
INTERNATIONAL STANDARD



1940

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Balance quality of rotating rigid bodies

First edition — 1973-05-01

UDC 62-755

Ref. No. ISO 1940-1973 (E)

Descriptors : rotating machines, vibration, rotation, balancing, tests.

FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 1940 was drawn up by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, and circulated to the Member Bodies in December 1969.

It has been approved by the Member Bodies of the following countries :

Australia	Greece	South Africa, Rep. of
Belgium	Israel	Spain
Canada	Italy	Sweden
Czechoslovakia	Japan	Switzerland
Denmark	Netherlands	Thailand
Egypt Arab Rep. of	New Zealand	United Kingdom
Germany	Poland	U.S.A.

The Member Body of the following country expressed disapproval of the document on technical grounds :

France

Balance quality of rotating rigid bodies

0 INTRODUCTION

Balancing is the process of attempting to improve the mass distribution of a body so that it rotates in its bearings without unbalanced centrifugal forces. Of course, this aim can be attained only to a certain degree: even after balancing, the rotor will possess residual unbalance. These recommendations are concerned with the permissible residual unbalance.

By means of the measuring equipment available today, unbalance may now be reduced to rather low limits. However, it would be uneconomical to exaggerate the quality requirements. To what extent the unbalance must be reduced, and where the optimal economic and technical compromise on balance quality has to be struck, can, in individual cases, be correctly determined only by extensive measurement in the laboratory or in the field.

It is not readily possible to draw conclusions as to the permissible residual unbalances from any existing recommendations on the assessment of the vibratory state of machinery, since there is often no easily recognizable relation between the rotor unbalance and the machine vibrations under operating conditions. The amplitude of the vibrations is influenced by many factors, such as the vibrating mass of the machine casing and its foundation, the bearing and the foundation stiffness, the proximity of the operating speed to the various resonance frequencies, etc. Moreover, the effect of the unbalances varies with their mutual angular position (see 3.2), and finally the machine vibrations may be due only in part to the presence of rotor unbalance.

1 SCOPE

This International Standard makes recommendations concerning the balance quality of rotating rigid bodies particularly as it relates to the permissible residual unbalance as a function of the maximum service speed.

It includes a tentative classification of various types of representative rotors in which the rotor groups are associated with ranges of recommended balance quality grades.

2 LIMITS OF APPLICABILITY

According to the table, page 5, various balance quality grades are assigned to different groups of rotors. Hence, it is possible by means of Figure 4 to determine the specific permissible residual unbalance of each rotor group as a function of the maximum service speed. These recommended balance quality grades are based on experience which was gained with rotors of various types, sizes, and service speeds. They are valid for rigid rotors, i.e. rigid from the point of view of balancing¹⁾. This "rigidity" is required not only at the rotational speed in the balancing machine but also throughout the whole operating range of the rotor under operational conditions. Later, similar recommendations will be proposed for "flexible" rotors, in which bending deflections occur as a function of rotational speed.

The recommendations are not intended to serve as acceptance specifications for any rotor group, but rather to give indications of how to avoid gross deficiencies as well as exaggerated or unattainable requirements; on the other hand, they may serve as a basis for more involved investigations, for example, when in special cases a more exact determination of the required balance quality is necessary. If due regard is paid to the recommended limits, satisfactory running conditions can most probably be expected. However, there may be cases when deviations from these recommendations become necessary.

The balance quality grades G are intended to afford a classification of balance quality in order to facilitate mutual understanding between the interested parties.

3 PERTINENT ASPECTS OF THE BALANCING PROBLEM

3.1 Representation of a state of unbalance

One and the same state of unbalance can be represented in various ways, as shown in Figures 1 a) to 1 g). In general, measurements yield analogue values corresponding to the state of unbalance illustrated in Figure 1 a) or 1 b). The unbalance correction process also takes

1) For definitions, see ISO 1925, *Balancing terminology*. (At present at the stage of draft.)

place in this way, except that in special cases a correction procedure corresponding to Figure 1 c) may be applied. If an investigation of the unbalance effect on the vibratory behaviour of a whole machine is intended, then an unbalance resolution according to Figure 1 d) may be useful, where S denotes the mass centre of the rotor or of the whole machine according to the purpose of the investigation. The representations in Figures 1 e) and 1 f) may be practical when transfer of the unbalances to different reference planes is to be carried out. The shortest and most general designation of quasi-static unbalance and couple unbalance is shown in Figure 1 f). The possibility of expressing the unbalance moment as couple unbalance in two arbitrary planes I and IIa is shown in Figure 1 g).

3.2 Unbalance effects

An unbalanced rotating body will cause not only forces on its bearings and foundation, but also vibrations of the machine. At any given speed, both effects depend essentially on the geometric proportions and mass distribution of rotor and machine, as well as on the stiffness of the bearings and foundation.

In many cases, the static unbalance is of primary importance as compared with the couple unbalance, i.e. two unbalances (in different planes) in the same direction usually cause a greater disturbance than two equal unbalances in opposite directions.

Similarly, there are cases in which couple unbalance is especially disturbing. For example, consider a rotor where the distance between the bearings is smaller than the distance between the correction planes, a situation encountered in a rotor with overhung disks at both ends. Then the bearing load due to a couple unbalance is larger than that caused by a static unbalance, provided the sum of the opposite unbalances in the correction planes representing the couple unbalance exceeds a certain fraction of the static unbalance assumed to be located in the middle between the bearings. Denoting the bearing distance by l and that of the correction planes by a , then, if the permissible residual static unbalance is U_R , the permissible residual unbalances U_C , forming the couple unbalance, are reduced to $U_C = U_R / 2a$.

3.3 Rotors with one correction plane

For disk-shaped rotors, the use of only one correction plane may be sufficient, provided the bearing distance is sufficiently large and the disk rotates with sufficiently small axial run-out. Whether these conditions are fulfilled must be investigated in each individual case. After single-plane balancing has been carried out on a sufficient number of rotors of the particular type, the greatest residual unbalance moment is determined and divided by the bearing distance. If the unbalances found in this way are acceptable even in the worst case, i.e. if they are not larger than half the recommended value multiplied by the rotor mass, then it can be expected that single-plane balancing is sufficient.

3.4 Rotors with two correction planes

If the rotor does not satisfy the conditions stated above in 3.3 for the disk-shaped rotor, then two correction planes are needed. This type of balancing is called two-plane (dynamic) balancing in contrast to the single-plane (static) balancing described in 3.3. For single-plane balancing, only static equilibrium in any angular position of the rotor is required. For two-plane balancing it is necessary that the rotor rotate, since otherwise the residual couple unbalance (see 3.2) would remain undetected.

In the case of rotors for which the centre of gravity is located within the mid-third of the distance between the bearings, one-half the recommended value of the permissible residual unbalance in Figure 4 should be taken for each correction plane if these are equi-distant from the centre of gravity. For other rotors, it may be necessary to apportion the recommended value in accordance with the rotor's mass-distribution, so long as the principal part of the mass is situated between the correction planes. In unusual cases, the distribution of the recommended value must be specially investigated taking into account, say, the permissible bearing loads.

3.5 Assemblies

Rotors may be supplied for balancing as integral single components or as assemblies. For each assembly, the unbalances of the component parts must be added vectorially and any unbalances resulting from inaccuracies of assembly must be taken into account, giving particular attention to the fact that the parts may be assembled later in a different position from that in the balancing machine.

The maximum unbalance due to fit and geometrical tolerances is then the sum of the greatest possible radial displacements in both cases (in the balancing machine and assembled-for-service condition, respectively) multiplied by the mass of the component concerned. Such displacements may arise from both radial clearance and radial run-out as well as from axial run-out.

Therefore, the permissible residual unbalances of the individual components and the limits of fit, as well as the limits for radial and axial run-out, are determined by the condition that the sum of the unbalances due to these causes must not be larger than the recommended value for the rotor-type to which the assembly belongs. Of course, a sensible relationship should be observed between the magnitudes of the residual unbalances of the individual components and of the unbalances due to fit-inaccuracies. If the unbalance tolerance for an assembly can not be achieved by single-part balancing, then the assembled parts must be balanced as a unit.

If the individual components are balanced separately, then the connecting elements, such as bolts and keys, may be attached all to one part or distributed among the components. However, prior agreement should be reached as to the attachment of such elements.