Vibration Acceptance Criteria

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Abstract

The effects of vibrating loads on structures can often be significantly greater than the effects of static loads of equal or greater magnitude. These effects can include: fatigue damage such as cracking and breakage, damage to operating equipment due to excessive ambient vibration and human discomfort, among others.

Traditionally, structures subjected to dynamic loads have been designed by trying to ensure that the major natural frequencies of the structure are not close to the frequency of the applied forces. While the calculation and study of the structure's natural frequencies presents a guide to the behaviour of the structure, it does not give the complete picture. Generally, the overall response of the structure to applied vibration forces should be determined and compared to defined acceptance criteria. Similarly, where vibration may be causing problems on existing structures, the overall response should be measured with appropriate equipment, and compared to acceptance criteria.

This article outlines the details of the codes/standards defining the acceptance criteria for vibration, particularly for vibration of industrial structures.

1. Structural Integrity

The German Standard DIN 4150 Part 3 provides vibration velocity guidelines for use in evaluating the effect of vibration on structural integrity (see Table 1). The guideline limits presented in the standard are based on experience, and are defined as 'safe limits' up to which no damage due to vibration effects has been observed for a particular class of building. "Damage" is defined by DIN4150 to include even minor non-structural damage. For continuous long term vibration, 10 mm/s peak vibration velocity is seen as a safe limit for structural integrity in industrial buildings.

Although these limits are defined in the code as being for vibration in the horizontal direction at the top floor of a building, ASPEC's experience with vibration studies at a number of Australian industrial plants has shown that these limits are effective for local vibration levels as well. Structural damage has been observed on members whereby the vibration velocity exceeds approx. 20-40 mm/s.

Table 1: Safe Limits for Structural Integrity for Long Term Continuous Vibration (DIN4150)

	Type of Structure	Guideline values for velocity in mm/s, of vibration in horizontal plane of highest floor, at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	10
2	Dwellings and buildings of similar design and/or occupancy	5
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	2.5

These guidelines are very useful as a first pass to determine the suitability of vibration levels. Where there are significant structural integrity concerns however, a detailed vibration and fatigue analysis, often using Finite Element methods (FEA), may be required. Again this analysis should consider the full response of the structure to the applied vibration forces, and the resulting loads and stresses developed in the structure.

2. Equipment Serviceability

High levels of vibration can adversely affect the life of operating equipment and can increase the frequency of breakdowns, leading to excessive maintenance. A great deal of work is often conducted to measure the balance and vibration of individual pieces of equipment, but often the level of ambient vibration transmitted through the supporting structure can have a significant effect on the life of equipment.

Equipment manufacturers may provide information on acceptable levels of ambient vibration; however where this information is not available, AS2625.1 and AS2625.2 provide guidelines for evaluating the effect of ambient vibration on the life of equipment.

Depending on the class of the equipment (e.g. small, medium, large etc), AS2625 defines RMS vibration velocity limits corresponding to different qualitative evaluation zones (see Figure 1).

The four zones are defined in the standard as:

- GOOD (Zone A): The vibration of newly commissioned machines would normally fall within this zone.
- ALLOWABLE (Zone B): Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.
- JUST TOLERABLE (Zone C): Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.
- NOT PERMISSIBLE (Zone D): Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

These guidelines are especially useful where sensitive equipment is required to operate in the vicinity of highly vibrating equipment.

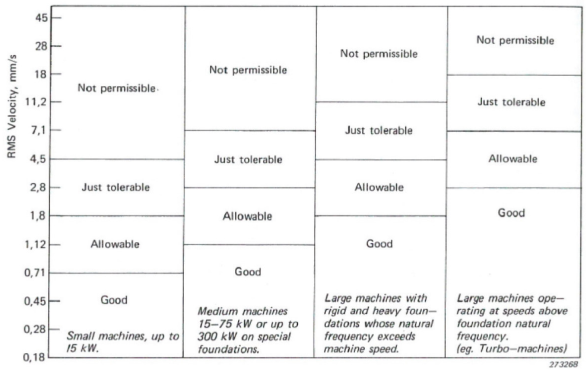

Figure 1: Machine Vibration Criterion Chart (AS2625)

3. Human Body Perception & Response

The human body can detect magnitudes of vibration lower than those which would normally cause mechanical or structural problems. The "discomfort" or "annoyance" produced by whole body vibration is a very influential factor and may be the one of the limiting parameters in the design of the structure.

Data on human exposure to vibration has been incorporated into AS2670: Evaluation of human exposure to whole-body vibration. Vibration exposure limits are given as a function of:

- Direction of motion, either horizontal or vertical.
- Frequency of vibration.
- Acceleration of the oscillations.
- Exposure time.

The method prescribed in AS2670.2 for vibration between 1 and 80 Hz, is to compare the magnitude of RMS vibration (acceleration) to established base curve levels which are approximately equal to a level of significant human annoyance and/or complaints about interference with activities (see Figure 2). A more complicated analysis is required for vibration below 1 Hz.

Depending on the type of building these base curves are multiplied by a factor to determine an acceptable level of vibration (see Table 2).

For example the level of acceptable vibration in industrial buildings (workshop) is generally of the order of 0.1 m/s (at approx. 20 Hz or 1200 RPM), which is much greater than that of residential buildings (0.013 m/s at night) etc. This is taken from the base curve value at 20 Hz in Figure 2 multiplied by the appropriate working environment factor (8), shown in Table 2.

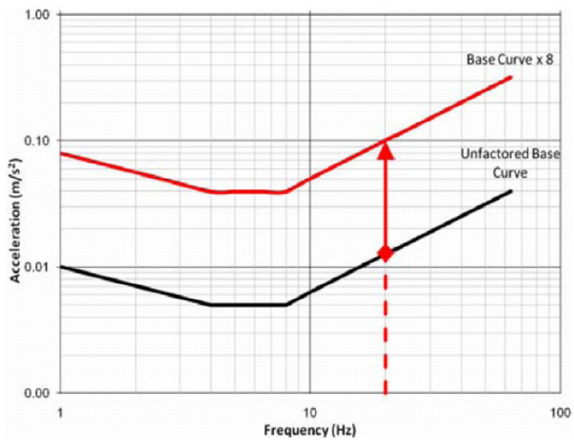

Figure 2: Vertical Axis Base Curve Acceleration for Human Comfort (AS2670)

Table 2: Base Curve Factors for Differing Working Environments (AS2670)

Place	Time	Continuous or intermittent vibration	Transient vibration excitation with several occurrences per day
Critical working areas (for example some hospital operating-theatres, some precision laboratories etc)	Day	1	1
	Night		
Residential	Day	2 to 4	30 to 90
	Night	1.4	1.4 to 20
Office	Day	4	60 to 128
	Night		
Workshop	Day	8	90 to 128
	Night		

It is also important to be clear as to the convention used to describe the vibration amplitude. Vibration acceptance levels can be expressed in Peak values or RMS values.

Peak values, or "Zero-to-Peak" values, are a direct measure of the amplitude of an oscillating signal. RMS, or "Root Mean Square" is a statistical measure of a moving set of values. Other common types of amplitude measurement include "Peak-Peak" or an "Average" value (see Figure 3). All of these values can be determined from a vibration signal.

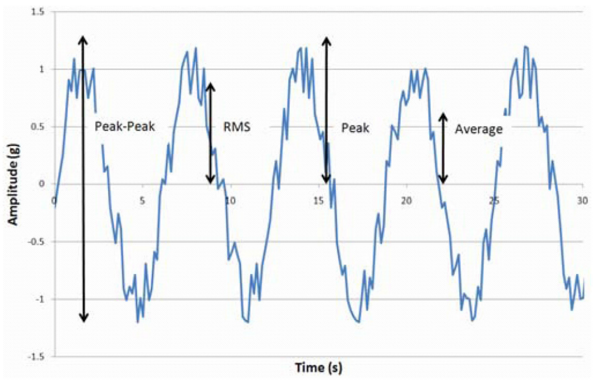

Figure 3: Example Vibration Trace with Definitions

4. Summary

Excessive vibration in structures can lead to a range of detrimental effects, and should be assessed against established acceptance criteria. The three main criteria (and relevant codes) that need to be considered when evaluating the effects of vibration are:

- Structural design with respect to fatigue life (DIN 4150)
- Equipment serviceability (AS2625)
- Human body perception and response (AS2670)

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