

Fault Diagnosis in Belt Drive Transmission Using Wavelet Spectrum

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ABSTRACT: Belt conveyors are the equipment widely used in coal mines and other manufacturing factories, whose main components are a number of idlers. The faults of belt conveyors can directly influence the daily production. A fault diagnosis method combining wavelet packet decomposition (WPD) and support vector machine (SVM) is proposed for monitoring belt conveyors with the focus on the detection of idler faults. Since the number of idlers could be large, one acceleration sensor is applied to gather the vibration signals of several idlers in order to reduce the number of sensors. The vibration signals are decomposed with WPD, and the energy of each frequency band is extracted as the feature. Then, the features are employed to train an SVM to realize the detection of idler faults.

The proposed fault diagnosis method is firstly tested on a test bed, and then a fault diagnosis system is designed for belt conveyors. And it is verified that the proposed system can locate the position of the faulty idlers with a limited number of sensors, which is important for operating belt conveyors in practices. Usually faults will be cut in, cut out and loose cut, those may arise due to the continuous rotation of belt drive at different speeds. The loads applied on belt and the loads will be 0, 0.5 and 1kg and speeds are 1430, 1467 and 1480rpm respectively.

I. INTRODUCTION

In order to simplify the work of people the usage of machines are very important in our daily lives. Furthermore, now a days we use machines to the maximum extent in our daily life activities. Belt conveyor is one of the important equipment in coal mines and some other manufacturing factories, especially in the large modern coal mining enterprises where almost all of the coal is transported by belt conveyor from the coal mining to the loading station. Some faults such as slipping, deviation, and belt tearing often occur in the working process of belt conveyors, and most of them are caused by idler fault. If the idler fault can be detected in easy stage, the operational failure of belt conveyor can be avoided and the economic losses can be reduced. There are few fault diagnosis systems for belt conveyor currently, and the intelligent level of existing systems is not high enough which cannot achieve the real time online diagnostic purpose. Therefore, it is of practical interest to design a fault diagnosis system that can easily test belt conveyor online without affecting its daily working. Vibration analysis is a commonly used tool in fault diagnosis for rotating machinery such as idler on belt conveyor. The key to the analysis of vibration signal is the extraction diagnosis and classification. By applying the concept of Condition Monitoring (CM) techniques the running condition of the machine can be analysed. The Vibration Monitoring (VM) is most commonly used analysis method to analyse the running condition of machine and it may provide the clear identification of most of the faults in the machine. Belt conveyors are the equipment widely used in coal mines and other manufacturing industries, whose main components are a number of idlers. The faults of belt conveyors can directly affect the daily production. A fault diagnosis method combining Wavelet Packet Decomposition (WPD) and Supper Vector Machine (SVM) is proposed for monitoring belt conveyors with the focus on the detection of idler faults. The proposed fault diagnosis is firstly tested on test bed and then on online monitoring and finally fault diagnosis system is designed for belt conveyors. A multi sensor data collection and Principal Component Analysis (PCA) are proposed to develop a framework for impeller fault detection.

Saravanan and Ramachandran used discrete wavelet transform to extract fault features for neural network in order to classify and identify the faults.

II. METHODOLOGY

2.1 Research and Project Selection

As a means of power transmission Belt drives are used widely throughout the industry because of their high power transmission efficiency. The efficiency of the belt drive depends to a large extent on the health of the belt and any damage to the belt will affect the efficiency of power transmission. Since this is a major issue that drives up costs throughout the industry, we felt that this would be a good project to pursue.

2.2 Project Requirements

The aim of the project is to study the power transmission efficiency with belts having faults. Thus this required a power source such as a battery, an electric motor along with pulleys of different diameters and belts having different degree of damage to simulate the transmission of power. Along with that sensors such as 3- directional accelerometers along with a suitable data acquisition system to record and study the vibrations.

2.3 Conceptual Design

In order to achieve the project objective a proper setup is needed. A conceptual design is developed with the project objective in mind. The project requires a source of mechanical energy in the form of rotary motion, which is satisfied by the power unit comprising of an electric motor and a battery. The project requires power to be transmitted between two points by the means of a belt, so a set of pulleys of different diameters have to be designed to enable the transfer of power between the input and the output shaft via a belt drive. The project aim is to measure the vibration is the belt transmitting power in a belt drive due to a faulty belt. Thus this requires belts having different degrees of damage or fault for testing. There is a requirement also for high precision sensors such as 3- axial accelerometers to measure the vibrations in all the 3 directions with high sensitivity.

2.4 Component Selection

Table 1: Motor details

Capacity	3phase, 415V, 50Hz
Power	0.37KW, 0.5Hp
Speed	1440RPM
Current	1.4Amps

Table 2: Motor starter details

Phase	3
Coil voltage	280/440
Amperes	15
Cycles	50

Table 3: Bearing details

Inside diameter	16mm
outside diameter	25mm
Ball bearing	Deep groove
Material	Steel
Race width	5mm
Bore type	Parallel

Table 4: Flat pulley details

Material used	Mild steel
Outer diameter	64mm
Inner diameter	16mm

Table 5: Cone pulley details

	Smaller pulley	Medium pulley	Larger pulley
Material used	Mild steel	Mild steel	Mild steel
Outer diameter	50mm	75mm	100mm
Inner diameter	16mm	16mm	16mm
Type	V-groove, Teeth groove	V-groove, Teeth groove	V-groove, Teeth groove

2.5 Fabrication

The experimental setup used for this study is designed and fabricated to collect the vibration data for different working condition. The following parts were selected and fabricated. The Motor of 0.5Hp, and maximum speed of 1440rev/min with power rating capacity of 0.37 K W. V belt pulley (inner diameter of 16mm and outer diameters of 50, 75 and 100mm) this type of pulleys are like cone pulleys. Which are connected to the motor and other cone pulley are mounted on a shaft diameter of 16mm. V belt and tooth belt is used to connect driver and driven shaft. Likewise a pair of flat pulleys, one is connected to the motor and other one to the shaft diameter 16mm and Flat pulley is of diameter 64mm. These units are mounted on a strong wooden base.

Experiments on V-belt and Tooth belt were conducted at three speed with lower speed at 1430 RPM, middle speed at 1467 RPM and higher speed at 1480RPM. For Flat belt experiments were conducted at single speed at 1419 RPM. And it is conducted for three different loads at zero load, 0.5 load and 1kg load. Driven pulley rotates at lesser speed than the driver pulley because the driven pulley is bigger in diameter than the driver pulley.



Fig1. Experimental setup

2.6 Model Testing

LabVIEW7® (Laboratory Virtual Instrument Electronic Workbench NI-National Instrument) application software model, developed (LabVIEWTM 7, 2003) with FFT analyser is used to acquire vibration signals data through four channel sensor input module Data Acquisition Device (NI-DAQNational Instruments-NI SCXI-1000 chassis through SCXI-1530-channel 0, SCXI-1530-channel 1 and SCXI-1530- channel 2). The photographic view of LabVIEW® software integrated with DAQ module and computer is shown in Fig.

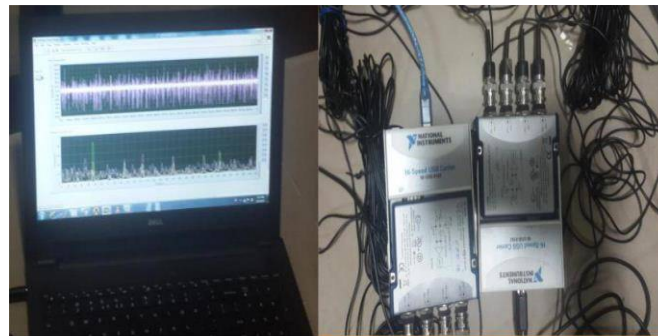


Fig2. Lab-VIEW® software integrated with DAQ module and computer

The 3-directional piezoelectric accelerometers (Model 621B40, IMI sensors, sensitivity is 1.02 mV/m/s² and frequency range up to 18 kHz) was used to acquire vibration signals in vertical, horizontal and axial directions for the belt in healthy condition.

These signals were later used to compare the signals with belts fault condition to identify the cause. The sensor continuously stores the vibration data from the belt. This data is analysed using a MATLAB program. The purpose of developing MATLAB program is to advance the existing technology and process data faster, but the program is not running throughout the operation of the belt and it is up to the user to run the program to analyse the data and determine the condition of the belt.

2.6.1 Healthy Condition

Initially experiments for V-belt and Tooth belt were conducted for three speeds of 1430 RPM, 1467 RPM and 1480 RPM. For Flat belt were conducted for 1419 RPM. Under good operating condition without any faults in the belt. The corresponding speed is measured by tachometer. Using LAB-VIEW 7.1 software the vibration signals in horizontal, vertical and axial directions were acquired. These signals were later used to compare the signals with belts fault condition to identify the cause.

2.6.2 Faulty Condition

Fault conditions were created in the belts to study and analyse the behaviour of the rotating system under different operating speeds

The first side –cut out fault is induced only at outer side of the V-belt, Tooth belt and Flat belt. The second side-cut in fault is induced only at inside portion of the V-belt and Tooth belt.

III. RESULTS AND GRAPHS

3.1 Healthy Condition

The vibration signals only in the axial directions are presented here for discussion purpose. Since the amplitude of vibration is observed high in axial direction than in horizontal or in vertical direction. A typical time domain vibration signals for Flat belt cut-out condition with load are shown in Fig.16. The frequency domain vibration signals of Flat belt cut-out condition with load are shown in Fig.

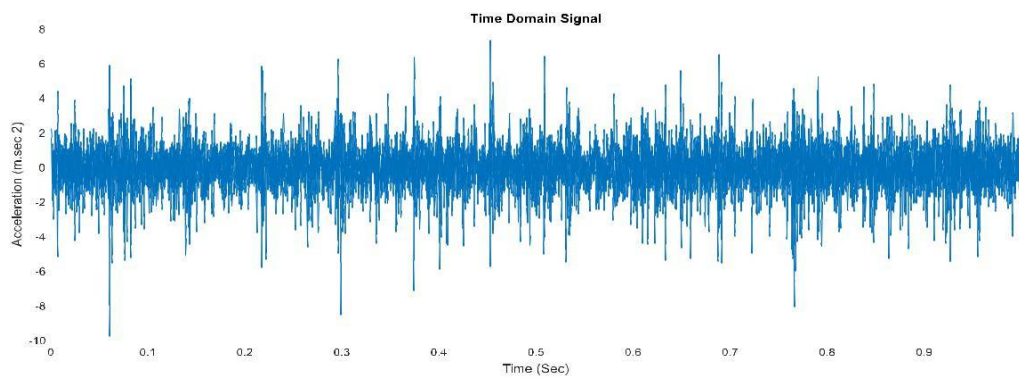


Fig3. Time domain graph for healthy Flat belt

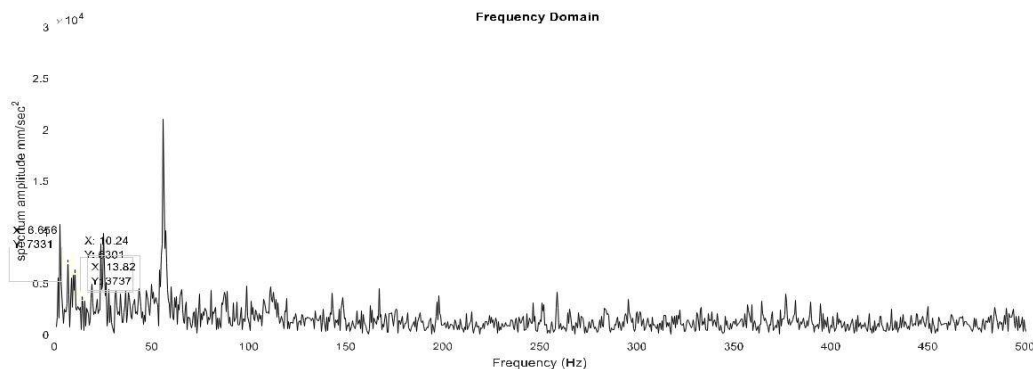


Fig4. Frequency domain graph for healthy Flat belt

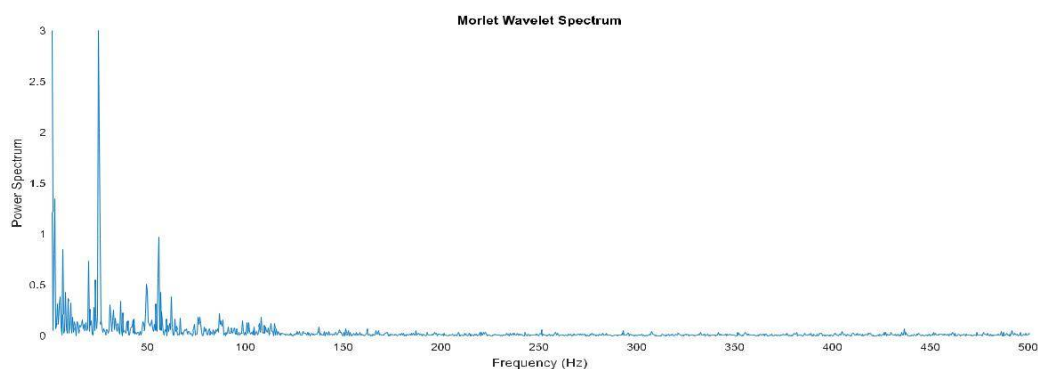


Fig5. Wavelet Spectrum graph for healthy Flat belt

The time and frequency domain vibration signals for healthy V-belt condition is shown in Fig.

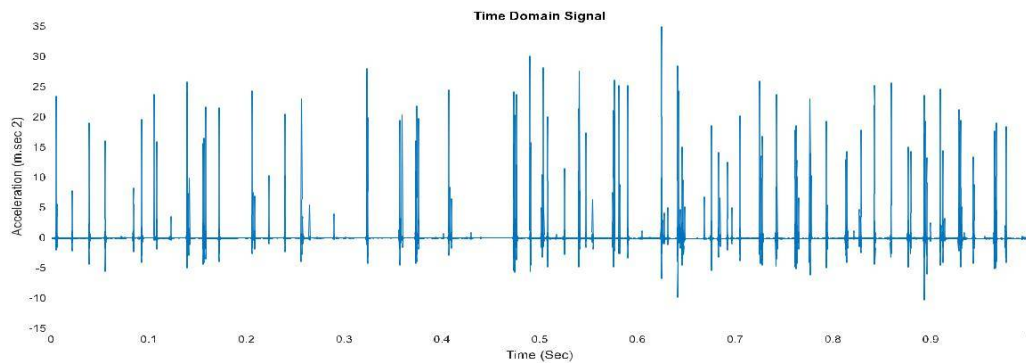


Fig6. Time domain graph for healthy V-belt

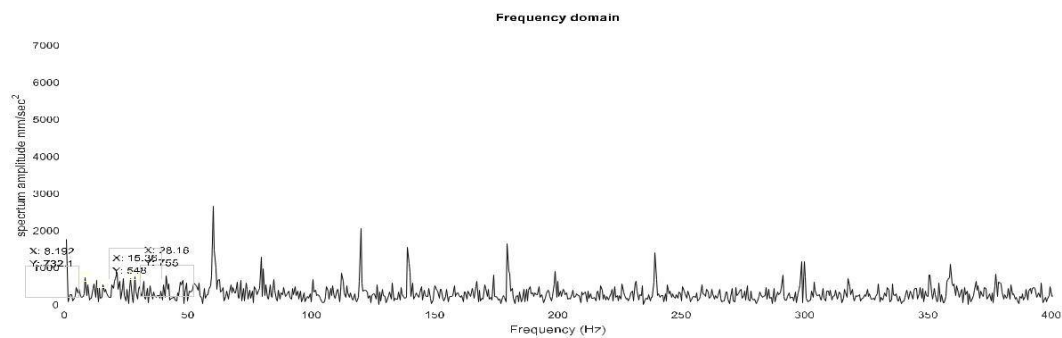


Fig7. Frequency domain graph for healthy V-belt

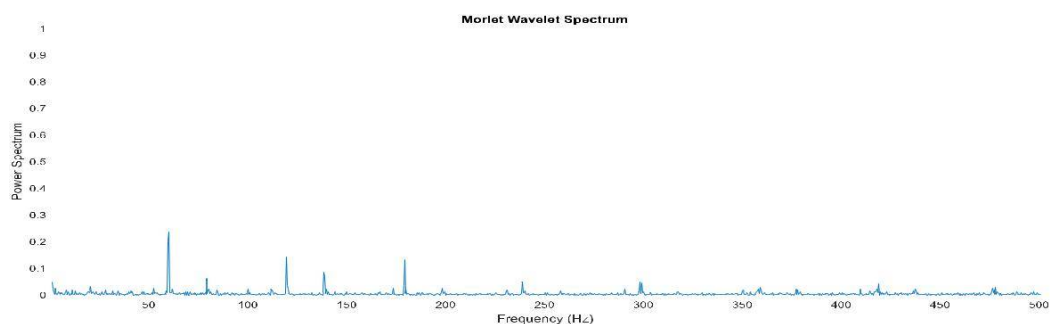


Fig8. Wavelet spectrum graph for healthy V-belt

The time and frequency domain vibration signals for healthy V-belt condition is shown below

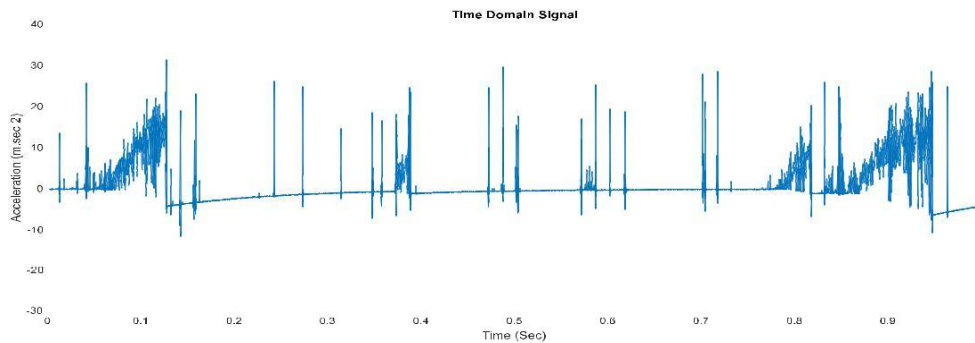


Fig9. Time domain graph for tooth belt

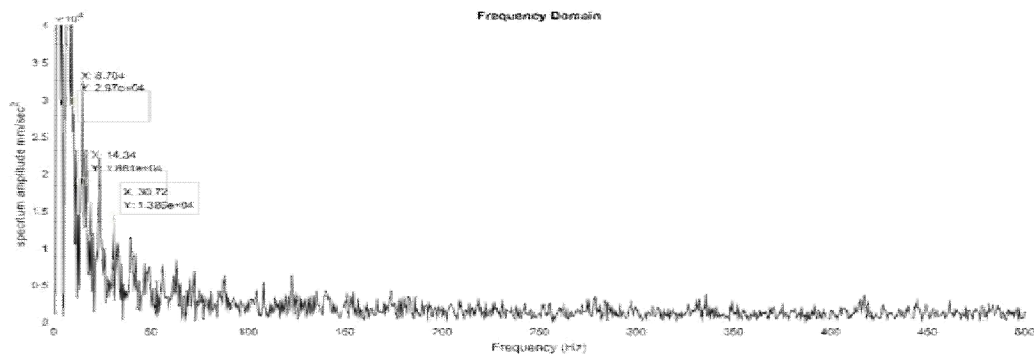


Fig10. Frequency domain graph for tooth belt

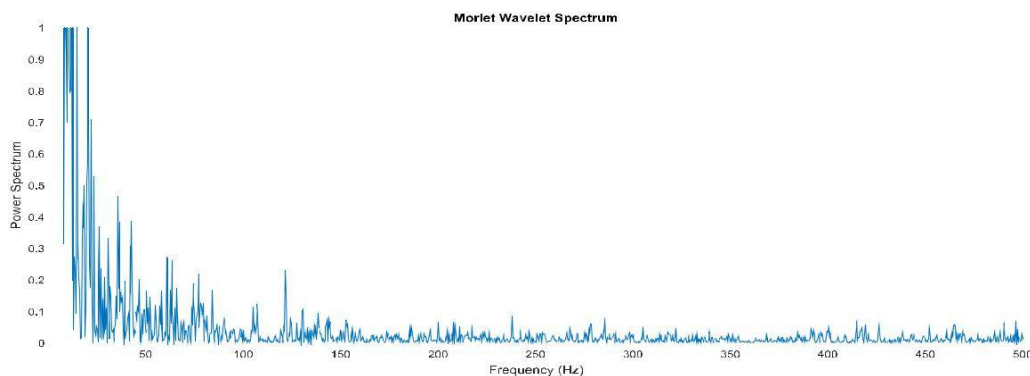


Fig11. Wavelet spectrum graph for tooth belt.

It is observed from the healthy running conditions that at lower speed, middle speed and as well as at higher speeds of the driver and the driven, there is smooth behaviour of the V-Belt, Tooth belt and Flat belt. Moreover, in speeds there is a small ignorable vibration level is observed, however this level is very low and negligible. This vibration level is used as a basic reference to compare the vibration level at various faulty conditions.

3.2 Fault Condition

3.2.1 Side Cut-Out Condition

The time and frequency domain vibration signals for a Flat belt side cut-out fault are shown in below figures.

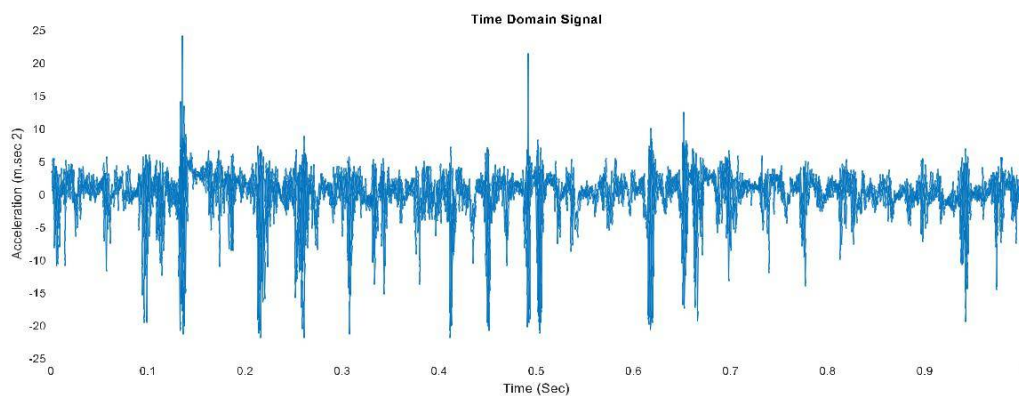


Fig12. Time domain graph for Flat belt

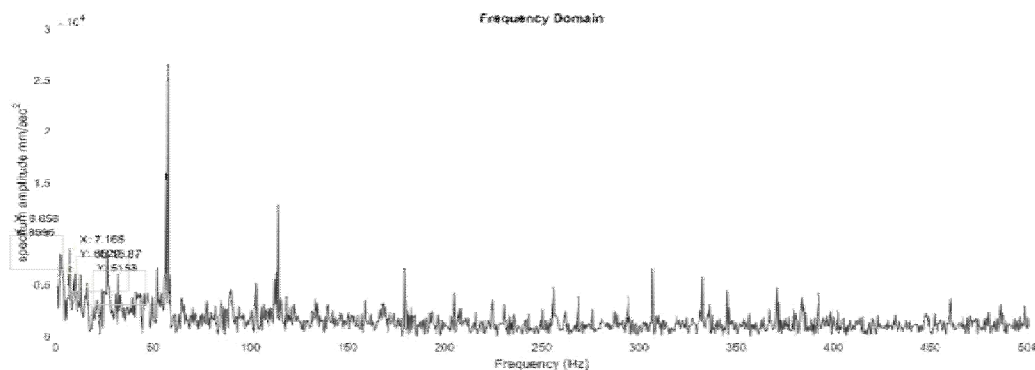


Fig13. Frequency domain graph for Flat belt

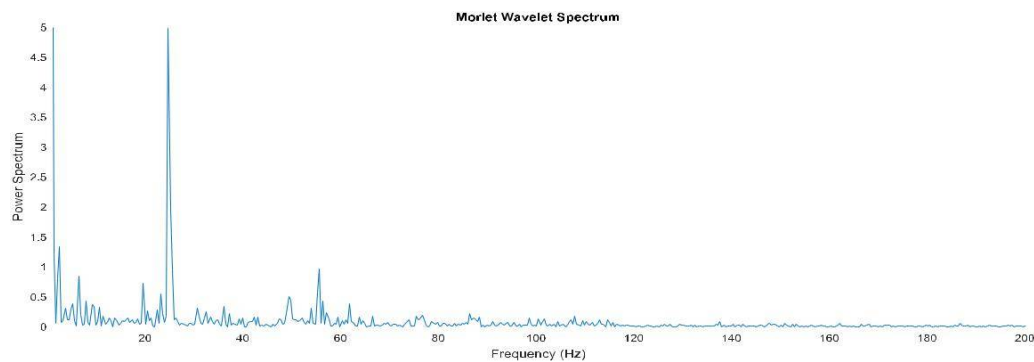


Fig14. Wavelet spectrum graph for Flat belt

The time and frequency domain vibration signals for a V-belt side cut-out fault are shown in below figures

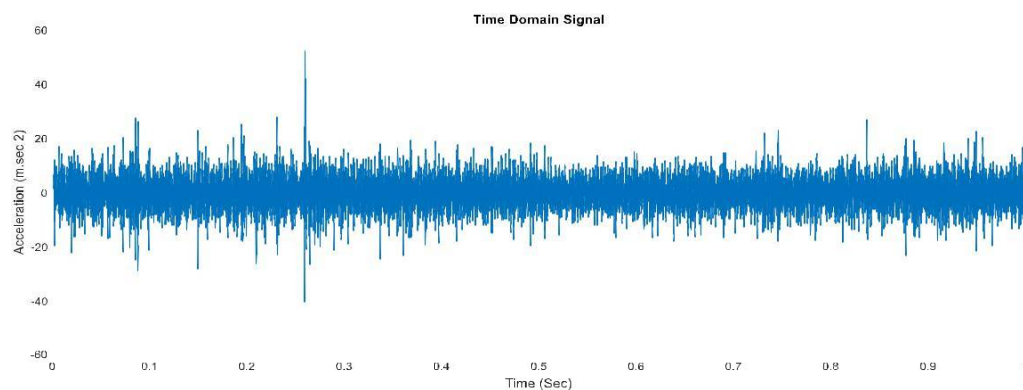


Fig15. Time domain graph for V-belt

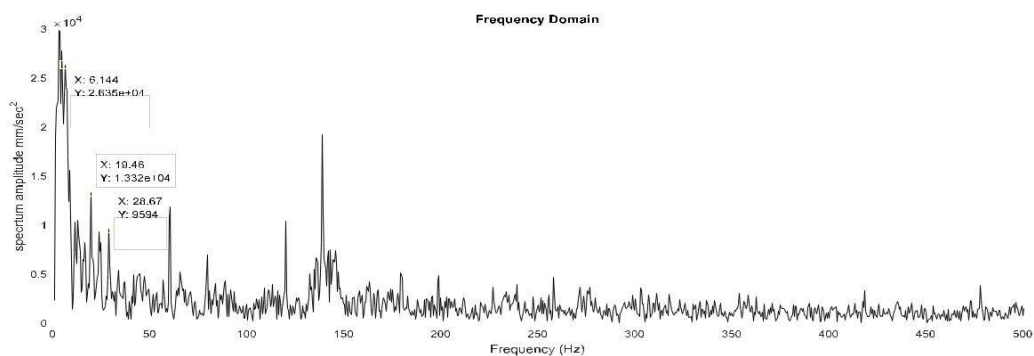


Fig16. Frequency domain graph for V-belt.

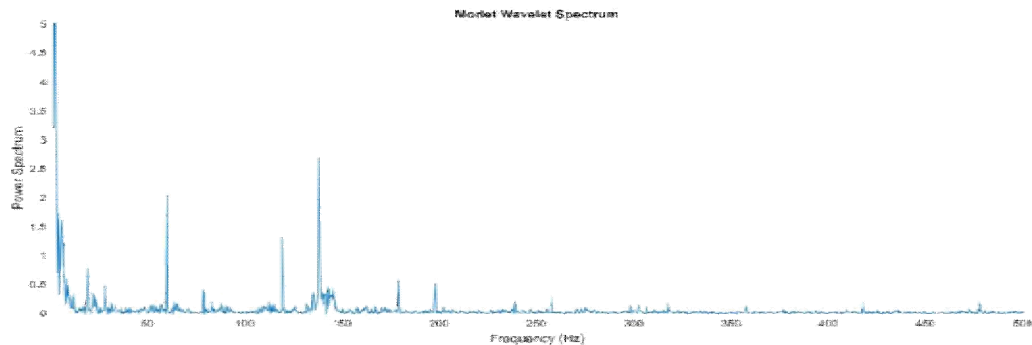


Fig17. Wavelet spectrum graph for V-belt

It is observed that the Side-Cut-Out in the belt has an effect on vibration level at lower as well as at higher speed. The vibration amplitude is increasing in nature compared to healthy condition. Where, the two vibration amplitudes indicates that first one for the Driven shaft take place at the beginning and followed by the Driver shaft in the graph. When comparing the speeds highest speed has more vibration compared to other speeds.

3.2.2 Side Cut-In

The time and frequency domain vibration signals for a V-belt side cut-in fault are shown in below figures.

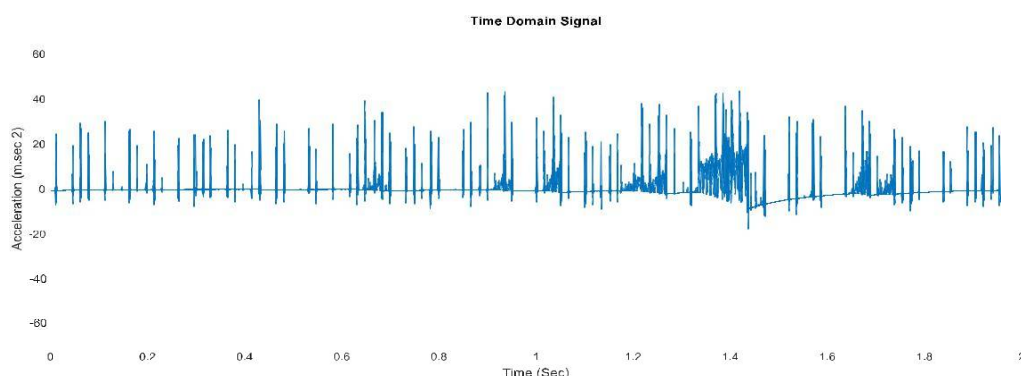


Fig18. Time domain graph for V-belt.

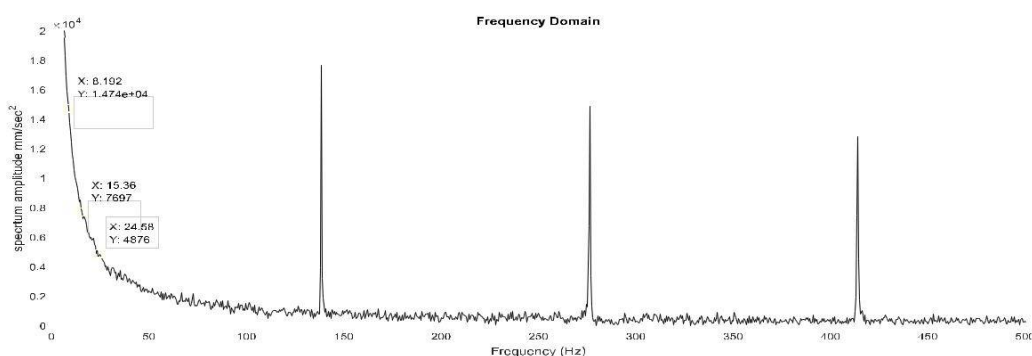


Fig19. Frequency domain graph for V-belt

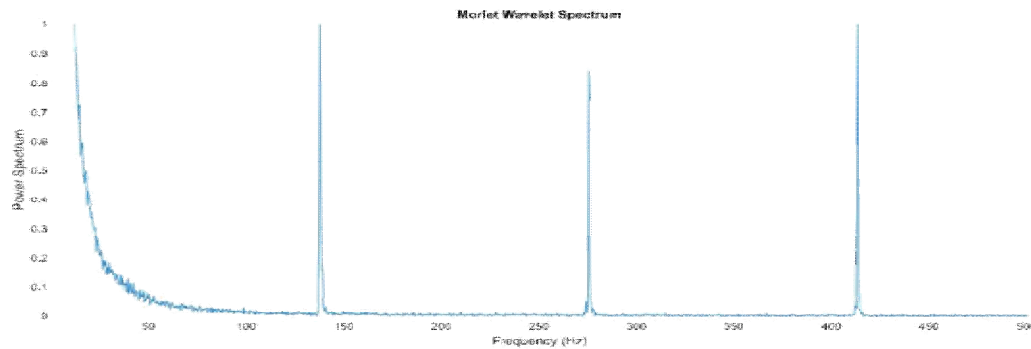


Fig20. Wavelet spectrum graph for V-belt.

The time and frequency domain vibration signals for a Tooth belt side cut-in fault are shown in below figures.

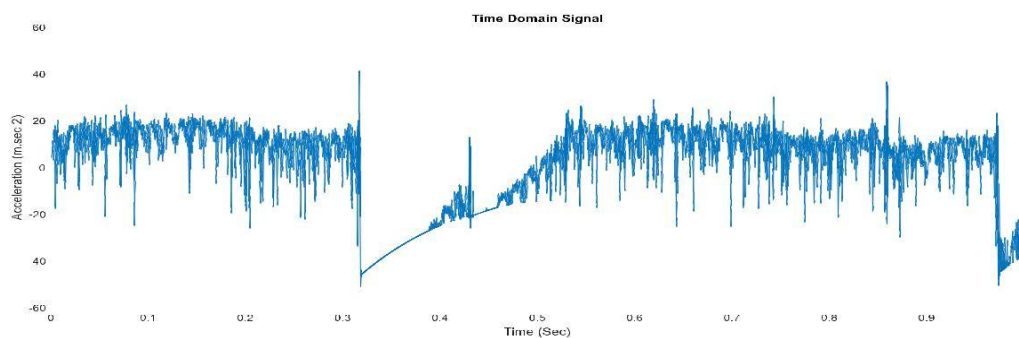


Fig21. Time domain graph for tooth belt.

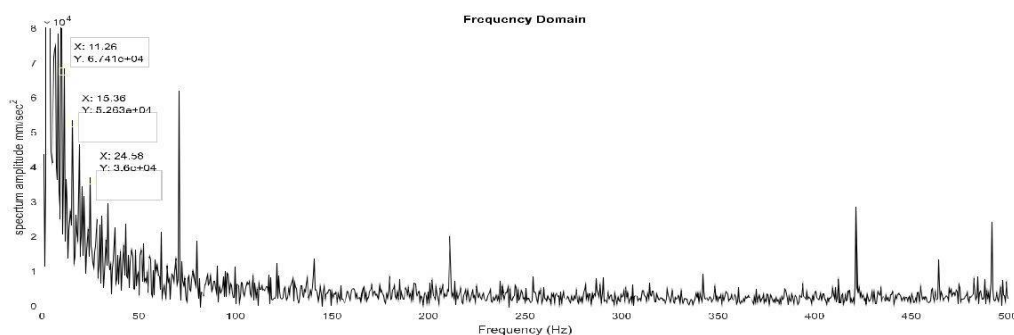


Fig22. Frequency domain graph for tooth belt.

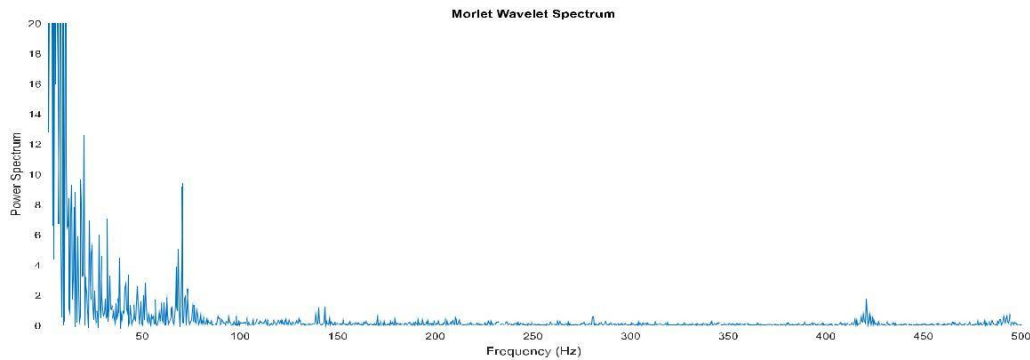


Fig23. Wavelet spectrum graph for Tooth belt.

It is observed that the Side-Cut-In in the belt has an effect on vibration level at lower as well as at higher speed. The vibration amplitude is increasing in nature compared to healthy condition.

Morlet Wavelet Based Enveloped Power spectrum for healthy and faulty belt conditions at different speed. The Morlet Wavelet Based Enveloped Power Spectrum gives a better reading of the vibration amplitude and hence helps to compare the faulty condition with the healthy condition

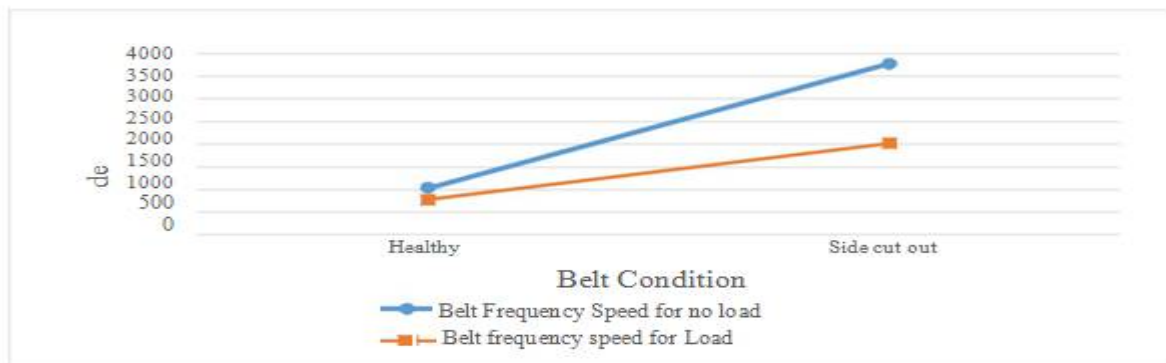


Fig24. Comparison of amplitude of belt frequency for a Flat belt.

In the above figures, a comparison has been made for two different condition. The amplitude of the belt was small for the healthy condition and it increases with increase in the fault.

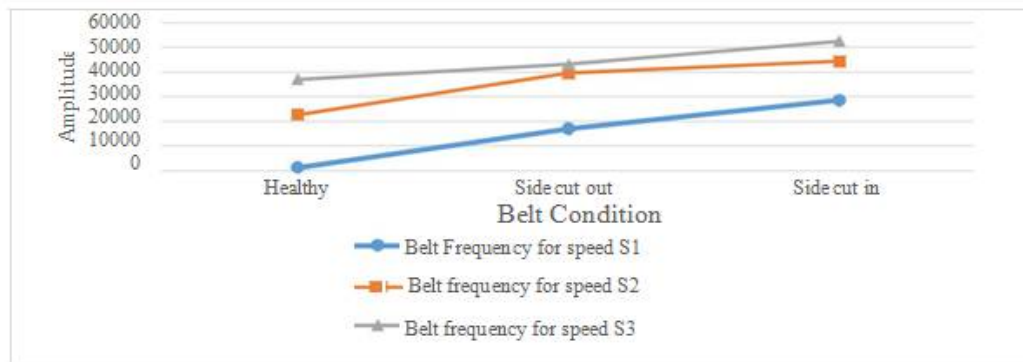


Fig25. Comparison of amplitude of belt frequency under NO-LOAD - V-belt.

S1-1430 RPM, S2-1467 RPM and S3-1480 RPM

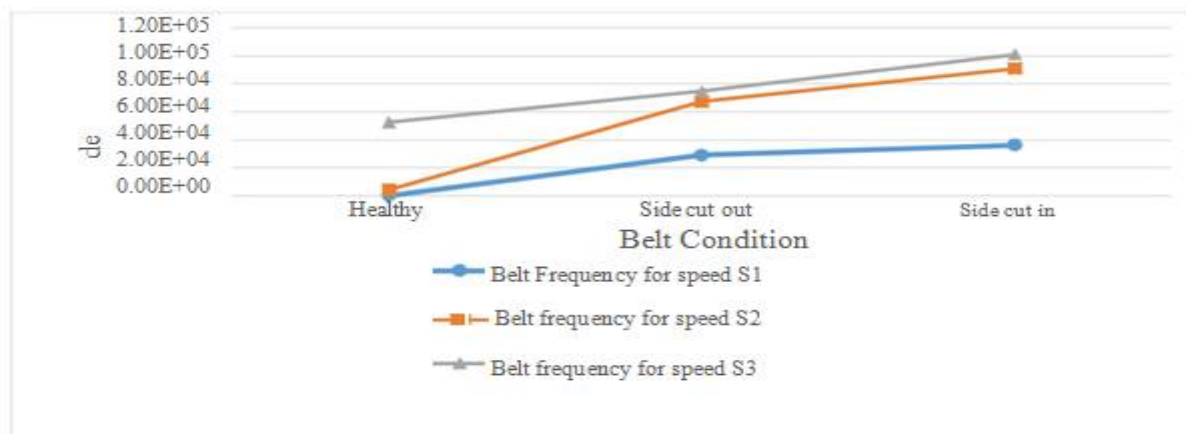


Fig26. Comparison of amplitude of belt frequency under LOAD - V-belt.

S1-1430RPM, S2-1467 RPM and S3-1480 RPM.

In the above figures, a comparison has been made for 3 different fault. The amplitude of the belt was small for the healthy condition and it increases with increase in the fault.

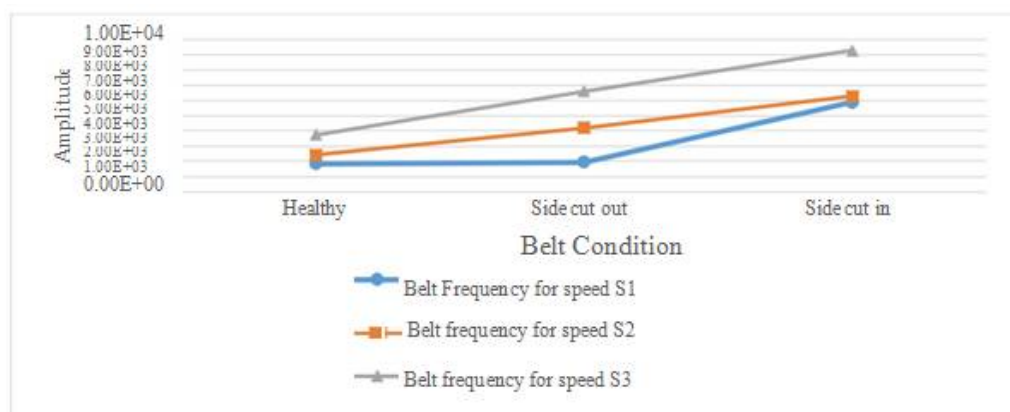


Fig27. Comparison of amplitude of belt frequency under NO-LOAD – Tooth belt.

S1-1430 RPM, S2-1467 RPM and S3-1480 RPM.

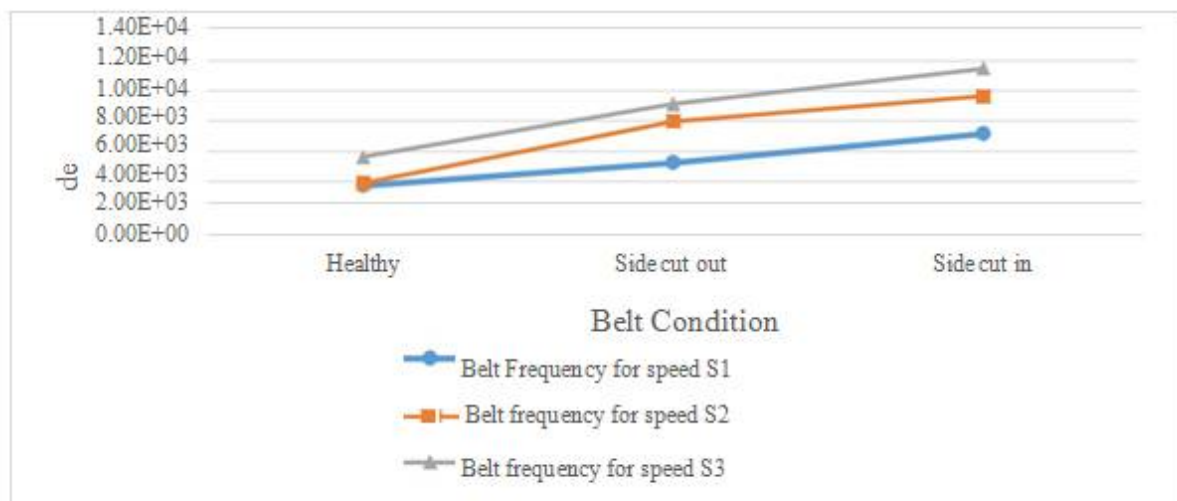


Fig28. Comparison of amplitude of belt frequency under LOAD - Tooth belt

In the above figures, a comparison has been made for 3 different speed of the belt. The amplitude of the belt was small for the lower belt speed and it increases with increase in the belt speed.

IV. CONCLUSION

Extensive experimental investigation was carried out on the belt drive simulator experimental setup which is designed and fabricated for this study. Initially for healthy conditions the vibration signals were acquired and further used to compare the vibration signals under three faulty conditions at lower speed of driver pulley at 1430 RPM, medium speed of driver pulley at 1467 RPM and at higher speed of driver pulley at 1480 RPM. Three fault like No-fault, Side-Cut out and Side-Cut-In are induced in the belt intentionally to study the conditions. At the healthy condition it is found that the V-belt, Tooth belt and Flat belt is running in smooth condition with very low vibration level. After recording the readings of the healthy condition, the two fault Side-cut-out and Side-Cut-In are induced in the belt and experiments were conducted for all the cases and corresponding vibration signals were acquired in three directions. It is found that the vibration level at higher speed is more compared at lower speed. Moreover, from the tests conducted it is concluded that the fault condition Side-cut-in is the most affected fault in the V-belt and Tooth belt compared with the other two faults and generates high vibration amplitude. Furthermore, when the speed increases the vibration amplitude increases with respect to fault created. Hence, it is found that there is a relation with severity of fault, vibration amplitude and speed.

REFERENCES

- [1]. Li, W., Wang, Z., Zhu, Z., Zhou, G. and Chen, G. "Design of Online Monitoring and Fault Diagnosis System for Belt Conveyors Based on Wavelet Packet Decomposition and Support Vector Machine" *Advances in Mechanical Engineering*, vol. 5, 2013, pp. 1–10.
- [2]. Bajrić, R., Zuber, N. and Isić, S. "Recent Advances in Vibration Signal Processing Techniques for Gear Fault Detection-A Review". *Applied Mechanics of Materials*, 430, 2013, pp.78-83.
- [3]. Ahmed, M., Gu, F. and Ball, A. "Fault Detection of Reciprocating Compressors using a Model from Principles Component Analysis of Vibrations" *Journal of Phys.: Conf.Ser.*, 364, p.012133, 2012.