Design Fabrication and Testing of Gearbox for Fault Detection.

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering
By:

RAVI KUMAR
107ME019

Under the guidance of:
Prof. S C Mohanty.

Department of Mechanical Engineering

Department of Mechanical Engineering.
National Institute Of Technology, Rourkela
2011

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

CERTIFICATE

This is to certify that the project entitled "Design Fabrication and Testing of Gearbox for Fault Detection" submitted by Ravi Kumar in partial fulfillment of the requirements for the awards of Bachelor of Technology, NIT Rourkela (Deemed university) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the project has not been submitted to any Institute/University for the award of any degree or diploma.

Date: 10.05.2011.

Place: Rourkela

Prof. S C Mohanty

Department of Mechanical Engineering,

National Institute of Technology, Rourkela

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ACKNOWLEDGEMENT

It is a great privilege for me to express my deep sense of gratitude to my Guide Professor S C Mohanty, Department of Mechanical Engineering, NIT Rourkela for introducing the present topic and to provide us stimulating guidance, constructive criticism and valuable suggestion throughout this project. I shall always cherish my association with him for his constant encouragement and freedom to thought and actions that he rendered to me throughout this project.

Finally, I deem it a great pleasure to thank one and all those who helped me carry out this project.

RAVI KUMAR

ROLL NO-107ME019

Place- Rourkela

Date-10.05.2011

MECHANICAL ENGINEERING DEPARTMENT

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

Table of Content Page no

FIGURES: Page no

TABULATION: Page no

GRAPHS: Page no

1. ABSTRACT

This project work focused on the design and testing of gearbox for fault detection. Gearboxes are very important things in many industries applications. Thus the interest for their health monitoring is growing and effective diagnostic techniques and methodologies are the objective of previous studies. Here we are going to detect different types of fault which occurs in gearbox. There are mainly three types of fault occurs. These faults are slightly worn, medium worn, broken teeth. With the help of vibration study (due to gears fault) through oscilloscope we can design such kind of system which can detect what kind of fault a gearbox has. A multistage faulty gearbox is used in the present study. The test setup comprises of a multistage gearbox, driven by an induction motor and loaded by a generator or by a brake motor. The gearbox is an automotive transmission gearbox with five gears including back gear, such as 1^{st}, 2^{nd}, 3^{rd}, 4th and back gears, under synchrony-meshed condition.

Here each gear will be tested under the constant load and constant speed (RPM) conditions.

Equipment:

1. Gearbox with faulty gears
2. Electric motor for power supply
3. Magnetic brake to create load
4. Variable Frequency Drive(VFD)
5. Propeller shaft, Hooke join and flange coupling

2. INTRODUCTION

In present condition lot of industries uses gearbox for various purpose like crane (to lift weight easily), lathe, automobiles etc. Other than this gearbox has lot of application so health monitoring of gearbox is very important. In this present study a faulty gearbox is used to produce vibration with the help of electric motor at constant speed and constant load is also applied at the time of vibration. Here we can measure vibration amplitude with the help of oscilloscope and accelerometer which is connected to oscilloscope directly. Magnetic torque motor attached directly to the output of gearbox shaft of gearbox which produce 20volt load through autotransformer. Variable frequency drive (VFD) is used to control the RPM of induction motor. Variable frequency drive (VFD) very important electronics device which fix constant speed of motor.

Here gearbox is derived at 1000rpm by the induction motor. Vibrations have been used and well established for many decades [4]. In many instances, an induction motor is used to drive a gearbox. And any fluctuating or transient load in the gearbox produces transients in the current drawn by the induction motor [3]. A multistage gearbox is used in the present study. The test setup comprises of a multistage gearbox, driven by an induction motor and loaded by a generator or by a brake motor. The gearbox is an automotive transmission gearbox with four gears, such as 1st, 2nd, 3rd, and 4th gears, under synchrony-meshed condition, as give fig1.Three types of artificially defect introduced and three cases of transient load conditions are discussed in the paper.

The line diagram of the multistage gearbox is given below. The artificial defects introduced in the gearbox are shown in table

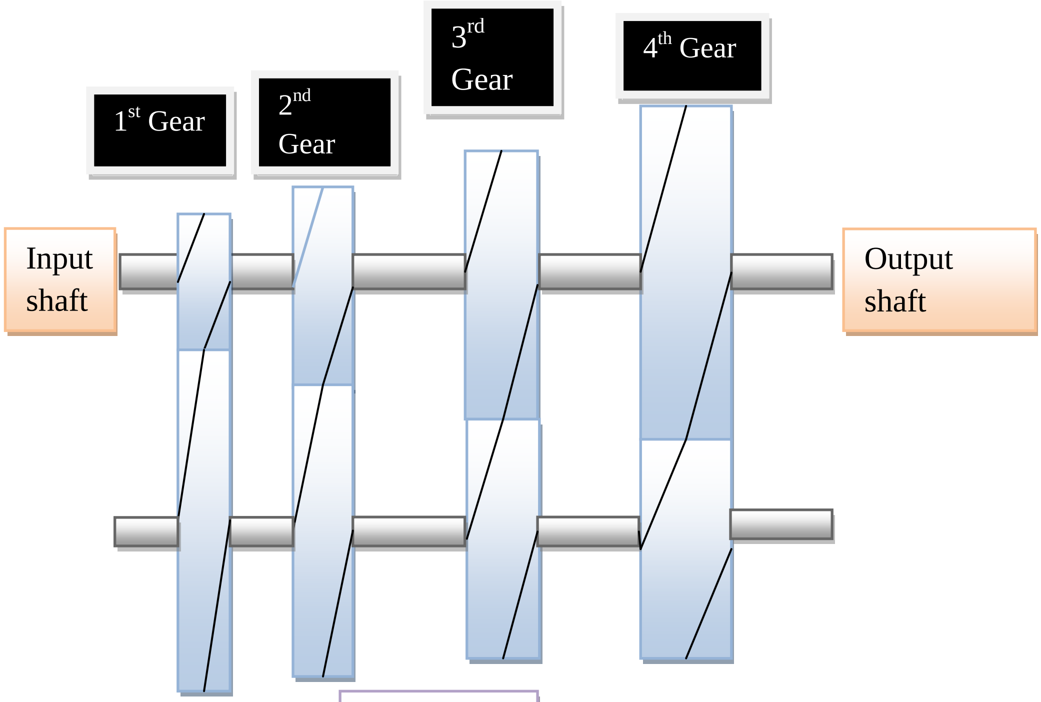


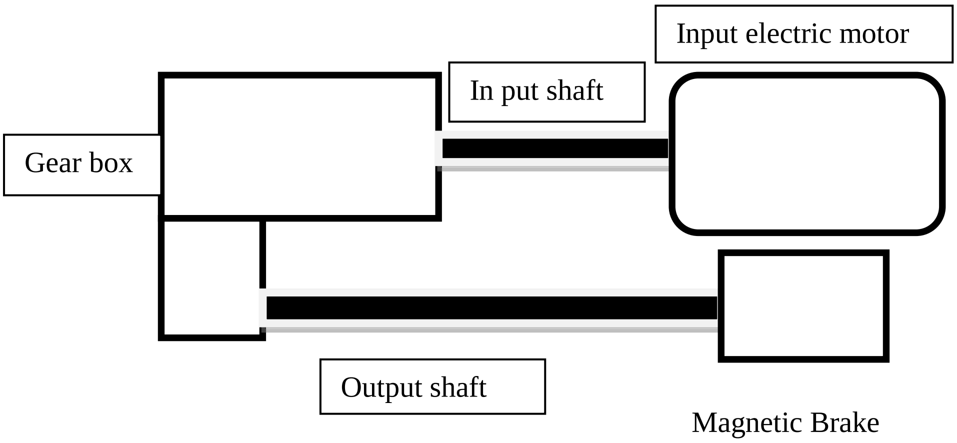
Fig. 1

Type of artificial defects:

Sl. no	Helical or spur gear	Type of defects
1	1st gear (main)	No defect
2	2nd gear (main)	half break teeth
3	3rd gear (main)	Rubbing at face
4	4th gear (main)	Fully one tooth break

Table.1

There is half teeth break in 2nd gear and rubbing teeth at face in 3rd gear and fully one teeth missing in 4th gear. It can be observed that for one teeth missing, there is a contact loss for a very small duration as the contact ratio of the gear [3]. But because of synchrony-meshed condition defect free gears will be responsible for continuous power transmission [3].



Schematic Diagram of experimental Test Rig

Fig.2

Vibration is commonly caused by the misalignment of gears or gear shaft, no proper lubrication, and sudden load apply. In this project work we are measuring variation in vibration at the time of motion of gears. Here only purpose of magnetic brake to provide load at the time of rotating of gears. Induction Motor provides motion to the gearbox and at different gear ratio we find different vibration reading and in place of magnetic brake we can use generator to produce electricity. We connect this whole apparatus to the accelerometer and this accelerometer connects to the oscilloscope to measure vibration.

3. LITERATURE REVIEW

Gearbox is a basic transmission system, which is widely used in mechanism system. Its state is directly correlated its running process. Presently, the common method on state monitoring and fault diagnosis of gearbox without disassembly is the vibration diagnosis, but gearbox vibration signals often mix much strong noise. On this condition, it is difficult to distinguish the gear fault consequently. How to remove the strong noise, and extract the feature of pulse fault signal is a key problem that we must resolve. Presently, wavelet transformation is widely used to resolve above problems [1].

Extensive research, testing, and analysis have been performed by many corporations and university researchers to increase the reliability of industrial and helicopter gearboxes. For example, helicopter power trains comprise almost 30% of maintenance costs and 22% of mechanically related malfunctions. Approximately 32% of serious rotorcraft accidents are due to transmission components while gearboxes are often the component responsible for maintenance induced faults. Predicting gearbox faults is particularly difficult since the calculated fatigue life of gearboxes has substantial statistical error.

Most gearbox analysis programs are focused on safety, cost reduction, attaining a pre-defined gearbox life, and increasing the life of a gearbox. Studies are typically conducted by analyzing vibration and temperature data captured from sensors that are carefully located on a gearbox. Sometimes acoustic pick-ups are used to capture noise data and "hear" the characteristic signature of a faulty gearbox nearing failure. Vibration waveforms are frequently compared to nominal or parametric data to determine if a fault is present in the gearbox. However, these techniques are somewhat limited due to the dynamics of speed versus load (torque) and the inability to model the multi-dimensional dynamics that occur in the real world. More recent techniques such as data fusion, neural networks, non-linear dynamical modeling and multivariate analysis have rendered more robust and more accurate methods of modeling and diagnosing gearbox faults under dynamic forces [2]

.

This paper deals with an experimental investigation of fault diagnosis in a multistage gearbox under transient loads. An induction motor drives the multistage gearbox, which is connected to a DC generator for loading purpose. The signals studied are the vibration transients, recorded from an accelerometer fitted at the tail-end bearing of the gearbox; and the current transients drawn by the induction motor. Three defective cases and three transient load conditions are investigated. Advanced signal processing techniques such as discrete wavelet transform (DWT) and a corrected multi resolution Fourier transform (MFT) are applied to investigate the vibration and current transients. It is observed from the vibration transients that the load removal is a high-frequency phenomenon. With increase in defect severity, not only the defective gear mesh frequency gains energy, but also large impact energy appears in low-frequency regions. Whereas in the current transients, though load removal is a low-frequency phenomenon, a very small transient is observed at high-frequency regions for defective gears. With increase in defect severity, energy is distributed to the sidebands of the gear mesh frequency across supply line frequency. A statistical feature extraction technique is proposed in order to find a trend in detection of defects. A condition monitoring scheme is devised that can facilitate in monitoring vibration and current transients in the gearbox with simultaneous presence of transient loads and defects [3].

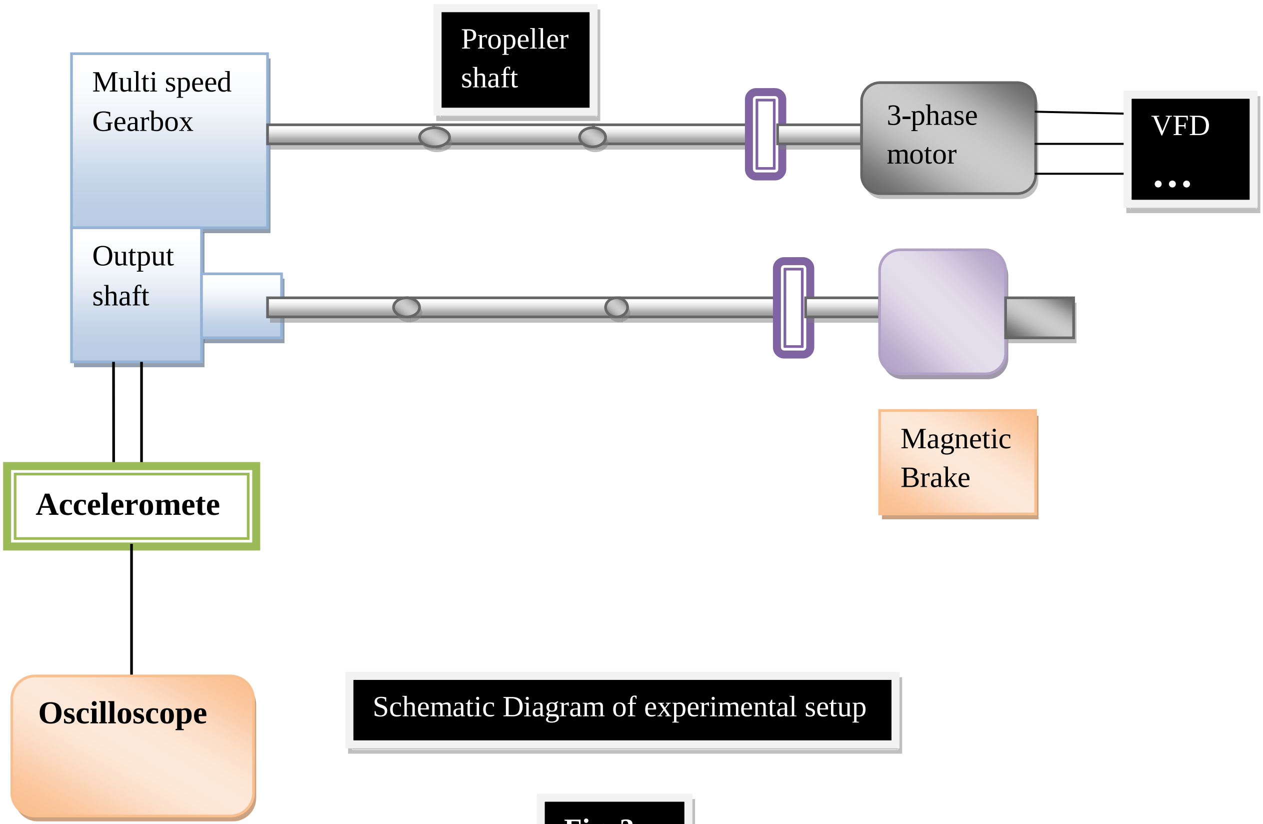
The diagnosis of artificial defects in a single stage gearbox using two non-destructive techniques (vibration and AE) and advanced signal processing techniques to discriminate between different load and defect states is the scope of the present study. Wavelet based techniques were developed and utilized in order to evaluate the vibration signals and extract diagnostic information out of them. A new concept of AE transducer mounting on rotating structures, without the use of the expensive solution of the slip-ring is presented. The AE signals are analyzed and their root-mean-square (RMS) values are calculated. The capability of the new approach of AE acquisition in discriminating between different loading and damage states is shown and discussed. Interesting findings on the effect of the oil temperature upon AE recordings only speculated theoretically so far are also presented. Both methods yielded interesting results and showed an ability to distinguish between healthy and defected gears [4].

Objectives of Research work

- To understand the limitations or boundary of these techniques in determinant faults
- To proposed a simpler technique of fault detection this takes care of these limitations into account
- To conduct experimental analysis based on these proposed technique

4. EXPERIMENTAL SETUP

This whole experiment consist 3-phase induction motor and multistage automotive gearbox with 4-gear. This gearbox is directly connected to 3-phase induction motor by propeller shaft, hook joint and flange coupling as given in fig 3. Output shaft of gearbox is directly connected to magnetic brake with the help of half shaft, universal hook join and flange coupling. Further, the induction motor is also connected to variable frequency drive (VFD). Here this variable frequency drive controls the rotational speed of the motor by varying the input frequency which further controls the speed of the gearbox output shaft. Here we are using oscilloscope to measure vibration in gearbox because of fault in gears. Here accelerometer uses to detect vibration in gearbox and this sends signal to oscilloscope.



Schematic Diagram of experimental setup

Fig. 3

Picture of experimental setup:-

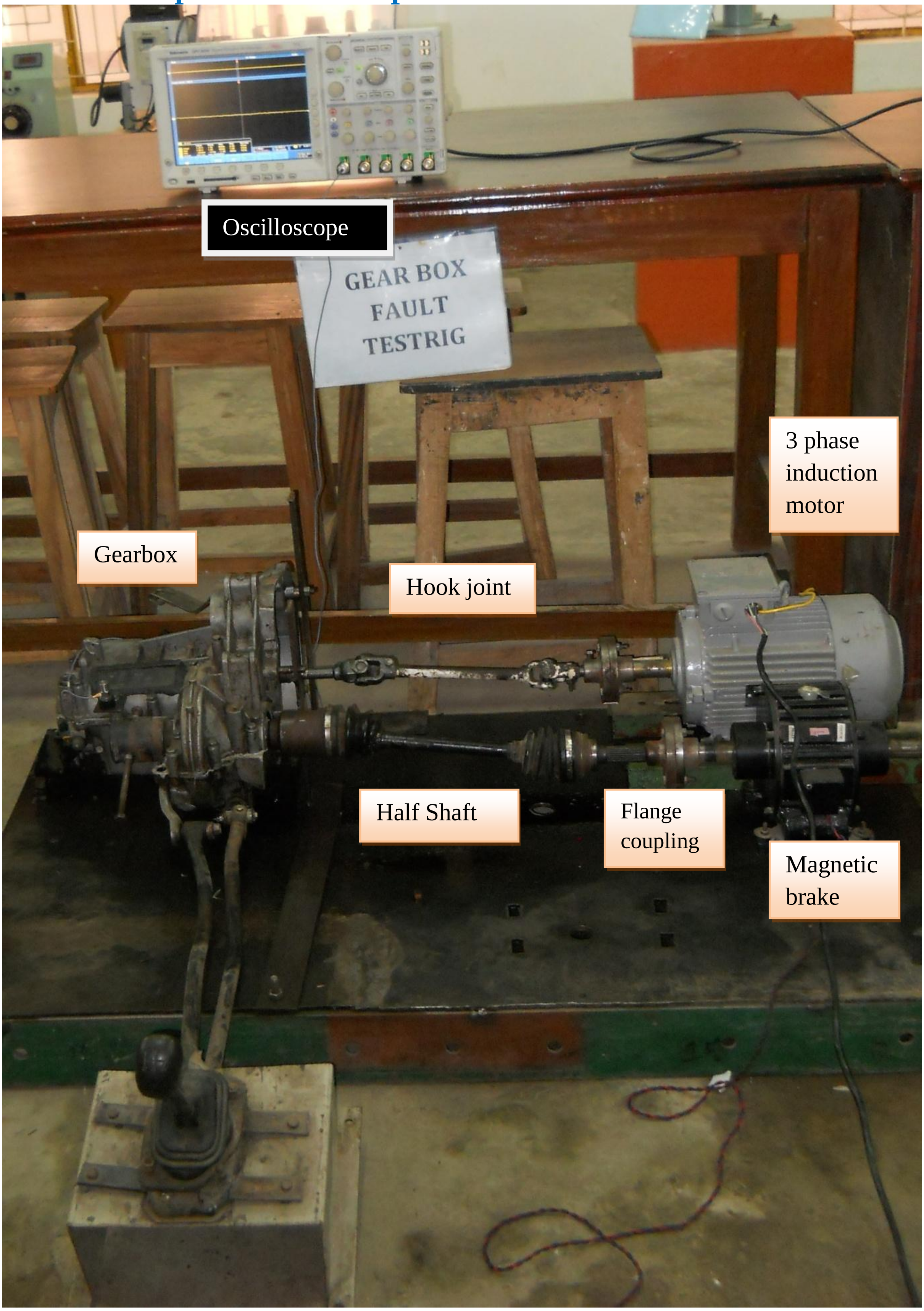


Fig. 4

Description of various parts of the experimental setup is as follows:-

4.1: 3 Phase Induction Motor: -

Actually here we are using 3 phase induction motor to drive gear input shaft. Whole setup runs with the help of induction motor. An induction motor is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction. The 3 phase induction motor is a rotating electric machine designed to operate from a three-phase source of alternating voltage. The stator is a three phase stator with the winding displaced angle by 120°. A 3 phase induction motor can be used for different applications with different speed and varying load requirements. Fig of 3 phase induction motor is given below-

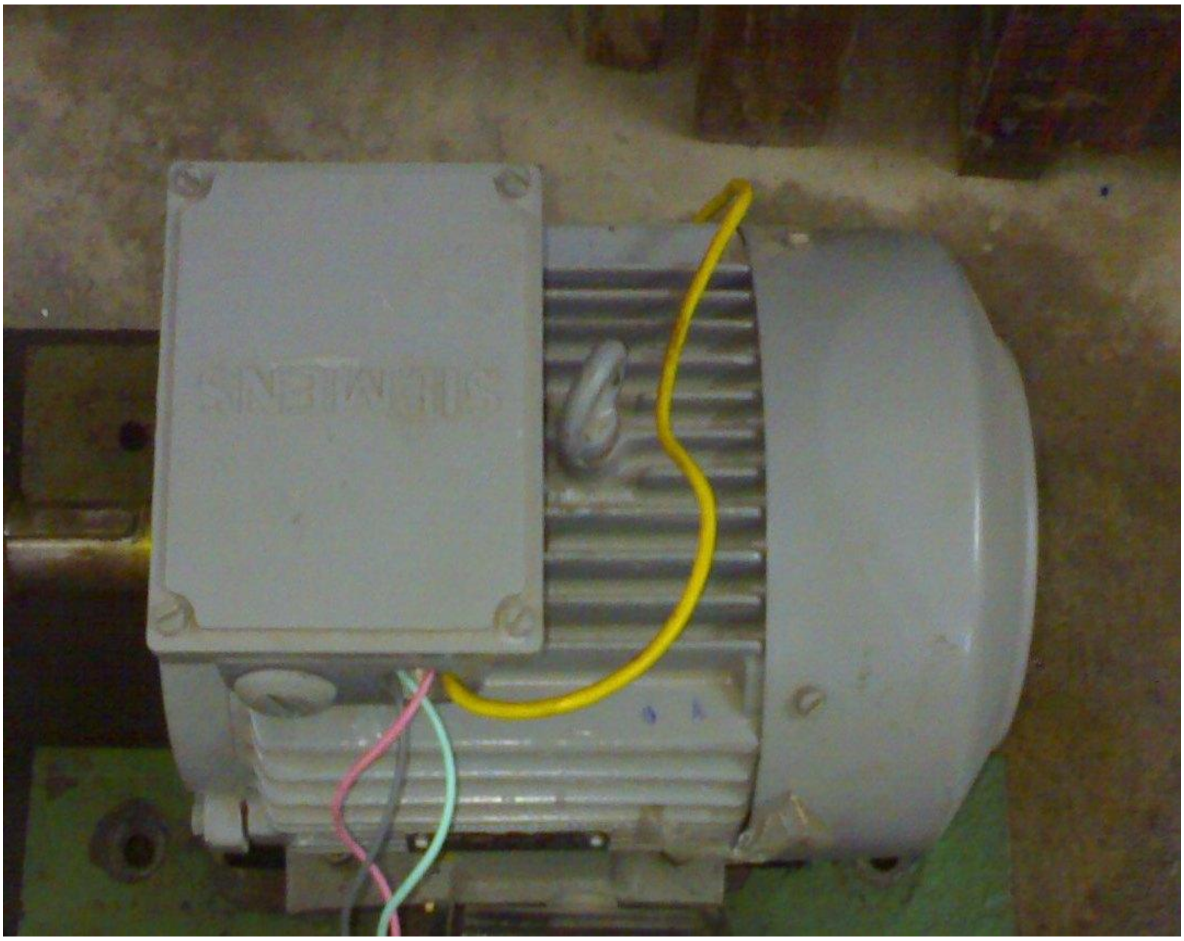


Fig.5

Advantages of 3 phase induction motor

- More economical than others because it uses less conductor material.
- Induction motor is less expensive motor because of quite simpler construction.
- Require less maintenance.
- Self starting.

Disadvantages of 3 phase induction motor:-

- Speed control is expensive
- Unfitness to operate at low speeds

Ratings of 3 phase induction motor:-

- Make: Siemens
- Rated Power: 2.2 kW

.

- Rated Speed: 2850 rpm
- Frequency: 50 Hz.
- Voltage: 415 V

.

- Current: 4.3 A.

4.2: Gearbox:-

Gearbox is very important mechanical device in industries. Gearbox is used to transmit speed from a power source from one shaft to another shaft. Mostly used in motor vehicle applications and cranes application. With the help of gears we can reduce the speed of a vehicle and also can increase. There are mainly three type of gearbox exist given as: manual transmission, semi manual transmission and automatic transmission. Manually clutch is used before shifting gear. Manual gearbox is mainly cheaper, lighter, and usually gives better performance and fuel efficiency. Many manual transmissions include both synchronized and unsynchronized gearing. This kind of gears is mainly shifted into only when the vehicle is in stopped condition.

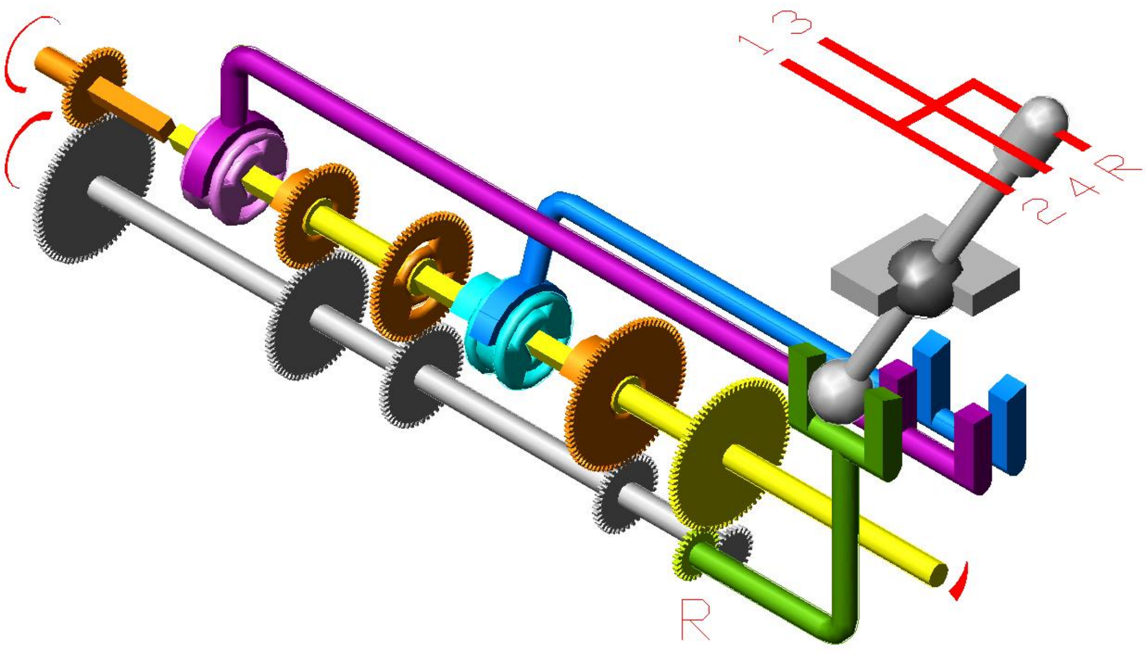


Fig. 6

Reference: http://en.wikipedia.org/wiki/Manual_transmission

This gearbox consists five gears including back gear. For experimental purpose, all gears are defective of gearbox excluding back gear. At different rpm of motor we drive gearbox to measure vibration. All gears having different kind of fault will produce different vibration. Actually these all gears are helical gear so motion of helical gear is very smooth relative to other gear drive. These helical gears are used at higher speed and high load capacity.

Fig.7

4.3: Universal Hooke Joint:-

A universal joint or Hooke's joint is a joint or coupling in a rigid rod that allows the rod to bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other. It connected by a cross shaft.

For experimental purpose here we are using hook joints to connect induction motor and gearbox to each other by propeller shaft, and output shaft of gearbox to magnetic brake by again propeller shaft. This provide constant speed ratio to both driving and driven shaft.

Fig. 8

4.4: Magnetic Brake: -

In this experiment Magnetic brake is using because of creating loading condition on output shaft of gearbox. Magnetic brake consist two metallic disk of same diameter, when we apply voltage through autotransformer than one of disk rotate in a direction and another one is in fixed condition.

When we switch on current supply in magnetic brake than a magnetic field setup between these two disks, first one disk which is rotating, try to rotate another disk in same direction but this disk is in fix condition to create loading. As we will increase current, load will increase. Here this brake is connected to output shaft with the help of half shaft and flange coupling.

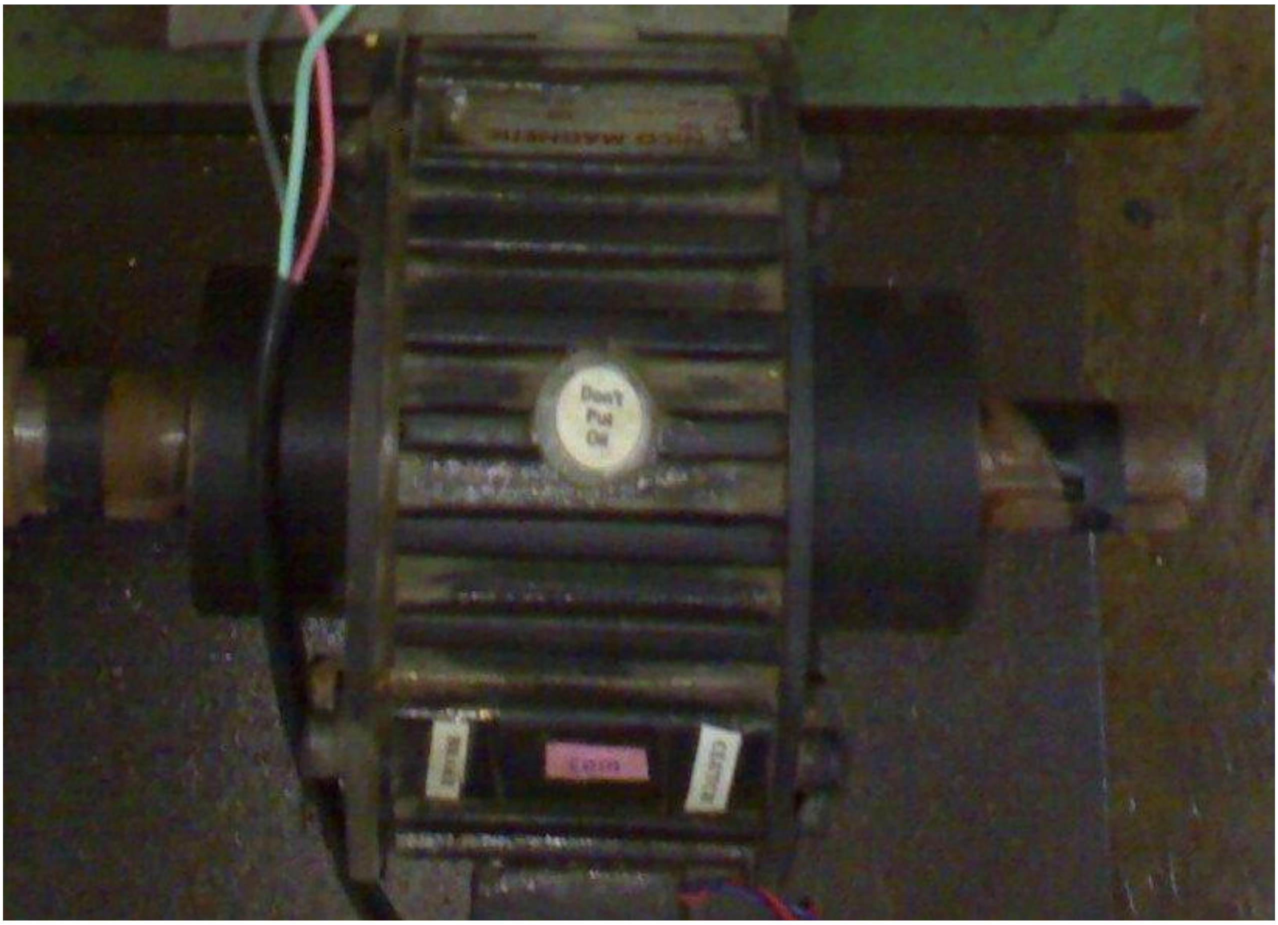


Fig.9

4.5: Flange Coupling:-

A flange coupling is a mechanical device used to connect two rotating shafts together at their ends for the purpose of transmitting power. Flange couplings don`t allow disconnection of shafts during operation.

In this experiment we are using two times flange coupling, 1st between 3 phase motor and input shaft of gearbox and 2nd coupling between magnetic motor and half shaft to connect output shaft of gearbox.

Type of coupling

- Rigid coupling (flange coupling) - used to join two shafts rigidly.
- Flexible coupling (universal joint) - when both shafts are misalignment.
- Torque limited coupling- adjustable friction drive coupling.

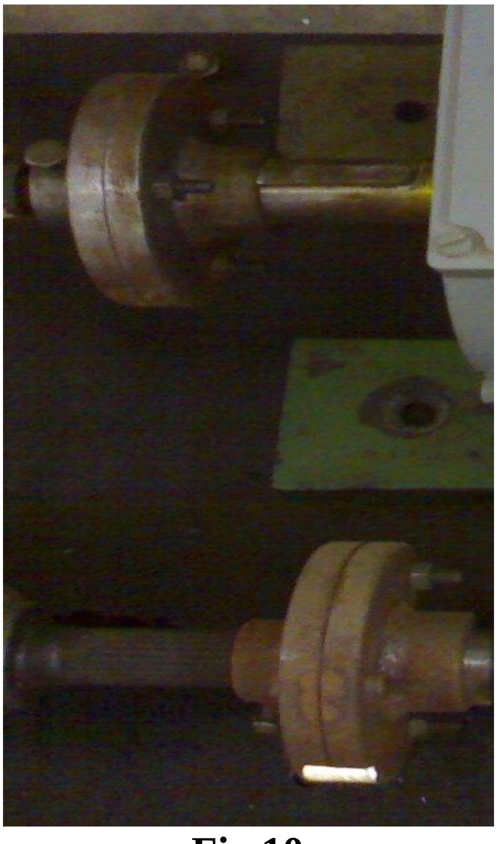


Fig.10

4.6: Half shaft:-

A half shaft is an automotive term used mainly to describe an axle on a front wheel drive vehicle, connecting the transmission to the driven wheels. Some rear wheel drive vehicles may also use half shafts, when the differential is rigidly mounted and an independent rear suspension is used. This half shaft is connected to magnetic brake with the help of flange coupling as given in fig.9.

Fig.11

4.7: Oscilloscope:-

The oscilloscope is basically a graph-displaying device. It generally draws a graph of an electrical signal. In most of the cases the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time.

This simple graph Oscilloscope has lot of application-

- Can determine the time and voltage values of a signal.
- Can calculate the frequency of an oscillating signal.
- Also can see the "moving parts" of a circuit represented by the signal.

- You can tell if a malfunctioning component is distorting the signal.
- You can calculate vibration of mechanical equipment.

Generally an oscilloscope looks like a small television, but it has a grid drawn on its screen and more controls than a television. The front panel of an oscilloscope normally has control sections divided into Vertical, Horizontal, and Trigger sections. Now a day's Oscilloscopes are used by everyone from television repair technicians to physicists. The advantages of an oscilloscope are not limited to the world of electronics. With the proper sensor, an oscilloscope can measure all kinds of phenomena. An automotive engineer also uses an oscilloscope to measure mechanical vibrations in engine [15].

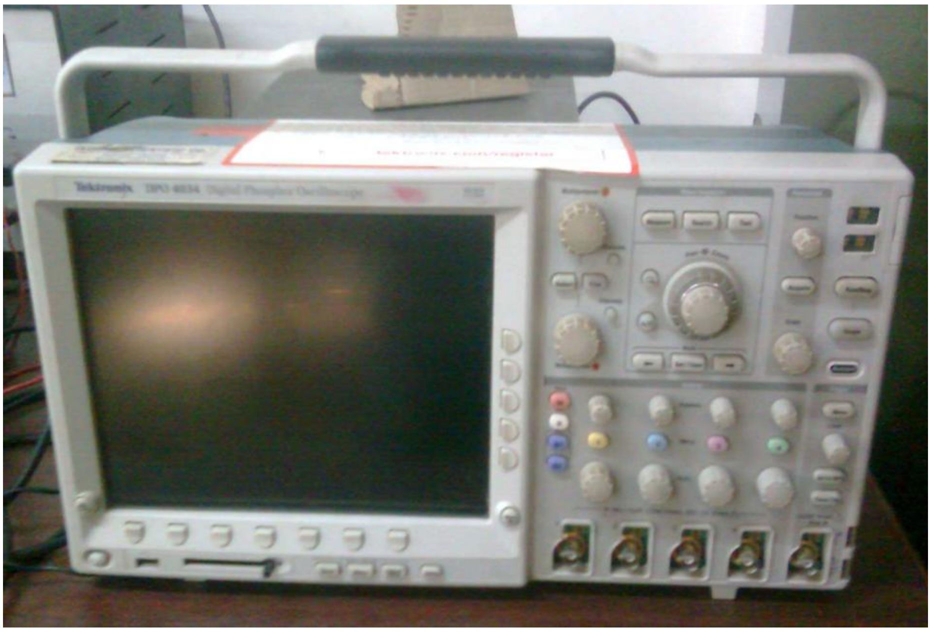


Fig.12

Rating of Oscilloscope:-

Make: Techno scientific co.

Voltage Range and Frequency Range: 100-240V and 50-60 Hz

115V and 400Hz

Power: 250watts

4.8: Variable frequency drive:-

A variable-frequency drive (VFD) is a electronic system, used to controlling the rotational speed of an alternating current (AC) motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a special type of adjustable Variable-frequency drives are also known as adjustable-frequency drives (AFD), variable-speed drives (VSD), micro drives or inverter drives. Since the voltage is varied along with frequency, sometimes these are also called VVVF (variable voltage variable frequency) drives.

Variable-frequency drives are widely used. In ventilation systems for large buildings, variable-frequency motors on fans save energy by allowing the volume of moved air to match the system demand. They are also used to control speed of pumps, elevator, conveyor, machine tool drives and DC or AC motors.

When a 3 phase induction motor is connected to voltage supply, it draws several times its rated current. As the load accelerates, the available torque usually drops a little and then rises up to a peak level while the current remains very high until the motor approaches full speed.

By contrast, when a VFD starts a motor, it initially applies a low frequency and low voltage to the motor. The starting frequency may be typically 2 Hz or less. Thus starting at such a low frequency avoids the high current that occurs when a motor is started by simply applying the utility mains voltage by turning on a switch. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate. Note, still, that cooling of the 3 phase motor is usually not good in the low speed range. Thus running of 3 phase motor at low speeds even with rated torque for long periods is not possible because of overheating problem of the motor. If continuous operation with high torque is required in low speeds, there external fan is usually needed. The manufacturer of the motor and in this condition cooling requirement is very important for VFD and 3 phase motor [17].

Benefits:-

Single-speed drives start motors abruptly, subjecting the motor to high torque and current surges up to 10 times the full-load current. In contrast, variable-frequency drives offer a "soft start" capability, gradually ramping up a motor to operating speed.

Fig.13. variable frequency drive

The VFD used in the experiment has the following ratings:

- Make: Pros tar.
- Rated Power: 3.7 kW
- Voltage: 380 V
- Current: 5 A
- Frequency: Input: 50 Hz
  Output: 0-240 Hz
- Type: 3 phase
- Weight: 4.5 kg

4.9: Accelerometer (Vibration sensor):-

An accelerometer is a device that measures the vibration, or acceleration of motion of a structure. Here this sensor attach to faulty gearbox with the help of a cast iron metal piece. And output of sensor goes to the oscilloscope. A big advantage of this sensor is that it has magnetic effect so can attach easily with cast iron metal.

Fig.14

4.10: Defective gears: -

Main working of gears is to transfer motion from one shaft to another shaft. Defects in gear can be any kind like slightly worm, broken teeth etc. Actually this is very important topic in this project work. Without defective gears we can`t proceed this work further to collect all experimental result. This gearbox is having three types of gear defects. Since previously we have described about defect of gears in this project. These are following types of defects

- Rubbing of gear teeth face
- Half teeth break
- Full teeth break

In this gearbox teethes are helical and made up of high carbon steel metal so wear and tear is very less and maintenance also not a big problem. Because of suddenly non uniform loading at the time of rotation, this kind of defect can occurs. Here we are measuring vibration on each gear at constant loading condition through the magnetic brake. Here we applies constant load of 20volts through magnetic brake. In fig.14 can see defect of gears.

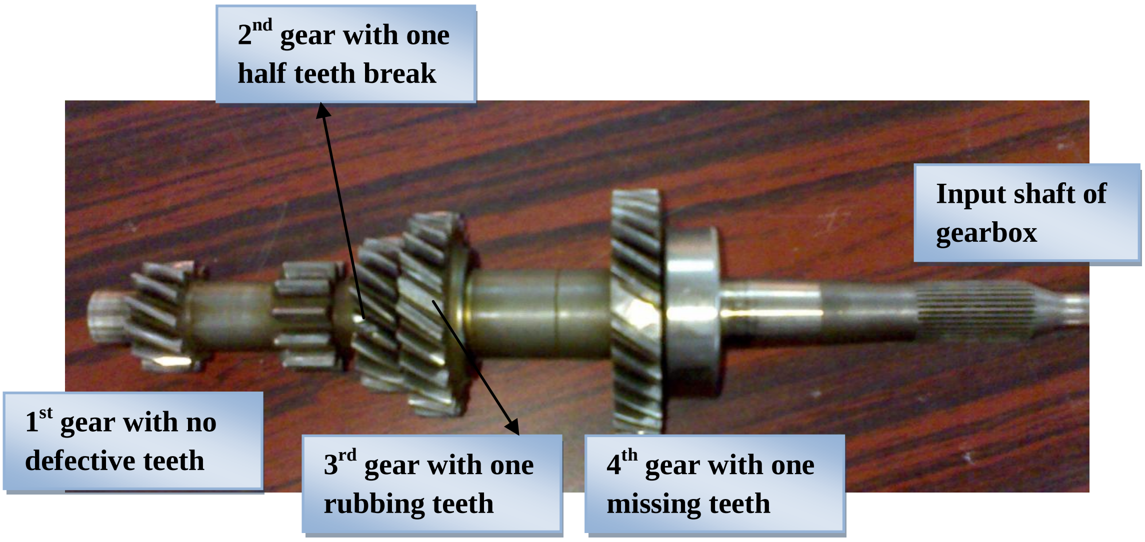


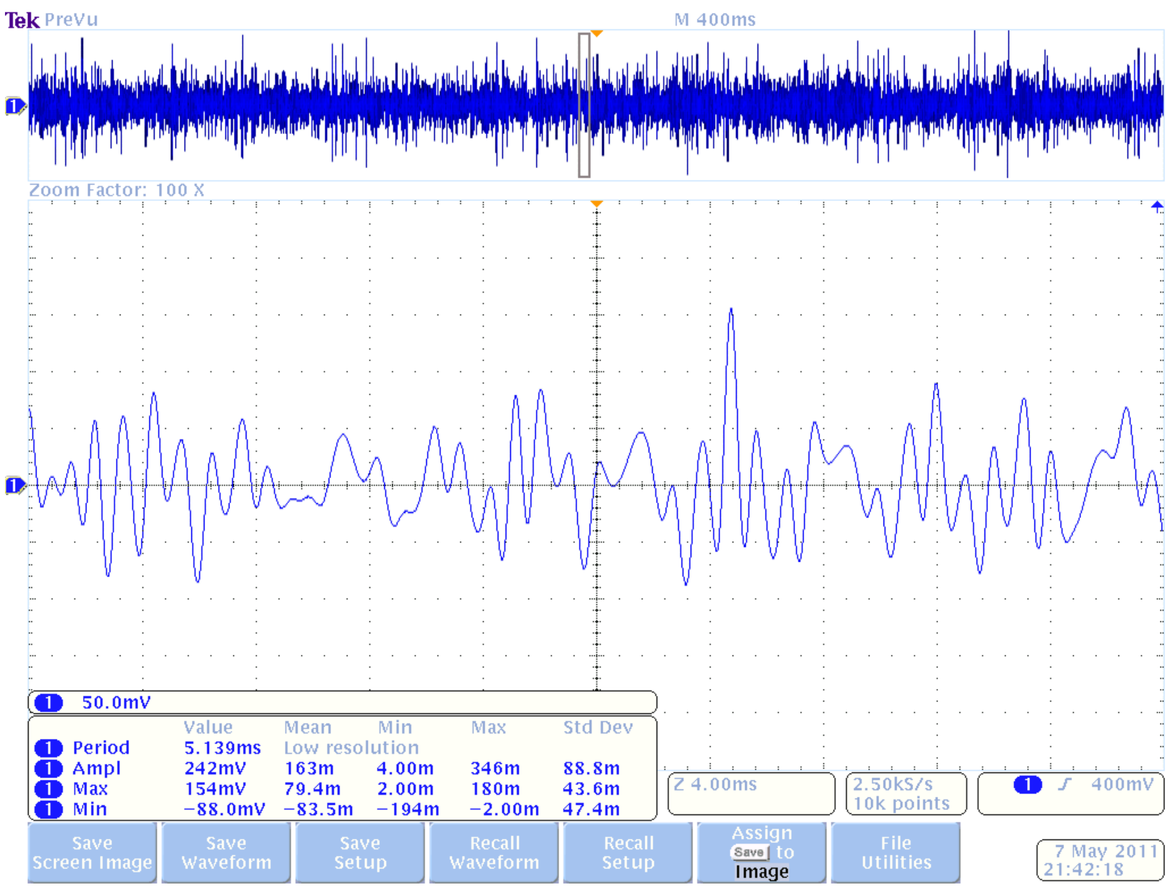
Fig.15. Defective gears

5. RESULTS AND DISCUSSION

The basic aim of this project work is to design a test rig and to carry out experimentation to detect different types of faults namely broken tooth, missing tooth and tooth profile error in a gear box. In the experimentation, vibration response measured from the gear box is analyzed to detect different faults. For this analysis gearbox rotates at loading condition and at constant speed of induction motor. Constant load is applied on the output shaft of the gear box by means of a magnetic brake. The motor speed is maintained at a constant speed of 1000 rpm by the Variable Frequency Drive (VFD). The vibration response from the gear box is recorded by a digital storage oscilloscope. The response is recorded both against time and frequency scales (FFT).

Vibration analysis Graph of Gearbox for Amplitude response and Frequency response (X axis represents time in millisecond and y axis represents voltage in mill volt):

For 1st gear: At constant 1000RPM and 20 volt load.

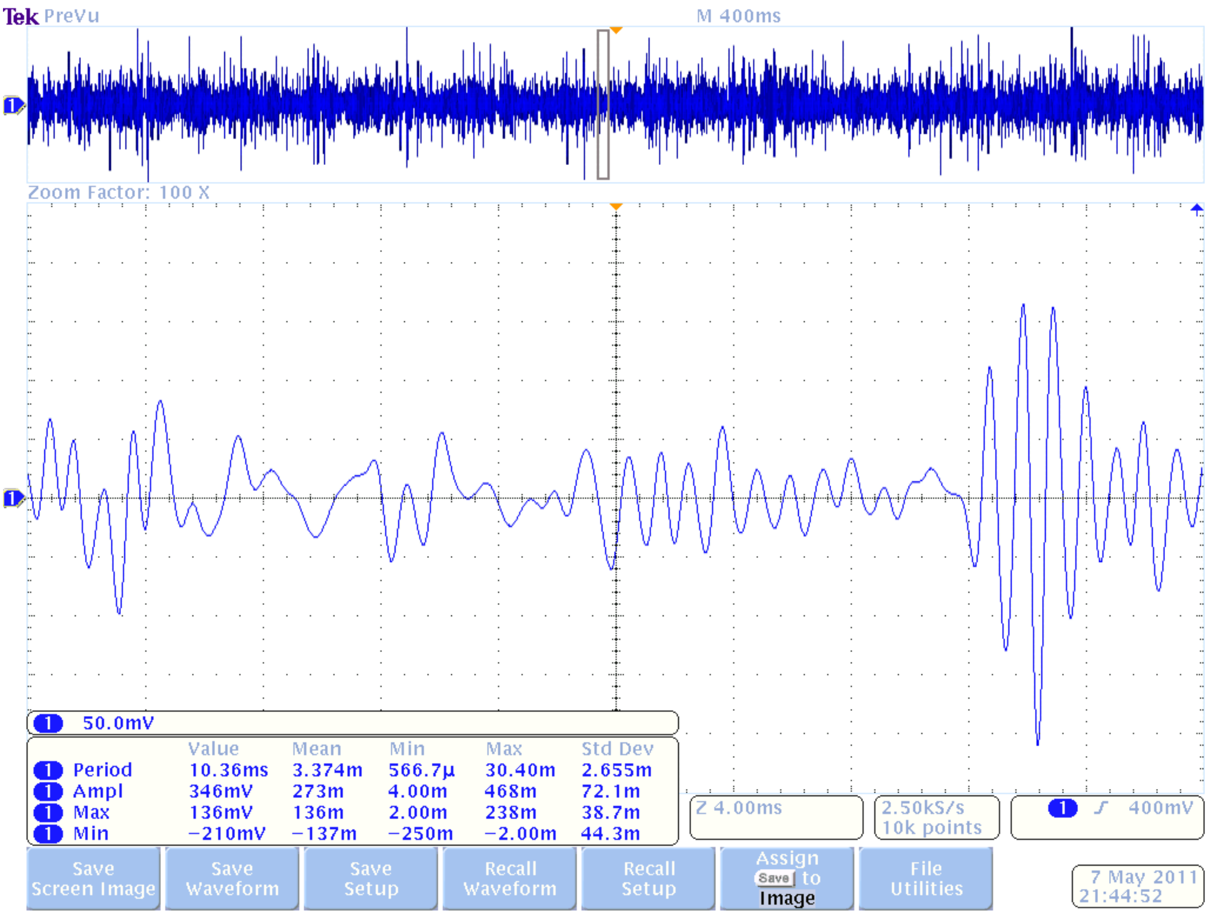


Graph 1

Sl. no	value	mean	minimum	maximum	Std. dev
period	5.139ms	-------	---------	--------	-------
amplitude	242mv	163m	4.00m	346m	88.8m
maximum	154mv	79.4	2.00m	180m	43.6m
minimum	-88.0mv	-83.5m	-194m	-2.00m	47.4m

Table1. For Graph 1

For 2nd Gear: At constant load of 20 volt and 1000RPM.

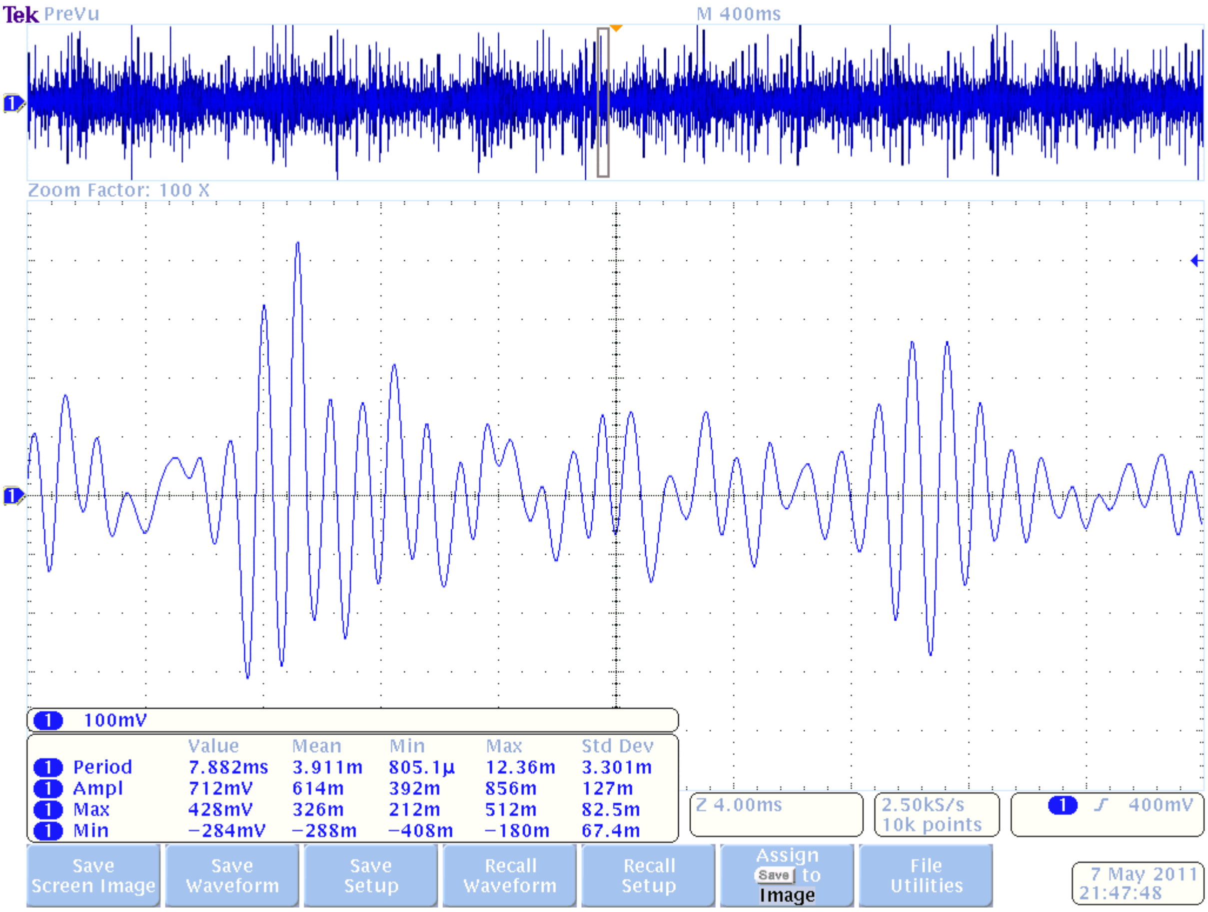


Graph 2

Sl. no	Value	Mean	Min	Max	Std dev
Period	10.36ms	3.37m	0.5667m	30.40m	2.655m
Amplitude	346mv	273m	4.00m	468m	72.1m
Max	136mv	136m	2.00m	238m	38.7m
Min	-210mv	-137m	-250m	-2.00m	44.3m

Table2. For Graph 2

For 3rd Gear: At constant load of 20 volt and 1000RPM.

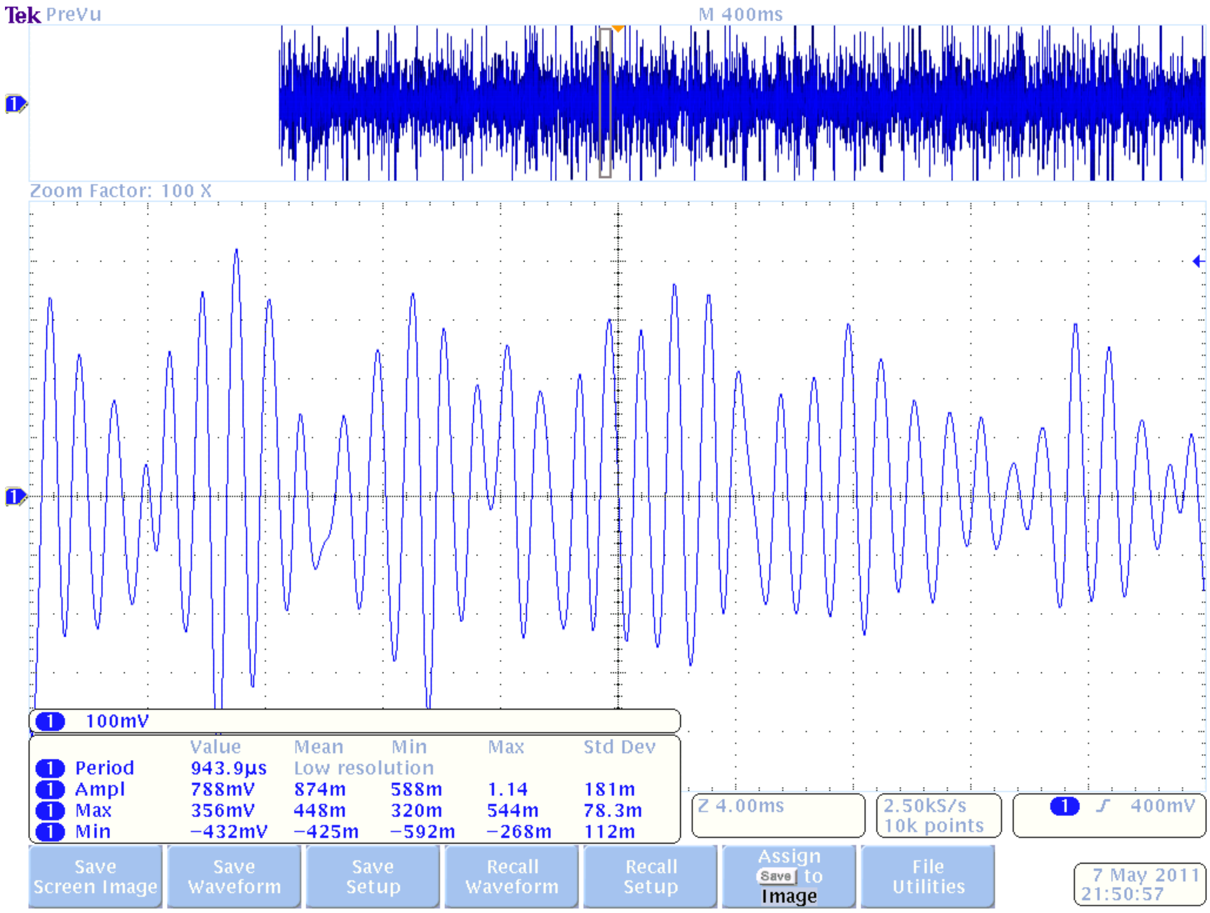


Graph 3

Sl. No	Value	Mean	Min	Max	Std dev
Period	7.882ms	3.911m	0.805m	12.36m	3.301m
Amplitude	712mv	614m	392m	856m	127m
Max	428mv	326m	212m	512m	82.5m
Min	-284mv	-288m	-408m	-180m	67.4m

Table3. For Graph 3

For 4th Gear: At constant load of 20 volt and 1000 RPM.



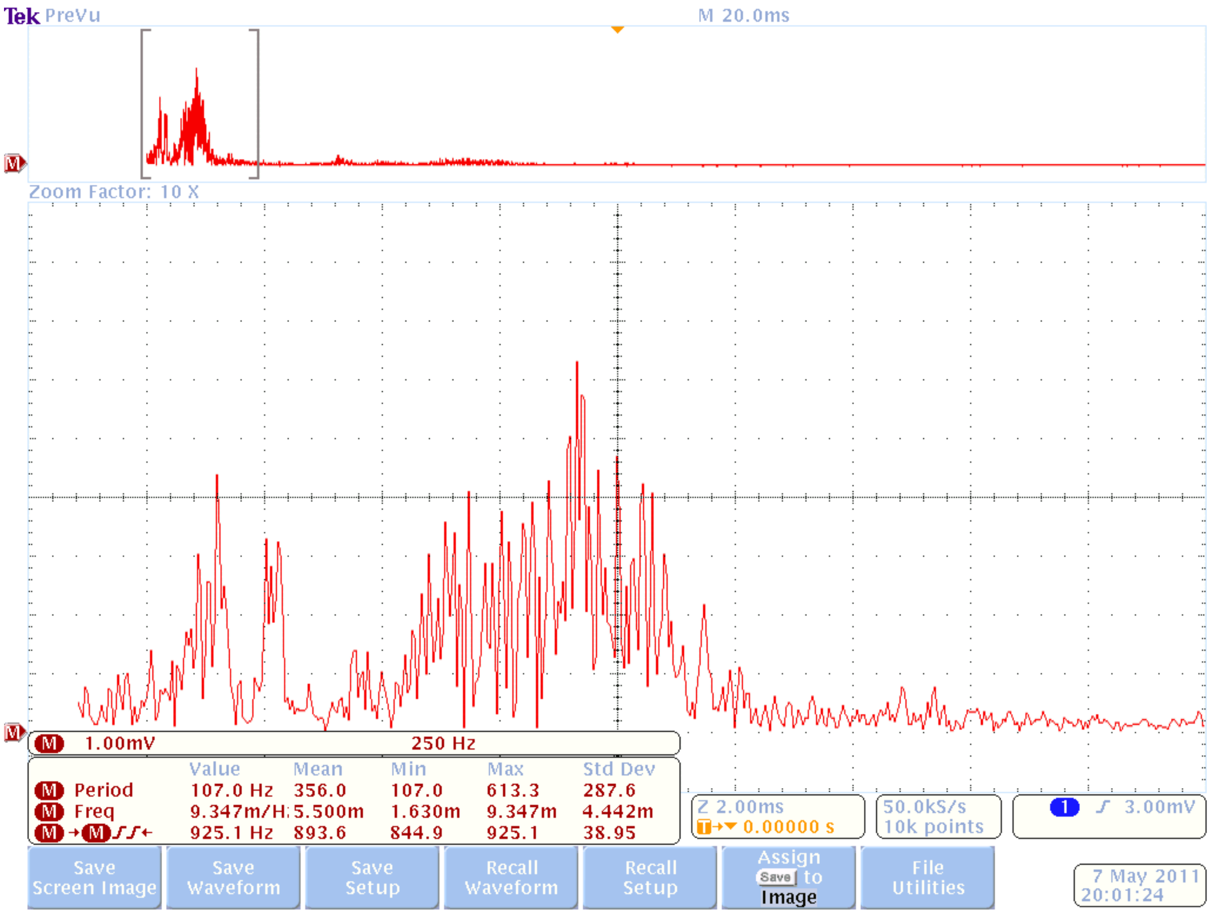
Graph4

Sl. No	Value	Mean	Min	Max	Std dev
Period	0.9439ms	-------	---------	--------	---------
Amplitude	788mv	878m	588m	1.14m	181m
Max	356mv	448m	320m	544m	78.3m
Min	-432mv	-425m	-592m	-268m	112m

Table4. For Graph4

Vibration analysis graph on FFT:

For 1st gear: At constant 1000RPM and 20 volt load.

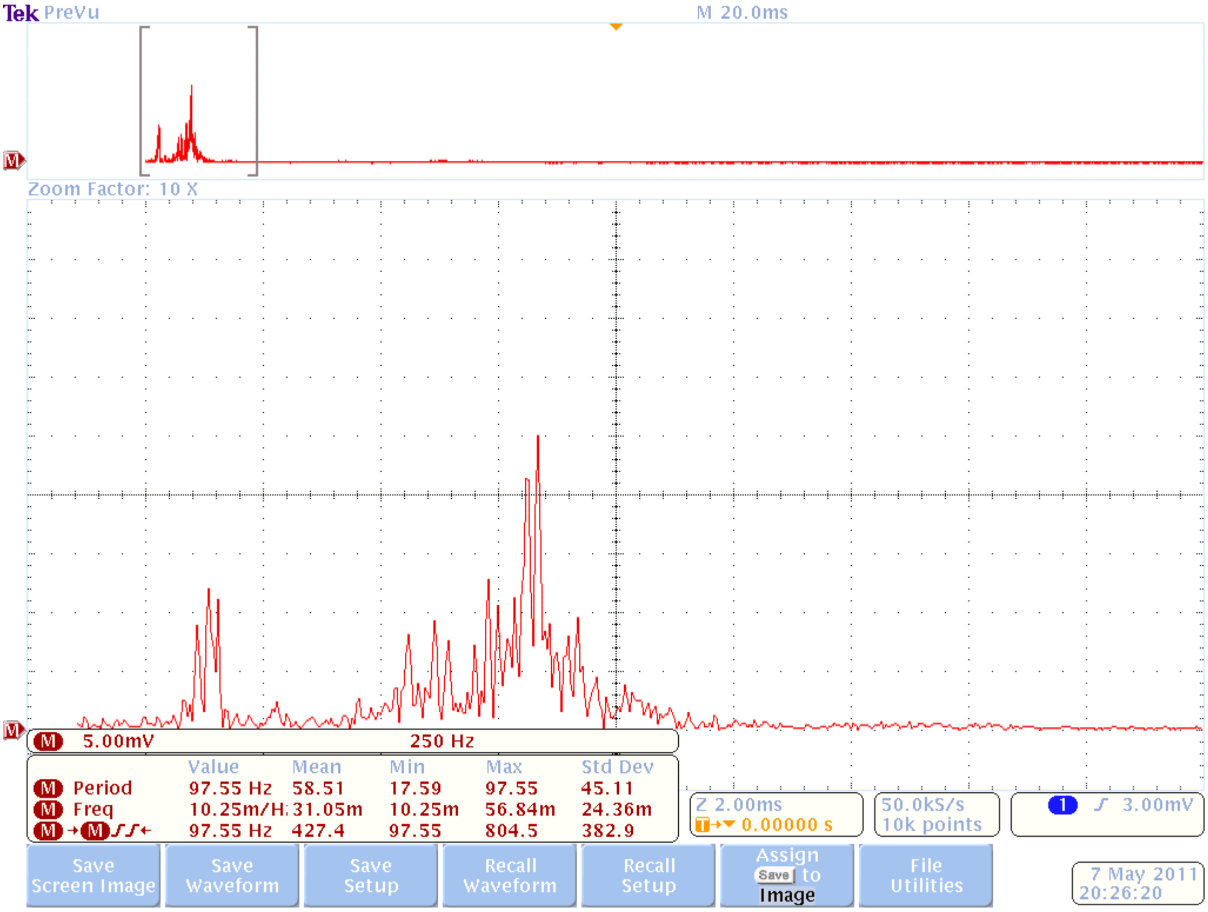


Graph 5

Sl. no	value	Mean	Min	Max	Std dev
Period	107.0Hz	356.0	107	613.3	287.6
Freq	9.347m/H	5.500m	1.630m	9.347m	4.442m
M	925.1Hz	893.6	844.9	925.1	38.95

Table5. For Graph5

For 2nd gear: At constant 1000RPM and 20 volt load.

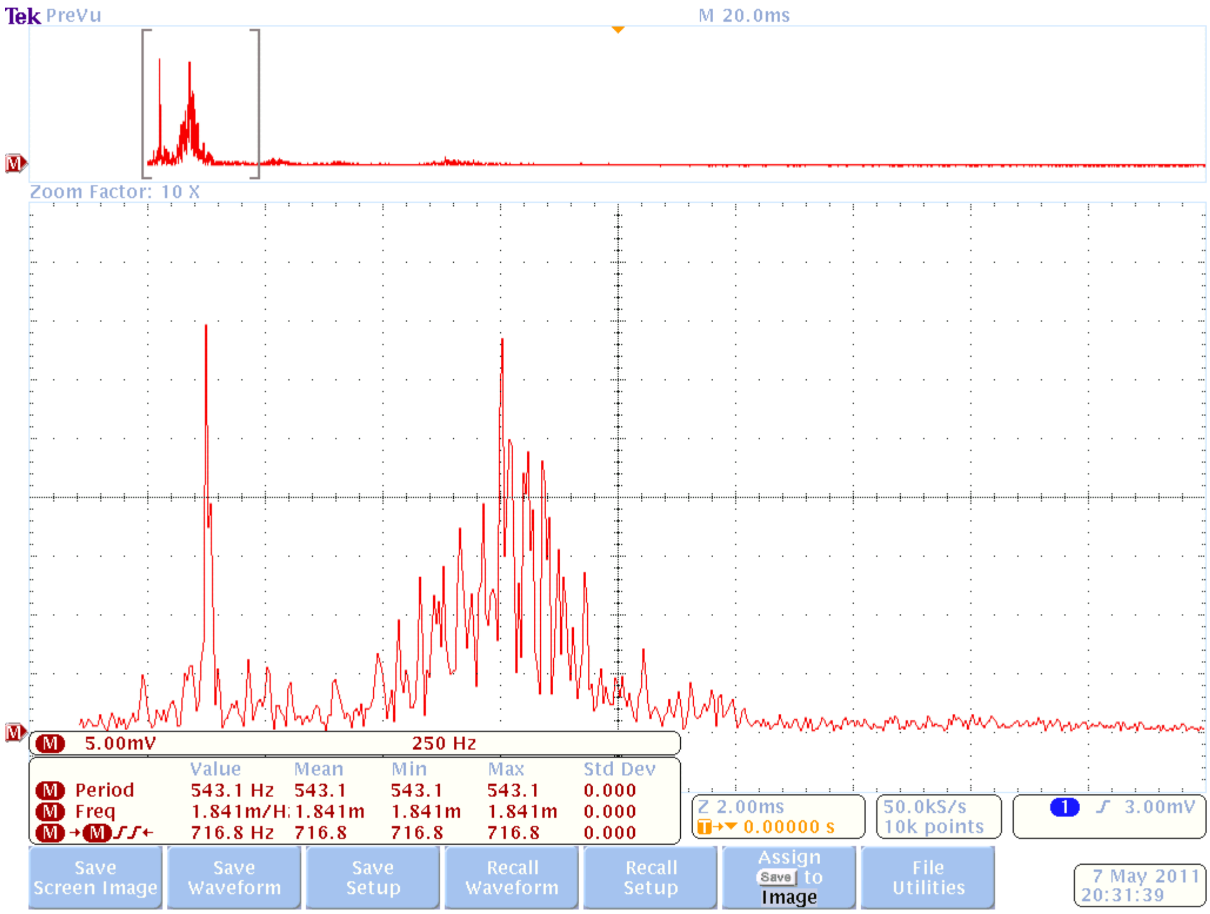


Graph 6

Sl. No	Value	Mean	Min	Max	Std dev
Period	97.55Hz	58.51	17.59	97.55	45.11
Freq	10.25m/H	31.05m	10.25m	56.84m	24.36m
M	97.55Hz	427.4	97.55	804.5	382.9

Table6. For Graph6

For 3rd Gear: At constant 1000RPM and 20 volt load.

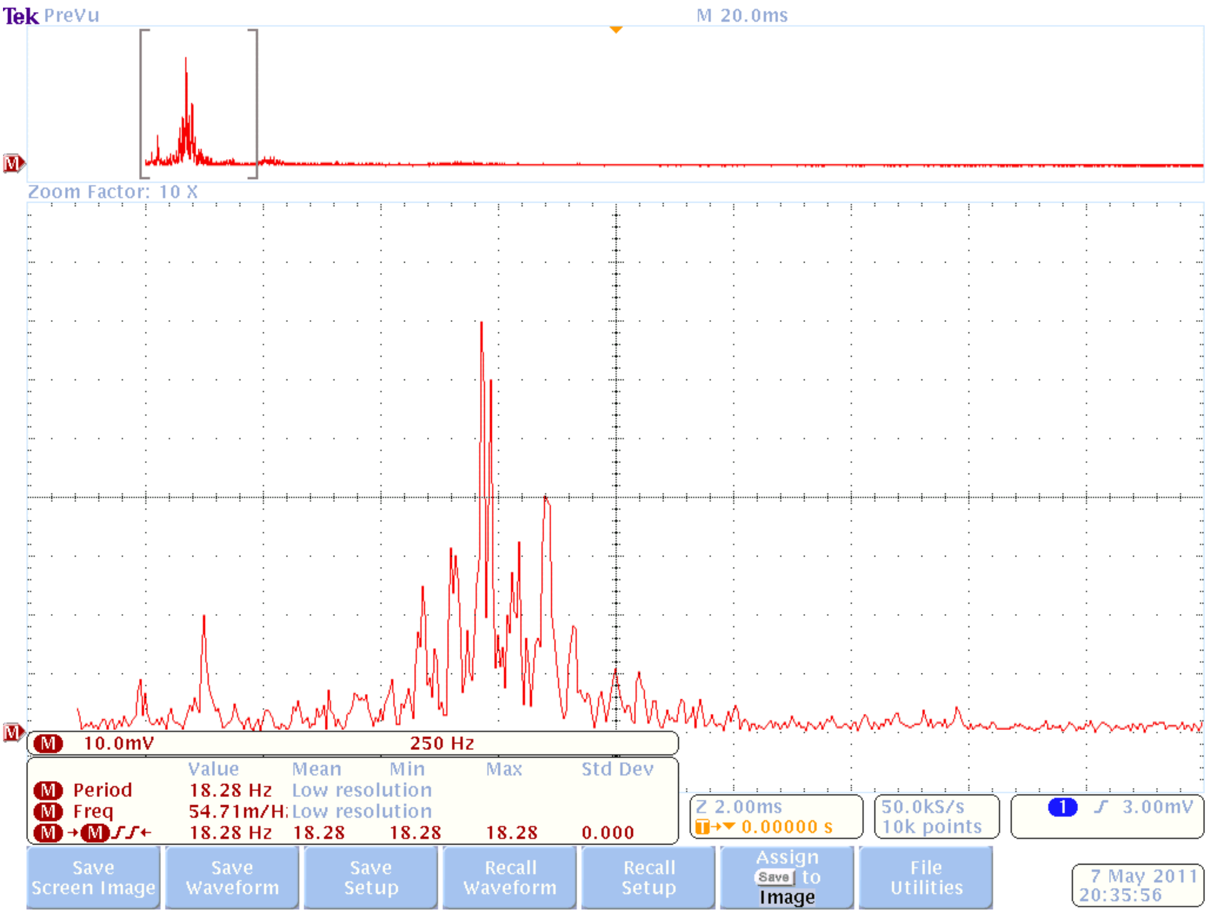


Graph 7

Sl. No	Value	Mean	Min	Max	Std dev
Period	543.1Hz	543.1	543.1	543.1	0.000
Freq	1.841m/H	1.814m	1.814m	1.814m	0.000
M	716.8Hz	716.8	716.8	716.8	0.000

Table7. For Graph7

For 4th Gear: At constant speed of 1000RPM and constant load of 20 volts.



Graph 8

Sl. No	Value	Mean	Min	Max	Std dev
Period	18.28	-------	---------	--------	--------
Freq	54.71m/H	-------	---------	---------	--------
M	18.28Hz	18.28	18.28	18.28	0.000

Table8. For Graph 8

Discussion:

After visualized these graphs, simply we can see the effect of dynamic vibration by the frequency response and amplitude response. In graphs 1 to graph 4 can see amplitude response increasing according to gear defect. In 1st gear which has no fault, amplitude response is minimum, in 2nd gear corresponding to 1st one vibration amplitude is high because it has half break teeth, in 3rd gear which has rubbing teeth, vibration amplitude is more than 2nd gear because no of teeth on 3rd gear high and rpm also high and in 4th gear which has one teeth missing, it shows much more high amplitude range in oscilloscope of 788 mv. Because 4th gear used to produce high speed and less power so at this high speed highly amplitude vibration occurs through missing teeth. Fast Fourier Transformation (FFT) Graphs also shows the frequency and delay period response in graphs, at each defect frequency response varies. Graph 5 to 8 shows FFT response according to their defect. Frequency response is high in 4th gear according to graph8 as compared to other one.

6. Conclusion

After analyzing these all graphs we got dynamic vibration amplitude values for different faults. So after these result we conclude that this whole system was a modern phenomena to get defect in a gearbox. Now days this kind of modern system is used by industrial purpose. If we match vibration response of a new faulty gearbox to the response of a gearbox with known fault so we can conclude what kind of fault this gearbox has before disassembling the whole system. Big advantages of this kind of system are that we reach directly at the fault after opening the whole system. So this becomes a less time consuming process to repair a faulty system. But there is lot of study possible in this field. Because fault can be any kind like misalignment of shaft, crack in gear, and bearing crack, but here we considered only 3 kinds of faults of a gear. So for further future study we can include these defects also. So In my opinion these aspects can be taken as future work of this project.

7. References

[1].**Application of Wavelet to Gearbox Vibration Signals for Fault Detection**
Yanking CAI,Yanping HE,Aihua LI,Jinru ZHAO and Tao WANG
Xi'an High-Tech Institute, 710025, Xi'an, china

[2].**FAULT DETECTION IN GEARBOXES WITH VIBRATION STIMULUS APPLIED REPRESENTATIVE OF IN-FIELD OPERATING ENVIRONMENT**

[3].**Vibration and current transient monitoring for gearbox fault detection using multiresolution Fourier transform**
Chinmaya Kara, A.R. Mohan

[4].**On the application of non-destructive testing techniques on rotating machinery.**
T.H. Loutas, J. Kalaitzoglou, G. Sotiriades and V. Kostopoulos

[5].**The Motor Vehicle (Thirteenth Edition),**
T.K. GARRETT (CEng, FIMechE, MRAeS) Sometime Editor of Automobile Engineer, K. NEWTON (MC, BSc, ACGI, AMInstCE, MIMechE) Late Assistant Professor, Mechanical and Electrical Engineering Department,(The Royal Military College of Science), W. STEEDS (OBE, BSc, ACGI, FIMechE)Late Professor of Mechanical Engineering ,(The Royal Military College of Science) Page no-750-760

[6]. http://ethesis.nitrkl.ac.in/1884/1/57_THESIS.pdf

[7]. http://www.allinterview.com/showanswers/86010.html

[8].http://www.inverter-china.com/blog/articles/ac-motor/Disadvantages-of-AC-Motors.html

[9]. http://en.wikipedia.org/wiki/Three-phase_electric_power

[10]. http://en.wikipedia.org/wiki/Manual_transmission

[11]. http://en.wikipedia.org/wiki/Transmission_(mechanics)

[12]. http://en.wikipedia.org/wiki/Universal_joint

[13]. http://en.wikipedia.org/wiki/Coupling

[14]. http://en.wikipedia.org/wiki/Half_shaft

[15]. http://www.cromptonusa.com/application/Oscilloscope.pdf

[16]. http://www.energymanagertraining.com/Journal/02112007/VariableFrequencyDrives.pdf

[17]. http://en.wikipedia.org/wiki/Variable_Frequency_Drive#VFD_Operation

[18]. http://www.omega.com/prodinfo/accelerometers.html

[19].http://2.imimg.com/data2/EP/PS/MY-974161/piezo-electric-acceleration-sensor-250x250.jpg

[20]. http://www.ehow.com/how_7669220_digital-storage-oscilloscope-tutorial.html