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Balancing — Vocabulary

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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 1925 was developed by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

This second edition was submitted directly to the ISO Council, in accordance with clause 5.10.1 of part 1 of the Directives for the technical work of ISO. It cancels and replaces the first edition (i.e. ISO 1925-1974), which had been approved by the member bodies of the following countries :

Belgium	Italy *	Spain
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The member bodies of the following countries expressed disapproval of one or other part of the document on technical grounds :

Australia
France

• Expressed approval of only one or other part of the document.

Balancing — Vocabulary

Scope and field of application

This International Standard establishes a vocabulary on balancing, in English and in French. An alphabetical index is provided for each of the two languages.

This International Standard will be supplemented later by lists of equivalent terms in German, Japanese and Spanish respectively, without definitions.

A general vocabulary on vibration and shock is given in ISO 2041.

NOTE — Terms in italics in the definitions are themselves defined elsewhere in this vocabulary.

References

ISO 1940, *Balance quality of rotating rigid bodies.*

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2953, *Balancing machines — Description and evaluation.*

1 Mechanics

1.1 centre of gravity : Point in a body through which passes the resultant of the weights of its component particles for all orientations of the body with respect to a uniform gravitational field.

For *centre of mass*, see 7.3.

1.2 principal inertia axis : For each set of Cartesian co-ordinates at a given point, the values of the six moments of inertia of a body $I_{x_i x_j}$ $(i, j = 1, 2, 3)$ are in general unequal; for one such co-ordinate system the moments $I_{x_i x_j}$ $(i \neq j)$ vanish. The values of $I_{x_i x_j}$ $(i = j)$ for this particular co-ordinate system are called the **principal moments of inertia** and the corresponding co-ordinate directions are called the **principal axes of inertia.**

NOTES

1 $I_{x_i x_j} = \int_m x_i x_j \, dm$, if $i \neq j$

$I_{x_i x_j} = \int_m (r^2 - x_i^2) \, dm$, if $i = j$

where $r^2 = x_1^2 + x_2^2 + x_3^2$

and x_i, x_j are Cartesian co-ordinates.

2 If the point is the *centre of gravity* of the body, the axes and moments are called **central principal axes** and **central principal moments of inertia.**

3 In balancing, the term *principal inertia axis* is used to designate the one *central principal axis* (of the three such axes) most nearly coincident with the *shaft axis* of the rotor, and is sometimes referred to as the *balance axis* or the *mass axis*.

4 The mass properties of a rigid body are the following ten scalar quantities :

a) **mass**;

b) **centre of gravity location** (three co-ordinates);

c) **moments of inertia** (three axes);

d) **products of inertia** (three pairs of axes).

1.3 equilibrium centre : Point at which the *shaft axis* (see 2.7) intersects the plane perpendicular to the shaft axis through the *centre of gravity* of a *rotor*, when the rotor is at a standstill.

1.4 critical speed : Characteristic speed such that the predominant response of the system occurs at a resonance.

NOTE — Depending on the relative magnitudes of the *bearing* stiffness and mass and the rotor stiffness and mass, the significant effect at a critical speed may be motion of the *journals* or flexure of the *rotor* (see *flexural critical speed*, 6.1, and *rigid-rotor-mode critical speed*, 6.2).

1.5 axis of rotation (spin axis) : Line about which a body rotates.

NOTES

1 If the *bearings* are anisotropic, there is no stationary axis of rotation.

2 In the case of rigid bearings, the axis of rotation is the *shaft axis*, but if the *bearings* are not rigid, the axis of rotation is not necessarily the shaft axis.

2 Rotors

2.1 rotor : Body, capable of rotation, generally with *journals* which are supported by *bearings.*

NOTES

1 The term *rotor* is sometimes applied to, say, a disk-like mass that has no journals (for example, a fly-wheel). In the sense of the definition of 2.1, such a disk-like mass becomes a rotor for the purpose of *balancing* only when it is placed on a shaft with *journals* (see 2.4).

2 In the case of balancing, the rotor to be balanced is sometimes referred to as a "workpiece".

2.2 rigid rotor : A *rotor* is considered rigid when it can be corrected in any two (arbitrarily selected) planes (see 4.6) and, after that correction, its *unbalance* does not significantly exceed the balancing tolerances (relative to the *shaft axis*) at any speed up to maximum *service speed* and when running under conditions which approximate closely to those of the final supporting system.

2.3 flexible rotor : *Rotor* not satisfying definition 2.2 due to elastic deflection.

2.4 journal : That part of a *rotor* which is in contact with or supported by a *bearing* in which it revolves.

2.5 journal axis : Straight line joining the centroids of cross-sectional contours of the *journal.*

2.6 journal centre : Intersection of the *journal axis* and the central radial plane of the *journal.*

2.7 shaft axis : The straight line joining the *journal centres*.

2.8 bearing : Part which supports a *journal* and in which the journal revolves.

2.9 bearing axis : Straight line joining the centroids of cross-sectional contours of the bearing.

2.10 perfectly balanced rotor : *Rotor* the mass distribution of which is such that it transmits no vibratory force or motion to its *bearings* as a result of centrifugal forces.

NOTE — When run at a different speed or when placed in different bearings, the rotor would not necessarily remain perfectly balanced.

2.11 inboard rotor : Two-journal *rotor* which has its *centre of gravity* between the *journals*.

2.12 outboard rotor : Two-journal *rotor* which has its *centre of gravity* located other than between the *journals*.

2.13 mass eccentricity : See 3.17.

2.14 local mass eccentricity (for distributed mass rotors) : For small axial elements cut from a *rotor* perpendicular to the *shaft axis*, the distance of the *centre of gravity* of each element from the shaft axis.

2.15 bearing support : Part, or series of parts, that transmits the load from the *bearing* to the main body of the structure.

2.16 foundation : Structure that supports the mechanical system.

NOTE — In the context of the *balancing* and vibration of rotating machines, the term foundation is usually applied to the heavy base structure on which the whole machine is mounted.

2.17 quasi-rigid rotor : Flexible *rotor* that can be satisfactorily balanced below a speed where significant flexure of the rotor occurs.

2.18 balancing speed : Rotational speed at which a *rotor* is balanced.

2.19 service speed : Rotational speed at which a *rotor* operates in its final installation or environment.

3 Unbalance

3.0 General

The definitions in this clause apply to unbalance in *rigid rotors*. They may also be applied to *flexible rotors*, but because *unbalance* in such *rotors* changes with speed, any values of *unbalance* given for those rotors must be associated with a particular speed.

3.1 unbalance : That condition which exists in a *rotor* when vibratory force or motion is imparted to its *bearings* as a result of centrifugal forces. (See 3.0.)

NOTES

1 The term unbalance is sometimes used as a synonym for *amount of unbalance*, or *unbalance vector*.

2 Unbalance will in general be distributed throughout the rotor but can be reduced to

a) *static unbalance* and *couple unbalance* described by three unbalance vectors in three specified planes, or

b) *dynamic unbalance* described by two unbalance vectors in two specified planes.

3.2 unbalance vector : Vector whose magnitude is the *amount of unbalance* and whose direction is the *angle of unbalance*.

3.3 amount of unbalance : Quantitative measure of *unbalance* in a *rotor* (referred to a plane), without referring to its angular position. It is obtained by taking the product of the *unbalance mass* by the distance of its *centre of gravity* from the *shaft axis*.

NOTES

1 Units of unbalance are, for example, ounces inches, grams millimetres, etc.

2 In certain countries, the terms "weight" and "mass" are used interchangeably.

3.4 angle of unbalance : Given a polar co-ordinate system fixed in a plane perpendicular to the *shaft axis* and rotating with the *rotor*, the polar angle at which an *unbalance mass* is located with reference to the given co-ordinate system.

3.5 unbalance mass : That mass which is considered to be located at a particular radius such that the product of this mass by its centripetal acceleration is equal to the *unbalance force*.

NOTE — The centripetal acceleration is the product of the distance between the *shaft axis* and the *unbalance mass* by the square of the angular velocity of the *rotor*, in radians per second.

3.6 static unbalance : That condition of *unbalance* for which the *central principal axis* is displaced only parallel to the *shaft axis*.

NOTE — The quantitative measure of static unbalance can be given by the resultant of the two *dynamic unbalance* vectors.

3.7 quasi-static unbalance : That condition of *unbalance* for which the *central principal axis* intersects the *shaft axis* at a point other than the *centre of gravity*.

3.8 couple unbalance : That condition of *unbalance* for which the *central principal axis* intersects the *shaft axis* at the *centre of gravity*.

NOTES

1 The quantitative measure of couple unbalance can be given by the vector sum of the moments of the two *dynamic unbalance* vectors about a certain reference point in the plane containing the centre of gravity and the shaft axis.

2 If *static unbalance* in a *rotor* is corrected in any plane other than that containing the reference point, the couple unbalance will be changed.

3.9 dynamic unbalance : That condition in which the *central principal axis* is neither parallel to nor intersects the *shaft axis*.

NOTE — 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*.

3.10 residual (final) unbalance : *Unbalance* of any kind that remains after *balancing*.

3.11 initial unbalance : *Unbalance* of any kind that exists in the *rotor* before *balancing*.

3.12 unbalance force : In a *rotor* referred to a *correction plane*, the centrifugal force at a given speed (referred to the *shaft axis*) due to the *unbalance* in that plane.

3.13 resultant unbalance force : Resultant force of the system of centrifugal forces of all mass elements of a *rotor* referred to any point on the *shaft axis*, provided the rotor revolves about the shaft axis.

NOTE — The resultant *unbalance force* always lies in the plane containing the *centre of gravity* of the rotor and the shaft axis.

3.14 unbalance moment : Moment of a centrifugal force of a mass element of a *rotor* about a certain reference point in the plane containing the *centre of gravity* of the rotor and the *shaft axis*.

3.15 resultant unbalance moment (resultant moment of unbalance forces) : The resultant moment of the system of centrifugal forces of all mass elements of the *rotor* about a certain reference point in the plane containing the *centre of gravity* of the rotor and the *shaft axis*.

NOTES

1 The angle and the magnitude of the resultant moment depend in general on the position of the reference point.

2 There exists a certain position of the reference point in which the magnitude of the resultant moment reaches its minimum (*centre of unbalance*).

3 The resultant moment is independent of the position of the reference point in the case where the *resultant unbalance force* is zero.

3.16 unbalance couple : For the case where the *resultant unbalance force* is zero, the resultant couple of the system of centrifugal forces of all mass elements of the *rotor*.

3.17 specific unbalance (mass eccentricity) : Amount of *static unbalance* (U) divided by mass of the *rotor* (M); it is equivalent to the displacement of the *centre of gravity* of the rotor from the *shaft axis*.

3.18 balance quality grade : For *rigid rotors*, the product of the *specific unbalance* by the maximum service angular velocity of the *rotor*[1)].

1) See ISO 1940.

3.19 controlled initial unbalance : *Initial unbalance* which has been minimized by individual *balancing* of components and/or careful attention to design, manufacture and assembly of the *rotor*.

4 Balancing

4.1 balancing : Procedure by which the mass distribution of a *rotor* is checked and, if necessary, adjusted in order to ensure that the vibration of the *journals* and/or forces on the *bearings* at a frequency corresponding to *service speed* are within specified limits.

4.2 single-plane (static) balancing : Procedure by which the mass distribution of a *rigid rotor* is adjusted in order to ensure that the residual *static unbalance* is within specified limits.

NOTE — Single-plane balancing can be done on a pair of knife edges without rotation of the *rotor* but is now more usually done on *centrifugal balancing machines*.

4.3 two-plane (dynamic) balancing : Procedure by which the mass distribution of a *rigid rotor* is adjusted in order to ensure that the residual *dynamic unbalance* is within specified limits.

4.4 multi-plane balancing : As applied to the balancing of *flexible rotors*, any balancing procedure that requires *unbalance* correction in more than two *correction planes*.

4.5 method of correction : Procedure by which the mass distribution of a *rotor* is adjusted to reduce *unbalance*, or vibration due to unbalance, to an acceptable value. Corrections are usually made by adding material to, or removing it from, the rotor.

4.6 correction (balancing) plane : Plane perpendicular to the *shaft axis* of a *rotor* in which correction for *unbalance* is made.

4.7 measuring plane : Plane perpendicular to the *shaft axis* in which the *unbalance vector* is determined.

4.8 reference plane : Any plane perpendicular to the *shaft axis* to which an *amount of unbalance* is referred.

4.9 acceptability limit : That value of an unbalance parameter which is specified as the maximum below which the state of *unbalance* of a *rotor* is considered acceptable.

4.10 unbalance tolerance : In the case of *rigid rotors*, that *amount of unbalance* with respect to a radial plane (*measuring plane* or *correction plane*) which is specified as the maximum below which the state of *unbalance* is considered acceptable.

4.11 field balancing : The process of *balancing* a *rotor* in its own *bearings* and supporting structure rather than in a *balancing machine*.

NOTE — Under such conditions, the information required to perform balancing is derived from measurements of vibratory forces or motions of the supporting structure and/or measurements of other responses to rotor *unbalance*.

5 Balancing machines and equipment[1]

5.1 balancing machine : Machine that provides a measure of the *unbalance* in a *rotor* which can be used for adjusting the mass distribution of that rotor mounted on it so that once per revolution vibratory motion of the *journals* or force on the *bearings* can be reduced if necessary.

5.2 gravitational (non-rotating) balancing machine : *Balancing machine* that provides for the support of a *rigid rotor* under non-rotating conditions and provides information of the amount and angle of the *static unbalance*.

5.3 centrifugal (rotational) balancing machine : *Balancing machine* that provides for the support and rotation of a *rotor* and for the measurement of once per revolution vibratory forces or motions due to *unbalance* in the rotor.

5.4 single-plane (static) balancing machine : *Gravitational* or *centrifugal balancing machine* that provides information for accomplishing *single-plane balancing*.

5.5 dynamic (two-plane) balancing machine : *Centrifugal balancing machine* that furnishes information for performing *two-plane balancing*.

NOTE — Dynamic balancing machines are sometimes used to accomplish *single-plane balancing*.

5.6 hard bearing (below resonance) balancing machine : Machine having a *balancing speed* range below the natural frequency of the suspension-and-rotor system.

5.7 resonance balancing machine : Machine having a *balancing speed* corresponding to the natural frequency of the suspension-and-rotor system.

5.8 soft bearing (above resonance) balancing machine : Machine having a balancing speed above the natural frequency of the suspension-and-rotor system.

5.9 compensating (null force) balancing machine : *Balancing machine* with a built-in calibrated force system which counteracts the unbalanced forces in the *rotor*.

5.10 direct reading balancing machine : *Balancing machine* which indicates the *unbalance* directly.

1) See ISO 2953.

5.11 swing diameter : Maximum workpiece diameter that can be accommodated by a *balancing machine*.

5.12 mandrel (balancing arbor) : Machined shaft on which work is mounted for *balancing*.

5.13 field balancing equipment : Assembly of measuring instruments for providing information for performing *balancing* operations on assembled machinery which is not mounted in a *balancing machine*.

5.14 unbalance indicator : On a *balancing machine*, the dial, gauge or meter with which a measured *amount of unbalance* or the effect of this *unbalance* is indicated.

5.15 practical correction unit : Unit corresponding to a unit value of the *amount of unbalance* indicated on a *balancing machine*. For convenience, it is associated with a specific radius and correction plane and is commonly expressed as units of an arbitrarily chosen quantity such as drill depths of given diameter, weight, lengths of wire solder, plugs, wedges, etc.

5.16 counterweight : Weight added to a body so as to reduce a calculated *unbalance* at a desired place.

NOTE — Such weights may be used to bring an asymmetric body to a state of balance or to reduce bending moments within a body, for example crank-shafts.

5.17 compensator : Facility built into a *balancing machine* which enables the *initial unbalance* of the *rotor* to be nulled out, usually electrically, so speeding up the process of plane setting and calibration.

5.18 angle indicator : Device used to indicate the *angle of unbalance*.

5.19 angle reference generator : In *balancing*, a device used to generate a signal which defines the angular position of the *rotor*.

5.20 angle reference marks : Marks placed on a *rotor* to denote an angle reference system fixed in the rotor; they may be optical, magnetic, mechanical, or radioactive.

5.21 vector measuring device : Device for measuring and displaying the amount and angle in terms of an *unbalance vector*, usually by means of a point or line.

5.22 component measuring device : Device for measuring and displaying the *amount* and *angle of unbalance* in terms of selected components of the *unbalance vector*.

5.23 balancing machine minimum response : Measure of the machine's ability to sense and indicate a minimum *amount of unbalance* under specified conditions.

5.24 balancing machine accuracy : Limits within which the *amount* and *angle of unbalance* can be measured under specified conditions.

5.25 correction plane interference (cross-effect) : Change of *balancing machine* indication at one *correction plane* of a given *rotor*, which is observed for a certain change of *unbalance* in the other correction plane.

5.26 correction plane interference ratios : Interference ratios (I_{AB}, I_{BA}) of two *correction planes* A and B of a given *rotor* are defined by the following relationships :

$$I_{AB} = \frac{U_{AB}}{U_{BB}}$$

where U_{AB} and U_{BB} are the *unbalances* referring to planes A and B respectively, caused by the addition of a specified *amount of unbalance* in plane B; and

$$I_{BA} = \frac{U_{BA}}{U_{AA}}$$

where U_{BA} and U_{AA} are the unbalances referring to planes B and A respectively, caused by the addition of a specified amount of unbalance in plane A.

NOTES

1 The correction plane interference ratio for a *balancing machine* on which the *plane separation* has been carefully adjusted should be a minimum.

2 The ratio is usually given as a percentage.

5.27 plane separation : Of a *balancing machine*, the operation of reducing the *correction plane interference ratio* for a particular *rotor*.

5.28 balancing machine sensitivity : Of a *balancing machine* under specified conditions, the increment in *unbalance* indication expressed as indicator movement or digital reading per unit increment in the *amount of unbalance*.

5.29 nodal bar : A rigid bar coupled through *bearings* to a flexibly supported *rigid rotor*, its motion being essentially parallel to that of the *shaft axis*.

NOTES

1 Its function is to provide correction plane separation by locating the motion transducers at centres of rotation corresponding to centres of percussion located in *correction planes*.

2 A motion transducer so located has minimum *correction plane interference ratio*.

5.30 plane separation (nodal) network : Electrical circuit, interposed between the motion transducers and the *unbalance indicators*, that performs the *plane-separation* function electrically without requiring particular locations for the motion transducers.

5.31 parasitic mass : Of a *balancing machine*, any mass, other than that of the *rotor* being balanced, that is moved by the *unbalance force(s)* developed in the rotor.

5.32 proving (test) rotor : *Rigid rotor* of suitable mass designed for testing *balancing machines* and balanced sufficiently to permit the introduction of exact *unbalance* by means of additional masses with high reproducibility of the magnitude and angular position.

5.33 permanent calibration : Property of a *hard-bearing balancing machine* that permits the machine to be calibrated once and for all, so that it remains calibrated for any *rotor* within the capacity and speed range of the machine.

NOTE — The machine must be set for different rotor dimensions (see 5.37).

5.34 unbalance reduction ratio (URR) : The ratio of the reduction in the *unbalance* by a single balancing correction to the *initial unbalance*.

$$\text{URR} = \frac{U_1 - U_2}{U_1} = 1 - \frac{U_2}{U_1}$$

where

U_1 is the amount of initial unbalance;

U_2 is the *amount of unbalance* remaining after one *balancing* correction.

NOTES

1 Unbalance reduction ratio is a measure of overall efficiency of unbalance correction.

2 The ratio is usually given as a percentage.

5.35 calibration rotor : *Rotor* (usually the first of a series) used for the *calibration* of a *balancing machine*.

5.36 calibration : Process of adjusting a machine so that the *unbalance indicator(s)* read(s) in terms of selected correction units in specified *correction planes* for a given *rotor* and other essentially identical rotors; it may include adjustment for angular location if required.

5.37 setting : Of a *hard bearing balancing machine*, the operation of entering into the machine information concerning the location of the *correction planes*, the location of the *bearings*, the radii of correction, and the speed if applicable.

5.38 mechanical adjustment : Of a *balancing machine*, the operation of preparing the machine mechanically to balance a *rotor*.

5.39 self-balancing device : Equipment which compensates automatically for changes in *unbalance* during normal operation.

5.40 minimum achievable residual unbalance : Smallest value of *residual unbalance* that a *balancing machine* is capable of achieving.

5.41 claimed minimum achievable residual unbalance : Value of minimum achievable *residual unbalance* stated by the manufacturer for his machine, and measured in accordance with the procedure specified in ISO 2953.

5.42 measuring run (on a *balancing machine*) : A run consisting of the following steps :

a) mechanical adjustment of the machine, including the drive, tooling and/or adaptor;

b) setting of the indicating system;

c) preparation of the *rotor* for the balancing run;

d) acceleration of rotor;

e) obtaining measurement of *unbalance*;

f) deceleration of rotor;

g) any further operations necessary to relate the readings obtained to the actual rotor being balanced;

h) any other required operation, for example, safety measures.

NOTES

1 In the case of mass production *balancing*, steps a) and b) are usually omitted from the initial measuring run. For subsequent measuring runs, steps a), b) and c) are omitted in all cases.

2 A measuring run is sometimes referred to as a check run.

5.43 balancing run (on a *balancing machine*) : Run consisting of one *measuring run* and the associated correction process.

5.44 floor-to-floor time : Time including the time for all necessary *balancing runs* and check runs, together with the times for loading and unloading.

NOTE — The time is normally expressed in minutes.

5.45 production rate : Reciprocal of *floor-to-floor time*.

NOTE — The rate is normally expressed in pieces per hour.

5.46 traverse test : Test by which the *residual unbalances* of a *rotor* can be found (see ISO 1940) or with which a *balancing machine* may be tested for conformance with the claimed minimum achievable residual unbalance.

5.47 vertical axis freedom : Freedom of a horizontal *balancing machine* bearing carriage or housing to rotate by a few degrees about the vertical axis through the centre of the support.

6 Flexible rotors

6.1 (rotor) flexural critical speed : Speed of a *rotor* at which there is maximum flexure of the rotor and where that flexure is significantly greater than the motion of the *journals*.

6.2 rigid-rotor-mode critical speed : Speed of a *rotor* at which there is maximum motion of the *journals* and where that motion is significantly greater than the flexure of the rotor.

6.3 (rotor) flexural principal mode : For undamped *rotor/bearing* systems, that mode shape which the rotor takes up at one of the (rotor) *flexural critical speeds*.

6.4 modal balancing : Procedure for *balancing flexible rotors* in which balance corrections are made to reduce the amplitude of vibration in the separate significant principal flexural modes to within specified limits.

6.5 n^{th} modal unbalance : That *unbalance* which affects only the n^{th} principal mode of the deflection configuration of a *rotor/bearing* system.

NOTE — This n^{th} modal unbalance is not a single unbalance but an unbalance distribution $u_n(z)$ in the n^{th} principal mode. It can be mathematically represented with respect to its effect on the n^{th} principal mode by a single unbalance vector $\vec{U}_n$ obtained from the formula

$$\vec{U}_n = \int_0^1 u_n(z)\,\phi_n(z)\,dz$$

where $\phi_n(z)$ is the mode function.

6.6 equivalent n^{th} modal unbalance : The minimum single unbalance $\vec{U}_{ne}$, equivalent to the n^{th} modal unbalance in its effect upon the n^{th} principal mode of the deflection configuration.

NOTES

1 There exists the relation $\vec{U}_n = \vec{U}_{ne}\,\phi_n(z_e)$, where $\phi_n(z_e)$ is the mode function value for $z = z_e$, the axial co-ordinate of the transverse plane where $\vec{U}_{ne}$ is applied.

2 A set of balance masses distributed in an appropriate number of *correction planes* and so proportioned that the mode under consideration will be affected, may be called the equivalent n^{th} *modal unbalance* set.

3 An equivalent n^{th} modal unbalance will affect some modes other than the n^{th} mode.

6.7 modal unbalance tolerance : With respect to a mode, that amount of *equivalent modal unbalance* that is specified as the maximum below which the state of *unbalance* in that mode is considered acceptable.

6.8 multiple-frequency vibration : Vibration at a frequency corresponding to an integral multiple of the rotational speed.

NOTE — This vibration may be caused by anisotropy of the *rotor*, non-linear characteristics of the rotor/*bearing* system, or other causes.

6.9 thermally induced unbalance : That change of condition exhibited by a *rotor* if its state of *unbalance* is significantly altered by its temperature changes.

NOTE — The change of condition may be permanent or temporary.

6.10 low speed balancing (relating to *flexible rotors*) : Procedure of *balancing* at a speed where the *rotor* to be balanced can be considered rigid.

6.11 high speed balancing (relating to *flexible rotors*) : Procedure of *balancing* at speeds where the rotor to be balanced cannot be considered rigid.

7 Rotating rigid free-bodies

7.0 General

The definitions in this clause apply to rotating rigid free-bodies. However, when such a body is mounted on a *balancing machine*, it can be considered as a *rotor* and in this case the definitions in clauses 1 to 5 may be used.

7.1 rigid free-body : System of particles with rigid internal connections and no external constraints.

7.2 rotating rigid free-body : Rigid free-body rotating about an axis.

NOTE — The rotation axis is not stationary, if it is not a *central principal axis*.

7.3 centre of mass : That point associated with a body which has the property that an imaginary particle placed at this point with a mass equal to the mass of a given material system has a first moment with respect to any plane equal to the corresponding first moment of the system.

For *centre of gravity*, see 1.1.

NOTE — The position of the mass centre $\vec{r}_c$ of a material system consisting of point masses m_i (i = 1, 2, ..., N) located at positions $\vec{r}_i$ is defined by

$$\vec{r}_c = \frac{\sum_{i=1}^{N} m_i \vec{r}_i}{\sum_{i=1}^{N} m_i}$$

7.4 principal axis location : The axis location defined by the offset of the *centre of mass* from the *design axis* and the tilt angle of the principal axis from the design axis.

7.5 design axis : Axis about which parts and assemblies are designed and about which it is intended that the body be balanced.

NOTE — The *design axis* is normally referred to as the *spin axis*.