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Time Frequency Approach to Extract Fault Signals of Helical Gear

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ABSTRACT:

The purpose of this study will use vibration signature for diagnosis gearbox faults. The time-frequency method is often used to approach fault monitoring and diagnosis in this research, and the results are then compared through different analysis. Experimentation on collecting data of current waveform through a self-designed equipment have been carried out.. This experimental procedure may show both a regular and a damaged gearbox, including wear and tooth fracture. Three accelerometers were utilized to collect vibration signals from the gearbox, and a Laser tachometer was employed to measure speed. Speed of rotation of the shaft is measured. The findings indicate that frequency domain analysis utilizing the fast-Fourier transform was successful. Wear and tooth breakage conditions are less sensitive. The approach of short-time Fourier transform, on the other hand, was able to keep an eye on the gearbox for any problems. In the case of gearbox faults, the Wavelet Transform (WT) approach performed well. After applying time synchronous averaging to the vibration signal, it was possible to identify it (TSA). As a result of a single incipient fault in the gear and bearing, the gear-bearing system encounters many failures, leading to catastrophic failure. The current study will investigate a more complicated problem, such as a transmission with a compound gear-bearing issue. To improve the diagnostic procedure' efficiency, vibration measurements are obtained at a variety of speeds and loads.

Keywords: Gear tooth defect, diagnosis, vibration analysis etc

INTRODUCTION:

Vibration signal is the most widely used method for gearbox monitoring systems and problem detection. Accelerometers mounted on the gearbox housing are commonly used to obtain this signal. The goal of gearbox fault diagnostics is to detect existing defects and identify the cause of such faults while they are still in the initial phases of development [1]. Another goal of fault diagnostics is to detect probable gearbox defects while they are in operation. The major component of the vibration signal of a gearbox in gearbox vibration analysis is gear teeth frequency and its harmonics. The GMF sidebands provide information about the current state of the gearbox. The size of sideband amplitudes and the quantity of sidebands can reflect the severity of defects and their causes [2]. Cepstral analysis was commonly used to check the condition of a gearbox. This approach worked well for detecting sidebands in vibration spectra, and it could be used to indicate gearbox status. The cepstrum permits reliable assessment of sideband periodicity since it calculates average sideband spacing across a large frequency range. As a result, it might be used for both detecting and diagnosing gear defects. This paper reflects the various kinds of faults encountered in various industries gears, as well as the various detection methods needed to evaluate them. From a simple motor to massive cruise ships and planes, there is probably no machine that can run without gears. Today's gears are made in a variety of ways, depending on their usefulness, system needs, and operating circumstances [3]. Spur gears, helical gears, bevel gears, and worm gears are among them. Many gear failures are caused by design flaws, manufacturing flaws, maintenance issues, inspection methods, and unavoidable recurring loads that produce surface fatigue, wear, and lubricant degradation. In general, each kind of failure leaves distinct signs on gear teeth, and a thorough inspection frequently provides sufficient information to determine the reason of failure [4]. Gears and bearings can fail in a variety of ways, although there is typically little indication of difficulties until total failure occurs, other from an increase in noise and vibration as shown in Fig 1.

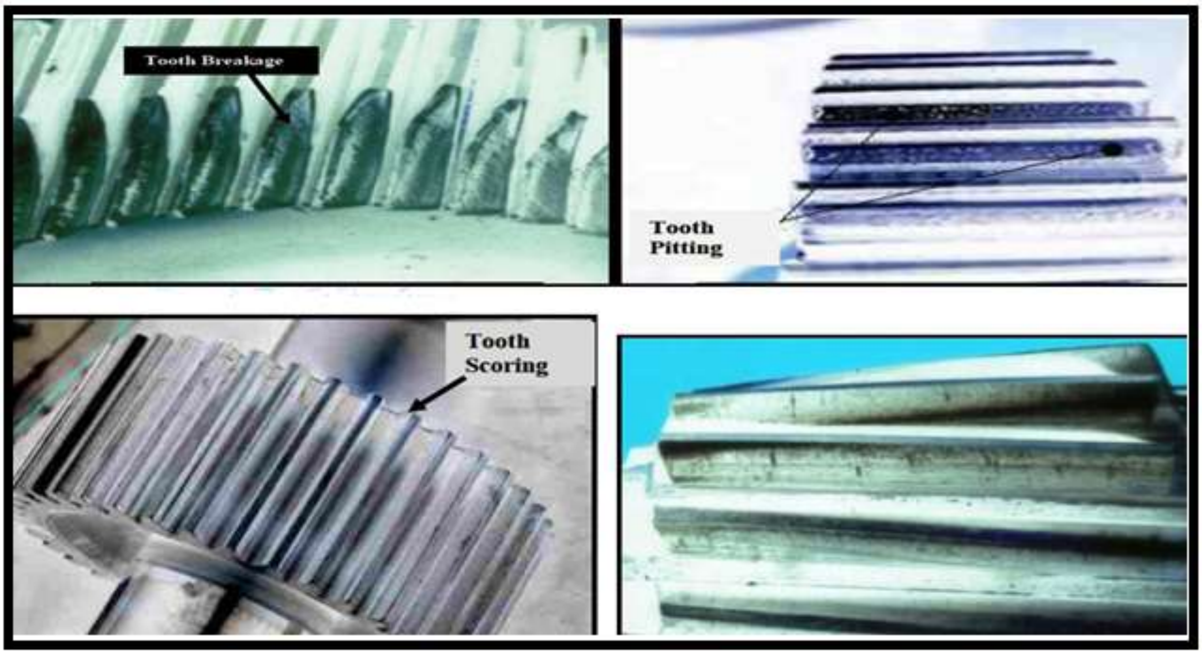


Fig 1: Different Defects of Gear

Rotating machines must also operate under various loading and speed circumstances. In the search for high-reliability operations, the detection, localization, and investigation of defects in such devices are critical [5]. Vibration analysis has been utilized as a support for equipment maintenance choices and as a predictive technique. Machines, on the whole, don't break down or fail without notice, which is usually signaled by higher vibration levels. It is feasible to establish both the type and severity of the flaw, and so forecast the machine's failure, by monitoring and analyzing the machine's vibration. Imbalance, misalignment, looseness, and distortion, defective bearings, gearing and coupling inaccuracies, critical speeds, various forms of resonance, friction whirl, rotor/stator misalignments, bent rotor shafts, defective rotor bars, and so on are the most common causes of mechanical vibration [6]. The following are a few of the most typical gear defects that may be diagnosed via vibration analysis.

EXPERIMENTAL SETUP:

The motor and gearbox were mounted on the base as shown in Figure 2. The output shaft of the AC motor is mechanically linked to the input shaft of the gearbox to provide mechanical power to the gearbox and its downstream components. The motor and gearbox are connected by two flanges built into the motor housing and gearbox casing [7-9]. The complete system may be used in a number of situations [10-11].

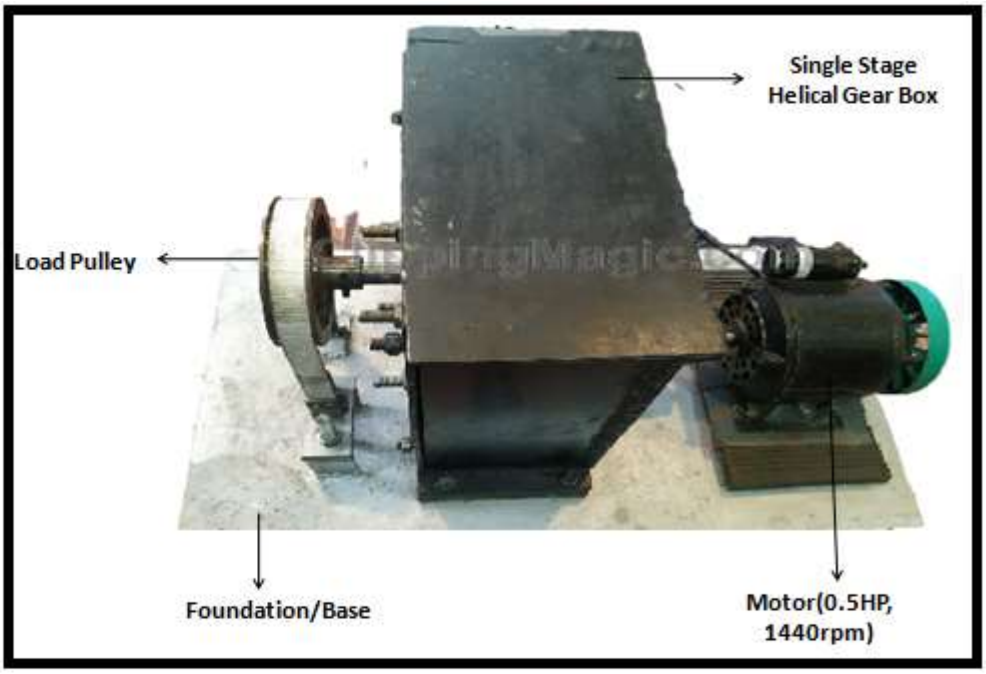


Fig 2: Experimental test rig

Gear Materials:

Gears may be made of a number of materials, including steel, brass, bronze, cast iron, ductile iron, aluminum, powdered metals, and polymers, to name a few. Steel is the most common material overall, however this has evolved throughout time. In our opinion, there are three aspects that are most important when selecting a high-quality gear material. Strength, durability, and cost, which includes both material and production expenses, are the three factors.

Mild steel, commonly known as "low carbon steel," is a form of carbon steel having a low carbon content. The quantity of carbon in mild steel is generally 0.05 percent to 0.25 percent by weight, depending on the source, but greater carbon steels are often defined as having a carbon[13].Helical gears made of low alloy carbon steel are extensively used as power transmission components in vehicles because their hardened surfaces enhanced their strength and wear resistance. EN8 is an unalloyed medium carbon steel used in situations where greater qualities than mild steel are needed but the expense of a steel alloy is prohibitive. EN8 is an unalloyed medium carbon steel used in situations where greater qualities than mild steel are needed but the expense of a steel alloy is prohibitive. EN8 may be heat treated to produce exceptional surface hardness and moderate wear resistance using flame or induction hardening techniques [14].

Results:

The next stages are separated into the results produced according to the fault conditions are shown in Fig 3.

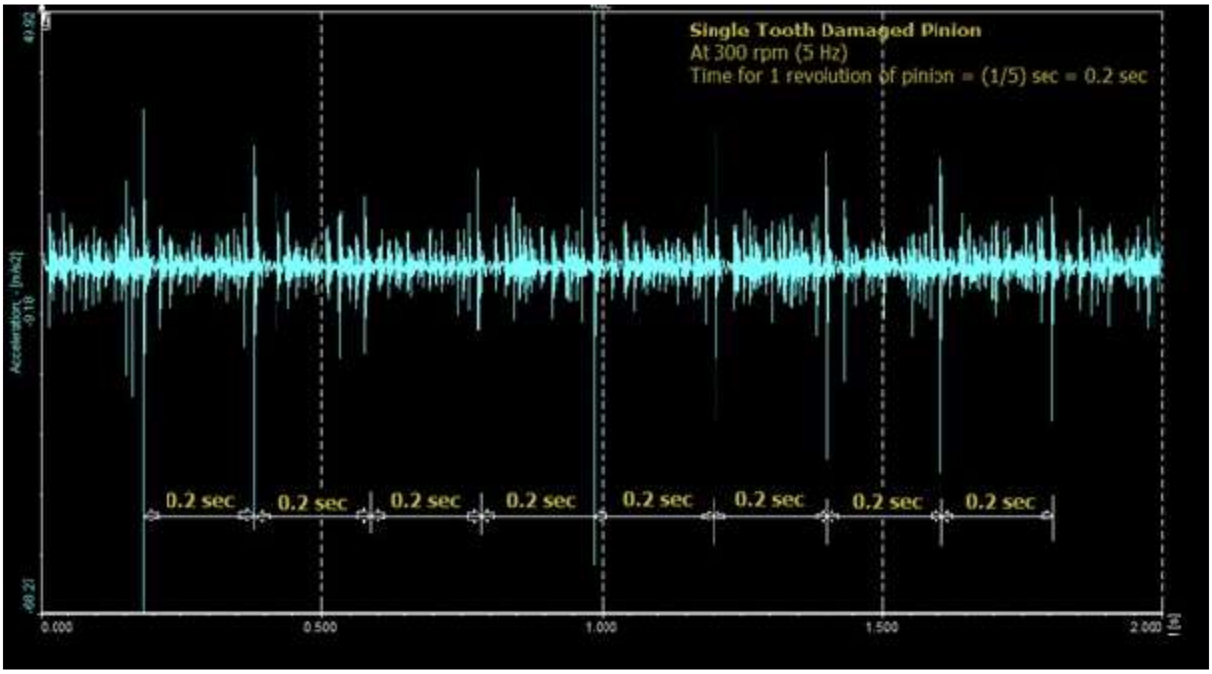


Fig 3: Waveform for a Tooth Damaged Pinion at 350 RPM

In this graph, the waveform is represented by the vertical axis displaying the acceleration curve and the horizontal axis plotting time. When a single tooth in a pinion with 17 teeth is lost, the injured tooth comes into contact with the mating gear once per revolution, therefore the peak is visible once every revolution. The pinion, on the other hand, rotates at the same rate as the input shaft, which is 300 revolutions per minute. When this speed is translated to revolutions per second, the pinion's frequency of rotation is 5 Hz (Hz). It signifies that the pinion spins at a rate of five revolutions per second. This indicates that one pinion revolution takes (1/5) second, or 0.2 second. It also implies that every 0.2 seconds, the one broken tooth will make contact with the mating gear. As a result of the damage, the amount of vibration acceleration increases throughout the meshing period. We may conclude that time waveform analysis is the most effective technique of identifying gear tooth degeneration. The DEWEsoft X1 software has the ability to transform a time waveform into a Fast Fourier Transform (FFT) spectrum. This option transforms sections of the problematic pinion's graphs into FFT power spectrums, which are then compared to the healthy pinion's FFT spectrums to calculate the FFT difference. The comparison is carried out with the help of a Microsoft PowerPoint feature. The first FFT is transparent, and the second is placed on top of it. When the number of teeth in a single damaged pinion is compared to the number of teeth in a healthy pinion, the number of teeth in the single damaged pinion varies. As a result, a problematic pinion should have 16 teeth, whereas a good pinion should have 17 teeth. The FFT power spectrum reaches its apex at Gear Mesh Frequency. The peak recorded for a healthy pinion at its GMF is higher than the peak measured for a damaged pinion at its GMF in all three cases described below. This is caused by a change in the number of teeth, which is caused by a change in GMF [15-19].

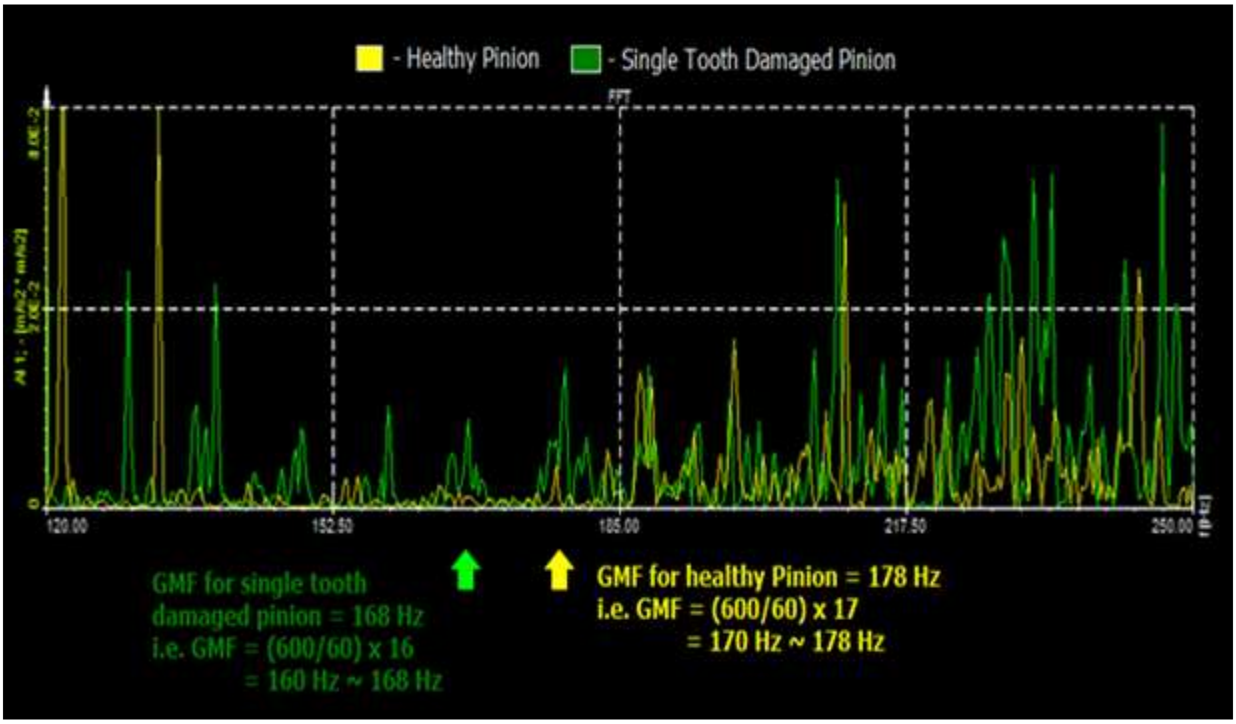
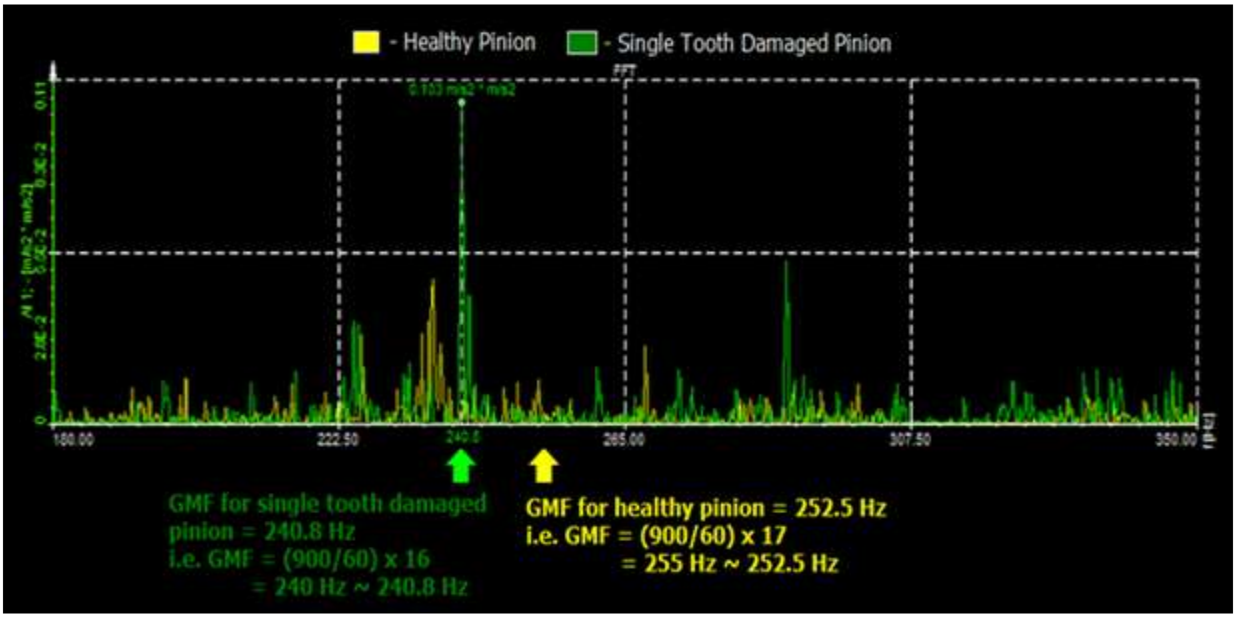


Fig.4: At 650 rpm



Graph 5 At 950 rpm

Teeth Damage on Both Sides:

A double tooth on a 17-tooth pinion with two peaks appears at the end of each revolution because the damage occurs twice in a rotation with the mating gear when the double tooth is damaged. However, in the experimental situation, the input shaft rotates at a speed of 300 rpm, which implies that the pinion likewise rotates at a speed of 300 rpm. In this case, the peak may be detected every 0.1 second since the two injured teeth are precisely opposite each other. At the moment of meshing, the damage causes an increase in the amplitude of the vibration to occur. The similar phenomena is seen in Fig 6.

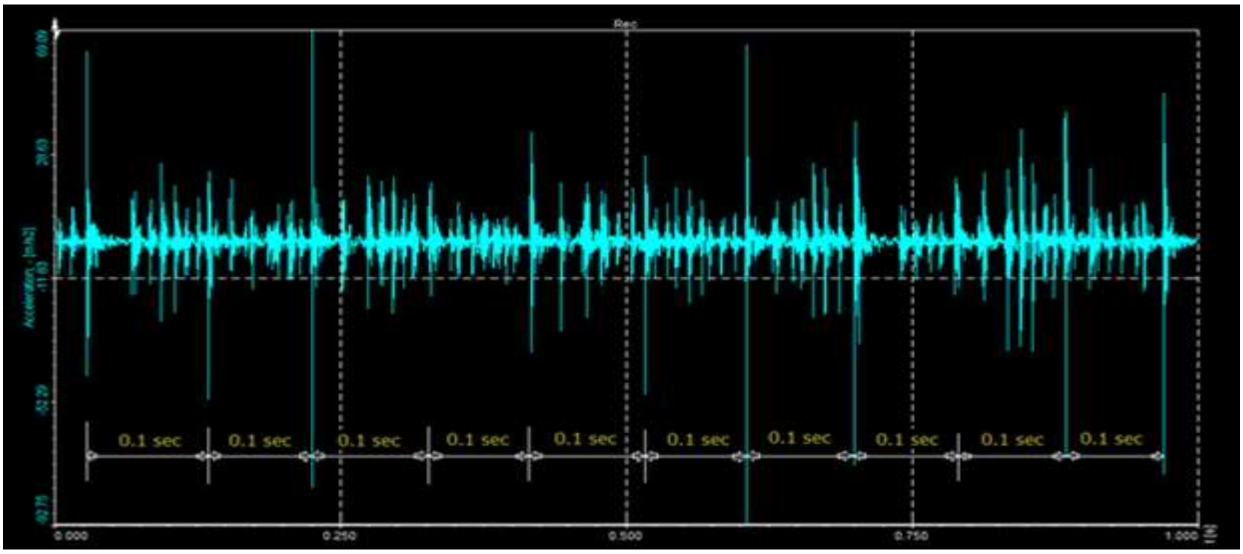


Fig 6: Waveform for Double Teeth Damaged Pinion at 350 rpm

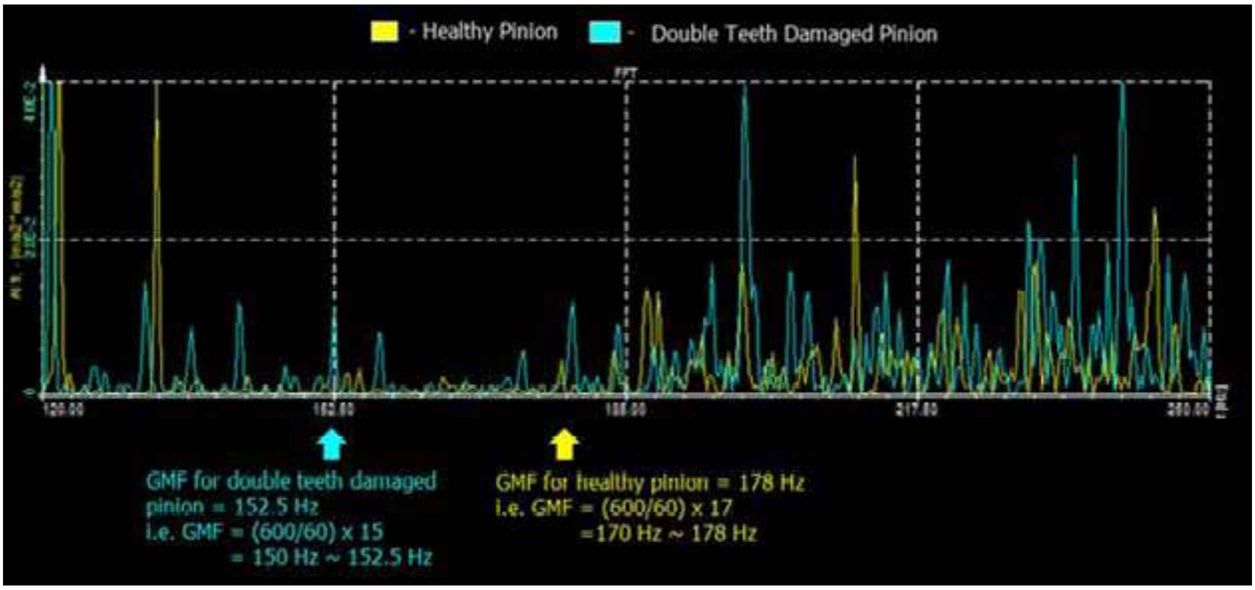


Fig 7: At 950 rpm

There is a difference in the number of teeth between the double teeth damaged pinion and the healthy pinion due to the two damaged teeth. As a result, it is assumed that a problematic pinion has 15 teeth and a healthy pinion has 17 teeth. At Gear Mesh Frequency, the peak can be seen in FFT.

Conclusions:

Following a study of the graphs, tables, and findings, several conclusions were drawn.

1) The damaged tooth meshes with the matching gear once every revolution, resulting in a single-tooth damaged pinion rotating at 300 revolutions per minute (5 Hz). Because the pinion spins at a frequency of 5 Hz, or 5 revolutions per second, one pinion rotation takes (1/5) second to complete. As the injured tooth interacts with the adjacent teeth, it has a major effect on the succeeding teeth. As a result, the peak is seen every 0.2 seconds.

2) The damaged teeth mesh twice every revolution with the corresponding gear, resulting in a double-toothed damaged pinion rotating at 300 revolutions per minute (5 Hz). Because the pinion spins at a frequency of 5 Hz, or 5 revolutions per second, one pinion rotation takes (1/5) second to complete. As the injured tooth interacts with the adjacent teeth, it has a major effect on the succeeding teeth. As a consequence, the peak emerges approximately every 0.2 seconds. Graph 3 shows a peak every 0.1 second. As a result of this, it is possible to identify defects such as single and double tooth damage simply by analyzing the time waveform and speed.

References:

[1] X. Lou, K.A. Loparo, Bearing fault diagnosis based on wavelet transform and fuzzy inference, Mech. Syst. Signal Process. 18 (2004) 1077–1095.

[2] A. Djebala, N. Quelaa, N. Hamzaoui, Detection of rolling bearing defects using discrete wavelet analysis, Meccanica 43 (2008) 339–348.

[3] D. Wang, Q. Miao, X. Fan, H. Huang, Rolling element bearing fault detection using an improved combination of Hilbert and Wavelet transforms, J. Mech. Sci. Technol. 23 (2009) 3292–3301.

[4] M. Singh, R. Kumar, Thrust bearing groove race defect measurement by wavelet decomposition of pre-processed vibration signal, Meas. J. Int. Meas. Confed. 46 (2013) 3508–3515.

[5] V.N. Patel, N. Tandon, R.K. Pandey, Defect detection in deep groove ball bearing in presence of external vibration using envelope analysis and Duffing oscillator, Meas. J. Int. Meas. Confed. 45 (2012) 960–970.

[6] J.B. Ali, N. Fnaiech, L. Saidi, B. Chebel-Morello, F. Fnaiech, Application of empirical

[7] mode decomposition and artificial neural network for automatic bearing fault diagnosis based on vibration signals, Appl. Acoust. 89 (2015) 16–27.

[8] A. Djebala, M.K. Babouri, M.N. Ouelaa, Rolling bearing fault detection using a hybrid method based on Empirical Mode Decomposition and optimized wavelet multi-resolution analysis, Int. J. Adv. Manuf. Technol. 79 (2015) 2093–2105.

[9] W.J. Wang, P.D. McFadden, Early detection of gear failure by vibration analysis-I calculation of time frequency distribution, Mech. Syst. Signal Process. 7 (3) (1993) 193–203.

[10] P.D. Mcfadden, Detection of gear faults by decomposition of matched differences of vibration signals, Mech. Syst. Signal Process. 14 (5) (2000) 805–817.

[11] J. Lin, L. Qu, Feature extraction based on Morlet wavelet and its application formechanical fault diagnosis, J. Sound Vib. 234 (2000) 135–148.

[12] Aditendra Jaiswal, Dr. K. S. Zakiuddin, V. V. Shukla (2013), Fault Diagnosis of Gear by Vibration Analysis, International Journal of Latest Trends in Engineering and Technology (IJLTET), ISSN: 2278-621X, Vol. 3 Issue 1, Page No. 26-31.

[13] C. Sujatha (2010), Vibration and Acoustics: Measurement and Signal Analysis, Tata McGraw Hill Education Private Limited.

[14] G. Diwakar, Dr. M R S Satyanarayana, P. Ravi Kumar (2012), Detection of Gear fault using vibration analysis, International Journal of Emerging Technology and Advanced Engineering, ISSN: 2250-2459, Vol. 2, Issue 9, Page No. 123-136.

[15] Kobra Heidarbeigi, Hojat Ahmadi, M. Omid (2010), Adaptive Vibration Condition Monitoring Techniques for Local Tooth Damage in Gearbox, Modern Applied Science, ISSN 1913-1844 E-ISSN 1913-1852, Vol. 4, Page No. 104-110.

[16] Leila Nacib, Komi Midzodzi. Pekpr, Saadi Sakhara (2013), International Journal of Advances in Engineering & Technology, ISSN: 2231-1963, Vol. 5, Issue 2, Page No. 139-145.

[17] Rusmir Bajric, Denijal Sprecic, Ninoslav Zuber (2011), Review of Vibration Signal Processing Techniques Towards Gear Pairs Damage Identification, International Journal of Engineering & Technology (IJET - IJENS), Vol. 11 No. 4, Page No. 97-101.

[18] Shawki Abouel-seoud, Ibrahim Ahmed, Mohamed Khalil (2012), An Experimental Study on the Diagnostic Capability of Vibration Analysis for Wind Turbine Planetary Gearbox, International Journal of Modern Engineering Research (IJMER), Vol. 2, Issue 3, Page No. 667-675.

[19] V. B. Bhandari (2010), Design of machine elements, McGraw-Hill Education India Pvt. Ltd. Third Edition.