

# A Micro Crack Detection & Condition Monitoring of Bearing Using DWT Method in Catia

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**Abstract-** Nowadays, fault detection in induction motors has gained importance. Motor health monitoring is performed to diagnose their operating condition using vibration signals. These signals are processed using different signal processing methods to extract the characteristic parameters permitting localization of the fault. In this paper, we propose a diagnostic method based on Hilbert and Discrete Wavelet Transforms for the detection of bearing faults in asynchronous machines. The discrete wavelet transform (DWT) is intended to provide the detail coefficients while the Hilbert transform (HT) is used to obtain the temporal envelope then the envelope spectrum of the detail. The kurtosis value indicates the optimum decomposition wavelet level containing the significant frequencies corresponding to faults for early detection. The result obtained by HT-DWT is more suitable for the analysis of emergency signals. This technique is effective for either stationary or non-stationary signals. Healthy case is compared to faulty case in order to extract frequencies characterizing different faults. The validation of this approach is evaluated by comparing theoretical with experimental results.

**Keywords-** vibration, inner race, outer race, detail, envelope spectrum.

## I. INTRODUCTION

Rolling element bearings find widespread applications in rotating machinery due to their high load carrying capacity and low-friction characteristics. Bearings are subjected to time and space varying dynamic loads while transmitting power from a shaft which has been supported by the bearings. The load on the bearing will be transferred to the housing in which it is fixed through the bearing elements viz., inner race, rolling elements and outer race.

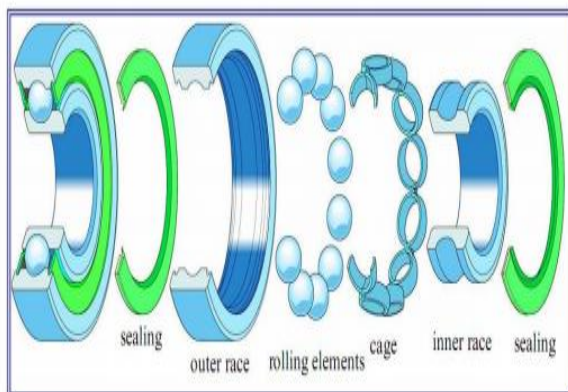


Fig 1. Exploded view of bearing assembly Load transmission between bearing surfaces in relative motion can be made easier in effective manner by interposing rolling elements between surfaces though the arrangement results in high stresses in the restricted regions of load transmission.

The rollers in between the races are positioned by the bearing element called cage. The cage also prevents contacts between adjacent rolling elements. In most industrial applications, the outer race is fixed in a stationary housing whereas the inner race to rotating shaft and the rolling elements, altogether while spinning about its own axis, rotate about the axis of bearing. The exploded view of bearing assembly has been shown in Figure 1.1

Rolling bearings have been conceptualized on this principle and are among the most critical components of rotating machinery. The high stresses developed in bearing elements are cyclic in nature and cause fatigue in these elements after certain time. Fatigue causes minute cracks at subsurface level, which are propagated to the surface as loading continues. Fatigue, therefore, restricts the life of a bearing and causes localized defects such as cracks, pits and spalls which are prone to failure.

On the other hand, another type of defects, which are due to manufacturing inaccuracy or abrasion during operation or insufficient lubrication or improper installation etc. are called distributed defects.

The distributed defects include surface imperfections such as surface waviness, roughness, abrasive wear of bearing elements etc. and unequal rolling element diameter.

Although the amplitude of surface imperfections is in the order of microns or less, significant vibration can still be produced in the wide frequency range.

## II. BEARING

The history of bearing used by mankind is as old as invention of the wheel. Bearing is simply defined as the mechanical part which guides, supports the rotating elements and reduces the friction in rotating part during the operation of the machine. Bearings are classified into two main category; rolling element bearings and journal bearings. The terms antifriction bearings, bearings rolling bearings and rolling element are used for bearings in which the load on rotating component or rotating load is transferred through finite rolling parts in contact with rotating and fixed parts. In sliding contact bearing rotating part is in direct contact of the fixed parts. Rolling bearings exist in a large range of applications across almost all industries and they play very important role in all aspects of modern human life.

Rolling element bearings are further classified as ball bearing and roller bearing based on shape and type of contact of rolling element. Both ball and roller bearings are further classified as per their geometrical change in shape for the load requirement as Radial, Angular and Thrust bearings. Rolling bearings are widely used bearing because of wide range of availability, easy to use and versatility. Wide ranges of bearings are being designed for carrying both radial and thrust loads. Well designed and precisely manufactured bearings can use for wide range of operating condition of variety load and rotating speed. Now a day, rolling bearings are easy to maintain due to advancement in materials and lubrication and bearing design.

## III. BEARING MONITORING

### 1. Bearing Defects:

There are two types of defects occur in rolling element bearing: one local defects, In which defect crack pits, spalls, defects generated due to fatigue are considered. And second is distributed defect. Waviness, surface roughness, off sized rolling element, misaligned races, and defect generated during manufacturing and installations are common distributed defects in rolling element bearings.

### 2. Common

**Causes of Bearing Failures** There are many causes for developing defects in different parts of bearing. It is difficult to identify exact cause of bearing defects. Moreover one or more following reasons are responsible to damage the bearings. If it is taken care about all the causes it is improve the operation of bearing, reduce catastrophic failure and increases the life of bearing.

**2.1 Foreign Matter:** Foreign matter is one of most common cause to create the trouble in bearing is wear and pitting. This could be in the form of abrasive matter, dirt, dust,

steel chips, etc. the affected surface areas usually distributed number of identifying marks like scratches, indentation and pits. This type of defect may be identified by intermittent noise from the bearing during operation. One of the common reasons of foreign matter in bearing is adhesion with lubrication.

**2.2 Bearing Fatigue:** When bearing is rotated the rolling component rolls and changes its position in different loading zone. Thus the component is under the repetitive compression and tensile stress. This action is eventually converting in removal of metals from its running surfaces of the component. This will create the local defect in bearing known as Spalling or flaking. The damaged bearing would produce excessive vibration.

**2.3 Brinelling:** Permanent deformation caused by sudden impact load during operating condition or heavy loading during rotation of bearing. In this kind for deformation would be displaced or upset between the contact surfaces of bearings. Fretting corrosion of raceway surface is known as false brinelling. It is complex phenomena of mechanical and chemical action. In presence of oxygen small impact motion or vibration caused false brinelling.

**2.4 Corrosion:** Corrosion in bearing is caused by the chemical attack on the bearing metal by presence water and acids in working atmosphere. Red and brown strip on surfaces are sign of corrosion. In extreme condition of corrosion in bearing early fatigue would be developed. Pitting on surfaces is result of corrosion. It produces uneven and noisy signals.

**2.5 High Temperature:** Temperature of bearing is increases due to excessive heat generation or poor heat removal (lubrication) from the bearing. Surface cracks or rings generated in direction perpendicular to direction of motion in both the contact elements. High temperature is reduces the hardness of component of bearing leads the early failure of bearing.

**2.6 Improper:** Installation Bearing inner race and shaft is assembled in press or interference fit. Improper installation of bearing in housing and on the shaft may cause axial or radial preloading. Loose fits, tight fits, misalignment, housing shape, incorrect bearing selection and applying blows during installation are the common improper installation. Misalignment causes axial force on the bearing and generates excessive heat during operation.

## IV. OBJECTIVE OF THE STUDY

The objective of this study is establishing good condition monitoring system for cylindrical roller bearings. Many researchers used Combination of signal processing technologies and AI techniques and found good results in monitoring of bearing condition. This work attempts to analyse the nonlinear vibration responses of a rigid horizontal rotor supported on rolling element bearings and to develop a fault diagnosis system for rotor bearing system. Finite number of rolling elements rotating with

different velocities with respect to the inner race, generate a time varying stiffness component.

## V. LITERATURE REVIEW

**JayF. Tu, Strain field analysis and sensor design for monitoring machine tool spindle bearing force:** The fluctuating strain field produced by the rolling motion of the spindle bearing is analyzed by an elastic model and verified with experimental data. This strain field analysis is of considerable practical significance because of its close correlation to spindle bearing preload, cutting forces, and bearing running conditions.

Based on the model, a conventional sensing scheme with strain gages mounted in a groove ground around the bearing outer ring is optimized by selecting proper sensor sizes, locations, and configurations such that signal cross-over error is minimized. In addition, the feasibility of a non-invasive sensing scheme achieved by attaching high sensitivity sensors on the outside surface of the spindle housing is studied. From the strain model, it is found that the level of strain field at the housing surface is substantially lower, and its distribution is not concentrated.

Therefore, high sensitivity sensors and different sensing schemes are needed. Simulation results show that, compared with the conventional scheme, the output of this scheme requires less signal processing when the force acting on the bearing is fluctuating.

**Gregory F Simmons, Journal Bearing Design, Lubrication and Operation for Enhanced Performance:** The increasing introduction of intermittent power sources combined with the de-regulation of electricity markets has led to increased instability in the electrical grid. This has led to increased start-up and shutdown of regulating power sources such as hydro-electric power plants and operation at non-ideal operating states both of which increase the wear and tear on machines.

Likewise, the push for a less environmentally intrusive society has raised the importance of utilizing equipment with reduced impact on the natural surroundings. These challenges lead to a need to improve the robustness of existing and new equipment to guarantee their usefulness in a future with increased operational instability. As a part of this improvement process, this work is focused on the guide/journal bearings which support the rotating portion of power generating machines. These bearings are studied using a multi scaled approach covering small and large scale laboratory experiments as well as investigations of a full scale machine.

A journal bearing test machine was constructed to investigate a number of new synthetic lubricants and polymer bearing materials. These tests found that a significant reduction in power loss could be accomplished

without significantly affecting the bearing's minimum film thickness by changing from a traditional mineral oil to a high viscosity index oil of much lower base viscosity grade.

The high viscosity index lubricants were then improved to reduce start-up friction as well. Further studies were conducted in small scale to determine the optimum lubricant characteristics for the startup problem. This knowledge was used to develop new lubricants to test in the journal bearing test machine which showed large reductions in power loss in the bearing and pumping system as well as greatly reduced bearing operating temperature.

**Ke Hu, Zheng Xie, Zuo-Cai Wang, Wei-Xin Ren and Lei-Ke Chen, Internal force monitoring design of long span bridges based on ultimate bearing capacity ratios of structural components:** In order to provide a novel strategy for long-span bridge health monitoring system design, this paper proposes a novel ultimate bearing capacity ratios based bridge internal force monitoring design method. The bridge ultimate bearing capacity analysis theories are briefly described. Then, based on the ultimate bearing capacity of the structural component, the component ultimate bearing capacity ratio, the uniformity of ultimate bearing capacity ratio, and the reference of component ultimate bearing capacity ratio are defined. Based on the defined indices, the high bearing components can then be found, and the internal force monitoring system can be designed.

Finally, the proposed method is applied to the bridge health monitoring system design of the second highway bridge of Wuhu Yangtze river. Through the ultimate bearing capacity analysis of the bridge in eight load conditions, the high bearing components are found based on the proposed method. The bridge internal force monitoring system is then preliminary designed.

The results show that the proposed method can provide quantitative criteria for sensors layout. The monitoring components based on the proposed method are consistent with the actual failure process of the bridge, and can reduce the monitoring of low bearing components. For the second highway bridge of Wuhu Yangtze river, only 59 components are designed to be monitored their internal forces.

## VI. APPROACHES

System is developed to yield solution with two different approaches

- Automated Modeling
- Automated Design

In automated modeling approach design parameters are taken through UI, those parameters are used to replace variables in HLCT to give the specific outputs in the form of .CAT Product file. This output can be saved in .igs, .stp



such neutral CAD formats. Special Draft command button is provided to automatically generate drafted sheet.

General representation of this approach is shown in fig.6.1 In Automated Design approach, solution for design problem is generated on the basis of KB saved in the system. All the KB is saved in the form of VB code and it is integral part of the HLCTs. KB is organized in the form of rules and formulae. General representation of this approach is shown in fig.6.1

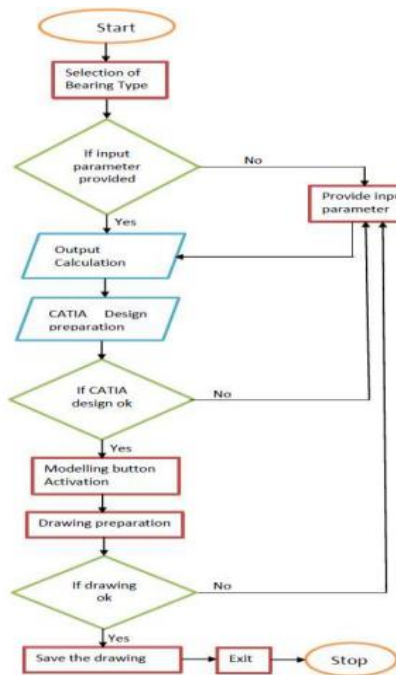


Fig 2. Flow chart for automated modeling and drafting approach.

### 1. Used Methodology

The central idea to wavelets is to analyze (a signal) according to scale. Imagine a function that oscillates like a wave in a limited portion of time or space and vanishes outside of it. The wavelets are such functions: wave-like but localized. One chooses a particular wavelet, stretches it (to meet a given scale) and shifts it, while looking into its correlations with the analyzed signal. This analysis is similar to observing the displayed signal (e.g., printed or shown on the screen) from various distances. The signal correlations with wavelets stretched to large scales reveal gross ("rude") features, while at small scales fine signal structures are discovered. It is therefore often said that the wavelet analysis is to see both the forest and the trees.

In such a scanning through a signal, the scale and the position can vary continuously or in discrete steps. The latter case is of practical interest in this thesis. From an engineering point of view, the discrete wavelet analysis is a two channel digital filter bank (composed of the lowpass and the highpass filters), iterated on the lowpass output. The lowpass filtering yields an approximation of a signal

(at a given scale), while the highpass (more precisely, bandpass) filtering yields the details that constitute the difference between the two successive approximations.

A family of wavelets is then associated with the bandpass, and a family of scaling functions with the lowpass filters. The wavelets are mathematical relations that examine the data corresponding to the resolution or scale. They help in the study a signal at distinct resolutions in distinct windows. For example, if the signal is visualized in a prominent window, the gross characteristics may be noticed, but if they are visualized in a smaller window, only small items can be noticed.

The wavelets offer certain advantages compared to Fourier transforms. For example, they are doing a good job in the estimation of signals having discontinuities with high spikes. The wavelets can also model the music, speech, music, non-stationary stochastic signals and video. The wavelets may be used in applications such as human vision, turbulence, Bearing monitoring Signal compression, earthquake prediction and radar etc.

## VII. RESULTS AND DISCUSSION

System gives the solution for industrial real time problems by using KBE approach. In this approach loading conditions and material property (strength) is taken as input. By using KB saved in the system and input parameters, optimum design solution is calculated as per the formulae provided in to the system and 3D CAD assembly solution is directly given in to the CATIA V5-R19. Ball bearing, Roller bearing, Taper roller bearing and cylindrical bearing these are the four different types of bearing which can be created by using the developed system.

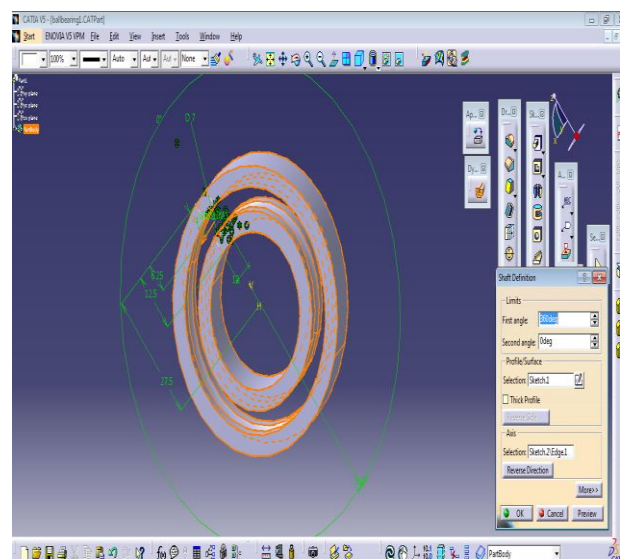


Fig 3. Sizing.

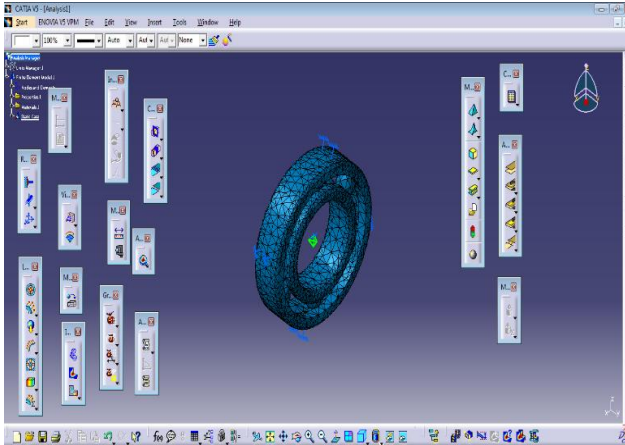


Fig 4. Mesh analysis.

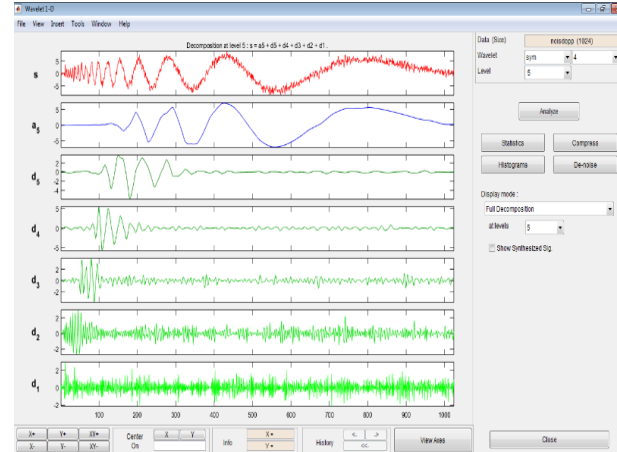


Fig 5. DWT analysis.

Table 1. Equilibrium.

Components	Applied Forces	Reactions	Residual	Relative Magnitude Error
Fx (N)	- 1.000e+001	1.000e+001	2.3093e-014	1.2570e-013
Fy (N)	-6.6972e-016	-4.2283e-014	-4.2953e-014	2.3381e-013
Fz (N)	3.6380e-012	-3.5051e-012	1.3287e-013	7.2326e-013
Mx (Nxm)	2.3647e-014	-2.2856e-014	7.9099e-016	1.5657e-013
My (Nxm)	- 1.7977e-010	1.7977e-010	8.8096e-017	1.7438e-014
Mz (Nxm)	6.5000e-002	-6.5000e-002	5.2736e-016	1.0439e-013

## VIII. CONCLUSIONS

This work has presented a novel approach to diagnose bearing faults. It is shown that DWT can reliably extract features for classification tasks, allowing early fault detection at incipient levels. This work shows that wavelet-based analysis techniques can be efficiently used in condition monitoring and fault diagnosis of bearings.

In the first part of the paper, it was found that the peak locations in spectrum of the vibration signal could be efficiently used in the detection of a fault in ball bearings. For the identification of fault location and its size, the RMS extracted from the terminal nodes of a wavelet tree can be reliably used as discriminating feature. It was found that the choice of the mother wavelet Sym6 combined with the use of the RMS feature produce excellent classification results.

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