

Balance quality requirements of rigid rotors —

Part 1: Method for determination of permissible residual unbalance —

[ISO title: Mechanical vibration —
Balance quality requirements of rigid
rotors — Part 1: Determination of
permissible residual unbalance]

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the General Mechanical Engineering Standards Committee (GME/-) to Technical Committee GME/21 upon which the following bodies were represented:

- British Engine Group of SMMT
- British Maritime Technology
- British Steel Corporation
- Department of Trade and Industry (National Engineering Laboratory)
- Electricity Supply Industry in England and Wales
- Institute of Sound and Vibration Research
- Institution of Electronic and Radio Engineers
- Institution of Mechanical Engineers
- Lloyds Register of Shipping
- Ministry of Defence
- Motor Industry Research Association
- Power Generation Association (BEAMA Ltd.)
- Society of British Aerospace Companies Limited
- Society of Environmental Engineers
- United Kingdom Atomic Energy Authority

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Engineering Equipment and Materials Users Association
- Coopted member

This British Standard, having been prepared under the direction of the General Mechanical Engineering Standards Committee, was published under the authority of the Board of BSI and comes into effect on 30 June 1987

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Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
0 Introduction	1
1 Scope and field of application	1
2 References	1
3 Pertinent aspects of the balancing problem	1
4 Permissible unbalance related to rotor mass	2
5 Quality grades relating service speed and permissible residual specific unbalance	4
6 Determination of balance quality requirements	4
7 Allocation of permissible residual unbalance to each correction plane on the basis of U_{per}	5
8 Determination of the residual unbalances	11
9 Sources of errors in balancing	12
Annex Example for the general method described in 7.3.3.1 for two-plane balancing	15
Figure 1 — Different representations of the same state of unbalance of a rigid rotor	3
Figure 2 — Maximum permissible residual specific unbalance value corresponding to various balance quality grades	7
Figure 3 — Rotor dimensions to be used for simplified method	8
Figure 4 — Rotor with overhung discs at both ends	9
Figure 5 — Rotors with couple correction planes I and II at a distance b less than one-third of the bearing span l	10
Figure 6 — Rotor dimensions to be used for general method calculations	10
Figure 7 — Determination of the response of the permissible residual unbalance to a trial mass	12
Figure 8 — Test procedure for determining the residual unbalance in one plane	13
Figure 9 — Error sources in end-drive elements	14
Figure 10 — Rotor dimensions	15
Table 1 — Balance quality grades for various groups of representative rigid rotors	6
Table 2 — Typical examples of recommended deviations	12
Publications referred to	Inside back cover

National foreword

This Part of BS 6861 has been prepared under the direction of the General Mechanical Engineering Standards Committee. It is identical with ISO 1940/1-1986 “*Mechanical vibration — Balance quality requirements of rigid motors — Part 1: Determination of permissible residual unbalance*” which was prepared by Technical Committee ISO/TC 108 of the International Organization for Standardization (ISO) and in the development of which the United Kingdom played an active part. A further Part of this British Standard, concerned with errors associated with the determination of residual unbalance, is to be published in due course. BS 6861-1 supersedes BS 5265-1, which has been withdrawn.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

The comma has been used as the decimal marker. In British Standards it is current practice to use a full point on the baseline as the decimal marker. Wherever the words “International Standard” or “part of ISO 1940” appear, referring to this standard, they should be read as “British Standard” or “Part of BS 6861” respectively.

Cross-references

International standard	Corresponding British Standard
ISO 1925-1981	BS 3851:1982 Glossary of terms used in the mechanical balancing of rotating machinery (Identical)
ISO 5343-1983	BS 5265 Mechanical balancing of rotating bodies Part 3:1984 Recommendations for criteria for evaluating flexible rotor balance (Identical)
ISO 5406-1980	Part 2:1981 Methods for the mechanical balancing of flexible rotors (Identical)

The Technical Committee has reviewed the provisions of ISO 2371 and ISO 2953, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A related British Standard to ISO 2371-1974 is BS 4924:1973 “Specification. Description and evaluation of field balancing equipment”.

A related British Standard to ISO 2953-1985 is BS 3852 “Balancing machines” Part 1:1979 “Method of description and evaluation”.

Textual errors. When adopting the text of the international standard, the textual errors listed below were discovered. They have been marked in the text and have been reported to ISO in a proposal to amend the text of the international standard.

- a) In 3.1, paragraph 2, line 2, 3.15 g mm should read 3.16 g mm.
- b) In Figure 1(a) the value 3.15 should read 3.16.
- c) In 7.3.3.1, line 12, *h* should be read *b*.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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.

The measuring equipment available today enables unbalance to be reduced to low limits. However, it would be uneconomical to exaggerate the quality requirements. It has therefore become necessary to determine to what extent the unbalance should be reduced, and where the optimum economic and technical compromise on balance quality requirements would be struck.

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 once-per-revolution vibrations is influenced by characteristics of the rotor, of the machine, of the structure and of the foundation, and by the proximity of the service speed to the various resonance frequencies, etc. Moreover, the machine vibrations may be due only in part to the presence of rotor unbalance.

1 Scope and field of application

This part of ISO 1940 gives recommendations for determining unbalance and for specifying related quality requirements of rigid rotors; it specifies

- a) a representation of unbalance in one or two planes;
- b) methods for determining permissible residual unbalance;
- c) methods for allocating it to the correction planes;
- d) methods for identifying the residual unbalance state of a rotor by measurement;
- e) a summary of errors associated with the residual unbalance identification.

In Table 1 and Figure 2 recommendations are given, based on worldwide experience, concerning the balance quality requirements of rigid rotors, according to their type, mass and maximum service speed.

This part of ISO 1940 is also intended to facilitate the relations between manufacturer and user of machines. Terminology specified in this part of ISO 1940 may be used for establishing technical specifications. (For definitions, see ISO 1925.)

Detailed consideration of errors associated with the determination of residual unbalance is not included in this part of ISO 1940 (ISO 1940/2 will deal with these errors). This part of ISO 1940 does not define permissible residual unbalances for flexible rotors; these are covered in ISO 5343. The methods for balancing are not described.

The recommended balance quality grades 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; they may also serve as a basis for more involved investigations, for example, when a more exact determination of the required balance quality by measurement in the laboratory or in the field 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, e.g. because of unusual construction or geometry.

2 References

- ISO 1925, *Balancing — Vocabulary*.
 ISO 2371, *Field balancing equipment — Description and evaluation*.
 ISO 2953, *Balancing machines — Description and evaluation*.
 ISO 5343, *Criteria for evaluating flexible rotor balance*.
 ISO 5406, *The mechanical balancing of flexible rotors*.

3 Pertinent aspects of the balancing problem

3.1 Representation of a state of unbalance

One and the same state of unbalance of a rigid rotor can be represented by vectorial quantities in various ways, as shown in Figure 1 a) to Figure 1 f). For most rotors, unbalances are measured in two planes as illustrated in Figure 1 a) to Figure 1 c). The unbalance correction process generally takes place in this way.

For example, if the representation of Figure 1a) is adopted, unbalance corrections of 2,24 g mm and 3,15 g mm¹⁾ would be applied in planes I and II respectively, at the appropriate angular orientation around the rotor. Comparison of Figure 1 a) and Figure 1 c) shows that a shorter distance between the correction planes normally leads to a larger sum of corrections and increases the angular difference between their vectors.

¹⁾ See national foreword for details of textual errors.

Alternatively, a representation similar to Figure 1 d) may be used; in such a case, correction would have to be made in the plane of the resultant unbalance vector, together with corrections in each of planes I and II.

If an investigation of the unbalance effect on the vibratory behaviour of a whole machine is intended, an unbalance resolution according to Figure 1 e) may be useful, where the point S denotes the mass centre of the rotor.

The representation in Figure 1 f), with the resultant unbalance vector passing through the centre of unbalance, C, may be useful for some rotors. The associated couple unbalance is a minimum in this case and the couple vectors lie in a plane normal to the vector of the resultant unbalance.

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 dynamic stiffness of the bearings and the foundation.

In many cases, the static unbalance is of primary importance as compared with the couple unbalance. 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); under such circumstances, the bearing load due to a couple unbalance may be larger than that caused by a static unbalance.

3.3 Rotors with one correction plane

For disc-shaped rotors, the use of only one correction plane may be sufficient, provided that the bearing distance is sufficiently large and the disc rotates with sufficiently small axial run-out. Whether these conditions are fulfilled shall be investigated in each individual case. After single-plane balancing has been carried out on a sufficient number of rotors of a particular type, the greatest residual couple unbalance is determined and divided by the bearing distance. If, even in the worst case, the unbalances found in this way are acceptable, it can be expected that single-plane balancing is sufficient.

3.4 Rotors with two correction planes

If a rigid rotor does not satisfy the conditions specified in 3.3 for the disc-shaped rotor, 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 for the rotor to rotate, since otherwise the residual couple unbalance would remain undetected.

The permissible residual unbalance at each of two correction planes will be dependent on the position of the correction planes and the bearings and also on the relative phase angle between the two residual unbalances. Three ways for determining the permissible residual unbalance are given in clause 6. Methods for allocating the permissible residual unbalance to the correction planes are described in clause 7.

3.5 Assemblies

Some rotors may be balanced as integral single components, others as assemblies. For each assembly, the unbalances of the component parts shall be added vectorially and any unbalances resulting from inaccuracies of assembly shall be taken into account, particular attention being paid to the fact that the parts may be assembled later in a different position from that in the balancing machine.

If the unbalance tolerance for an assembly cannot be achieved by balancing each component separately, the assembly shall be balanced as a unit.

If the individual components are balanced separately, prior agreement should be reached as to the attachment of connecting elements such as bolts and keys. (A future International Standard dealing with the handling of shaft keys during balancing is in preparation.)

4 Permissible unbalance related to rotor mass

In general, the larger the rotor mass, the greater the permissible residual unbalance. It is, therefore, appropriate to relate the value of the permissible residual unbalance, U_{per} , to the rotor mass, m , in terms of permissible residual specific unbalance value, e_{per} , as given by the following formula:

$$e_{\text{per}} = \frac{U_{\text{per}}}{m}$$