over Temperature	-40°C to +85°C		±20		°/s	
Power-Supply Sensitivity (1-10Hz)	Sine wave, 100mVpp; VDD=2.5V		0.2		°/s	
Power-Supply Sensitivity (10 - 250Hz)	Sine wave, 100mVpp; VDD=2.5V		0.2		°/s	
Power-Supply Sensitivity (250Hz - 100kHz)	Sine wave, 100mVpp; VDD=2.5V		4		°/s	
Linear Acceleration Sensitivity	Static		0.1		°/s/g	
SELF-TEST RESPONSE						
Relative	Change from factory trim	-14		14	%	1
GYROSCOPE NOISE PERFORMANCE	**FS_SEL=0**					
Total RMS Noise	DLPFCFG=2 (100Hz)		0.05		°/s-rms	
Low-frequency RMS noise	Bandwidth 1Hz to10Hz		0.033		°/s-rms	
Rate Noise Spectral Density	At 10Hz		0.005		°/s/ √Hz	
GYROSCOPE MECHANICAL FREQUENCIES						
X-Axis		30	33	36	kHz	
Y-Axis		27	30	33	kHz	
Z-Axis		24	27	30	kHz	
LOW PASS FILTER RESPONSE	Programmable Range	5		256	Hz	
OUTPUT DATA RATE	Programmable	4		8,000	Hz	
GYROSCOPE START-UP TIME	**DLPFCFG=0**					
ZRO Settling (from power-on)	to ±1°/s of Final		30		ms	

Figure23: Gyroscope Specification Data Sheet