Vibration Sensing technique for monitoring condition of ball/rolling bearings and gearboxes

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SUMMARY

The paper introduces some details of new hand-held sensor with extended vibration frequency measurement range till 20 kHz. The sensor provides new diagnostics capabilities especially for rolling/ball bearings and gearboxes. It is related to discovering the unknown before behavior of one point contact metal to metal. It is found that traditional transfer function is incorrectly described after resonance frequency response of the contact. Theoretically and by experiments is shown that frequency response of such contact after resonance is linear in logarithmic axis and linearly dependence of applied to that contact forces. The measurement range of stick sensors traditionally supposed to lay from several Hz to 1 kHz and its resonance usually lay at the 2-3 kHz. So, such sensors widely recommended using to approximately 1 kHz. Discovered linearity’s provide possibility electronically compensate decreasing of frequency response after resonance and measuring vibration accurately after resonance in the over 10 times wider range about 4 to 20 kHz. The new extended frequency response of stick sensor required two things to be implemented to work properly: electronics compensation which up signal approximately on 15 dB/octave in a range of 5-20 kHz and force sensor for measuring the applied forces all the time. Then new stick sensor response presented as the ratio of vibration frequency compensated signal and the forces signal in real time. Such stick sensor works in two ranges: in traditional 10 Hz - 1 kHz and extended 4-20 kHz which allow somebody measuring regular vibration as well as controlling bearing and gearboxes by hand-held devises w/o any surface preparation.

KEYWORDS
Bearing – Gearboxes - Monitoring - Vibration
It is well known that frequency range of the vibration measurement system usually limited by accelerometer mounting technique. It is illustrated by Fig. 1, where comparison of frequency responses of different accelerometer mounting technique presented.

![Fig. 1](image1)

Low frequency vibration measurements traditionally considered the case of the vibration sensor uses hand probe which resonance lays in range of 1 kHz to 3 kHz even own resonance of used accelerometer might be very high.

Such low resonance allows measure overall vibration in required range of 10 Hz to 1 kHz but limited of using hand probe mounted sensors for high frequency measurements for example for rolling/ball bearing condition discovering which required frequency range of 3-4 kHz to 15-20 kHz.

![Fig. 2](image2)
Traditionally in the past it was considered that no possible to make high frequency vibration measurements by hand held vibration sensor which illustrated at Fig. 2, where experimental frequency responses of different mounting technique presented, and at Fig. 3, where traditional transmissibility function of the metal to metal contact model presented, gave no chance for the measurements success: the response looks non-linear and non-stable.

We found the way [1] to use after resonance frequency of hand held vibration sensor for the high frequency measurements. We discovered that in reality the one point metal to metal contact provide the linear (in log axes) and stable after resonance frequency response. The hand probe sensor which provides such response has shown on Fig. 4 and its typical frequency response – on Fig. 5. The experiments with different surfaces and materials did show the linearity in log axes of the after resonance curve.
The explanation had been found by considering deeper the mechanical contact physics. Such considering bring a more accurate model of one point material contact and more correct transmissibility function presented at Fig. 6, which shows that after resonance frequency response is theoretically also linear and stable.

The linearity and stability means that it could be compensated. The example of schematic for such compensation is shown on Fig. 7 and the schematic amplitude-frequency characteristic at Fig. 8, curve 2. The experimental compensated frequency response is presented on Fig. 9 and shows that hand held vibration probe could be used for high frequency vibration measurements.

Even the response is linear the central resonance frequency is depends of equivalent sensor mass or applied to the probe forces and then could change the sensitivity of the compensated output. Such fact illustrated at Fig. 10 where frequency responses of hand probe sensor with different applied forces presented. The range from 2 lb to 7 lb might be recommended for repeatable measurements. Sensitivity in such range could be controlled and compensated by force sensor (see Fig. 4 and Fig. 11 - we used as force sensor compression load cell FC22-3-1-0000-0010-L and Force-Resistor sensor RSR-400).
The high frequency response hand held vibration sensor could measure as low frequency as well high frequency vibration in the same time and consists, for example, of two channels – low frequency and high frequency - structure diagram of which shown on Fig. 11 [2]. Low frequency channel has a traditional structure. High frequency channel utilized the described technology and compensation schematic like shown on Fig. 7 and force sensor which by microprocessor realized the required sensitivity compensation. Plots of sensitivity of vibration sensor and resistor value of force sensor vs. applied forces shown on Fig. 12 to illustrate possibility for microprocessor to compensate of changing sensitivity when applied force changed.
The Fig. 13 illustrates almost identical vibration spectrums from field testing of high speed compressor using high frequency two channel analyzer and compare results from the same measurements points from high frequency stud mounted sensor with flat frequency response and designed hand probe high frequency sensor.

BIBLIOGRAPHY
