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Spur Gear Damage Analysis Using Variation of Speed Range

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Abstract—Gears having an acoustic signal is generally noisy and non-stationary in nature. The faulty gears may spread and increase the damage to the entiremechanism. This paper discussed how to diagnosesgear defect identification using dual tree complex wavelet transform and Variation of speed range. The acoustic signal from the healthy gear mesh is used as the reference signal, comparing the faulty gear signal and improper chamfering. Gear with seeded defects in one or more of teeth is analyzed. The proposed method is used to determine the effectiveness of gear from signal by performing simulations. The parameters such as RMS, Peak, Kurtosisand crest factor are measured. Acoustic signalsare used for tooth tip breakage, fatigue cracking, pitting, estimating the severity of defects. It helps in avoiding gear teeth fractures damage and motors gear health.

Index Terms—*Gear Assembly Monitoring, speed Range, Gear Diagnosis, spur Gear, Gear Comparison Defects,Improper Chamfering,DTCWT*.

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I. Introduction

A gear in rotator machine having a number of teeth meshes with another gear part to transmit torque.Mostly, both of the gear parts have identical shapes but may differ in size. Gearsthat work in the sequence of two or more is called as gear train.Faults, such as tooth tip breakage, fatigue cracking, pitting, generated during operation of gear weaken the gear teeth, reduce stiffness of local meshand change the behaviour by introducing an impulse during meshing of the affected tooth. Devices in gear change the speed, torque and direction of a power source. Gear machinecan mesh with another gearrackin non-rotator tooth in gear mesh. It can produce translational displacement instead of rotational motion. In the machine, one gear is larger than the other gear; a mechanical advantage of gear is produced, with the rotational speed and torques of the two gears differing in an inverse relationship.Some signals have a long time duration but narrow bandwidth such as rub & buzz noise.Some signals have a short time duration but wide bandwidth such as impacts or transients.Some signals have a short time duration and narrow bandwidth such as decayed resonance.Some signals have a time-varying bandwidth such as an imbalanced shaft generating noise dependent on RPM or machine speed.

Figure. 1. Damaged Gear

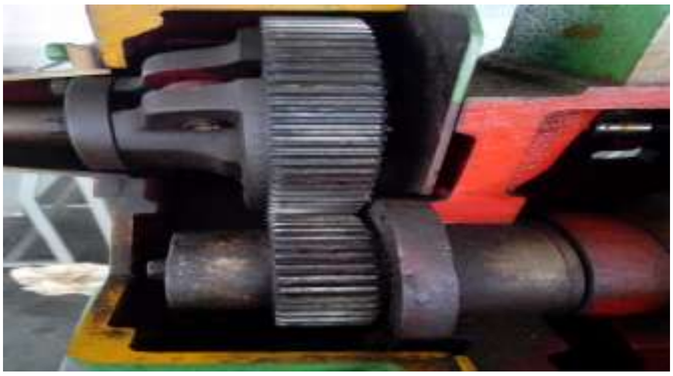

Figure. 2. Improper Chamfering

The gears are classified into different categories according to the number of teeth and itsconstruction. Basically it depends upon gear teeth design.

Spur gears are used in series for large gear reductions. The teeth on spur gears are straight and are mounted in parallel on different shafts. Spur gears are used in washing machines, screwdrivers, windup alarm clocks and other devices. The gears produce loud sound due to the gear tooth engaging and colliding. On each impact, spur gears make loud noise and causes vibration in machines. Thespur gears are not used in a machines like cars because spur gears have high noise. The spur gears have gear ratio in the range of 1:1 to 6:1.

Frequency domain has been analyzed in rotatory machine condition such as bearings and gear faults [1], [2] in detail.Li et al has analyzed the spur gear in spalling defects in machines and measured the fault ratio in rotatory machine [3]. The other research work has shown the analysis on fault in ball bearing using Continuous Wavelet Transform (CWT) [4], [5]. It measures the angle of the tooth rotated in spur gear using Labview. Badour et al have used the effectiveness of discrete wavelet transform (DWT) in analyzing the signals in terms of the data quantity and energy difference, which helps in indicating the presence of the fault gear [5].

Gear fault detection using multi-scale morphological filters, time frequency analysis and wavelet techniques by vibration signal is achieved successfully [6], [7].The continued variation in the contact length during meshing of spur gears directly influences the gear load experience.Belsak et al have analyzed the operational factors such as speed, torque and specific film thickness on the generation of acoustic emission on spur gears [8]. The effectiveness of the gear defects is identified by acoustic signals. In this paper fault analysis in rotator gear machine using dual tree complex wavelet transform in spur gear is reported to identify the defects in gear. It can also measure the performance of the machines. Section II of this paper deals with design methodology, section III describes about the design specifications, the simulated results of various gear parameters are explained in section IV. The section V includes conclusion of the research work.The interested readers many refer other important references related to this research work from [9] through [14]. Fig. 1 shows a gear assembly.

II. Design Methodology

The dual-tree discrete wavelet transform (DWT) provides advantages over the critically sampled DWT for signal processing. The dual-tree DWT is implemented as two separate two-channel filter banks. The low pass (scaling) and high pass (wavelet) filters of one tree (h_0, h_1) must generate a scaling function and wavelet that are approximate of Hilbert Transforms of the scaling function and wavelet generated by the low pass and high pass filters of the other tree respectively. Therefore, the complex-valued scaling function and wavelet formed from the two trees are approximately analytic. The design of the filters is particularly important for the transform to occur correctly. The main characteristics of low-pass filters in the two trees must differ by half a sample period. These are as follows.

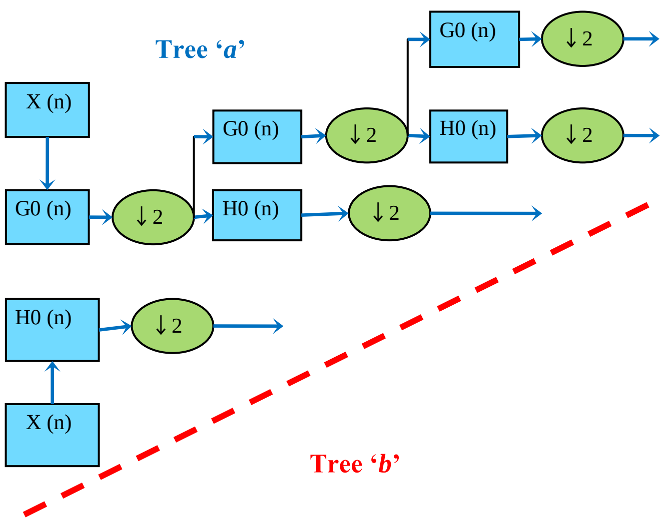

Figure. 3. Dual Tree Complex Wavelet Transform

- Reconstruction filters are the reverse of analysis
- All filters from the same orthonormal set
- Tree *b* filters are the reverse of tree *a* filters
- Both trees have the same frequency response

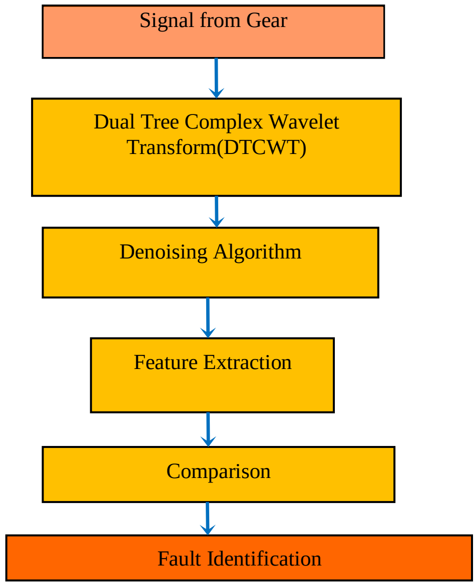

Figure. 4. Proposed Block Diagram of Gear Mechanism

A. *Filter Design for the Dual-Tree CWT*

In the case of filter design for real wavelet transforms, there are various approaches available for the design of filters for the dual-tree CWT. The following method describeshow to construct filters satisfying the under mentioned desired properties.

- Approximate half-sample delay property
- PR (orthogonal or biorthogonal)
- Finite support (FIR filters)
- Vanishing moments/good stopband
- Linear-phase filters (desired, but not required to be a wavelet transform for approximate.

Technique based on the dual-tree complex wavelet transform (DTCWT) is proposed in this paper. The signal of the engineering was processed by the method of spectral kurtosis based on a dual tree complex wavelet packet transform. The best decomposition layer and component can be chosen. The fault feature information is extracted effectively by Hilbert envelope demodulation, where the feasibility and effectiveness of the method are verified. The research has provided a reference for extracting the fault feature information of a gearbox fault diagnosis in rotating machines. A result of the denoising signals from the cracked gear can retain the valuable information as much as possible compared to those DWT and SGWT-based NeighCoeff shrinkage denoising method. Fig. 3 show the proposed system using complex wavelet transform.

Moreover, only the complex filter responses need be linear-phase. This can be represented by the following equation.

$g_0(n) = h_0(N - 1 - n)$

One approach to dual-tree filter design is to let h0(n) be some existing wavelet filter. Then, given h0(n), we need to design g0(n) so as to simultaneously satisfy and the PR conditions.

Unfortunately, this will sometimes result in g0(n) being substantially longer than h0(n) for relatively short g0(n)). By jointly designing h0(n) and g0(n), we can obtain a pair of filters of equal length, where both are relatively short. It should be noted however, that filters for the dual-tree CWT are generally somewhat longer than filters for real wavelet transforms with similar numbers of vanishing moments, because of the additional constraints that the filters must approximately satisfy.

The discrete wavelet packet transform has a larger energy leakage of frequency band, which obviously affected the results of the envelope demodulation. It is necessary to have a method with a lower energy leakage of the frequency band before envelope demodulation. The dual tree complex wavelet transform (DT-CWT) was a new signal processing method that had many good qualities. Because the energy leakage of the frequency band was smaller when the signal was decomposed by a dual tree complex wavelet transform, the dual tree complex wavelet transform was used to extract the fault feature information in the field of fault diagnosis. Fault diagnosis is conducted typically during data acquisition, feature extraction, and fault detection and identified as shown in Fig. 4. Feature Extraction for effectiveness of fault diagnosis in rotator mechanism in gear. Signal capture is shown in Fig. 5.

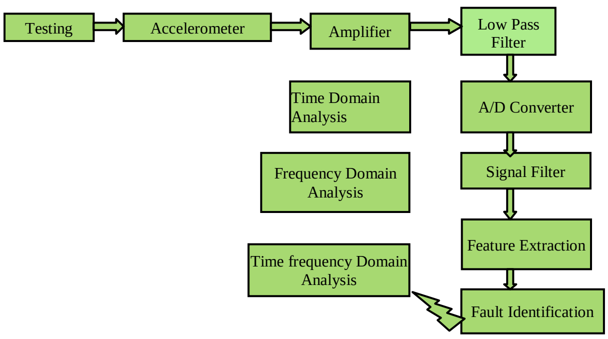

Figure. 5.Signal Capture setup

III. Design Specification

Gear design specification for signal analysis have fillet curve is the concave portion of the tooth profile where it joins the bottom of the tooth space. Friction and wear between two gears is also dependent upon the tooth profile. There are many tooth profiles that provides a constant velocity ratio. In many cases, given an arbitrary tooth shape, it is possible to develop a tooth profile for the mating gear that provides a constant velocity ratio. Spur gear having steel material and the speed of rotation 1000 rpm, spur gear having 32 number of tooth, the width between tooth have 25.4 mm, pressure angle for spur gear is 20^0.

TABLE I

Spur Gear and Machine Load

Sl. No.	Parameters	Value
Pinion		
1.	Material	Steel
2.	Rev. speed(rpm)	1000
3.	Effective mass(kg)	0.7
4.	Tooth Number	32
5.		
6.	Module	3.18
7.	Tooth width(mm)	25.4
8.	Pressure Angle(deg)	20
Spur Gear		
1.	Material	Steel
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3.	Effective mass(kg)	0.7
4.	Tooth Number	32
5.	Module	3.18
6.	Tooth width(mm)	25.4
7.	Pressure Angle(deg)	20
Machine Load		
1.	Tooth load	2500
2.	Viscosity	130
3.	Damping Ratio	0.17

IV. Results And Discussion

The MATLAB simulation results are shown in Fig. 6 through Fig 8. Figure captions indicate type of analyses.

A. Analysis of Healthy Gear Sound

The gear signals from the gear box mesh are analyzed. Healthy gear signals are compared with the faulty gear signals.Themeasured parameters are speed, peak, RMS, crest factor, kurtosis of signal Fig. 6.

B. Analysis of Improper Chamfering and Tooth Damage Gear

The faulty gear signal and improper chamfering signal are captured. Analysis is done for compared with healthy gear sound signal parameter such as speed, peak, RMS, crest factor, kurtosis of signal Fig. 7 and Fig. 8.Signals are captured in different speed(rpm) like 300,400,700.

V.CONCLUSION

This paper has proposed an analysis the fault in gear system mechanism using various speed capture from the gear rotatary to measure the gear signal parameter such as RMS,peak,kurtosis and crest factor analysis. This method to analyze the effectiveness of the gear mechanism, an acoustic signal analysis is used as a suitable one for precise gear defect identification and estimating the severity of defects in gear tooth fracture. The gear health monitoring, gear defect identification and angle measurement between multiple damaged teeth is also analyzed. By the captured signal from the gear mesh, the condition of fault are identified.

ISSN: 2321-8169
358 – 362

SPEED	PEAK	RMS	CREST FACTOR	KURTOSIS
300	0.215	0.054	3.021	4.18
400	0.296	0.059	3.776	5.71
700	0.421	0.078	5.122	7.32

Figure. 6. Statistical Parameters for Healthy Gear

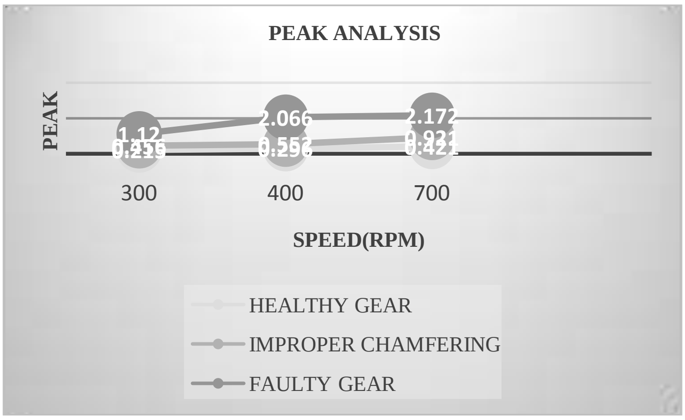
SPEED	PEAK	RMS	CREST FACTOR	KURTOSIS
300	0.456	0.084	5.228	6.9
400	0.552	0.09	6.532	8.25
700	0.921	0.121	7.112	8.8

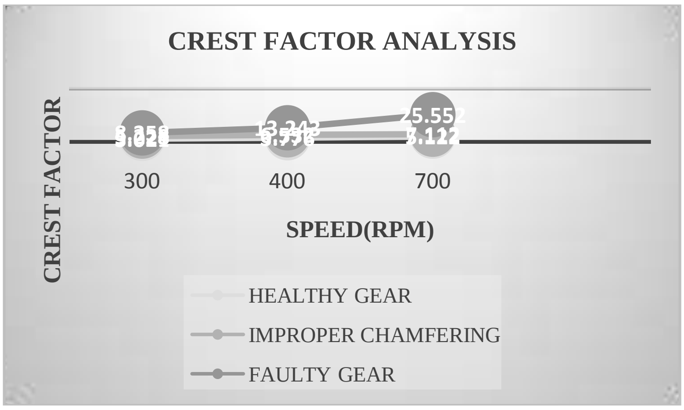
Figure. 7. Statistical Parameters for Improper Chamfering

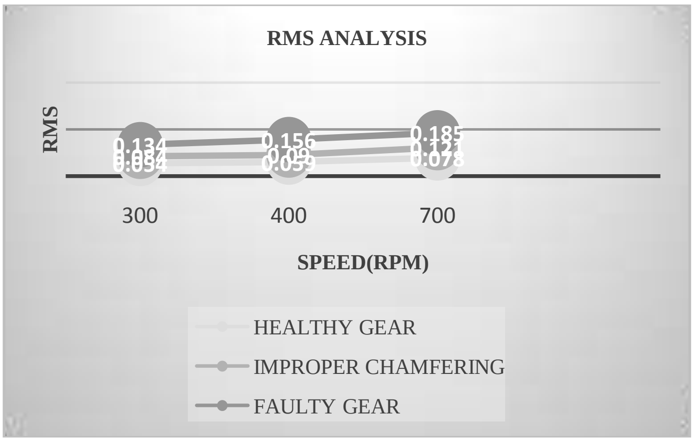
SPEED	PEAK	RMS	CREST FACTOR	KURTOSIS
300	1.12	0.134	8.358	8.91
400	2.066	0.156	13.243	9.45
700	2.172	0.185	25.552	11.24

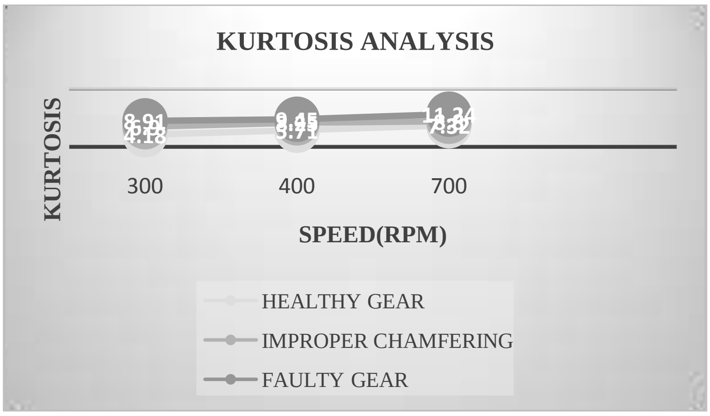
Figure. 8. Statistical Parameters for Tooth Damage Gear Fault

COMPARISON OF HEALTHY GEAR, IMPROPER CHAMFERING AND FAULTY GEAR









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