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PCN CM GEN APPENDIX Z-2 ISSUE 1

COMPENDIUM OF SPECIMEN NARRATIVE EXAMINATION QUESTIONS FOR CATEGORY 3

Contents

Category 3 – Narrative

1) A belt-driven centrifugal fan in an enclosed air handling unit has been fitted with IEPE accelerometers connected to an external switch box with a BNC connector.

a) Discuss where and how transducers are best fixed onto the machine (3).

b) Considering the measurement chain from the machine bearing to the switch box BNC connector only, list at least three typical measurement error symptoms. (3)

c) Considering the measurement chain from the machine bearing to the switch box BNC connector only, list at least four typical measurement error reasons. (4)

Ref	Question 1 Answers	Marks
a.	Discuss where and how transducers are best fixed (3). MARKING SCHEME: Any three of the following: Both motor bearings radially (horizontally or vertically) (1) Fitted on the motor axially (1) Both fan bearing radially (horizontally or vertically) (1) Fitted on a fan bearing axially (1) Attached using glue on screwed stud mounts (1)	3
b.	Considering the measurement chain from the machine bearing to the switch box BNC connector only, list at least three typical measurement error symptoms. (3) MARKING SCHEME: Any four of the following: Ski ramp on spectra (1) Clipped spectra peaks (1) No reading / reading too low / reading too high (1) Different reading or erratic reading (1) Spurious peaks on spectra (1) Incorrect reading (1)	3
c.	Considering the measurement chain from the machine bearing to the switch box BNC connector only, list at least four typical measurement error reasons. (4) MARKING SCHEME: Any four of the following: Poor sensor contact or faulty attachment (1) Incorrect bonding of glued stud (1) Stud bottomed in transducer (1) Base strain sensitivity (1) Incorrect point identification (1) Transducer / Cable / Connector fault (1) Ground loop (1)	4

2) **A 2-pole electric induction motor-driven centrifugal pump (non-critical <200 kW, 50 Hz supply frequency, 2% slip), with rolling element bearings is to be included in a route-based vibration monitoring (VM) program using IEPE accelerometer(s).**

a) **List at least three common faults detectable by VM, include both low frequency and high frequency examples. List typical frequencies each fault will generate. (3)**

b) **Describe the features of the IEPE accelerometer, include what IEPE means, the frequency range it covers, and where and how it will be located. (3)**

c) **Describe (at least two) types of vibration units and type of display you would record, and why. (2)**

d) **What speed will the motor actually run at? Give an example of a "vibration severity" value which you would consider to be unacceptable for long term operation. Include units and the units' qualifier. (2)**

Ref	Question 2 Answers	Marks
a.	List at least three common faults detectable by VM, include both low frequency and high frequency examples. List typical frequencies each fault will generate. (3) MARKING SCHEME: Any three of the following: Unbalance, LF or 1x (1), Misalignment, LF or 1x 2x (1), Looseness, LF or 1x 3x (1), Bearing Noise, HF or 500Hz – 2000Hz or similar (1), Bearing Damage, HF or 500Hz – 2000Hz or similar (1), Cavitation, HF or 200Hz – 1000Hz or similar (1)	3
b.	Describe the features of the IEPE accelerometer, include what IEPE means, the frequency range it covers, and where and how it will be located. (3) MARKING SCHEME: must have: IEPE = Integrated Electronics Piezo-electric (1) 5Hz – 25kHz or similar (1) Any one of the following: On bearing housing or structural part (1) Horizontal, Vertical and Axial (1) Attach with Screw Glue or Probe (1)	3
c.	Describe (at least two) types of vibration units and type of display you would record, and an example of which fault it will detect. (2) MARKING SCHEME: Any two of the following: Vibration Severity or Overall Velocity or rms velocity and one of: unbalance, looseness, misalignment and one of: spectra, trend (1) Overall Acceleration or Acceleration rms and one of: bearing noise, cavitation and one of: spectra, trend (1) Peak acceleration and bearing damage and one of: spectra, trend (1) Displacement (0)	2
d.	What speed will the motor actually run at? Give an example of a "vibration severity" value which you would consider to be unacceptable for long term operation. Include units and the units' qualifier. (2) MARKING SCHEME:	2

Ref	Question 2 Answers	Marks
	Any one of: 49Hz or 2840 r/min or 2840 cpm (1) Any one of: > 5 mm/s rms, any value over 5 mm/s rms, See ISO 10816-7 (1) Note: Units Qualifier means: rms, pk or pk-pk	

3) Describe the three types of vibration transducer. For each type of transducer give the following information:

a) Type, Units, Typical Frequency Range

b) Typical Sensitivity

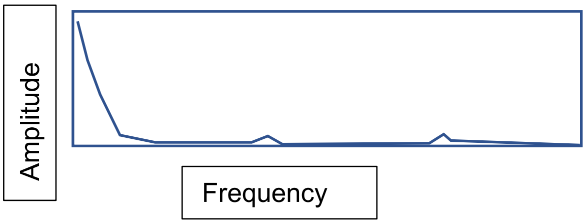
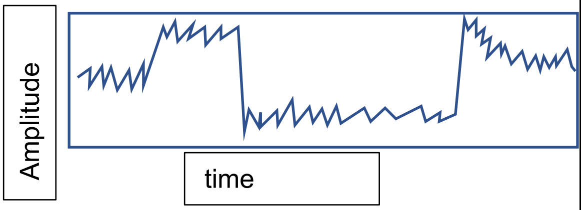
c) Example Fault, Example Machine or Component Application. (Total 10 marks)

Ref	Question 3 Answers	Marks
a.	MARKING SCHEME: Selection of following: Any three of the following: Accelerometer, m/s2, g, 2Hz – 10000Hz, 100 mV/g (2) plus any one of: Unbalance, Looseness, Misalignment, Bearing noise, Bearing Damage, Cavitation, etc. (1) plus one of: Ball bearing, roller bearing etc. (1)	4
b.	MARKING SCHEME: Selection of following: Any three of the following: Velocity Transducer, mm/s, 10Hz – 1000Hz, 100 mV/mm/s (2) plus any one of: Unbalance, Looseness, Misalignment etc. (1) plus one of: Fan, Blower, Centrifuge etc (1).	4
c.	MARKING SCHEME: Selection of following: Any three of the following: Proximity Probe, Displacement Sensor, 0 – 1000Hz, 8 mV/µm (2) plus any one of: Unbalance, Looseness, Rubs, Misalignment, Oil Whirl etc. (1) plus one of: Steam Turbine, Journal Bearing etc (1)	4

(Only 10 max to be awarded)

4) Briefly describe some typical symptoms indicating a poor signal, and suggest what may be the cause. (10 marks)

Answer

Symptom of poor data	Possible causes
Ski Slope in the FFT 	Low frequency noise in signal due to: movement of transducer during measurement, or tribo-electric noise due to cable movement, or intermittent power supply to transducer due to cable breakage
Sudden jumps in time signal 	Intermittent signal due to: Faulty cable, or Faulty amplifier, or Faulty power supply, or Mechanical shocks to the transducer
Unbelievably high or low value, eg 100g or 0.01µm as an rms reading Bias voltage may be outside expected range	High values due to: Signal noise (eg line frequency), or Mechanical shocks to the transducer, or Transducer fault Low values due to: Short circuit, or) Bias Open circuit, or) Voltage Broken cable, or) wrong Broken transducer, or) Failed power supply)
Line frequency (and harmonics) in spectrum	Ground loop. Note Generators run at line frequency, so check the run down data if line frequency interference is suspected.
Tribo electric noise	Changes and induced signals in the electrical properties of the cable due to movement flexing the insulation.

High reading from a single measurement point, with no indication of increased levels from neighbouring points	Single poorly taken reading, eg due to incorrectly mounted sensor.
Signal contains multiple harmonics of main vibration component, but only seen from a single measurement point on the machine: Note this is particularly difficult to diagnose as the signal may not be significantly higher or lower, but the frequency content will not resemble that from neighbouring measurement points	Loose attachment of the transducer; cracked piezo-electric crystal, or dirt on mating surface causing transducer to rock.

If in doubt, repeat the measurement.

5) **Describe the effect of transducer mounting on the frequency response of an accelerometer. (10 marks)**

Answer:

In the ideal case an accelerometer should be mounted rigidly to the machine, using a rigid stud, such as attached to a drilled and tapped hole, with a prepared flat surface around it. This arrangement will give a natural frequency above 30kHz.

If electrical properties require the use of an insulated mounting, the stiffness will be reduced slightly, typically giving a natural frequency of around 28kHz.

A stud attached with a stiff adhesive, such as iso-cyanate (once fully cured) will also give a natural frequency of around 28kHz.

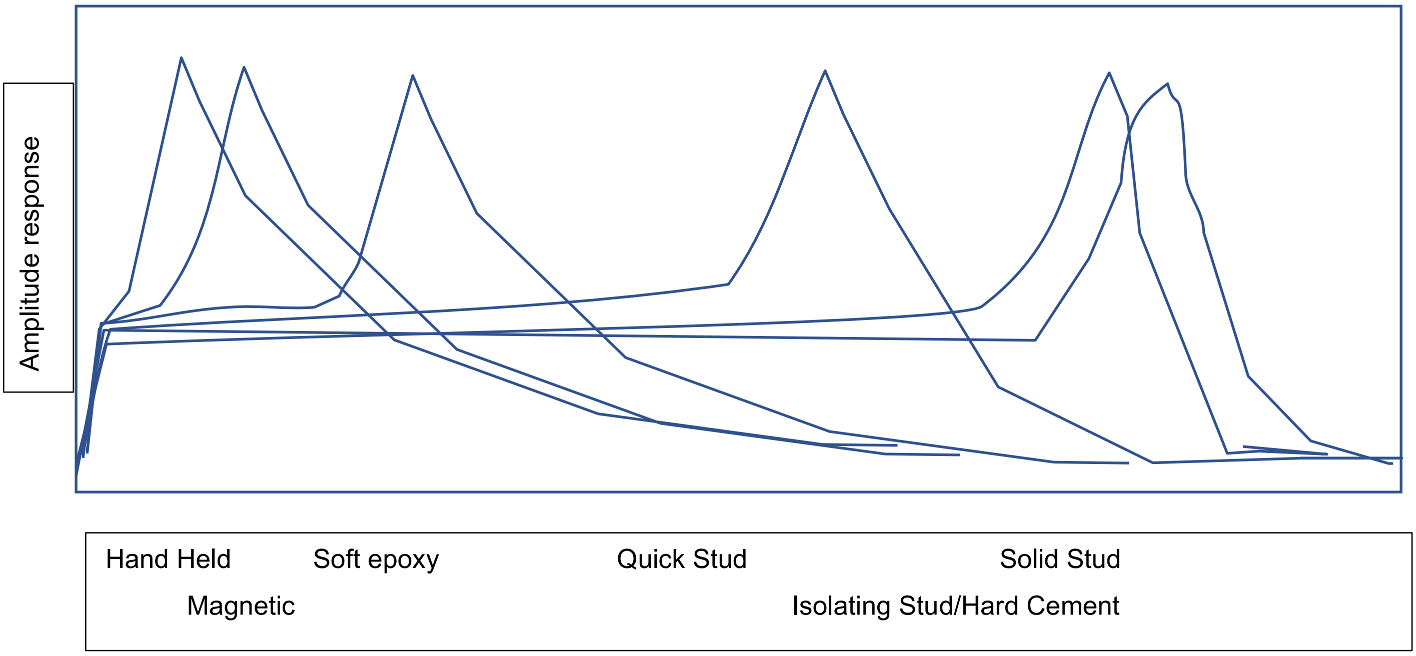
Quick fix studs also result in some loss of stiffness, particularly if dirt is allowed to accumulate on the mating surface. A new clean quick fix stud may have a natural frequency as high as 20kHz, but a worn stud with a dirty surface may be as low as 10kHz.

Soft epoxy, such as two-part resin can give natural frequencies of around 8kHz.

Using a permanent magnet mount can give varying results depending on the condition of the mounting surface. Where a flat steel disc has been attached to mark the measurement position, and cleaned regularly, up to 7kHz is possible, but on a painted curved surface, care is required to achieve a natural frequency of 2kHz.

A hand held “Stinger” is generally not recommended, but will give varying results depending upon the material and length of the probe, and the skill and strength of the operator. Maximum natural frequencies are in the range 0.5-2kHz.

Above the natural frequency, the sensitivity of the measurement drops off rapidly.



6) **What parameters are included in the calculation of kinematic frequencies for rolling element bearings? parameters are included in the calculation of kinematic frequencies for rolling element bearings? (10 marks)**

Answer:

Kinematic frequencies for rolling element bearings define the over-roll frequencies for different components of the bearing. The key parameters used to calculate these frequencies are:

d	diameter of the rollers
D	pitch diameter of the bearing
n	number of rollers
N	shaft speed
$\cos\alpha$	cosine of the contact angle.

Often the shaft speed is set to 1 Hz to allow the equation to apply at a given speed

The equations are slightly different depending whether the inner or outer race is fixed (or neither in the case of some aero-derivative gas turbines)