Lifetime Reliability • Solutions

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

The Lifetime Reliability Solutions
Certificate Course in Maintenance and Reliability
Module 2 – Machinery Vibration Analysis Fundamentals

Session 11
Standards for Machinery Acceptance Testing and Balancing

1. Introduction.

An important question we have not yet considered is 'What is an acceptable level of vibration for the machines that are under our care?'

Since the 1960's there have been numerous Standards published internationally dealing directly or indirectly with the vibration of rotating machinery.

The first Australian Standards were the AS2625 series of which appeared from 1983. They were specifically geared to acceptance testing of new or repaired machines. There were some associated Standards dealing with the vocabulary of vibration, shop balancing and requirements for instruments.

Very recently there has been a new series of ISO Standards published that significantly extend and update the AS2625 series and these will undoubtedly be adopted or adapted by Australian Standards in due course.

However, the AS2625 series and associated Standards are still the current Australian Standards and we will look at the requirements of these Standards first. Then we will quickly review the additional scope of the new ISO Standards before looking at the related matter of shop balancing.

2. Australian Standards for Machinery Acceptance Testing.

This series of Standards was issued from 1983 onwards and was based on ISO Standards developed in the 1960's.

The basis of these Standards is the measurement of Vibration Severity which is the RMS Velocity measurement of machine vibration in the frequency band 10 Hz to 1000 Hz. There were four condition grades - Good, Satisfactory, Unsatisfactory and Unacceptable - assigned to various measured levels of vibration, according to the classification of each machine.

Note that none of these Standards make any reference to Condition Monitoring as they were purely intended as guidelines for specifying new machinery and post-overhaul performance.

2.1 **AS 2625 Part 1 – 'Rotating and reciprocating machinery – Mechanical vibration: Part 1 – Basis for specifying evaluation standards'.**
This Standard sets out the basic principles of the method and application of the series of Standards. It proposes a table of vibration severity levels in 4dB steps (a ratio of 1:1.6).

The following Table sets out the guidelines.

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

AS 2625 PART 1 SEVERITY GUIDELINES
Range: 10 Hz to 200 Hz Shaft Speed
Vibration Bandwidth: 10 Hz to 1000 Hz
Class I Machines. Small machines to 15 kW
Class II Machines. 15-75 kW on light foundations
15-300 kW on heavy foundations
Class III Machines Above 300 kW on heavy and rigid foundations
Class IV Machines Above 300 kW on flexible foundations (soft mount)
Classes V and VI not listed

<table>
<tr><th>RANGES OF VIBRATION SEVERITY</th><th colspan="4">QUALITY JUDGEMENTS</th></tr>
<tr><th>RMS Velocity (mm/s RMS)</th><th>I</th><th>II</th><th>III</th><th>IV</th></tr>
<tr><td>0.28
0.45
0.71</td><td>A</td><td rowspan="2">A</td><td rowspan="3">A</td><td rowspan="4">A</td></tr>
<tr><td>1.12</td><td rowspan="2">B</td></tr>
<tr><td>1.80</td><td rowspan="2">B</td></tr>
<tr><td>2.80</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4.50</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>7.10</td><td rowspan="4">D</td><td rowspan="2">C</td></tr>
<tr><td>11.2</td><td rowspan="3">D</td><td rowspan="2">C</td></tr>
<tr><td>18.0</td><td rowspan="2">D</td></tr>
<tr><td>28
45</td><td>D</td></tr>
</table>

2.2 AS 2625 Part 3 – 1983 "Measurement and evaluation of vibration severity of large machines in situ". For machines with power ratings more than 300 kW.

Rigid Mounting Class III in Part 1.
Flexible Mounting Class IV in Part 1.

2.3 AS 2625 Part 4 – 1986 "Measurement and evaluation of vibration severity of small rotating machines". For machines with power ratings less than 300 kW.

Machine classifications are determined firstly by speed, then mounting conditions and then by coupling type. The resulting classification is then applied to the Part 1 table.

<table>
<tr><th colspan="6">SHAFT SPEED (RPM)</th></tr>
<tr><th colspan="3">LESS THAN 2000</th><th colspan="3">GREATER THAN 2000</th></tr>
<tr><th>MOUNTING</th><th>DRIVE</th><th>CATEGORY</th><th>MOUNTING</th><th>DRIVE</th><th>CATEGORY</th></tr>
<tr><td rowspan="2">Rigid mounting</td><td>Rigid drive</td><td>I</td><td rowspan="2">Rigid mounting</td><td>Rigid drive</td><td>II</td></tr>
<tr><td>Flex drive</td><td>II</td><td>Flex drive</td><td>III</td></tr>
</table>

Lifetime Reliability • Solutions

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

Flexible mounting	Rigid drive	II	Flexible mounting	Rigid drive	III
	Flex drive	III		Flex drive	IV

2.4 AS 1359 Part 114 – 1997 "Rotating electrical machines – General requirements. Part 114: Vibration measurements and limits".

This Standard superseded AS 2625 Part 2 in 1997. It is much more comprehensive in description and test requirements and includes proximity probe displacement allowances. All new motors sent out for re-work should be acceptance tested according to the requirements of this Standard.

Three grades are given – N (Normal) R (Reduced) and S (Special).

The N grades are listed below.

LIMITS OF VIBRATION SEVERITY VS SHAFT HEIGHT FOR 'N' GRADE

SPEED	FREE SUSPENSION				RIGID MOUNTED
RPM	56-132 mm	132-225 mm	225-400	>400	>400
600-3600	1.8	2.8	3.5	3.5	2.8

The shaft height for an electrical machine is the vertical distance between the shaft centreline and the baseline of a typical foot-mounted frame for that machine.

2.5 Other Standards.

Several other Standards in this series are noted here.

AS 2606 1983 "Vibration and shock – Vocabulary". A useful glossary of terms.
AS 2641 1983 "Vibration and shock – Balancing Vocabulary".
AS 2679 1984 "Requirements for instruments for measuring vibration severity".

3. New ISO Standards.

At the time of writing these notes there were five new ISO Standards published under the general title of **"Mechanical vibration – Evaluation of machine vibration by measurement on non-rotating parts".** A sixth Standard is expected to be published shortly to complete the series. We understand that it will deal with hydraulic pumps and motors.

Some brief notes on each of these new Standards.

3.1 ISO 10816-1:1995(E). Part 1: General Guidelines.

This is comparable to AS 2625 Part 1 in that it sets out the ground rules for the series. Significant differences are as follows.

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

- It includes specific reference to the use of these guidelines for 'operating condition monitoring' as well as acceptance testing.
- The frequency range is no longer restricted to the 10 to 1000 Hz band.
- Reference is made to high frequency acceleration measurements required for bearing condition monitoring and an informative Annex is given on this subject.
- Provision is made for measurements in displacement, velocity and acceleration.
- Diagrams are provided showing suggested measurement locations for horizontal and vertical electrically driven machines and also reciprocating machines.
- Reference to the required instrumentation to provide acceptable measurements of broadband vibration.
- Two Evaluation Criteria are proposed: one to consider the magnitude of the measured vibration; the other considers changes in magnitude (ie, for condition monitoring purposes).
- The former wordy descriptions for machine evaluation (Good, Satisfactory, etc) are replaced by four Zones, A, B, C and D. The determination of these zones is quite flexible even though the suggested values in Annex B for Velocity are exactly the same as for AS 2625 Part 1.
- Guidelines for seismically measured Displacement and Acceleration are also given.
- Guidelines are also proposed for the setting of Alarms and Trips.

In summary, this Standard represents a much more 'real world' approach to the business of machinery acceptance testing. One hopes that it will be adopted by Australian Standards in the near future.

3.2 ISO 10816-2: 1996(E). Part 2: Large land-based steam turbine generator sets in excess of 50 MW.

This Standard applies the principles set out in Part 1 and suggest vibration velocity zone boundaries for two different speed ranges. Unlike AS 2625 Part 3 there is no consideration given to mounting considerations.

3.3 ISO 10816-3: 1998(E). Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.

This Standard covers a very wide range of machines and is complex to apply. It is recommended that engineers with responsibilities in this area should become acquainted with this Standard.

The proposed Evaluation zone boundaries are tabulated for four different groupings of machines and, interestingly, the velocity values do not necessarily follow the numbers used in Part 1. Values are given for RMS Velocity (the preferred parameter) and also for RMS Displacement values.

3.4 ISO 10816-4:1998(E). Part 4: Gas turbine driven sets excluding aircraft derivatives.

This is a new Standard without a precedent in the AS 2625 series. RMS velocity values are given for a wide range of turbine speed ranges.

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

3.5 ISO 10816-6: 1995(E). Part 6: Reciprocating machines with power ratings above 100 kW.

This again is a new Standard and ,while it is relatively short, it is fairly complex in its application.

Limiting values are proposed for Displacement, Velocity and Acceleration and seven different Evaluation Zones listed.

Forms for data collection are suggested to assist with the process of collection and evaluation of data. A vibration severity grade nomogram is also supplied.

The experience of the writer suggests that the condition and reliability of reciprocating engines is poorly defined by vibration measurements alone and this Standard seems to be a bit 'over-the-top' for either acceptance testing or condition monitoring purposes.

4. Mechanical Balancing (Workshop Balancing).

Mechanical Balancing (also called Workshop Balancing) is not to be confused with In-Situ Balancing which is a distinctly different technique.

There is often confusion and uncertainty in industry as to how the quality of 'shop balancing' can be related to the measured vibration of the rotor in the machine after balancing, and hence to the AS 2625 guidelines.

The short answer is that the two (generally speaking) cannot be directly related. However, a thorough understanding of the principles of shop balancing will assist to provide a result that will be more than satisfactory.

4.1 Mechanical Balancing Standard.

AS 3709-1989 'Vibration and shock – Balance quality of rotating rigid bodies' is the relevant Standard. Every machinery engineer *must* have access to a copy of this Standard.

On the following pages we reproduce the key evaluation tables from the Standard.

It is important to note that this Standard is taken from an ISO Standard that had its origins in the 1960's. Therefore the 'General Examples' tabulated there for Rotor Types represent the reasonable target eccentricities for the technology of those days.

With modern balancing machines and a precision approach to rotor assembly it is possible to aim for at least one - and preferably two – grade improvements compared to what is tabled.

For example, it is quite possible to balance a quality pump rotor to G1 whereas the Standard suggests G6.3 for this type of component.

However, working to these tolerances demands a much greater appreciation of fits and tolerances in machining and the assignment of keyway masses and the like.

4.2 The Balancing Process.

In the balancing shop the rotor is supported on its bearing journals in a pair of pedestals and driven at a speed which may well be a lot less than its service speed.

There are two different kinds of balancing machines:

a) **Soft Bearing Machine.** The rotor is supported in a suspension 'swing' assembly and the natural frequency of the supported assembly is typically very low. Therefore the rotor turns about its centre of mass and the eccentricity is measured directly by vibration probes attached to the swing assembly.
b) **Hard Bearing Machine.** The rotor is supported in trunnion assemblies that are rigidly mounted. Therefore the rotor is forced to run within its geometric centre and the force response is measured at the pedestals.

Both types of machines are capable of good results although the writer considers that the soft bearing machine has accuracy advantages for large, slow-moving rotors. These types of machines can also be taken to sites and used without special foundations as are required for hard bearing machines.

Regardless of the machine type the operator will run the rotor at a relatively slow speed and increase the speed with each improvement to balance until he is running the rotor as fast as either available driving power or safety dictates. Material will either be added to the rotor or removed according to the situation.

When the balance is completed to the required tolerance the operator will usually conduct a residual balance check as required in the Standard and prepare a Balance Quality Certificate for the client.

4.3 Required Information.

It is essential that the following information is supplied in writing to the balancing shop when the Order is raised for the balancing job.

- **The service speed of the rotor.**
- **The balance grade required.**
- **Where mass corrections are to be applied.**
- **Material for welding purposes**
- **The location of the bearing journals for mounting the shaft in the balancing machine. (**Mark with tape).

The balancing machine operator will use the first two items of information to determine the maximum residual eccentricity or unbalance allowable.

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

4.4 Quality Grades.

Quality Grades are quoted for G4000 to G0.4 and refer to the product of shaft eccentricity and circular velocity. The same number can describe eccentricity (in microns) and residual unbalance (in gram-mm/kilogram of rotor mass).

The selection of the best balancing grade that is achievable and practical will ensure that the rotor will give very acceptable balance performance in the machine.