Mechanical vibration – Methods and criteria for the mechanical balancing of flexible rotors


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Vibration och stöt – Metoder och kriterier för balansering av flexibla roteror


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Vibrations mécaniques — Méthodes et critères
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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 11342 was prepared by Technical Committee ISO/TC 108, Mechanical vibration and shock, Subcommittee SC 1, Balancing, including balancing machines.


Annexes A, B, C, D, E, F, G, H and J of this International Standard are for information only.
Introduction

The aim of balancing any rotor is satisfactory running when installed on site. In this context "satisfactory running" means that no more than an acceptable level of vibration is caused by the unbalance remaining in the rotor. In the case of a flexible rotor, it also means that no more than an acceptable magnitude of deflection occurs in the rotor at any speed up to maximum service speed.

Most rotors are balanced by their manufacturers prior to machine assembly because afterwards, for example, there may be only limited access to the rotor. Furthermore, balancing of the rotor is often the stage at which a rotor is approved by the purchaser. Thus, while satisfactory running on site is the aim, the balance quality of the rotor is usually initially assessed in a balancing facility. Satisfactory running on site is in most cases judged in relation to vibration from all causes, while in the balancing facility primarily once-per-revolution effects are considered.

Section 2 of this International Standard classifies rotors into groups in accordance with their balancing requirements and establishes in Section 3 methods of assessment of residual unbalance.

This International Standard also shows in Section 3 how criteria for use in the balancing facility may be derived from either vibration limits specified for the assembled and installed machine or unbalance limits specified for the rotor. If such limits are not available, this International Standard shows how they may be derived from ISO 10816-1 and parts 1 to 4 of ISO 7919, if desired in terms of vibration, or from ISO 1940-1 if desired in terms of permissible residual unbalance.

ISO 1940-1 is concerned with the balance quality of rotating rigid bodies and is thus not directly applicable to flexible rotors because they may undergo significant bending deflection. However, in subclauses 2.3 and 3.4 of this International Standard, methods are presented for adapting the criteria of ISO 1940-1 to flexible rotors.

As this International Standard is complementary in many details to parts 1 and 2 of ISO 1940, it is recommended that, where applicable, they should be considered together.
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Section 1: General

1.1 Scope

This International Standard classifies rotors into groups in accordance with their balancing requirements, describes balancing procedures, specifies methods of assessment of the final state of unbalance, and gives guidance on balance quality criteria.

All rotors are classified into those which can be balanced by rigid rotor, modified rigid rotor, or high-speed (flexible rotor) balancing techniques.

Two methods are specified for evaluating the balance quality of a flexible rotor in a balancing facility before machine assembly: the first assesses the vibration level, and the second assesses the rotor residual unbalance. If the rotor balance tolerances suggested herein are achieved during correction in a balancing facility, the specified vibration limits of the assembled machine in service (see ISO 10816-1 and parts 1 to 4 of ISO 7919) will most probably be achieved. Accordingly, the criteria specified are those to be met when the rotor is tested in the balancing facility, but they are derived from those specified for the complete machine, when installed, or from values known to ensure satisfactory running of the rotor when it is installed.

As in the case of parts 1 and 2 of ISO 1940, this International Standard is not intended to serve as an acceptance specification for any rotor group, but rather to give indications of how to avoid gross deficiencies and/or unnecessarily restrictive requirements. This International Standard may also serve as a basis for more involved investigations, for example when a more exact determination of the required balance quality is necessary. If due regard is paid to the specified methods of manufacture and limits of unbalance, satisfactory running conditions can most probably be excepted.

There are situations in which an otherwise acceptably balanced rotor experiences an unacceptable vibration level in situ, owing to resonances. A resonant or near-resonant condition in a lightly damped structure can result in excessive vibratory response to a small unbalance. In such cases, it may be necessary to alter the natural frequency or damping of the structure rather than to balance to very low levels, which may not be maintainable over time.

The subject of structural resonances and modifications thereof is outside the scope of this International Standard.

The methods and criteria given are the result of experience with general industrial machinery. They may not be directly applicable to specialized equipment or to special circumstances. Therefore, there may be cases where deviations from this International Standard may be necessary.

1.2 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

1) Information on such exceptions is welcomed and should be communicated to the national standards body in the country of origin for transmission to the secretariat of ISO/TC 108.
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.


1.3 Definitions

For the purposes of this International Standard, the definitions relating to mechanical balancing given in ISO 1925 and many of the definitions relating to vibration given in ISO 2041 apply.

Definitions given in ISO 1925 relating to flexible rotors are given for information in annex H.

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2) To be published.
Section 2: Balancing methods

2.1 Fundamentals of flexible rotor dynamics and balancing

2.1.1 Unbalance distribution

The rotor design and method of construction can significantly influence the magnitude and distribution of unbalance along a rotor. Rotors may be machined from a single forging or they may be constructed by fitting several components together. For example, jet engine rotors are constructed by joining many shell, disc and blade components. Generator rotors, however, are usually manufactured from a single forging, but will have additional components fitted. The distribution of unbalance may also be significantly influenced by the presence of large local unbalances arising from shrink-fitted discs, couplings, etc.

Since the unbalance distribution along a rotor is likely to be random, the distribution along two rotors of identical design will be different. The distribution of unbalance is of greater significance in a flexible rotor than in a rigid rotor because it determines the degree to which any flexural mode of vibration is excited. Moreover, the effect of unbalance at any point along a rotor depends on the bending deflection of the rotor at that point.

The correction of unbalance in transverse planes along a rotor, other than those in which the unbalance occurs, may induce vibrations at speeds other than that at which the rotor was originally corrected. These vibrations may exceed specified tolerances, particularly at or near the flexural critical speeds.

In addition, some rotors which become heated during operation are susceptible to thermal distortions which can lead to changes in the unbalance. If the rotor unbalance changes significantly from run to run, it may be impossible to balance the rotor within tolerance.

2.1.2 Flexible rotor mode shapes

If the effect of damping is neglected, the modes of a rotor are the flexural principal modes and, in the special case of a rotor supported in isotropic bearings, are rotating plane curves. Typical curves for the three lowest principal modes for a simple rotor supported in flexible bearings near to its end are illustrated in figure 1.

For a damped rotor/bearing system, the flexural modes may be space curves rotating about the shaft axis, especially in the case of substantial damping, arising perhaps from fluid-film bearings. A possible substantially damped second mode is illustrated in figure 2. In many cases, the damped modes can be treated approximately as principal modes and hence regarded as rotating plane curves.

It must be stressed that the form of the mode shapes and the response of the rotor to unbalances are strongly influenced by the dynamic properties and axial locations of the bearings and their supports.

2.1.3 Response of a flexible rotor to unbalance

The unbalance distribution can be expressed in terms of modal unbalances. The deflection in each mode is caused by the corresponding modal unbalance. When a rotor rotates at a speed near a critical speed, it is usually the mode associated with this critical speed which dominates the deflection of the rotor. The degree to which large amplitudes of rotor deflection occur in these circumstances is determined by:

a) the magnitude of the modal unbalances;

b) the proximity of the associated critical speeds to the running speeds; and

c) the amount of damping in the rotor/support system.