Vibration Analysis of Precision Gear using Con-Tactless Sensors

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Abstract— Torsional vibration, in rotating machines, can be defined as the oscillatory motion of a rotor as it rotates. Torsional vibration can also be viewed as the cyclic variation of shaft speed. Torsional vibration, in rotating machines, can cause failures, such as: gear-tooth breakage, blade failure due to blade fatigue in steam turbines, break-off of shafts, and overloading of components fitted onto the shaft. Common sources of torsional vibration include electromagnetic torques from line frequency in electric motors and generators as well as long drive trains with massive inertial components. Even in good condition, machines generate vibrations. Many such vibrations are directly linked to periodic events in the machine's operation, such as rotating shafts, meshing gear teeth, rotating electric fields, and so on. The frequency with which such events repeat often gives a direct indication of the source and thus many powerful diagnostic techniques are based on frequency analysis. The measurement of torsional vibration is important in analysis and diagnostics of rotating equipment.

Keywords: Gear, Torsional Vibration, Spur Gear

I. Introduction

The transducer used to detect the torsional vibration of the shaft included a shaft encoded with black and white stripes, an infrared fiber optic probe, an analog incremental demodulator and an A/D converter. Commercially, there are only few measurement systems available that measure this type of vibration as compared to lateral vibration measurement systems. Torsional vibration measurement is an important content in the study of gear teeth generated vibration. Geiger torsional vibration analyzer is a typical mechanical torsional vibration measuring instrument and was used in torsional vibration study in the earliest stage. This instrument is designed, whose signal acquisition and signal record are both realized by mechanical devices, simple and practical. It is widely used in the study of torsional vibration. But some difficulties arise while using this analyzer for signal record.

A. Torsional Vibration Measurement.

The transducer used to detect the torsional vibration of the shaft included a shaft encoded with black and white stripes, an infrared fiber optic probe, an analog incremental demodulator and an A/D converter. Commercially, there are only few measurement systems available that measure this type of vibration as compared to lateral vibration measurement systems. Torsional vibration measurement is an important content in the study of gear teeth generated vibration. Geiger torsional vibration analyzer is a typical mechanical torsional vibration measuring instrument and was used in torsional vibration study in the earliest stage. This instrument is designed, whose signal acquisition and signal record are both realized by mechanical devices, simple and practical. It is widely used in the study of torsional vibration. But some difficulties arise while using this analyzer for signal record.

B. Objective

1) To find area of potential failure is in the shaft of a rotating machine which may be gear teeth
2) To model and study the measurement of a torsional vibration of a geared system using proximity pick up and identify the waveform
3) To develop an algorithm for calculating the torsional vibration amplitude.
4) Evaluate the torsional vibration amplitude.

C. System Description & Work

1) DC Motor

Specifications: Input Voltage: 230V.DC, Compatible pedal wheel for speed control, Weight: 1.2Kg, Power: 62.14 Watts (H.P: 1/12), RPM: 6500

2) Proximity Sensor

A proximity sensor is a sensor to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors targets. For example, a capacitive photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target. The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance.

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object. Proximity sensors are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.

3) Signal Conditioning Circuit

Angular displacement can be measured at the end of a shaft with encoders or at intermediate points with a gear magnetic pickup or proximity probe arrangement. The aim of this signal condition circuit is to modify the signal obtained from the proximity sensor as an output. The output of proximity sensor cannot be directly connected to digital storage oscilloscope; therefore electronic circuit is required for signal processing. This circuit works on 230 V AC voltage supply, this supply is converted into 24 V AC supply by using transformer. The filter circuit is used to convert this AC supply into DC supply. Regulator circuitry is used to convert DC supply into regulated DC supply of 24V. Again this 24 V DC supply is converted into 12 V DC supply for signal processing of proximity pick up the circuit diagram is shown in Fig

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In this signal conditioning circuit two proximity sensors are used PX1 and PX2 respectively. In PX1 circuit, 12 V DC supply is provided as supply voltage. This supply voltage is divided by divider circuit for providing the input voltage to comparator circuit. Comparator circuit is used to compare the reference voltage with the voltage from proximity pick up as output. 1K is used to supply sinking voltage for smooth generation of waveform. LED is also used for signal indication to the operator. Probe of digital storage oscilloscope is connected to the output of PX1 sensor for generation of square waveform.

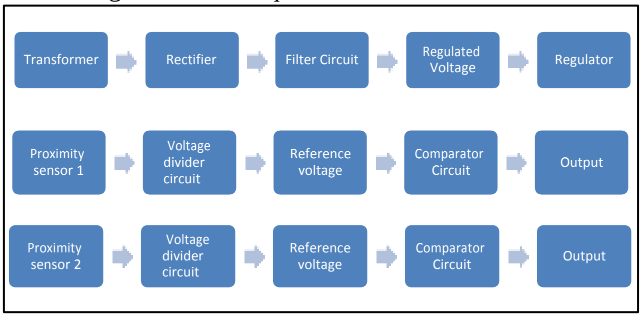


Fig. 1.1: Flow chart for Electronics signal processing

II. EXPERIMENTAL SETUP

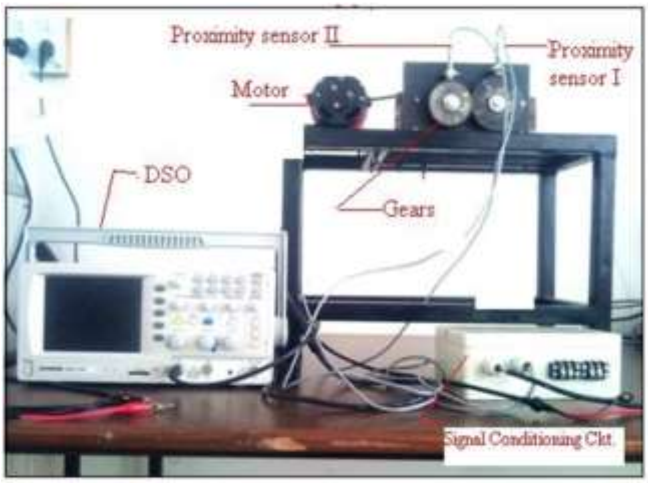


Fig. 1.2: Experimental setup

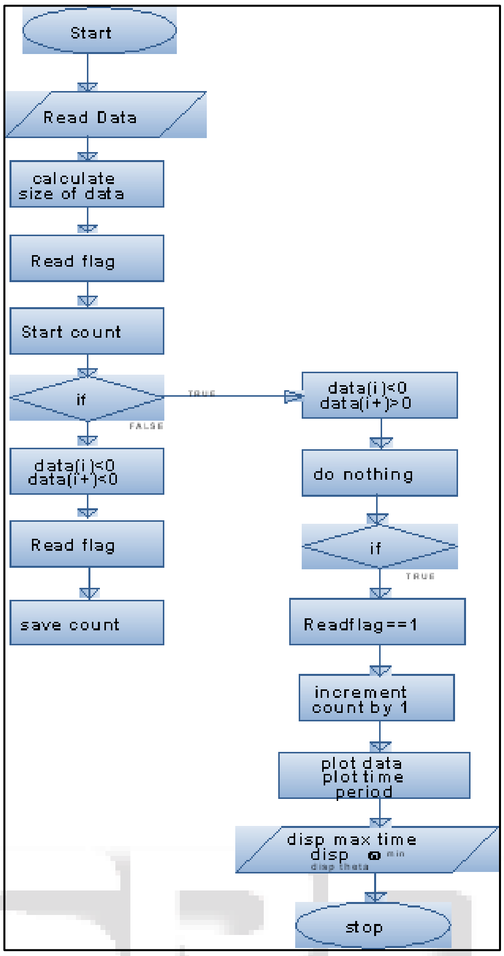


Fig. 1.3: Flowchart for MATLAB programme

III. EXPERIMENTAL ANALYSIS

Sr.No.	Speed of the gear (rpm)	Frequency Indicated by DSO (Hz)	Signal pulse frequency. f = (speed x No.of teeth) / 60	Tmax (millisecond)	Tmin (millisecond)	Amplitude (rad) θ
1	404.4	243.9	242.64	4.2962	3.6623	0.0131
2	426.3	272.5	255.78	4.2982	3.6623	0.0131
3	543.3	344.8	325.98	9.7807	3.1798	0.0545
4	683	395.3	409.8	5.2741	4.1776	0.0111
5	735.7	469.5	441.42	5.2741	2.8838	0.0296

Table 1: Speed of gear and signal pulse frequency

IV. RESULT AND DISCUSSION

The proximity sensor 1 is mounted on the gear. The speed of this gear is measured with tachometer. The output of the proximity sensor is fed to the signal conditioning circuit, as shown in Fig 4.1., the output of this circuit input is given to the channel 1 of the digital storage oscilloscope. The excel data from DSO is given as input to the MATALB program and processed, which gives the values of Tmax (maximum time spacing of the pulse),Tmin (minimum time of pulse spacing) & θ the torsional vibration amplitude as the output results. These values are tabulated in Table 5.1. The sample calculation of frequency of ‘proximity sensor I’ is as given below:

Speed (N) = 404.4 rpm No. of teeth = 36

Signal pulse frequency = No. of teeth x speed / 60

= (36 x 404.4)/ 60
Signal pulse frequency. = 242.64 Hz
From DSO displayed frequency = 243.9 Hz

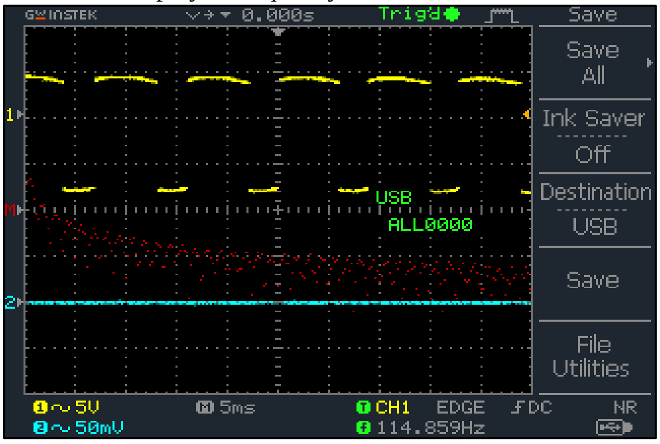
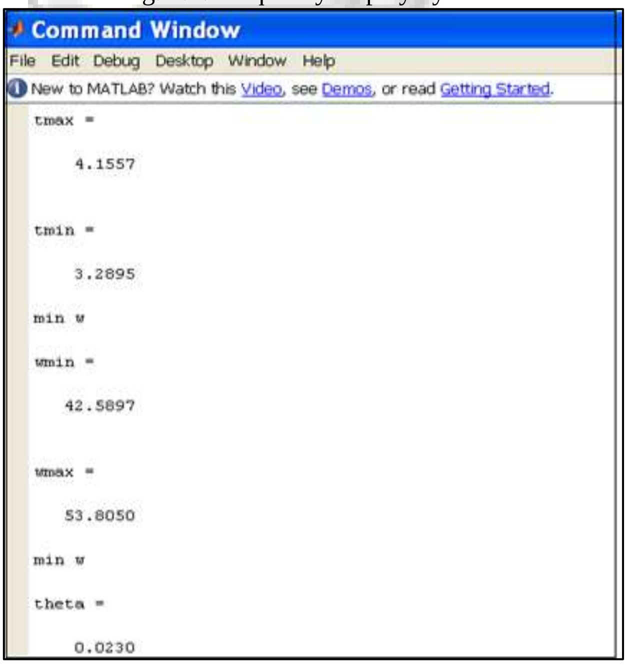


Fig. 1.4: Frequency display by DSO



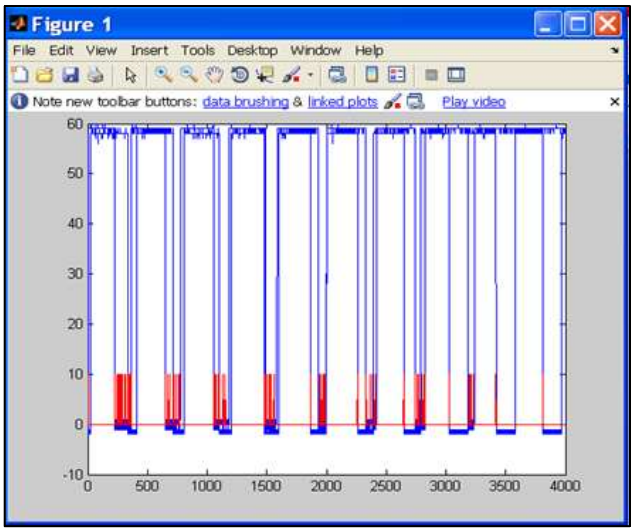


Fig. 1.5: command window showing output

V. CONCLUSION

The development of Torsional Vibration measurement system has been successfully carried out. This developed approach can be used to measure torsional vibration amplitude in the rotating machinery. Torsional vibration measurement system indigenously designed and manufactured as per concept of the torsional vibration generation process to fulfill all requirement. The MATLAB program is developed. Output of MATLAB program is in numerical as well as in graphical format. The developed setup is showing satisfactory results for low speed range, the probable reason at high speed the gear teeth pulses are not recorded by the DSO.

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