INTERNATIONAL STANDARD

ISO 1940-1

Second edition
2003-08-15

Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state —

Part 1:
Specification and verification of balance tolerances

Vibrations mécaniques — Exigences en matière de qualité dans l'équilibrage pour les rotors en état rigide (constant) —

Partie 1: Spécifications et vérification des tolérances d'équilibrage

Reference number
ISO 1940-1:2003(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1940-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 1, *Balancing, including balancing machines*.

This second edition cancels and replaces the first edition (ISO 1940-1:1986), which has been technically revised. The most important change is the introduction of reference planes for balance tolerances instead of using the correction planes as tolerance planes.

ISO 1940 consists of the following parts, under the general title *Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state*:

— *Part 1: Specification and verification of balance tolerances*

— *Part 2: Balance errors*

Introduction

A general introduction to balancing standards will be given in ISO 19499 (under preparation). For rotors in a constant (rigid) state, only the resultant unbalance and the resultant moment unbalance (resultant couple unbalance) are of interest, both together often expressed as dynamic unbalance.

The balancing machines available today enable unbalance to be reduced to low limits. However, it would be uneconomical to reduce the unbalances to these limits. On the contrary, it is necessary to specify the balance quality requirement for any balancing task.

Of similar importance is the verification of residual unbalances. For this verification, different balance errors have to be taken into account. An improved procedure to handle errors of the balancing machine is described in connection with ISO 1940-2.

Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state —

Part 1:
Specification and verification of balance tolerances

1 Scope

This part of ISO 1940 gives specifications for rotors in a constant (rigid) state. It specifies

a) balance tolerances,

b) the necessary number of correction planes, and

c) methods for verifying the residual unbalance.

Recommendations are also given concerning the balance quality requirements for rotors in a constant (rigid) state, according to their machinery type and maximum service speed. These recommendations are based on worldwide experience.

This part of ISO 1940 is also intended to facilitate the relationship between the manufacturer and user of rotating machines, by stating acceptance criteria for the verification of residual unbalances.

Detailed consideration of errors associated with balancing and verification of residual unbalance are given in ISO 1940-2.

This part of ISO 1940 does not cover rotors in a flexible state. The balance quality requirements for rotors in a flexible state are covered by ISO 11342.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1925:2001, *Mechanical vibration — Balancing — Vocabulary*

ISO 1940-2, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 2: Balance errors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1925 apply. For the convenience of users, some of these definitions are cited below.

NOTE Some of these definitions are at present under review.

3.1
balancing
procedure by which the mass distribution of a rotor is checked and, if necessary, adjusted to ensure that the residual unbalance or the vibration of the journals and/or forces on the bearings at a frequency corresponding to service speed are within specified limits

[ISO 1925:2001, definition 4.1]

3.2
unbalance
condition which exists in a rotor when vibration force or motion is imparted to its bearings as a result of centrifugal forces

[ISO 1925:2001, definition 3.1]

3.3
initial unbalance
unbalance of any kind that exists in the rotor before balancing

[ISO 1925:2001, definition 3.11]

3.4
residual unbalance
final unbalance
unbalance of any kind that remains after balancing

[ISO 1925:2001, definition 3.10]

3.5
resultant unbalance
vector sum of all unbalance vectors distributed along the rotor

NOTE 1 See notes to definition 3.6.

[ISO 1925:2001, definition 3.12]

NOTE 2 This can be expressed as

$$\vec{U}_\mathrm{r} = \sum_{k=1}^{K} \vec{U}_k$$

where

$\vec{U}_\mathrm{r}$ is the resultant unbalance vector (g·mm);

$\vec{U}_k$ are the individual unbalance vectors, numbered 1 to K.

3.6
resultant moment unbalance
vector sum of the moments of all the unbalance vectors distributed along the rotor about the plane of the resultant unbalance

NOTE 1 The resultant unbalance together with the resultant moment unbalance describe completely the unbalance of a rotor in a constant (rigid) state.

NOTE 2 The resultant unbalance vector is not related to a particular radial plane, but the amount and angular direction of the resultant moment unbalance depend on the axial location chosen for the resultant unbalance.

NOTE 3 The resultant unbalance vector is the vector sum of the complementary unbalance vectors of the dynamic unbalance.

NOTE 4 The resultant moment unbalance is often expressed as a pair of unbalance vectors of equal magnitude, but opposite directions, in any two different radial planes.

NOTE 5 This can be expressed as

$$\vec{P}_{\mathrm{r}} = \sum_{k=1}^{K} \left(\vec{z}_{U_{\mathrm{r}}} - \vec{z}_k \right) \times \vec{U}_k$$

where

$\vec{P}_{\mathrm{r}}$ is the resultant moment unbalance (g·mm^2);

$\vec{U}_k$ are the individual unbalance vectors, numbered 1 to K;

$\vec{z}_{U_{\mathrm{r}}}$ is the axial position vector from a datum mark to the plane of the resultant unbalance $\vec{U}_{\mathrm{r}}$;

$\vec{z}_k$ is the axial position vector from the same datum mark to the plane of $\vec{U}_k$.

NOTE 6 Adapted from ISO 1925:2001, definition 3.13.

3.7
couple unbalance

pair of unbalance vectors of equal amount but opposite angles, in two radial planes, forming a moment unbalance with the plane distance

3.8
dynamic unbalance

condition in which the central principal axis has any position relative to the shaft axis

NOTE 1 In special cases it may be parallel to or may intersect the shaft axis.

NOTE 2 The quantitative measure of dynamic unbalance can be given by two complementary unbalance vectors in two specified planes (perpendicular to the shaft axis) which completely represent the total unbalance of the rotor in a constant (rigid) state.

NOTE 3 Adapted from ISO 1925:2001, definition 3.9.

3.9
amount of unbalance

product of the unbalance mass and the distance (radius) of its centre of mass from the shaft axis

NOTE Units of amount of unbalance are gram millimetres (g·mm).

[ISO 1925:2001, definition 3.3]

3.10
angle of unbalance

polar angle at which the unbalance mass is located with reference to the given rotating coordinate system, fixed in a plane perpendicular to the shaft axis and rotating with the rotor

[ISO 1925:2001, definition 3.4]

3.11
unbalance vector
vector whose magnitude is the amount of unbalance and whose direction is the angle of unbalance

[ISO 1925:2001, definition 3.5]

3.12
state of a rotor
state determined by the unbalance behaviour with speed, the types of unbalance to be corrected, and the ability of the rotor to maintain or to change the position of its mass elements and their centres of mass relative to each other within the speed range

NOTE 1 Unbalances in most cases to not change considerably with speed. Contrary to the definitions used up to now (ISO 1925) even modal unbalances are not speed dependent. Only a special cases do unbalances change considerably with speed.

NOTE 2 Mass elements are useful means to describe the mass distribution of a rotor and possible changes with speed. Mass elements can be finite elements, or parts or components.

NOTE 3 The rotor state is also influenced by its design, construction and assembly.

NOTE 4 The response of the rotor to unbalance can change with the speed range and its bearing support conditions. The acceptability of the response is determined by the relevant balance tolerances.

NOTE 5 The speed range covers all speeds from standstill to the maximum service speed, but can also include an overspeed as a margin for service loads (e.g. temperature, pressure, flow).

NOTE 6 With regard to balancing, only changes in the position of rotor mass elements not symmetric to the shaft axis need to be considered.

3.13
constant (rigid) rotor state
state of a rotor where the unbalances are not changing considerably with speed, only the resultant unbalance and/or the resultant moment unbalance are out of specified limits, and the position of all mass elements of the rotor relative to each other remains sufficiently constant within the speed range

NOTE The unbalance of a rotor in its constant state can be corrected in any two (arbitrarily selected) planes.

4 Pertinent aspects of balancing

4.1 General

Balancing is a procedure by which the mass distribution of a rotor is checked and, if necessary, adjusted to ensure that the residual unbalance or the vibration of the journals and/or forces at the bearings at a frequency corresponding to service speed are within specified limits.

Rotor unbalance can be caused by design, material, manufacturing and assembly. Every rotor has an individual unbalance distribution along its length, even in a series production.

4.2 Representation of the unbalance

One and the same unbalance of a rotor in a constant (rigid) state can be represented by vectorial quantities in various ways, as shown in Figures 1a) to 1f).

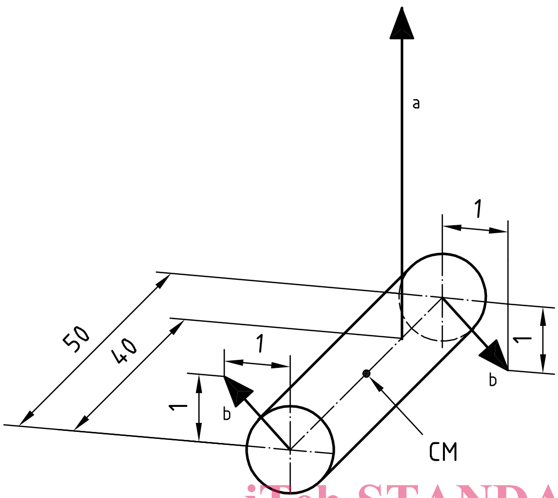
Figures 1a) to 1c) show different representations in terms of resultant unbalance and resultant couple unbalance, whereas Figures 1d) to 1f) are in terms of a dynamic unbalance in two planes.

NOTE 1 The resultant unbalance vector may be located in any radial plane (without changing amount and angle); but the associated resultant couple unbalance is dependent on the location of the resultant unbalance vector.

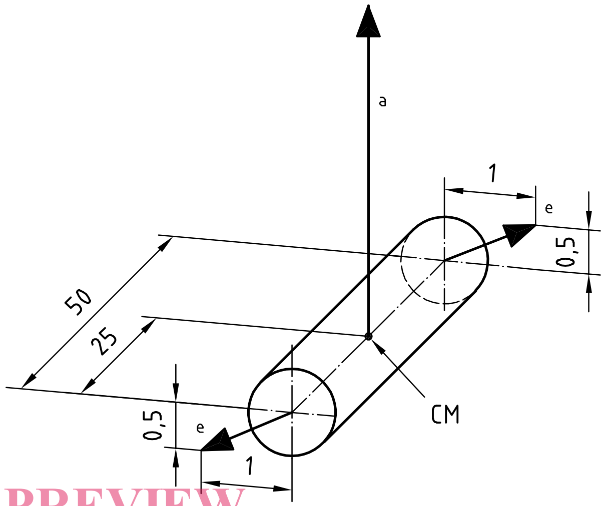
NOTE 2 The centre of unbalance is that location on the shaft axis for the resultant unbalance, where the resultant moment unbalance is a minimum.

If single-plane balancing is sufficient (see 4.5.2), or when considerations are made in terms of resultant/couple unbalance (see 4.5.4), the representation in Figures 1a) to 1c) is preferable. In the case of typical two-plane considerations, the representation in Figures 1d) to 1f) will be advantageous.

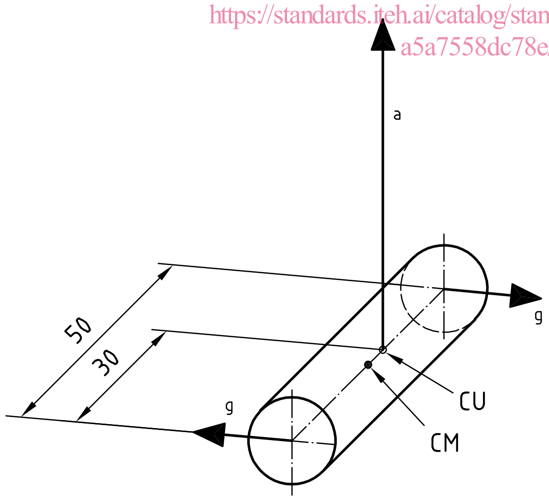
Dimensions in millimetres



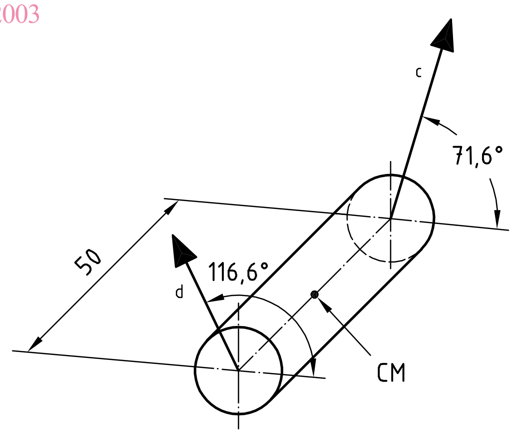
a) A resultant unbalance vector together with an associated couple unbalance in the end planes



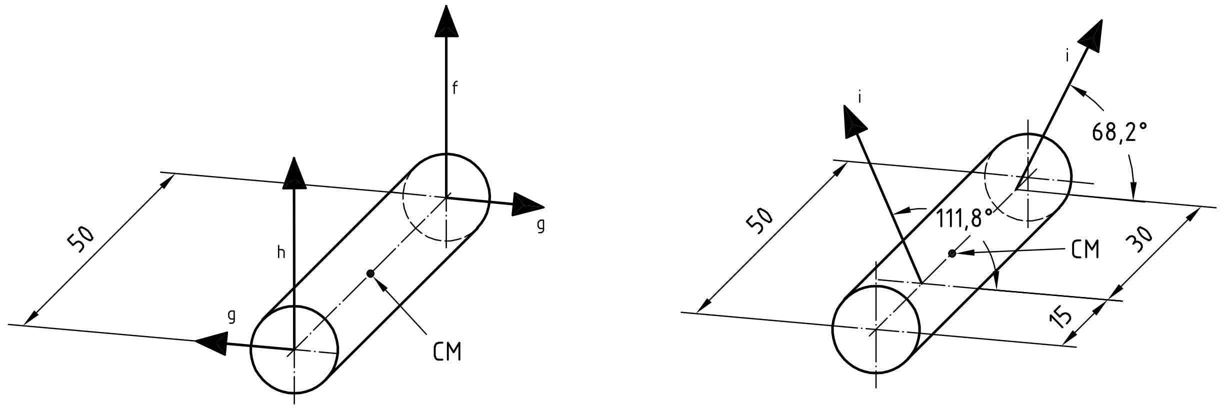
b) Special case of a), namely unbalance vector located at mass centre CM (static unbalance), together with an associated couple unbalance in the end planes



c) Special case of a), namely resultant unbalance vector located at the centre of unbalance CU. The associated couple unbalance is a minimum and lays in a plane orthogonal to the resultant unbalance vector



d) An unbalance vector in each of the end planes



e) Two 90° unbalance components in each of the end planes

f) An unbalance vector in each of two other planes

[a] Unbalance is 5 g·mm.
[b] Unbalance is 1,41 g·mm.
[c] Unbalance is 3,16 g·mm.
[d] Unbalance is 2,24 g·mm.
[e] Unbalance is 1,12 g·mm.
[f] Unbalance is 3 g·mm.
[g] Unbalance is 1 g·mm.
[h] Unbalance is 2 g·mm.
[i] Unbalance is 2,69 g·mm.

CM is the centre of mass.

CU is the centre of unbalance.

Figure 1 — Different representations of the same unbalance of a rotor in a constant (rigid) state

4.3 Unbalance effects

Resultant unbalance and resultant moment unbalance (resultant couple unbalance) have different effects on forces on the bearings and on the vibration of the machine. In practice, therefore, both unbalances are often considered separately. Even if the unbalance is stated as a dynamic unbalance in two planes, it should be noted that in most cases there will be a difference in effects if the unbalances dominantly form either a resultant unbalance or a resultant couple unbalance.

4.4 Reference planes for balance tolerances

It is desirable to use special reference planes to state balance tolerances. For these planes, only the magnitude of each residual unbalance must stay below the respective tolerance value, whatever the angular position may be.

There are always two ideal planes for balance tolerances for a rotor in a constant (rigid) state. In most cases these planes are near to the bearing planes. Moreover, the aim of balancing is usually to reduce vibrations and forces transmitted through the bearings to the environment. In order to facilitate this approach, this part of ISO 1940 takes the bearing planes A and B as reference planes for balance tolerances (tolerance planes).

4.5 Correction planes

4.5.1 General

Rotors out of balance tolerance need correction. These unbalance corrections often cannot be performed in the planes where the balance tolerances were set, but need to be performed where material can be added, removed or relocated.

