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**Mechanical vibration — Susceptibility and
sensitivity of machines to unbalance**

iTeh STANDARD PREVIEW

*Vibrations mécaniques — Susceptibilité et sensibilité des machines aux
balourds*

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ISO 10814:1996

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Reference number
ISO 10814:1996(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10814 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 1, *Balancing, including balancing machines*.

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Annexes A to C of this International Standard are for information only.

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Introduction

Rotor balancing during manufacture (as described in ISO 1940-1 and ISO 11342, for example) is normally sufficient to attain acceptable vibration levels in service if other sources of vibration are absent. There are exceptions, however, where additional balancing during commissioning becomes necessary. Furthermore, after commissioning, some machines may require occasional or even frequent field rebalancing.

If the vibration levels are unsatisfactory during commissioning, the reason may be inadequate balancing or assembly errors. Another important cause may be that an assembled machine is especially sensitive to relatively small residual unbalances which are well within normal balance tolerances.

If vibration magnitudes are unsatisfactory, the first step often is an attempt to reduce the vibration by field balancing. If high vibration can be reduced by relatively small correction masses, high sensitivity to unbalance is indicated. This can arise, for example, if a resonant speed is close to the normal service speed and the damping in the system is low.

A sensitive machine which is also highly susceptible to its unbalance changing, may require frequent rebalancing *in situ*. This may be caused, for example, by changes in wear, temperature, mass, stiffness and damping during operation.

If the unbalance and other conditions of the machine are essentially constant, occasional trim balancing may be sufficient. Otherwise it may be necessary to modify the machine to change the resonant speed, damping or other parameters. Therefore, there is a need to consider permissible sensitivity values of the machine.

The repeatability of the sensitivity of a machine is influenced by several factors and may change during operation. Some thermal machines, especially those with sleeve bearings, have modal vibration characteristics which vary with certain operational parameters such as steam pressure and temperature, partial steam admission or oil temperature. For electrical machines, other parameters such as the excitation current may influence the vibration behaviour. In general, the machine vibration characteristics are influenced by the design features of the machine, including coupling of the rotor and the support conditions including the foundation. It should be noted that the latter may vary with time, for example owing to wear and tear.

This International Standard is only concerned with once-per-revolution vibration caused by unbalance; however it should be recognized that unbalance is not the only cause of once-per-revolution vibration.

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Mechanical vibration — Susceptibility and sensitivity of machines to unbalance

1 Scope

1.1 This International Standard defines methods for determining machine vibration sensitivity to unbalance and provides evaluation guidelines as a function of the proximity of relevant resonant speeds to the service speed.

It includes a classification of certain machines in groups associated with the susceptibility to a change in unbalance.

This International Standard also makes recommendations on how to apply the numerical sensitivity values in some particular cases.

1.2 Machines are classified into three types in clause 4, and sensitivity values assigned to different groups of machines are shown in clause 5. The sensitivity values should be used on simple machine systems, preferably with rotors having only one resonant speed over the entire service speed range. They may also be used for machines that have more resonant speeds in the service speed range if the resonant speeds are widely separated (e.g. more than 20 % spaced).

The proposed sensitivity values are not intended to serve as acceptance specifications for any machine group but rather to give indications of how to avoid gross deficiencies as well as exaggerated or unattainable requirements. They may also serve as a basis for more involved investigations, for example, when in special cases a more exact determination of the required sensitivity is necessary. If due regard is paid to the proposed values, satisfactory running conditions can be expected in most cases.

The consideration of these values alone does not guarantee that a given magnitude of vibration in service is not exceeded. Many other sources of vibration can occur which are not the subject of this International Standard.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1925:1990, *Mechanical vibration — Balancing — Vocabulary*.

ISO 2041:1990, *Vibration and shock — Vocabulary*.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 1925 and ISO 2041 and the following definitions apply.

3.1 susceptibility to unbalance: An indication of the likelihood of a machine having a significant change of unbalance over a certain period of operation.

3.2 sensitivity to unbalance: A measure of the vibration response of a machine to a change in unbalance.

NOTE 1 It is usually numerically expressed in the two ways shown in 3.2.1 and 3.2.2 below.

3.2.1 local sensitivity: Ratio of the magnitude of the change of the displacement or velocity vector in a specified measuring plane to the magnitude of a change in the unbalance in a specified plane in the rotor at a specified speed.

In technical terms, the local sensitivity can be expressed as:

$$S_{k,r} = \frac{|\Delta \bar{S}_k|}{|\Delta \bar{U}_r|} \quad \dots (1)$$

where

$|\Delta \bar{S}_k|$ is the change in once-per-revolution vibration in plane k ;

$|\Delta \bar{U}_r|$ is the change in trial unbalance attached to plane r in the rotor (or change in trial unbalance set).

NOTE 2 The local sensitivity is frequently referred to as the "influence coefficient". It is a dimensional quantity.

3.2.2 modal sensitivity, M_n : Ratio of the change of the modal displacement vector to a change of the modal eccentricity (modal unbalance divided by modal mass). It is a non-dimensional quantity.

In practical determinations of modal sensitivity, care should be taken to extract the relevant modal components.

Modal sensitivity for excitation of the machine by unbalance for mode n can be shown to be:

$$M_n = \frac{\left(\frac{\Omega}{\omega_n}\right)^2}{\sqrt{\left[1 - \left(\frac{\Omega}{\omega_n}\right)^2\right]^2 + 4\zeta_n^2\left(\frac{\Omega}{\omega_n}\right)^2}} \quad (2)$$

where

Ω is the rotational speed;

ω_n is the n th undamped resonant speed;

ζ_n is the damping ratio of the n th mode.

Under conditions where the rotational speed equals a resonant speed, M_n becomes approximately $1/(2\zeta_n)$. For light damping, this is the maximum amplification at resonance denoted by Q_n ; it is influenced only by the level of damping in the system.

NOTE 3 Modal sensitivity is sometimes referred to as the vibration magnification factor for mode n .

4 Machine susceptibility classification

4.1 Type I: Low susceptibility

Machines of this type have a low likelihood of experiencing significant unbalance changes during operation.

Typically, they have large rotor masses in comparison to the support housing and operate in a clean environment, have negligible wear and exhibit minimal rotor distortion caused by temperature changes.

EXAMPLES:

Paper machine rolls, printing rolls and high-speed vacuum pumps.

4.2 Type II: Moderate susceptibility

Machines of this type have a moderate likelihood of experiencing significant unbalance changes during operation, such as rotors in an environment with large temperature changes and/or moderate wear.

EXAMPLES:

Pumps in clean media, electric armatures, gas and steam turbines, small turbo generators for industrial applications and turbo compressors.

4.3 Type III: High susceptibility

Machines of this type have a high likelihood of experiencing significant unbalance changes during operation, such as blowers running in deposit producing environments, pumps operating in sludge, rotors with high wear or running in corrosive environments.

EXAMPLES:

Centrifuges, fans, screw conveyors and hammer mills.

5 Modal sensitivity values

5.1 Modal sensitivity ranges A to E

In figures 1 to 3, modal sensitivity is classified for service speeds below and above a resonant speed of the machine system. The range limits are chosen in such a way that, close to a resonant speed, the magnification factor is constant. The curves in figures 1 to 3 are derived from equation (2). The range limits depend on the type of machine in the susceptibility classification (the damping ratio being lower, in the same sensitivity range, for type III than for type I machines).

Generally, for the sensitivity ranges below, the corresponding running conditions given in table 1 can be expected.

Examples of how to use figures 1 to 3 are given in annex B.

Table 1

Modal sensitivity range	Expected running conditions
A: Very low sensitivity	Very smooth resonant speed; difficult to detect
B: Low sensitivity	Smooth, low and stable vibrations
C: Moderate sensitivity	Acceptable, moderate and slightly unsteady vibrations
D: High sensitivity	Sensitive to unbalance; regular field balancing may be required
E: Very high sensitivity	Too sensitive to unbalance; to be avoided

5.2 Characteristics of modal sensitivity

5.2.1 While range A will theoretically appear to be the most desirable, considerations of cost and feasibility may often make it necessary to operate with higher modal sensitivities.

5.2.2 For high-performance machines (e.g. those that have a short period between planned maintenance cycles), it may be permissible to allow higher values of modal sensitivity.

5.2.3 For machines for which field balancing is not practical or not economical, smaller values of modal sensitivity may have to be selected.

5.2.4 Consideration of the sensitivity does not always give sufficient assurance that, at all parts of the machine, vibration limits are not exceeded (see clauses 7 and 8).

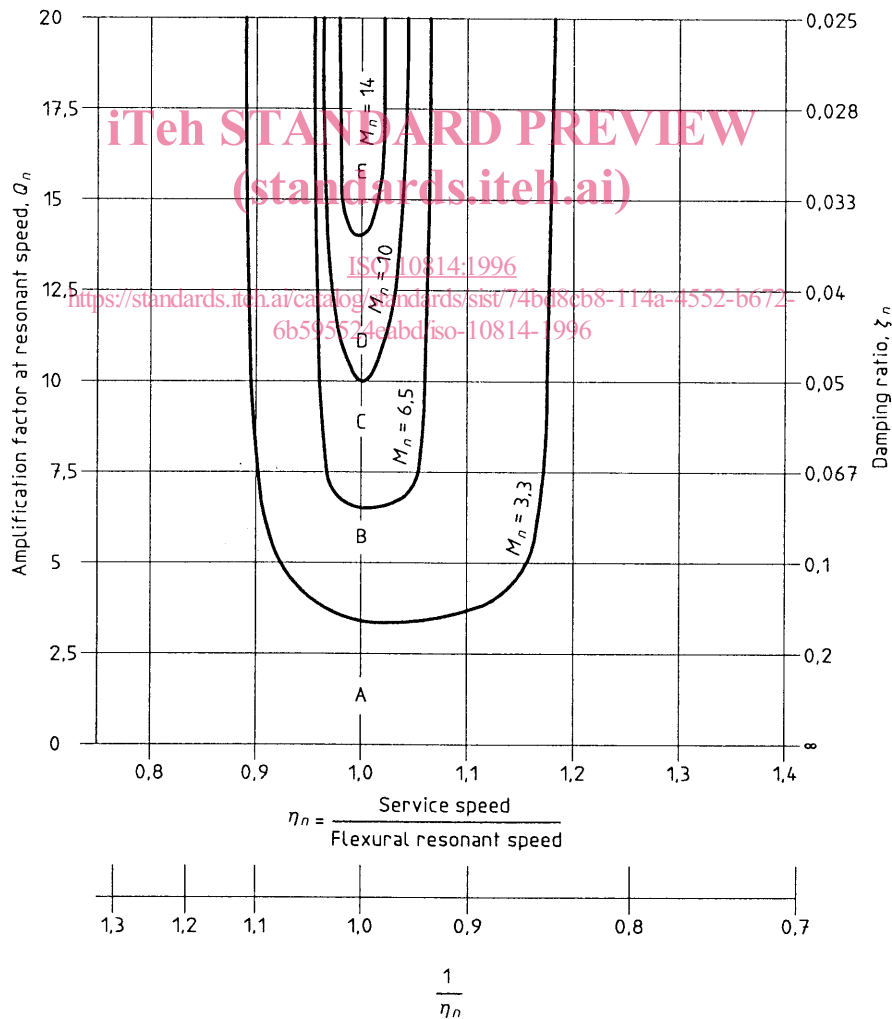


Figure 1 — Modal sensitivity ranges A to E for type I machines

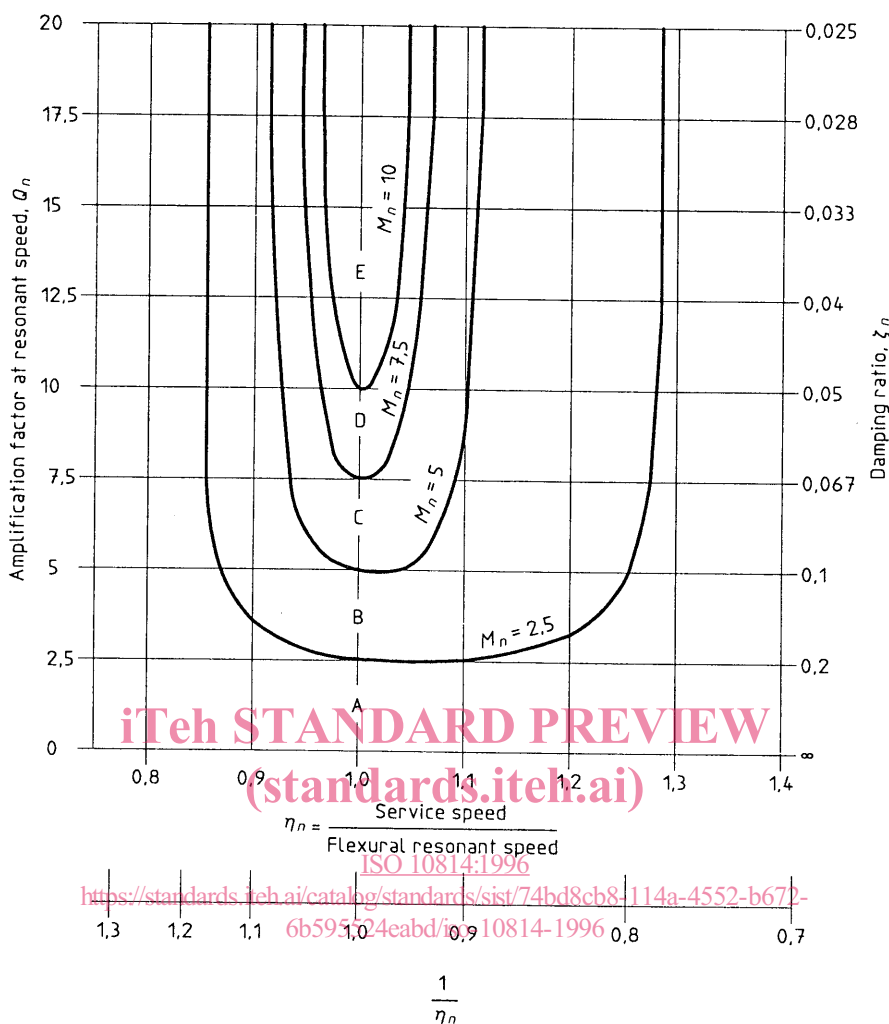


Figure 2 — Modal sensitivity ranges A to E for type II machines

5.3 Accelerating rotors

Higher values of the modal sensitivity are permissible for machines which, in service, always accelerate rapidly through all resonant speeds because steady-state response has insufficient time to develop. Machines which are only started and stopped infrequently may also be acceptable with higher values of modal sensitivity.

Figure 4 illustrates, for a single degree of freedom system, the reduction in the modal sensitivity as a function of the rotational acceleration. However, for most practical acceleration rates, this effect is small and can be neglected.

Such a reduction in the modal sensitivity may be calculated before referring to figures 1 to 3 (as these figures are only applicable for slowly accelerating rotors), taking the following points into account:

- a) passing through a resonant speed is assumed to happen with constant rotational acceleration;
- b) the modal sensitivity shall be tested (where possible) under steady-state conditions as close to the resonant speed as possible;
- c) the maximum amplitudes during rapid acceleration or deceleration will occur at rotor speeds different from the resonant speeds because of the delay in response.

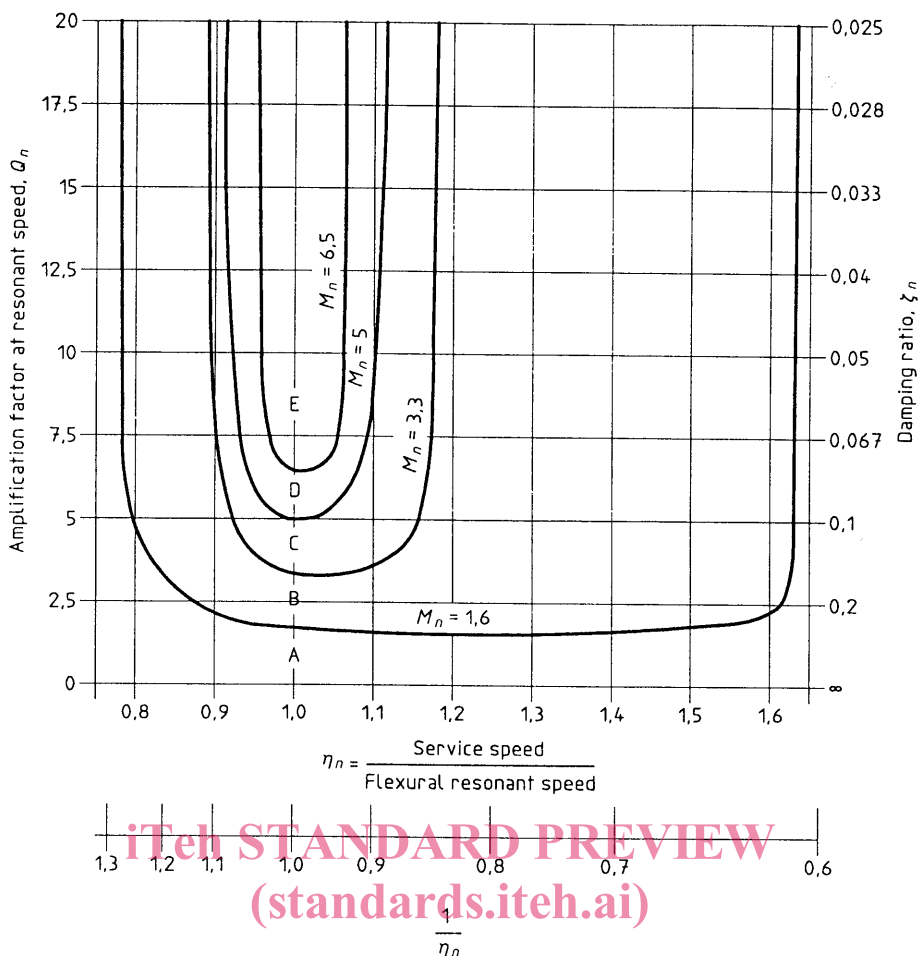


Figure 3 — Modal sensitivity ranges A to E for type III machines

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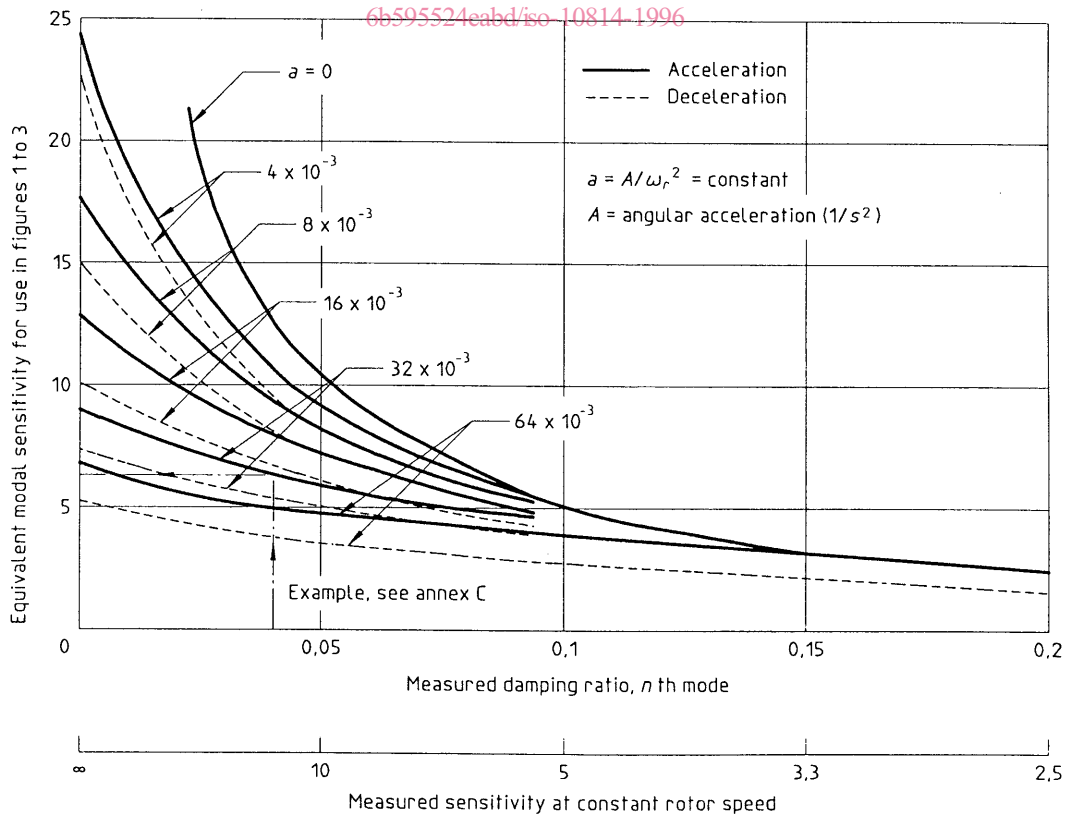


Figure 4 — Reduction of modal sensitivity as a function of the damping ratio and the rotational acceleration