Universal Single Sensor for Machinery Condition Monitoring: Vibration, Bearing Health and Temperature

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Abstract. This paper introduces the new Single Sensor contained in typical accelerometer housing and DIN rail Condition Transmitter (vibration channel) allows measuring vibration in a range of 2 Hz to 20 kHz, bearing health based on shock pulse (resonance) method and temperature in a range of -40°C to +120°C. The sensor design based on flex piezoelectric technology and has integrated electronics. The connection with DIN rail transmitter is realized by current line drive which provided low sensitivity to electrical hazards, possible long cable length without signal loss at high frequencies. The sensor is explosion proof and DIN rail transmitter has inserted Ex barrier.

It is specially designed to provide early warning of absolute vibration level as well as typical ball/rolling element bearing faults such as cracked races, spalling, brinelling, and looseness. It has six modes (outputs) of detection that are working simultaneously. The options include RMS velocity, true PK acceleration, AC acceleration, temperature, bearing condition and lubrication condition. The diagrams of the channel and test results are discussed.

Key Words: Vibration, Rolling/Ball Bearing, Transmitter, Condition Monitoring.

Introduction

Machinery and mechanical systems face potential failure when the ability to function normally is compromised due to worn components or when operating conditions diverge from normal. Continuous monitoring of vibration levels help avoids expensive unplanned shutdowns by detecting machinery faults before they become catastrophic events. It is known that machinery vibration changes when problems such as worn bearings occur.

Bearings are needed whenever one part of a machine slides against another and can be classified as either sliding or rolling contact bearings. For rolling contact bearing condition monitoring, a new field programmable and cost-effective sensor has been designed, the Rolling/Ball Bearing Condition Transmitter. The sensor units are constructed with a two pin independent polarity connector and can work directly with PLC or DCS systems. All parameters and configurations of the units are USB programmable through a PC.

Methods

Two groups of methods are widely adopted for the determination of rolling bearing health and presence of faults. Although not always possible, the best results are obtained when both methodologies are adopted.
The first group of methods, which are diagnostics orientated, is based on the separation and analysis of discrete components of certain frequencies which make up excited oscillations in the bearing. The diagnostic features are frequency components of the spectrum and characteristics of the signal pulse shape associated with the characteristic frequencies of the bearings: the pulse peak value (usually harmonic amplitude), the ratio of the harmonic energy to the noise level, and the amplitudes of spectrum components at the pulse repetition frequency. To analyze these parameters use is made of vibration signal spectra, spectra of AM-envelopers of narrow-band high frequency components of the vibration signal in a range of 0.1 to 40 kHz and vibration time waveforms.

The second group of methods is based on the determination of the technical condition of the bearing as a whole. In a case of loss of serviceability, it is paramount to determine the necessity for the bearing replacement (i.e. determine its health). The cause of failure may be determined later, if required, by visual inspection of the bearing. The condition of the bearing is evaluated by the degree of development of degradation; a process that may be separated into four known stages. The following is a list of possible diagnostics parameter: RMS and PK of acceleration, characteristics of amplitude distribution, moment characteristics (dispersion, excess), correlation and regression variances, amplitude discriminates, various parameters with use of peak (crest) factor and it combination with RMS and PK of vibration and comparison of vibration parameters in various frequency bands. One important property of field applicable methods is a strong ability to separate current process characteristics, such as speed and loading, from bearing defects. The RMS, Shock Pulse, Crest Factor, Kurtosis, High Frequency Resonance Technique (HERT), Spike Energy™, gSE, HFD etc. are the main methods of bearings condition related to the second group. Several popular methods for determining bearing condition are listed below.

- Real or true PK of Acceleration and HFD.
- True RMS of Acceleration
- Crest (peak) factor $\text{CF} = \frac{A_{pk}}{A_{rms}}$ (trend is required) [1]
- Shock pulse method (rpm is required) [2, 3]
- $W_1 \times \left(\frac{A_{pk}}{A_{rms}}\right) + W_2 \times A_{rms}$ [4]
- Enveloping with Spectrum Analyses, Cepstrum and others
- $K – \text{factor} = \frac{A_{pk} \times A_{rms}}{A_{pk0} \times A_{rms0}}$ and other high order moments (rpm is required)
- Strum factor $K_0/K = \left(\frac{A_{pk0} \times A_{rms0}}{A_{pk} \times A_{rms}}\right)$
- Kurtosis (rpm is required)
- Modulation deepness of envelop signal (rpm is required)

2. Operation

The describing vibration channel is designed to use the first and forth methods (from the second group) listed above. Additionally it is provided velocity and temperature measurements. The channel connection diagram is shown on the Figure 1.
The technical specification of the sensor is follow:

- frequency range 3 Hz to 20 kHz; the acceleration range is +/-200 g for current output and +/-50 g for voltage output;
- sensitivity on the base frequency is 10 uA/g and 100 mV/g with maximum errors of 3%; the resonance is over 32 kHz;
- temperature measurement range is -40 to +120 degree C.

The technical specification of transmitter is follow:

- inputs (customer selectable): 10 uA/g, IEPE or voltage 100 mV/g;
- outputs: AC acceleration 100 mV/g (3 Hz – 20 kHz); thru pk of acceleration (1 kHz – 20 kHz) 4-20 mA customer selectable ranges 0-8g, 0-16 g and 0-32 g; RMS of velocity (10 Hz-1 kHz) 4-20 mA customer selectable ranges 0-16 mm/s, 0-32 mm/s and 0-64 mm/s; temperature 4-20 mA in range of -40 to 120 degree C; bearing health 0-10 V based on resonance method and bearing lubrication quality 0-10 V;
- the transmitter included the Ex barrier and has marking [Exia]IIC, the sensor is rated 0ExiaIICT6 which allows to use channel in hazard areas w/o extra barriers or special power supplies.
The circuit of the transmitter input Ex protection is shown on the Fig. 2 and based on limitation of voltage and current by triple Zener diodes and 2 W resistors R5, R17 and R23.

![Circuit Diagram](image)

Fig. 2. The transmitter Ex input protection diagram.

The plot shows the comparison of normal and defective bearings by using the channel bearing output at different rotation speeds represented at Fig. 3.

![Plot](image)

Fig. 3. Bearing output of transmitter vs. rotation speed for bearing without defect (bottom line) and for bearing with combine defect (top line).
The laboratory and field testing of the channel did show that the channel might be an effective tool for machinery condition monitoring. The calculated MTTB $>$ 16 years or 140000 hours.

References


