DETECTION AND ANALYSIS OF FAULT ON TAPER ROLLER BEARING USING SIGNAL PROCESSING

DESERTATION-II

Submitted in partial fulfilment of the

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MECHANICAL ENGINEERING

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CERTIFICATE

I hereby certify that the work which is being present in Dissertation-II entitled "**Detection and Analysis of Fault on Taper Roller Bearing Using Signal Processing"** in partial fulfilment of the required for award of the degree of Master of technology and submitted in department of Mechanical Engineering, Lovely Professional University (Punjab) is record of my own work carried out during period of dissertation-II under the supervision of **Mr. Rajeev Kumar, Assistant Professor,** Department of Mechanical Engineering, Lovely Professional University (Punjab).

The matter presented in dissertation-II has not been submitted by me anywhere for the award of any other degree or to any other institute.

Date**:** **Mr. Gurjit Singh**

This is certifying that the above statement made by the candidate is accurate to best of my knowledge.

Date: Signature of Supervisor

Mr. Rajeev Kumar

HOD (ME)

The external viva-voce examination of the student was held on successfully _____

Signature of Examiner

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,

Gurjit Singh

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ABSTRACT

To reduce the friction between two parts, bearing can be used. It also increases the life of machine or apparatus where it is used because of low friction. To reduce the sudden failure monitoring process is needed. Monitoring can be done through image processing method, thermograph and vibration analysis. This project work tells about the detection of fault in taper roller bearing using signal processing techniques. We initiate the v-notch crack on the outer race of bearing. After this we placed our bearing into the vibration setup and run at different frequencies. The data is recorded in computer which is attached to vibration setup with the help of lab view software. After this we change the lab view files (lvm.) into Matlab files (mat.). Then calculate the values at different parameters with two frequency 35 Hz and 38 Hz at incipient level of misalignment. There are seven type of misalignment is used 0 mm, 0.25 mm, 0.5 mm, 0.75 mm, 1 mm, 1.25 mm, and 1.5 mm. The 0 mm misalignment means there is no default was present into our setup. We need the values at incipient level so we choose lowest misalignment which is at 0 mm and highest misalignment which is 1.5 mm. At these two misalignment values we concluded our results. These values are calculated for both 35 Hz and 38 Hz frequency. The result comes in the form of frequency graph. Three types of frequency graph are used - Time domain graph, FFT (Fast Fourier transformation) graph and CWT (Continues wavelet transformation) graph. We take a reading for 3 minute for one signal and at the 2100 RPM and 2280 RPM. We concluded that the while increases the misalignment the values of stranded deviation is decreases and Shannon value is increases.

CHAPTER 1

1 INTRODUCTION

1.1 Bearing

According to dictionary the bearing is a part of machine that rotates or move. Additional functions of bearing include the transmission of loads and the accurate positioning of component. A bearing may have to design for static and cyclic loads while using in different environments.

The bearing function is to ensure that the free rotation of shaft and it also support the shaft to holds it in correct position. Bearing is used for rotating parts of every machine in different places and different types of environment conditions. It permits the low friction, linear or rotator movement between the two surfaces. There are different types of bearing which are used for different speeds and applications but our main focus is on Tapper Roller Bearing (TRB). We did crack detection and analysis of fault on taper roller bearing with signal processing technique. It is possible to reduce the weight of the machine by increases the speed but it is not easy to do on heavy machines because while rotating of heavy duty machine they needs suitable bearing to support high dynamics faces and operating conditions like misalignment, axial thrust and soon. Lubrication is also play important part for to design the bearing because if the lubrication is not present into the bearing then wear and tear takes place. We use grease (lithium soap thickened grease) as lubricant into the bearing. It provides excellent mechanical stability, good corrosion resistance.

Table No. 1 – Grease specification

S. No.	Physical Appearance	Properties
1	Soap type	Lithium
2	Colour	Light brown
3	Operating temperature range	-20 to 110 ℃ (-5 to +230°F)
4	Designation	LGEP 2/ 0.4, 420 ml
5	Base oil type	Mineral
6	Dropping point ISO 2176	>180℃ (> 355°F)

1.2 Types of Bearing

Based on the principle and applications, the bearing is divided into two parts and these parts are also divided into sub parts written below

1) Anti-friction Bearing (Rolling Element Bearing)
    i) Ball bearing
    ii) Cylindrical roller Bearing
    iii) Tapper Roller Bearing
    iv) Spherical Roller Bearing
    v) Needle Roller Bearing
2) Sliding Contact Bearing (Plain Bearing/Journal Bearing/Sleeve Bearing)
    i) Hydrostatic Bearing
    ii) Hydrodynamic bearing

1.3 Tapper Roller Bearing:-

Taper roller bearings are separate from other bearings and having following components which are outer ring, inner ring, and roller assembly (containing the roller and casing). The non- separable inner ring and the roller assembly are called the cone of bearing and outer ring is called a cup of bearing. It can take large axial and large radial force. The inner and outer raceway are the segments of cones and the rollers are made tapper so that the conical surface of the raceway and the roller axes if projected, all meets at common point on the axes of bearing. This type of alignment takes the motion of the cone coaxial, and also eliminating the sliding motion in the bearing. This conical geometry is used foe to take a larger contact path to the rollers, which permits greater loads with the spherical bearing. While the geometry is in tangential speeds of the surface of roller are the same their raceway along whole length of the contact path then the no differtial scrubbing occurs. When roller are slides or rolls in the races of bearing, it can create a wear in the bearing that means difference in a speed create a scrubbing between the bearings. Wear will again generate and the close tolerance normally held in bearing and can gives different other problems. The roller is guided by the inner rings and casing between them. This gives the reduction to the roller from sliding. Larger the half angle contain larger the axial load which can produce.

Inner ring clearance is produce during mounting of the axial position of the cone relative to the cup of bearing. There are three types of taper roller bearing which are single row taper roller bearing, double row taper roller bearing and four row taper roller bearing. Single row

bearing is assembled in Paris and have face to face and back to back arrangements. The outer rings in snap rib are arranged in same as internal parts of single row tapper roller bearing. Double row taper bearing can take radial load and double load in axial directions. These bearings are also arranged in face to face and back to back arrangements. The four row taper roller bearings performance is also same like of double row tapper roller bearing. It can take more radial loads than double row taper roller bearing. The speed of four row tapper roller bearing is low than other two types of these bearing. Four row taper roller bearing are used for heavy machine parts. These bearing are used for combined load that is axial and radial both at one time. Taper roller bearing is made from high carbon chrome steels due to their expected performance. There are two types of hardness processes which are given to this bearing. These are through the hardened treatment of this bearing consistent hardness through the components. From case hardedge surface it combined with tough and flexible core. Taper roller bearing consists of four elements. These are cone, cup, taper rollers and cage. In operating conditions the cone, cup, rollers take the load and cage separates the rollers. The extension of raceway and taper rollers are designed to converge at a same point and that point is called apex. Due to this the true rolling motion occurs in the raceway at any point on roller body of bearing.

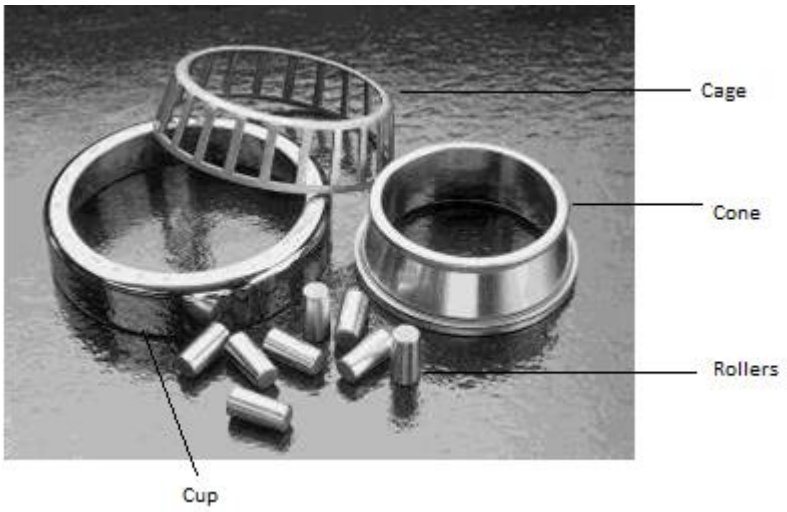

Figure 1 Component of Taper Single Row Rollers Bearing

Our research work is done on 30205 bearing. We artificially generate a crack on bearing by using EDM (Electric Discharge Machine) and did our work on it. After this we install bearing into bearing casing which is made by us because standard bearing casing give problem to hold the bearing into correct position. The specification of bearing is given below

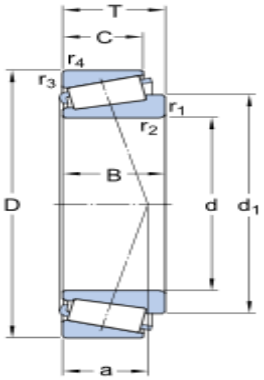

Figure 2 Taper Roller Bearing 30205 (Dimensions)

Table No. 2 – Bearing Specification

Sr.no	Dimensions	Size (mm)
1	D	25
2	D	52
3	T	16.25
4	d_1	38
5	B	15
6	C	13
7	A	12.33
8	$r_{1,2}$	1
9	$r_{3,4}$	1

1.4 Bearing Material

The selection of material is important to meet the application requirement. The heat treatment process that the material selection largely durability that impact on several bearing characters which include hardness, bearing microstructure, raceway surface finish and residual stress. The 30205 TRB is made up of 52100 chrome steel. Benefits of case hardening bearing include:

1) In surface residual stresses that retards propagation of fatigue cracks.
2) It has ability to continue take a heavy shock loads as a result to tough or ductile core.
3) Resistance increase due to metallurgical behaviour of surface.

1.5 Contact Geometry

Taper roller bearing have components with profile which results in uniform stress distribution with normal loading conditions along with effective rollers contact angles. At very high loads misalignment modified with minimize geometric stress concentration at the end of roller contact angle.

Bearing which is act at normal condition the service life is depend on some parameter which are written below

1) Maximum temperature of bearing not exceeded from the 300 F which is equal to 150 C.
2) The minimum temperature not less than from – 65 F which is – 50 C.
3) The hertizan stress contact is not more from 4000 MPa.

1.6 Types of Design and Cage Material

Taper roller bearing have cage do not take load and take only retain and used for to spacing between the rollers of this bearing. So most of this cage is made up of low carbon steel and mild steel.

1.6.1 Pin Type's Cage

These cages have two rings at each end of the roller. The pins of this bearing cage pass from the centre point of each roller of bearing. This type of casing have high load carrying capacity because of more rollers.

1.6.2 Polymer Cage

Now these days polymer bearing are mostly used in bearing casing because of benefits of this cage i.e. high load carrying capacity, high temperature capacity etc. these type of bearing which is made by this material is known as specialized bearing.

1.6.3 Cage made up of Non Ferrous Material

This material for bearing is used where thrust load is more as compare to radial load on the bearing.

1.7 Types of Taper Roller Bearing

There is different type of taper roller bearing according to their use and load carrying capacity which is explain below

1.7.1 Single Row Taper Roller Bearing

This is the most commonly used bearing. It has cone and cup assembly. During assembly we provide some clearance and put some pre load condition for to load carrying capacity.

Figure 3 Single Row Taper Roller Bearing

1.7.2 Single Row Taper Roller Bearing with Flange Cup

Flanged cup is attached to single row taper roller baring because to take facility of axial location or correctly aligned of roller on the bearing.

Figure 4 Taper Roller Bearing with Flange Cup

1.7.3 Two Roller Taper Roller Bearing

Taper roller bearing is also having double row and double cup system to carry maximum load capacity. This type of bearing having one piece but two different cones of bearing which is attached to each other with the help of a cup. On surface of cage of this type of bearing there is holes are provided because to stop the rotation of

cup while bearing is moving. This double roller bearing sustain at high speed and carry high load as compare to single row taper roller bearing.

Figure 5 Taper Roller Bearing having Double Row

1.7.4 Taper Roller Bearing with Double Cone

This type of bearing having two cup and attached as a single piece of bearing. This bearing are used where a fixed part moving shaft arrangement comes. For rotating housing conditions this bearing can be used on fixed shaft.

Figure 6 Taper Roller Bearing with Double Cone

1.7.5 Four Row Taper Roller Bearing

Taper roller bearing with four row is used at very high load carrying conditions environment for both thrust and radial load, by direct or indirect mounting. The main advantage of this bearing is for rolling mill. This type of bearing is direct mount on the machinery without any difficulty because it has two double cone, single cone with double cup and two cup spacer. A slot which is present in cage of this bearing is used to provide the lubrication to this taper roller bearing.

Figure 7 Four Row Taper Roller Bearing

1.8 Bearing life

Basic life and L10 is defined in ISO standards, it is that life 90% of a sufficiently large groups of identical bearing is expected to reach. The average or median life of bearing is called mean time between failures. It is about five times the calculate life.

$$L10 = \frac{(c/p)^e \times 10^6}{60 \times N}$$

Where c = dynamic capacity (dN or Lbs)

P = equivalent bearing load (N or Lbs)

N = rotating speed in RPM

e = 0.3 for ball bearing and 10/3 for roller bearing

L10 = lifespan of bearing

The bearings are not work on constant speed or load and for that to select the bearing for certain life in hours based on worst operation condition prove uneconomical. So duty cycles can be given for proper working of bearing. A complete duty cycle of bearing is one revolution of bearing. So to calculate the bearing life at different speed and load first find L10 value from upper formula then formula given below is to find combine individual L10 life's for complete duty cycle.

$$L10 = \frac{1}{\frac{T1}{Lp1} + \frac{T2}{Lp2} + \frac{T3}{Lp3}}$$

Where T1, T2, Tn = at different conditions it is percentage of time

T1 + T2 +..... Tn = 1

Lp1, Lp2, Lp3 = life of bearing in hours for each period of constant load and speed

When a bearing does not rotate a complete revolution, but oscillate back and forth in operation then a low radial load can be calculated using the formula given below

$P_e = P_o \times (\beta/90)^{1/e}$

Where P_e = equivalent dynamic load

P_o = loads which is actual oscillating

β = angle of oscillation (degree)

e = 0.3 for ball bearing and 10/3 for roller bearing

In some uses to produce high radial and thrust loads then there is not be physically possible or feasible to use a single bearing which is capable of taking both types of load. For these situations, a better design is provide to separate bearings to take the radial and thrust loads. When this happens, it is insure that the radial bearing takes only the radial load, and the thrust bearing takes only the thrust load.

Life adjustment factor gives the original equipment manufacturer to better predict the actual serve life of bearing. The adjustment calculated L10 rating life formula is given below

Lna = a1 x a2 x a3 x L10

Where Lna = rating life adjusting

a1 = reliability life adjustment factor

a2 = special bearing properties life adjustment factor, like materials

a3 = operating condition life adjustment factor, lubrication, cleanliness etc.

Life adjustment factor theoretically less than and greater than 1.0 depending upon their evaluation

1.9 Contact Mechanics

It is a study of contact stress which is produce between two bodies when they are contact to each other. This mechanics is only applied when the two bodies are actually contact to each other otherwise this phenomenon has not applicable. Tapered roller bearings is used as mechanical apparatus in most self moving machines and they with stand on the time varying loads. It is define the influence of the preload for taper roller bearing to avoid different type of failure like pitting and fatigue failure. The aim is to get the homogeneous flow of contact pressure in the inside and outside of bearing. The researchers focused on the Hertizan contact pressure of pure geometries.

The contact stress is very important to evaluate because there are different type of failure occur when there is contact friction between two bodies. The main cause of contact stress is failure due to pitting, cracks and flaking on material surface.

1.10 Taper Roller Bearing Adjustment

For accurate adjustment, the taper roller bearings are necessary. The procedure is as follows:

1. Make sure that every spacer is placed in the proper position, throughout the close and top adjacent to the face of every bearing.
2. Placed the circle onto the rig.
3. Assemble the slot nut on the ends of axle or make sure it is tighter. With a pull until the circle have sufficient pull to stop the circle from rotating, when on the loose from your hand as try to spin the circle. This will place the tapered roller bearing cones into the cups of taper roller bearing.

1.11 A.C Motor

Figure 8 Three Phase Motor

1.11.1 Specification of Motor

Table No. 3

Sr. no.	Component	Specification
1	Supply	A.C
2	RPM	1415
3	Power	1.5 KW
4	Phase	3
5	Current Rating	2.62 A

1.12 Belt specification

Table No. 4

Serial .no.	Component	Specification
1	Type	V –belt
2	Industry no.	A-35
3	Width	12.77 mm
4	Height	7.933 mm

1.13 VFD (Variable frequency drive)

Table No. 5

Serial no.	Component	Specification
1	Phase	3
2	Input Power	A.C
3	Voltage	240 to 480 VAC
4	Fluctuation	-5 to +5 %

CHAPTER 2

2.1 SCOPE OF THE STUDY

In today, the Crack propagation is the major cause of bearing failure. It is most used in rotating elements such as impeller, shaft, turbine blades, automobile parts etc. In this element the main component due to which the smooth working is done is bearing. Industries a small defect can cause more losses and condition monitoring is needed. In current situation there are various methods to check the crack propagation on the bearing but that methods gave the vibration analysis of defect generate on the bearing. If we neglect small crack then fault will propagate, in this report the crack propagation in bearing is observed when it is set to continuous work.

In this research work due to less time consume we find detection of cracks. One can run a healthy bearing for long period of time to check the natural crack onto the bearing surface or in inner and outer race of bearing. The bearing is run under continuous loading and at different load conditions. According to our need we can change the loading and we take a result on fluctuating loading at different load conditions and also check the fault which is introduced into the shaft by providing the centre loading. Therefore the condition monitoring of bearing as well as motor is needed to reduce the time of industry or any firm which is using taper roller bearing for their work.

The main use of taper rollers bearing is that it can be use in both the directions either from front and rear. It takes a large amount of thrust load and radial load in any direction. It gives a low friction because the area of contact between the rollers and bearing are very less as compare to other rollers. As we know taper roller bearing is separable that means the cup of the bearing is easily removed so it can be used according to our needs. If there is a heavy load apply on bearing than we cover the bearing with cup and use the bearing for working but if there is no heavy load than there is no need of cup to attached on the surface of bearing it can sustain that low load easily without cup. This behaviour of taper roller bearing is helpful for industries and farms that used heavy as well as low load at same conditions for that one type of bearing is suitable for all working.

Taper roller bearing has less friction in this than the working time of the company is also reduced from this.

CHAPTER 3

3.1 OBJECTIVES OF THE STUDY

The main focus of this report is on to find the initial stage of the crack and effect of crack when the load is applied on the one side of the shaft of two taper roller bearing casing (one bearing is healthy and other bearing have crack). In this report the main objective of report is to identify the crack and its effect on bearing after running the bearing for continuous hours.

To carry out different kinds of experiment we have special bearing test rig with having provision to changing RPM (Revolution Per Second) from 100 to 2800. This setup is capable of providing the loading condition to the bearing along with provision for changing the bearing very easily.

The main objective to our work is to carry out the experiment for the inner race and outer race (one bearing having inner race and other bearing having outer race) on the bearing 30205 (NBC, Taper Roller Bearing). Crack on the inner and the outer race is being introduced on the EDM (Electric Discharge Machine).

The other objective is to see the structure of crack and how our crack will propagate at different load conditions on taper roller bearing (30205 NBC) at the motor is rotating at same speed and also find the propagation of artificial generated crack on the inner and outer races of taper roller bearing.

CHAPTER 4

4.1LITERATURE REVIEW

Various scientists and technologies have worked on bearing defects and failure like contact stress, crack propagation etc. and give various techniques and method to solve or see that failures of bearing.

They have discussed about various techniques in their research papers. Here are some of the details knowledge of their outcomes which is comes from their papers in the shape of literatures.

Y. T Su, S.J Lin[1] (1991) investigates the vibration defective frequency subjected to different loading. In this experiment both single and multi-defect is analysed. The study concluded that the raw spectrum which is comes in single defective bearing having an equal frequency distribution. The larger signal means a large defect is there. This study also show that the there is no always differential to preloaded bearing from the light bearing with small defects.

S. Noguchi, T. Swamoto, S.Aihara[2] (1993) study about taper roller bearing. In taper roller bearing it works in contaminated oil which have small amount of tiny harder particle present in it. In this paper by re location technique surface profile is measure and calculate minute at wear on same point of contact. Due to contaminated oil pure into the bearing there is continues increase in wear rate of bearing during the whole process. At the raceway of bearing transform was deemed due to plastic deformation in case of the clean oil used for bearing. The study on the different sizes of particle used in contaminated oil, due to this wear rate comes at different particle of size is different, larger the particle size present in oil was more effect of wear rate of the bearing and reduces the bearing life.

S. Cretu, N. Mitu[3] (1995) study of vector techniques to solve the equilibrium in bearing dynamically. Bearing is used a taper roller bearing worked at full oil loaded condition, oil is use as lubrication purpose. This equilibrium conditions produce gyroscopic and centrifugal forces.

M. Craig, R.J.K. wood[4] **(2008)** explained that the condition monitoring technique is used on the basis of electro static charge. This is used in jet engine and gas turbines. In this paper while the testing of taper roller bearing, surface of wear is identify by condition of monitoring with electrostatic wear sensor to find the surface of wear. There are multi sensor used which includes accelerometer, thermocouples and ferromagnetic particle. For starting 7 hours running the wear is defined by wear, acceleration or temperature. On increasing time of charge with detection of inductive sensors, the particles and Ferro graphic is analysed. After completion of fifty three hours wear rate is defined by wear charge acceleration are increases and also increases in temperature. The test is stop after sixty hours and post processing test is done on outer race.

Yaguo Lei[5] **(2009)** explained that the WPT which is wavelet transform and empirical mode decay, short form is EMD, a evaluation techniques or the radial function are utilize by an new technology which is known as intelligent proposed method. It is proved that the promising technique in fault analysis of rotator machine. In this paper wavelet packet transformation, empirical decomposition mode, dimensionless parameters and the distance evaluation technique is used to detect the vibration signals. The dimensionless parameter is in time area is extracted from each of the vibration signal and processing signals to form a combined features. To calculate the evaluation factor of combined test we use distance evaluation technique.

S.P Harsha[6] **(2010)** explained the potential for machine conditioning based on the use of machine learning technique for the growth of a line fault analysis system. In this paper three learning techniques are used to calculate the fault these are SVM which is support vector machine, ANN which is artificial neutral network, SOM which is self organization maps, and the myth is apply on the rolling element bearing fault analysis. From this the result showed that the SVM, ANN techniques give the better result than SOM.

Hongxing chang[7]**(2011)** explained about the, this system can sense defects on the rolling bearing which cover with large affiance and precision. Machine vision process is apply on the repeated production with replacement of the workers those are human. Human eye is not good sufficient to see the defects accurately, the accuracy is very less in case of human eye. So a machine vision design is used to see the bearing faults on surface of the bearing. It is used for the deformation faults on seal. This study primarily does in material inspection like

raw material, while assembly inspection during loading and unloading, final inspection after all process full inspection of bearing, computer vision which follows three steps centre image inspection, left image acquisition, right side acquisition.

Rajesh Kumar, Manpreet Singh[8] (2012) explained that symlet technique is used to find the defect at outer race and width of taper bearing. Different sizes of defect are introduced with laser technique on the surface of outer race of taper roller bearing. Large amplitude waves are come when rollers of bearing cross the exit point and at the entry point of the signal. Due to this experiential the irregularity comes on grooves. At entry point, a complexity is comes on the signal which is reduce by symlet 5, due to this there is increases in the peak of the signal on the graph. Symlet wavelet method is used for measurement of width of outer race crack on tapered bearing it is customize test process setup. Defect of different sizes are introduced on surface of axial groove on outer race by laser engraving technique. In this paper desire information is extract from the wave signals which is difficult to access when position of defects are on the bearing outer race of contact line is passes through the defect point or area.

Manpreet Singh[9] (2012) explained by experimental analysis to break the vibration signal by using symlet 5 order mother wavelet due to this it is easy to measure the outer race defects of the bearing. The problem arise in detect of the inlet point and exit point of the defect in the signal which is improved by the peak value of signal at entry point or exit point at low load and insufficient looseness or tightening in bearing elements. The vibration signal is locate at the location of defect. In this paper wavelet technique is used to find groove race defects, by produce of vibration signal. In first step, the amplitude of the signal with absolute value is done by multiply all signals with each other and it helps to improve the problem result of detecting of weak signal in vibration signal and the size of the original signals. In the second step two symlet5 order wavelet is applied to pre-processing of the signal to measuring the size of defects in outer race groove of thrust bearing.

Jing Shan Zhao, Zhai Jing Feng[10] (2013) is investigates the gyroscopic moment of damage of taper roller bearing. Gyroscopic effect comes when roller rotates one complete circle on the raceway. Due to this repetition cyclic frequency at sides of bearing will be very large at bearing rotates at high speeds. Simulation and theoretical analysis showed that the gyroscopic effect not take direct abrasion to rollers, raceway but give boundary conditions to sides of bearing damage like pitting, cracks, spall of roller of bearing and raceway of bearing.

D.P. Jena, S.N. Panigarh[11] (2014) study the signal processing technique for measuring the defects occur in inner race and outer race of taper roller bearing. The vibration signal is also investigate simultaneously with continues wavelet transformation method. It is difficult to find the crack at starting point and exit point of signal. Average measuring width by actual use of continues wavelet transformation is 4.26% and by using of ridge wavelet method it gets 2.68%. They showed that experimentally done calculation is more suitable than the simulation values.

Zhai Qiang, Wang Niag[12](2014) study of double row taper roller bearing used at high speed machinery. With the combination of elasto hydro dynamic lubrication and local thermal approach, heat generation of bearing is checked at working conditions. The FEM method ADPL is used to simulate the results. The temperature produce in raceway is higher than as compare to other parts of bearing.

William Jacobs, Brecht Van Hooreweder Rene Boones, Paul Sas, David moens[13] (2014) study the various lubricant film during dynamic excitations and the analysed the wear of the bearing raceway after arises a series of accelerated lifetime tests under heavy load. In this paper, the analyzed wear surface is taken when external loading is given. As future scope of this research we test the bearing life time of accelerated bearing for longer time. Experiment analysis the pressure of external loads on the life period of rolling bearing. The testing of bearing is done by controlling the static load, axial or dynamic on one test rig. When there is increased in contact of two surface of rollers with raceway then there is destroy of lubrication film is take place when a dynamic load is applied which is investigate through electrical resistance in bearing. When the high dynamic load is applied it is necessary to polish the bearing surface to remove thin cracks and roughness from the surface of bearing.

Fars hid Sadeghi, Martin cores[14](2015) is study about butterfly wings formation about non metallic inclusions and investigates the effects of change in microstructure crack produce in bearing which is made up of steel material. The experimental study was done on the critical damage inside the butterfly wings and get through a value of crack formation and propagation. Due to this the large stiffness inclusion closet to the maximum shear depth are

more detrimental and the larger inclusion have highest probability to come under the critical region. From this experiment we found a model for simulate of sub surface of crack propagation in steel bearing. Butterfly wings are initiation about non metallic inclusion up to the failure. To check the stress distribution in hertz, loading of non metallic inclusion is done on the 2 d model which is prepared by finite element method. Continuum damage mechanism which is also written as CDM was used for a new variable constant value known as butterfly formation index also written as BEI which depends up on the wings formation. By experiments we find the value of critical damage and stimulate that damage also. In failure of bearing it is found that the location of generation of crack is depends up on the design of bearing surface.

T. Bruce, H. Long, R.S. Dwyerjoyce[15] (2015) explained about Crack propagation when we initiate crack by smaller addition of the mean value from 8 to 16 um length. When view from side cross section area, longer WEC which means white etching cracks found and to initiate this through inclusion which is closet and parallel to the raceway surface, than those which were wider in the x-direction than circumfertiael direction, even though damage of material is propagate a lot in both dictions. In wind turbine gearbox bearing which is WTGB, the failure mode is finds by the white etching method. In order to compare the damage parts of inclusions in different directions, throughout the circumfertiael direction or axial directions the inner raceway of bearing is sectioned. White etching cracks which is WEC, were attached to magnesium sulphite inclusions of span length 3µm to 45 µm and its depth to 630 µm from the raceway of bearing surface at very high range of angle. Longer etching cracks found the shorter inclusions crack which is closet and parallel to the raceway of bearing surface axially.

R.Rzadkowski E.Rokicki, L.Piechowsk R.Szczepanik Szczepanik[16] (2015) explained that variance increases in the starting stages of bearing when failure is take place and then it start decreasing and stabilized, again decrease at very fast rate before bearing failure completely. The blade eccentricity is provided by tip clearance. In this experiment, zero tip clearance arises only at the ends. In this paper, it is study about the failure of bearing which is present in the middle of rotor engine of the aircraft. The rolling elements of bearing are the important part in rotary machinery. FFT which is fast flourier technique is used for fault detection. The characteristic of a signal is easily found by their spectrum with the help of wavelet analysis for the non stationary signals.

Zhipeng F, Haoqun Ming. J. Zuo[17] (2015) explained that in Planet bearing fault is checked by the magnitude of changing in the bands related to the fault of point frequency, sidebands are complex but due to different modulation it is difficult to check the fault with Fourier band. In this paper, an amplitude and a frequency demodulated method is used to stop the problem comes by sides of band. They develop the equation for to calculate the fault comes by typical frequency of outer races and the inner races, consider the complex motion of bearing known as planet bearing. In this paper they also developed the vibration signal for every fault. They consider the effect of modulation for load passing through the time varies with different angles between the gear meshing and faults are introduced by impact force and the time varies and vibration path. Due to this result the signal model which is developed are derived through the equation of Fourier series in every fault and the vibration character is summarized.

Siyuan Ai, ZipingZhao[18] (2015) study of double row or two row taper roller bearing based on thermally model of ohm's law. The grease is used as lubricant into this bearing which is also used for high speed shafts of railway. Study on the different speeds and temperature is takes place according to different ratio of grease present in that bearing. The study shows the due to increases in speed the temperature of bearing is increases and at filling grease ratio. When we put low amount of grease then the power consumption is more at that time due to contact parts which reduce the bearing life.

Xian Yang, Chung yan[19](2015) study of four row taper roller bearing because at contact there is non- linearity formed which is not needed. In this boundary element approach is used. Due to this large pressure is comes at ends as compare to sides of bearing. The position of axially pressurized of rollers when steady on rollers and at the second roller there is more pressure as compare to other row rollers.

Van Cahn Tong, Seong Wok Hong[20] (2015) study of angular misalignment of taper roller bearing. Misalignment occurs in inner race and outer race of bearing. Proposed formulation takes place advantage on the slicing technique for load contact study of each roller. An angular difference increases of taper roller bearing torques of a constant dislocation preload, but decreases the taper roller bearing runs at constant force preload or weighty constant displacement.

Hussein Al-Bugharbee[21] **(2015)** explained that the bearing conditions by mixture of simple processing, first transform the signal. This study proposed myth for rolling bearing faults analysis. In this paper two main stages are used for verification of faults, signal pre-treatment and fault diagnosis. This method is simple and it uses as arrangement with simple processing to convert the signal and then rolling bearing condition.

Bogdan WARDAa, AgnieszkaChuadik[22] **(2016)** explained that the assumptions which are taken during the time of applying load on rolling bearing which allow the one of the effect of various factors on the life of bearing and the radial cylindrical bearing with a high accuracy. In this paper the results is showed about the fatigue life of the cylindrical bearing with skewed rings are comes by the roller bearing while manufacturing on the tilt ring angle. By the misalignment of bearing the angle is measured. To find the fatigue life of bearing, a myth is applied on bearing parameters included the profile of rolling formation. On the Radial bearing clearance or angular tilt of rings load is applied. Due to this the stress distribution is calculated by the value of fatigue life of bearing which is determined by the solving of the Bossiness problem experimentally and the half space with the Finite element method known as FEM.

Roberto Fernandez, Martinez Bryan, J. Mac Donald[23]**(2016)** studies the double row taper roller bearing. This bearing support radial load, axial load, pre load and torque at same time. The contact stress is produce in this bearing is difficult to measure and the cause of unwanted defects likes fatigue and pitting into the surface of material. In this paper, the FEM is used which is finite element method to define the stress on the races of bearing. But this method has some disadvantages of high cost. in this paper first 3-d model is generate on the software by taking original material properties for double row taper roller bearing (TRB), and simulation is done on that software. According to this a group of models are generated which are artificial neutral network, regression model, support vector machine, Gaussian process for to take a contact stress. The capacity of load is maximum obtain when radial loads are applied on the taper roller of bearing and 25% of contact ratio is obtained at the outer race when there is two contact point are there.

S .Shevchenko, O. krol[24] **(2016)** study on the standard bearing number 7000. They study about the modification of single row taper roller bearing. In this they made roller are of convex and raceway is in the form of concave. Due to curved shape the sensitivity of roller is

reduced and contact length is also increase or there is reduce the curvature of contact parts. Also the contact stress is reducing by 6% of normal taper roller bearing and that result the life of bearing is increase.

V. Rode-Casanova, F. Sanchez Marin[25] (2016) study about misalignment occurs in taper roller bearing. The misalignment is the major cause of failure of gear box transmission during work. In this paper it is study about the rack and pinion transmission is used to find the deflection comes in shaft and bearing. For this experiment there are 251 racks and pinion design space cases are used. The simulation is done on FEM for each combination differently and the contact problem is solved on software. Due to high stiffness, the misalignment of every parameter is linear at transmitted torque these parameters are axial displacement, angular misalignment and transversal displacement. On the bearing length the displacement is increase when we away from the midpoint of shaft in taper roller bearing.

Chapter 5

5.1 Research Methodology

Research methodology is the systematic, theoretical analysis of the methods to be applied to the field of study. It constitutes the theoretical analysis of method and principles connected with the branch of knowledge. It mainly consists of theoretical model, image, qualitative and quantitative techniques.

The testing and experiments works are to be carried out by standardized form on the basis of experimental and computational methods. This research work is being carried to check the behaviour when it is running at a certain load capacity.

5.2 Experimental Setup

The test rig is used for the fault diagnosis on bearing. A line diagram of coupled experimental setup is shown in figure 9 (front view) and figure 10 (top view). Motor shaft is provided with fixed three step pulley to change the speed of moving shaft. The motor shaft is connected with the drive shaft "1" with the help of three step pulley. The shaft is supported by bearing casing. The driven shaft "1" and "2" is attached to three step loading arrangement in the form of disk arrangement (1kg, 2kg, and 5kg steel loads). The second shaft is providing to increase the load capacity with same amount of loading which we given to shaft "1". At the middle of steel rod one step pulley is provided on both shafts with v-belt arrangement to attach both the shafts together. The real setup picture is shown in figure 11. For misalignment external plates system is attached. Each bearing casing is provided with the flat surface on the top to have provision for accelerometer (sensor) attached on it. The defective bearing is placed in the bearing casing 2 and sensor is placed right on the top of it for acquiring the signals.

5.3 DAQ (Data Acquisition System)

The integrated system piezo-electric uniaxial accelerometer (manufactured; PCB piezo-electronics, model no. 353B34) was placed right above bearing casing 2 in such a way that it should acquire the vertical acceleration.

A personal computer based DAQ system (manufactured; NI Corporation, model SEXI – 1000 along with SCXI – 1530 model having 4- channel input) was used to acquire and record the

vibration signal to the system. In SCXI – 1530 a signal conditioning module have been provided with low pass bessal filter aliasing reduction. The recorded signal is converted from .TDMS to XLS (format) and analysed in MATLAB environment.

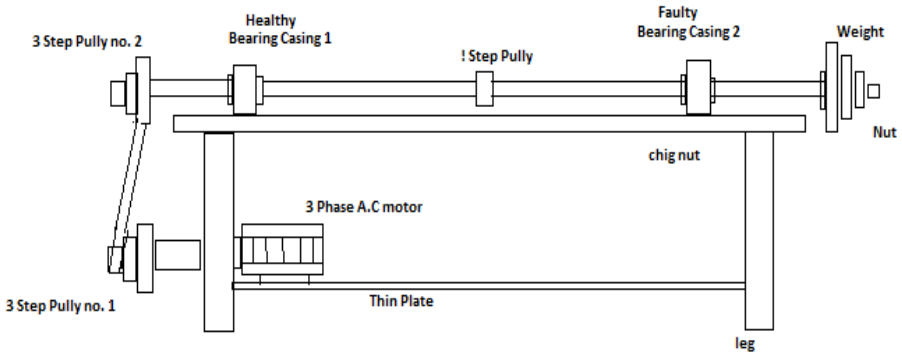

Figure no. 9 Front view of Vibration Setup

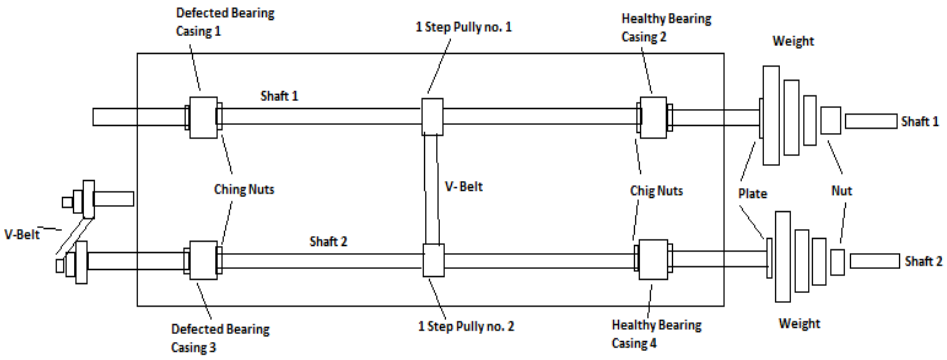

Figure no. 10 Top view of Vibration Setup

This form of signal can be seeing through the computer system using the lab view software and FFT can be done onto the lab view directly or manually in MATLAB.

Figure 11 Real Setup Front and Side View

Figure No. 12 Misalignment System

The variable frequency drive is used for to control the speed of motor. In this we can give frequency to motor and the motor will run at same frequency which we given. The bearing will run at different frequency to check the maximum amplitude and approximate natural frequency of the taper roller bearing.

The proximity will used for to check the wobbling of the shaft. This probe will attach to data acquisition system demodulator.

Lab view used to detect the entire signal coming from data acquisition system. FFT will directly perform on the signal coming in the lab view software.

5.4 Experiment Procedure

1. Mount the healthy bearing in the bearing casing.
2. Assemble the shaft and bearing casing on the bed.
3. Tighten the v belts to control unnecessary vibrations.
4. Check the misalignment of the bearing shaft with motor.
5. Align if any misalignment is there.
6. Mount the accelerometer on the casing.
7. Give a frequency to variable frequency drive to rotate the motor at identified frequency.
8. Take down the reading comes from there in lab view software.
9. Repeat the process at different frequency and different loading conditions.

6. Results and Discussion

6.1 Comparison of Time domain graph at 35 Hz and 38 Hz signal

6.1.1 Zero misalignments Time Domain Graph at 35 Hz

In this graph the upper most peak value range is 3.6 m/sec^{2}and the lowest range of peak is - 3.8 m/sec^2. The time domain graph is shown in figure no. 12 at 35 Hz signal. On the vertical side amplitude or magnitude is given and on horizontal side time values are given in the time domain graph. There are 70000 data points are comes in only 1 sec signal.

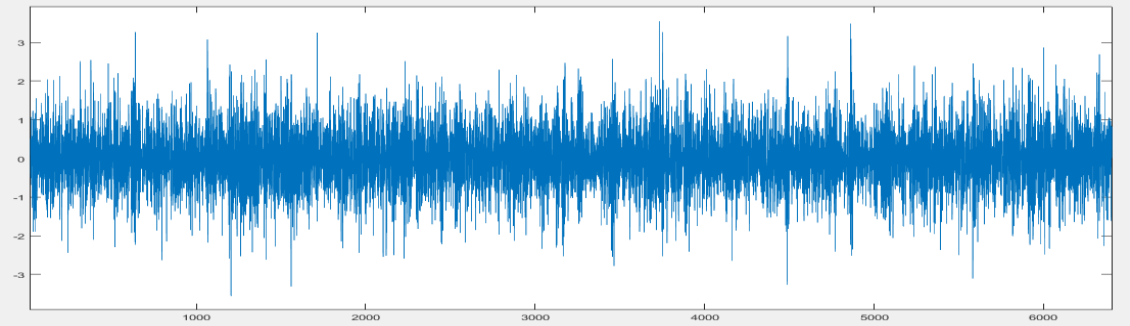

Figure 13 – Time Domain Graph of 35 Hz at zero misalignment

6.1.2 Zero Misalignment Time domain graph at 38 Hz

In this graph the upper peak value is 4.4 m/sec^2 and the lower peak value is -4.3 m/sec^2. The time domain graph of 38 Hz at zero misalingement is shown below:

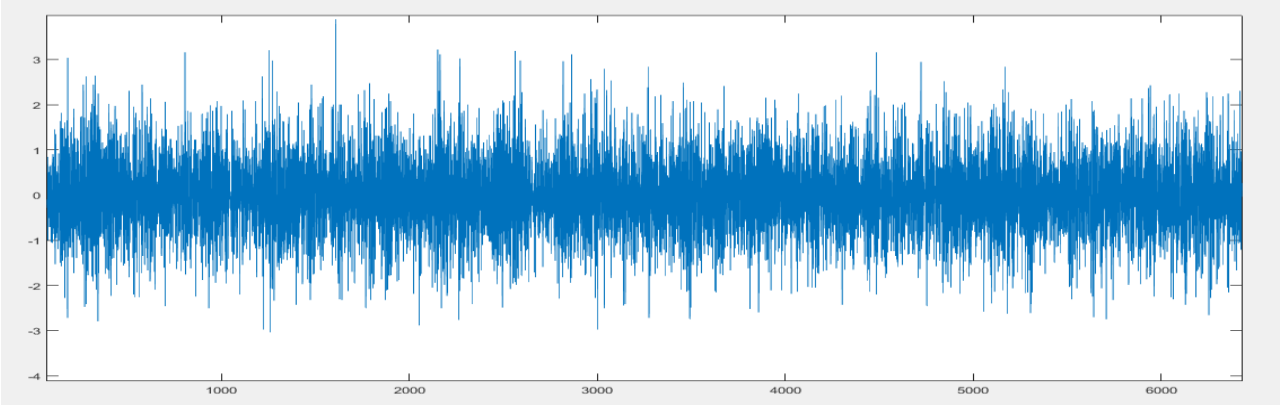

Figure 14 – Time Domain Graph at 38 Hz Signal Zero Misalignment

From Zero misalignment graph it is clear that while increasing the frequency of signal peak value is increases and signal is enlarged from the previous signal.

6.1.3 Time Domain Graph of 35 Hz at 1.5 mm misalignment

In this graph the maximum range of upper peak is 3.4 m/sec^{2}and the lower peak value is -2.9 m/sec^2. The time domain graph is shown below:

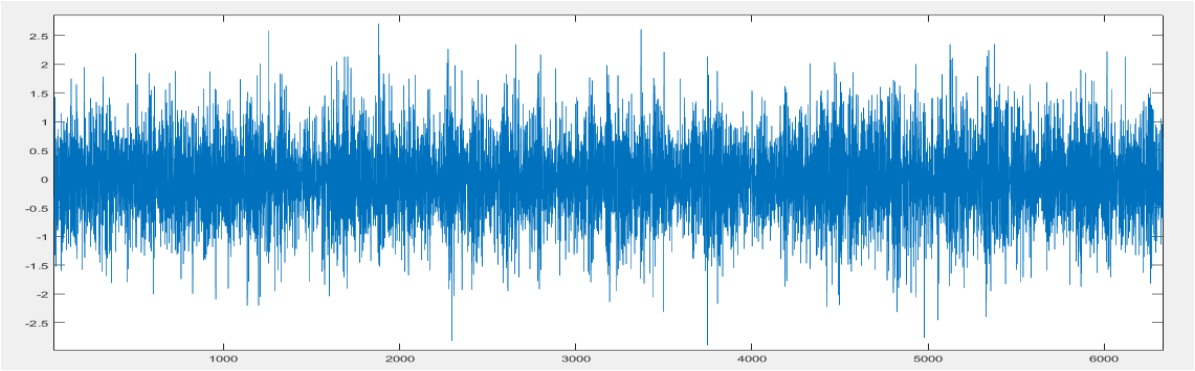

Figure No. 15 –Time Domain Graph of 1.5 mm Misalignment at 35 Hz

6.1.4 Time Domain Graph of 38 Hz at 1.5 mm misalignment

In this graph the maximum upper peak value is 3.5 m/sec^{2}and the lowest peak value is -3.4 m/sec^2. the time domain graph is shown below:

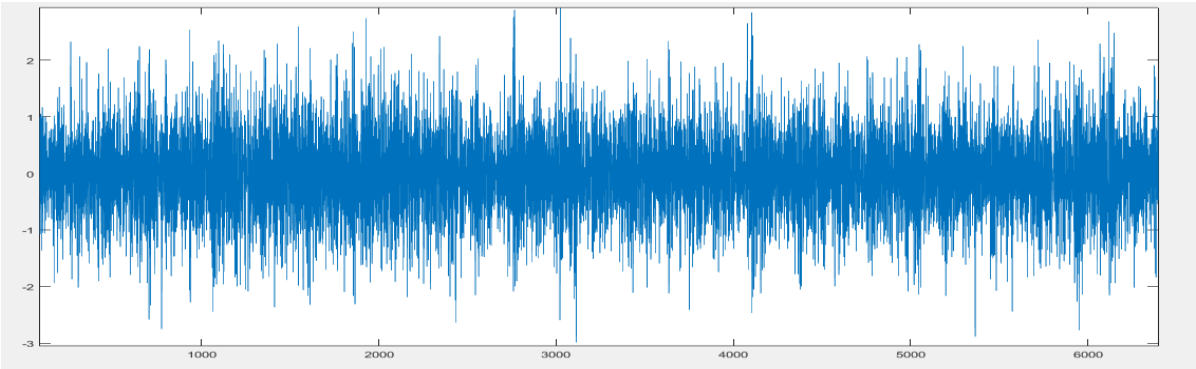

Figure No. 16 – Time Domain Graph of 38 Hz at 1.5 mm Misalignment

From 1.5 mm misalignment the time domain graph is 0.1 increases but it decreases the large value at lower peak value.

6.2 Comparison of FFT (Fast Fourier Transformation) Graph of 35 Hz and 38 Hz

6.2.1 FFT Graph of Zero Misalignment at 35 Hz

In this FFT graph the maximum peak is at 2550. The vertical side of the FFT graph is shown Energy and the horizontal side is shown its frequency (Hz). The graph is shown below:

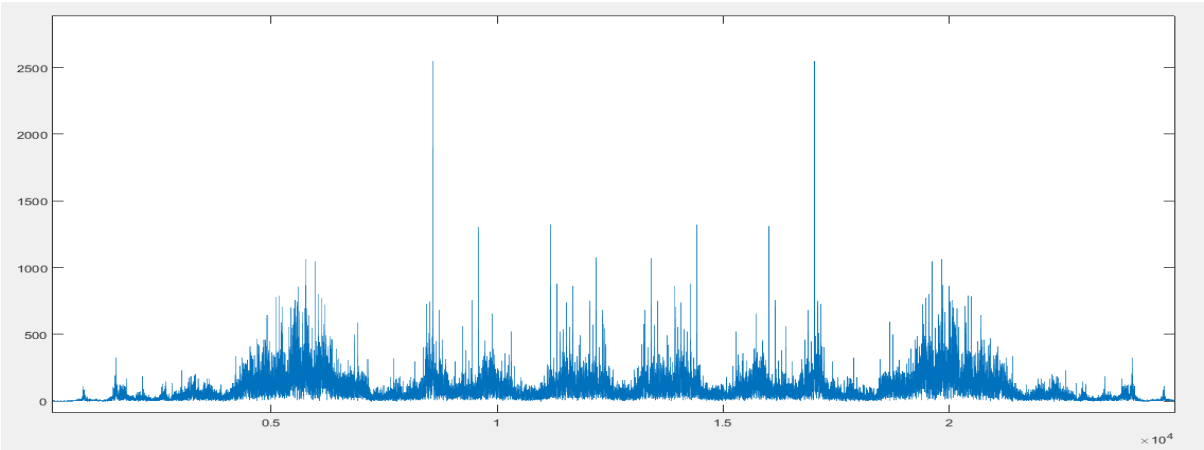

Figure No. 17 FFT Graph at Zero Misalignment (35 Hz)

6.2.2 FFT Graph of Zero Misalignment at 38 Hz

In this graph the maximum value of peak is 1492. The FFT graph is shown below:

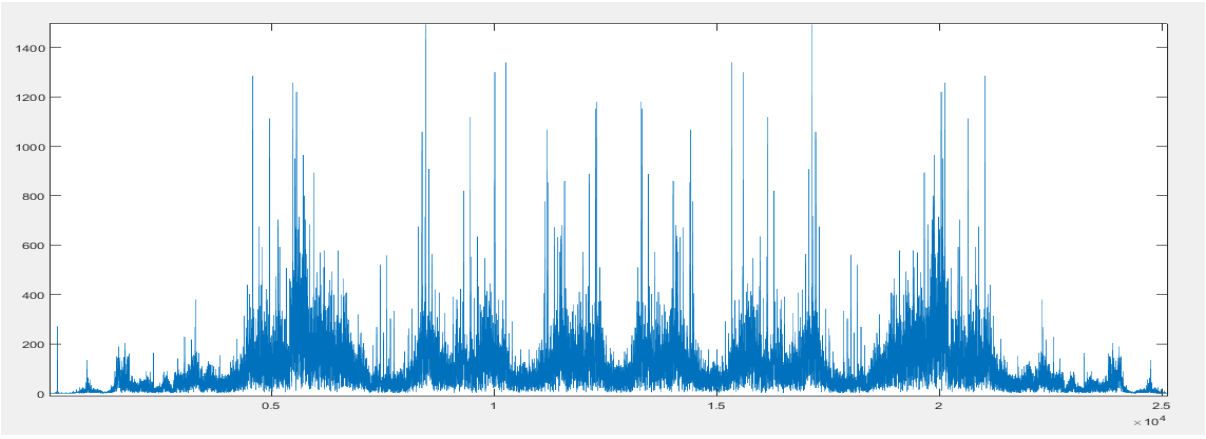

Figure No. 18 – FFT Graph at Zero Misalignment (38 Hz)

6.2.3 FFT Graph of 1.5 mm Misalignment at 35 Hz

In this graph the maximum peak value is 1365. The graph is shown below:

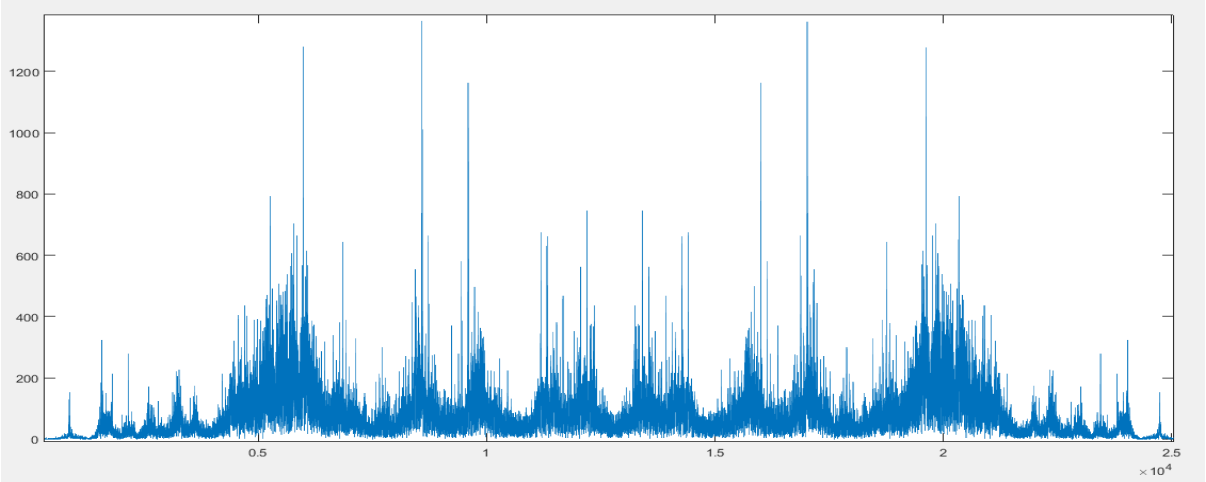

Figure No. 19 - FFT Graph at 1.5 mm Misalignment (35 Hz)

6.2.4 FFT Graph of 1.5 mm Misalignment at 38 Hz

In this graph the maximum peak value is 1470. The graph is shown below:

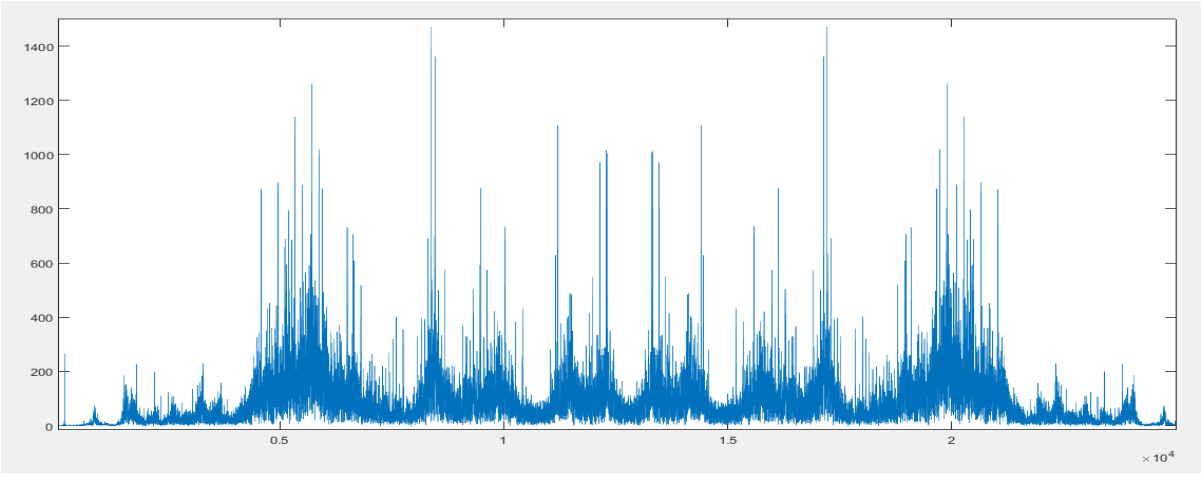

Figure No. 20 - FFT Graph at 1.5 mm Misalignment (38 Hz)

6.3 Comparison between CWT (Continuous Wavelet Transformation) Graph of 35 Hz and 38 Hz

6.3.1 Zero misalignments CWT Graph at 35 Hz

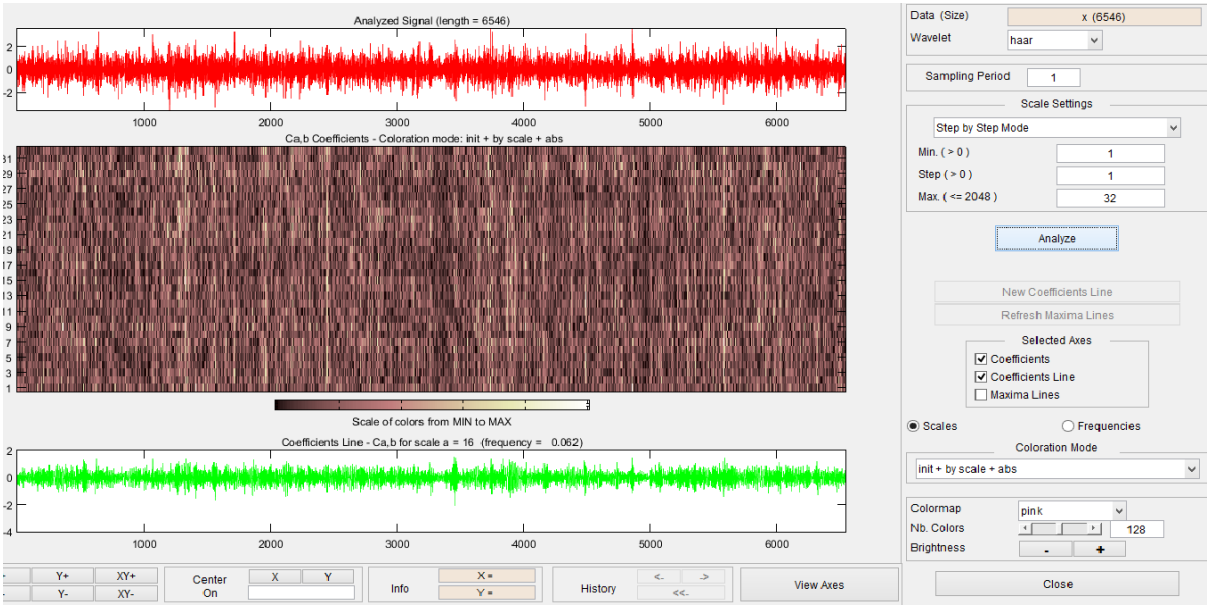

Figure No. 21 - CWT Graph of 35 Hz at zero misalignment

6.3.2 Zero misalignments CWT Graph at 38 Hz

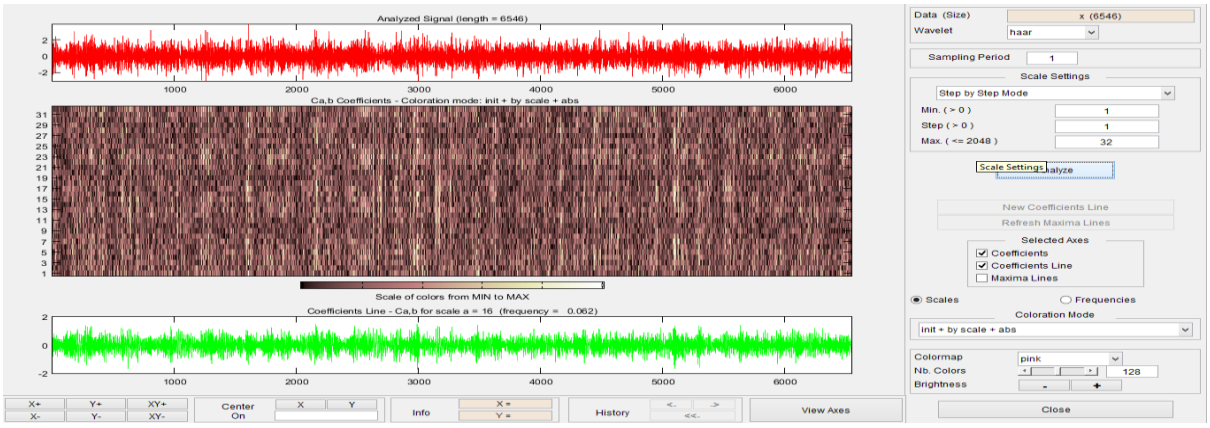

Figure No. 22 - CWT Graph of 38 Hz at zero misalignment

6.3.3 CWT graph at 1.5 mm misalignment at 35 Hz

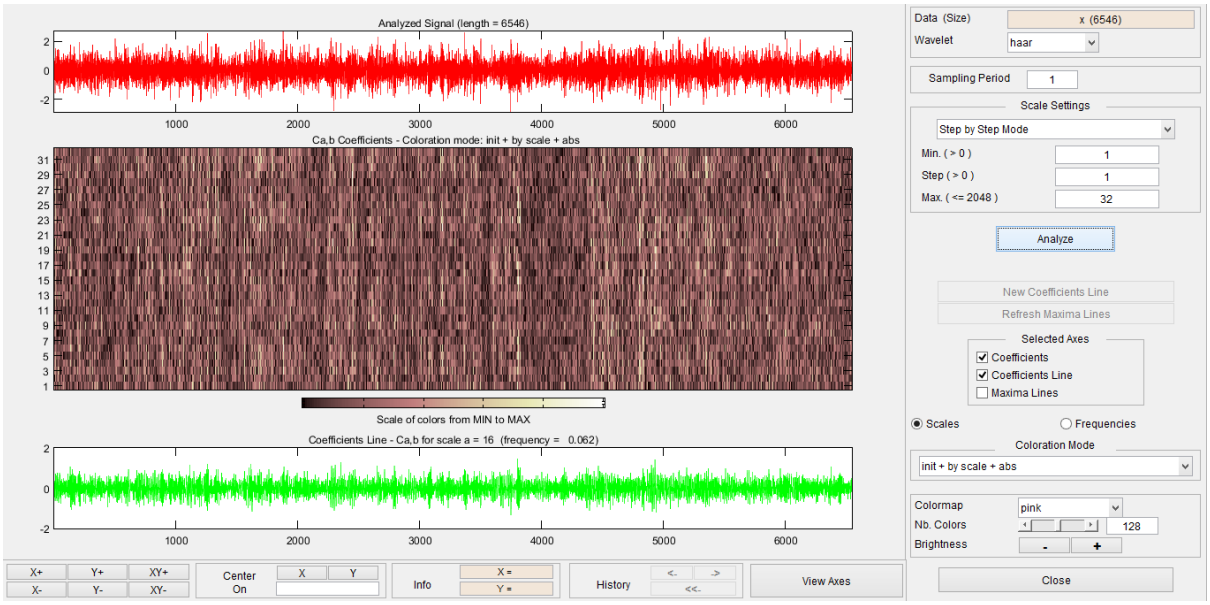

Figure No. 23 - CWT Graph of 35 Hz at 1.5 mm misalignment

6.3.4 CWT graph at 1.5 mm misalignment at 38 Hz

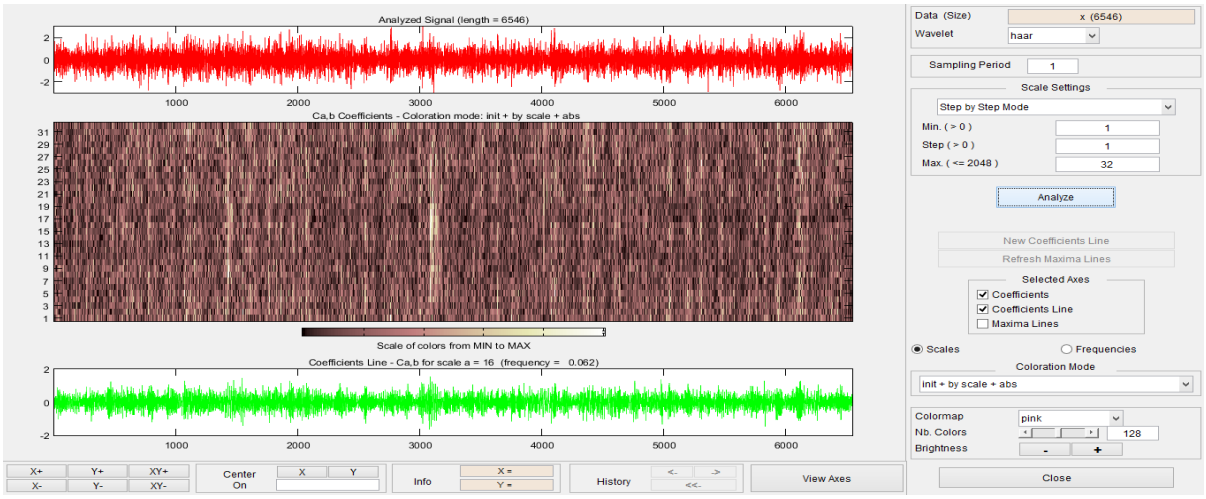

Figure No. 24 - CWT Graph of 38 Hz at 1.5 mm misalignment

6.4 Matlab Calculated value for 35 Hz Signal

To check the effectiveness of parameters Variance, Kurtosis, Skewness, Standard deviation, Mean, Range, Norm, Threshold and Sure is calculated. At different misalignment their is different values of all parameters are shown in Table No. 4. These values are for 35 Hz frequency signal. Where Var – variance, Kur – Kurtosis, Skew – Skewness, Stand dev. – Standard Deviation

35 Hz Signal

Misa ligament	Var	Kur	Skew	Std Dev.	Mean	Shannon	Range	Norm	Thre Shold	Sure
0	0.745	3.32	0.032	0.863	0.0022	-2140.3	7.0957	4363.7	1483	-728.3
0.25	0.652	3.11	0.020	0.807	0.0015	-1385.1	6.184	4190.7	1396	-984.2
0.5	0.42	3.28	0.073	0.648	0.00047	234.726	5.595	3334.8	805	-2806.1
0.75	0.607	3.14	0.042	0.779	0.00088	-3967.8	6.9853	0.00015	5033	-5121.1
1	0.585	2.99	0.024	0.765	0.0011	-736.28	5.7508	3999.01	1256	-1380.8
1.25	0.474	3.05	0.052	0.688	0.0013	81.9003	5.5957	14032.1	3748	-8932.2
1.5	0.538	3.06	14.32	0.733	-0.00008	-422.10	5.5956	3823.4	1128	-1773.9

Table No. 4 – Matlab Calculated values of 35 Hz Signal

In this table at 35 Hz frequency various parameters are shown which is calculated from Matlab software. There are seven types of misalignment we use for our calculation. Because of this misalignment values was at incipient level of vibration. We calculated only on these

parameters because work is not done on this parameter till now. After this calculation we done this experiment at 38 Hz frequency and compare these all values. In 35 Hz values all parameter at different level of misalignment is almost same or we can say that a very less amount of increment is shown but in the Shannon there is large amount of deflection we see.

6.5 Matlab Calculated value for 38 Hz Signal

For different type of misalignment their is different values of parameter are comes. Data is shown into the table no. 5. This data is calculated for 38 Hz frequency signal. Where Var – variance, Kur – Kurtosis, Skew – Skewness, Stand Dev. – Standard Deviation

38 Hz Signal

Misa ligament	Var	Kur	Skew	Std Dev.	Mean	Shannon	Range	Norm	Thre Shold	Sure
0	0.891	2.97	0.030	0.925	0.0017	-3573.3	6.193	4928.9	1919	530.37
0.25	0.809	3.05	0.037	0.899	0.0014	2774.3	6.1299	4696.1	1739	14.958
0.5	0.584	3.15	-0.001	0.764	0.00065	-804.9	6.3312	3980.1	1223	-1482.9
0.75	0.786	3.10	0.020	0.880	0.013	-10197.	7.5691	18053.1	6520	-709.57
1	0.716	3.13	0.057	0.846	0.0012	-1987.1	6.704	4384.8	1528	-595.5
1.25	0.649	3.18	0.034	0.806	0.0015	-5330.7	6.8285	16376.1	5398	-4009.2
1.5	0.665	3.06	-0.008	0.812	3.4E-05	-1448.1	5.973	4263.4	1383	-955.57

Table No. 5 – Matlab Calculated values of 38 Hz Signal

In this table 38 Hz signal calculation is recorded it is clearly show that the all values of signal is increase as compare to 35 Hz signal values and the Shannon values is also fluctuation at very high rate. When we compare the Shannon values of 38 Hz signal to the Shannon value of 35 Hz signal then it show that the 38 Hz value is approximately doubled from the 35 Hz signal values. But all other values are fluctuating some values of 35 Hz signal is more or some values of 38 Hz signal is more but only Shannon values is increase from all misalignment and with itself these values are also fluctuate.

All values of skewness is taken as positive values because negative sign in skewness is only shows the graph is at negative side of peak value so all values in skewness we taken a positive values. The average values of skewness for 35 Hz and 38 Hz signal is comes to be 2.08 and 0.0267 respectively. We increase the loading while different misalignment then damping of the system increases. Higher the damping stabilizes the signal amplitude generated by defect.

6.6 Sensitivity index

It is the study about how uncertainty the output value of a system is change for is apportioned for different types of input values or parameters. There are two types of sensitivity index, local sensitivity index and global or domain sensitivity index. Due to large fluctuation for Shannon entropy we calculate the sensitivity index and comes 859.1for 35 Hz frequency and for 38 Hz come to be 1062.6.

6.7 Effectiveness ratio

To check the response and effectiveness of all parameter of the defect for 35 Hz Signal take a ratio for defective or misalignment value to the healthy (0 mm) or non defective value of misalignment. Which shown in the table below with their average values.

Misalignment	Effective ratio for Standard deviation (std.)	Effective ratio for Shannon (shan.)
0.25	0.934	0.6471
0.5	0.750	-0.1096
0.75	0.902	1.8538
1	0.866	0.3410

1.25	0.796	-0.0382
1.5	0.849	0.1971

Table No. 6 – Effectiveness Ratio of 35 Hz Signal

Average value of Standard deviation is come to be 0.8495 and the average value for Shannon is comes to be 0.4818 for 35 Hz signal.

Misalignment	Effective ratio for Standard deviation (std.)	Effective ratio for Shannon (shan.)
0.25	0.971	-0.776
0.5	0.825	0.2252
0.75	0.9508	2.853
1	0.914	0.556
1.25	0.8708	1.4918
1.5	0.878	0.4052

Table No. 7 - Effectiveness Ratio of 38 Hz Signal

Average value of Standard deviation is come to be 0.9016 and the average value for Shannon is comes to be 0.7925 for 38 Hz signal. From these average values it is clearly shown that the standard deviation is increases with the increase of signal and Shannon is increase of two signals. For further analysis of the value we observe that only Standard deviation and Shannon is changes. So we calculate the misalignment effect on two signals and get the value of standard deviation as 1.932 and 1.902 at two signals on 0 mm and 1.5 mm misalignment. Which clearly show s that when misalignment is increase standard deviation is decrease.

7. CONCLUSION

Analysis is done on two different frequencies on outer race of taper roller bearing. We analysis a time domain graph and see that with increase the signal there is increases of the peaks of graph. Further we generate a FFT (Fast Fourier transformation graph) these graph shows that at zero misalignment there is increase in graphs peak value but at 1.5 mm misalignment peak of the graph is decreases. For further analysis we generate a CWT (continuous wavelet transformation) graph. After these graph we calculate the value of 0 mm and 1.5 mm misalignment on MATLAB software and compare the values of stranded deviation and Shannon at two frequencies because on these two value the values of result is changes so to proof our result we done sensitivity index value of two frequencies and effective ratio of two frequencies and see that standard deviation and Shannon of two signal is increase in effectiveness ratio but it decreases while we increases the misalignment on the system.

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