Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 008 - Vibration Levels and Shock Loads

DEFINITION

Vibration Levels can be considered to be continuous shock loads that are present at all times when the generating set is operational in-service.

Shock Loads should be considered as momentary one-off conditions resulting from rough handling, or extraordinary - very low frequency - vibration resulting from an event external to the generating set and its base frame.

DESCRIPTION

Cummins Generator Technologies manufacture ac generators (alternators) to ensure compliance with **BS 5000, Part 3**:

> **BS 5000-3:2006.** *Title: Rotating electrical machines of particular types or for particular applications. Generators to be driven by reciprocating internal combustion engines. Requirements for resistance to vibration.*

Vibration Levels.

Cummins Generator Technologies expect its alternators to be incorporated into generating sets that have been designed to ensure that the in-service **vibration levels** will not damage any of the alternators component parts. The manufacturers of the engine, radiator, exhaust system, electrical control panel, etc. will all have the same expectation. The reference standards that identify acceptable vibration limits are: **BS 5000-3:2006** and **ISO 8528-9.**

BS 5000-3:2006 states that the generator shall be capable of continuously withstanding linear vibration levels with a velocity of 9.0 mm/s RMS.

Alternators incorporated in generating sets designed to operate for short operating periods at a Peak Standby Duty as defined in **ISO 8528-9**, can be subjected to higher vibration levels, for these shorter periods of duration, with vibration levels < 18.0 mm/s.

Shock Loads.

Maximum Shock Loads – Level 1.

Cummins Generator Technologies have designed alternators to tolerate shock acceleration levels in the order of 3g in any of the three planes. This condition should be an abnormal situation rather than continuous and can therefore, be considered to be stressful without being destructive, providing the frequency of such events are not part of the normal continuous duty cycle.

If the generating set is likely to be subjected to shock loading levels above 3g, then it is expected the design of the generating set base frame will incorporate anti-vibration mounts that restrict the full effect of these events to ensure the generator shock loads are below the stated 3g level.

Maximum Shock Loads – Level 2.

For infrequent transient shock load occurrences an alternator manufactured by Cummins Generator Technologies will tolerate a level of 6g radially, but still only 3g axially.

Following any such severe event it would be prudent to:

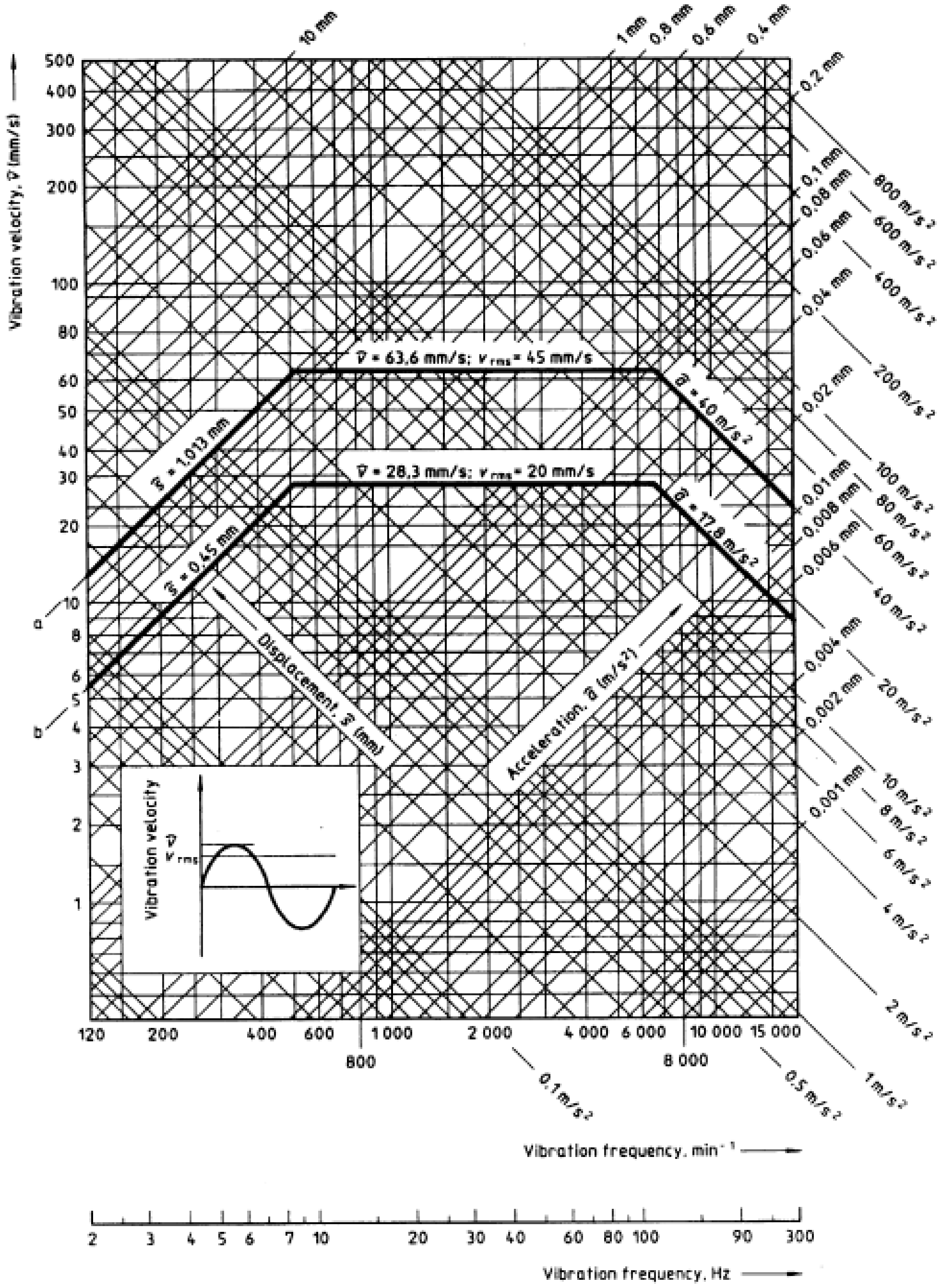
- Establish the condition of the bearings by monitoring their operating vibration levels and if possible assessing the results by comparing with historical maintenance data for the equipment package.
- Inspect the coupling assembly for signs of distress.
- Inspect the structure of the generating set for evidence of relative movement or structural distress.

TECHNICAL DISCUSSION

ISO 8528-9 explores the relationship between vibration velocity and vibration frequency. In Figure C1 (next page), example limiting curves for sinusoidal vibrations are published.

To help with understanding Figure C1 of **ISO 8528-9,** the following guide is offered. This will assist with understanding why the acceptable level lines have an inverted **U** shape, and why the graph has so many axes.

- **Low** frequency vibrations, typically <10Hz are considered as **DISPLACEMENT** mm.
- **Medium** frequency vibrations 10 < 100 Hz, and this is the range most commonly encountered in an alternator / engine assembly, are considered as **VELOCITY** mm/sec.
- **High** frequency vibrations, in our industry identified as those above 100Hz, are considered as an **ACCELERATION** m/sec^2.



Examples for limiting curves for sinusoidal vibrations

Curve a: Example RIC engine (see table C.1), v_{rms} = 45 mm/s

Curve b: Example generator (see table C.1), v_{rms} = 20 mm/s

Figure C.1 — Relationship between vibration velocity and vibration frequency

Accepting that a **Shock Load** is of a **Low** frequency and yet identified in terms of ‘g’ and therefore, an acceleration is somewhat contradictory to the above.

However, if 1g = 9.81m/s^2 it figures that the maximum allowable shock load of 3g is then 3 x 9.81 = 29.43m/s^2 call it 30m/s^2.

If now Figure C1 of **ISO 8528-9** is used to consider an acceleration of 30m/s^2 and this diagonal line is followed upwards and back towards the Y axis and considered at a frequency of 2Hz, then the actual Vibration velocity in mm/s is an horrific value, off the top of the Y axis scale.

But, for a sudden impact shock load to impart 3g, it would be a high momentary velocity that the generating set would be subjected to. Imagine the sudden deceleration when something is dropped onto a hard surface.

Remember that Figure C1 is a graph showing the limits associated with continuous operation VIBRATION levels, not extreme situation associated with a shock load.

In **ISO 8528-9** Table C1 provides RMS values for vibration velocity, displacement and acceleration for RIC engine driven ac generator sets. This table identifies values for the allowable vibration levels in terms of Displacement, Velocity, and Acceleration.

Table C1 also provides conversion factors to change a Velocity to Acceleration or Displacement. For information; converting 3g to Velocity gives 29.43/ 0.628 = 46.86 mm/s and converting 3g to Displacement gives 46.86 x 0.0159 = 0.745 mm.

These lines can be superimposed onto the graph; Figure C1, and then considered against the recommended maximum shock load levels 1 and 2.

Table C.1 — Rms values for vibration velocity, displacement and acceleration of RIC engine driven AC generating sets (see clause 10)

Declared engine speed	Rated power output of the generating set (cos φ = 0,8)		Vibration displacement[a], s_{rms}			Vibration velocity, v_{rms}			Vibration acceleration[a], a_{rms}		
			RIC engine[b c]	Generator[b] value 1	Generator[b] value 2	RIC engine[b c]	Generator[b] value 1	Generator[b] value 2	RIC engine[b c]	Generator[b] value 1	Generator[b] value 2
min^{-1}	kV A	kW	mm	mm	mm	mm/s	mm/s	mm/s	m/s^2	m/s^2	m/s^2
⩾ 2 000 but ⩽ 3 600	⩽ 15 (1-cylinder engine)	⩽ 12 (1-cylinder engine)	—	1,11	1,27	—	70	80	—	44	50
	⩽ 50	⩽ 40	—	0,8	0,95	—	50	60	—	31	38
	>50	> 40	—	0,64[d]	0,8[d]	—	40[d]	50[d]	—	25[d]	31[d]
⩾ 1 300 but < 2 000	⩽ 10	⩽ 8	—	—	—	—	—	—	—	—	—
	> 10 but ⩽ 50	> 8 but ⩽ 40	—	0,64	—	—	40	—	—	25	—
	> 50 but ⩽ 125	> 40 but ⩽ 100	—	0,4	0,48	—	25	30	—	16	19
	> 125 but ⩽ 250	> 100 but ⩽ 200	0,72	0,4	0,48	45	25	30	28	16	19
	> 250	> 200	0,72	0,32	0,45	45	20	28	28	13	18
> 720 but < 1 300	⩾ 250 but ⩽ 1 250	⩾ 200 but ⩽ 1 000	0,72	0,32	0,39	45	20	24	28	13	15
	> 1 250	> 1 000		0,29	0,35		18	22		11	14
⩽ 720	> 1 250	> 1 000	0,72	0,24 (0,16)[e]	0,32 (0,24)[e]	45	15 (10)[e]	20 (15)[e]	28	9,5 (6,5)[e]	13 (9,5)[e]

NOTE The relationship between vibration velocity and vibration frequency is shown in Figure C.1.

[a] The values of s_{rms} and a_{rms} are determined from the following equations by using the values given in the table for v_{rms}.

$s_{rms} = 0{,}0159 \times v_{rms}$

$a_{rms} = 0{,}628 \times v_{rms}$

[b] In the case of flange housing coupled generating sets the values measured at point 5 [see Figure 1 a)] shall meet the values for generators.

[c] The stated values for RIC engines are applicable for engines with power outputs of more than 100 kW. For smaller engines with power outputs below 100 kW, no typical values exist.

[d] These values are subject to agreement between the manufacturer and customer.

[e] The values given in parentheses are applied to generators mounted on solid concrete foundations. In these cases the axial measurement for points 7 and 8 in Figure 1 a) and b) shall be 50 % of the values given in parentheses.