



American
Gear Manufacturers
Association

Technical Resources

ANSI/AGMA 9110-A11

Metric Edition of
ANSI/AGMA 9000-D11

American National Standard

Flexible Couplings – Potential Unbalance Classification (Metric Edition)

ANSI/AGMA 9110-A11

American National Standard

Flexible Couplings — Potential Unbalance Classification (Metric Edition) ANSI/AGMA 9110–A11 [Metric Edition of ANSI/AGMA 9000–D11]

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Approved August 10, 2011

ABSTRACT

This standard describes potential coupling unbalance and identifies its sources. The standard breaks down the requirements into usable groups and outlines how to calculate the potential unbalance of the coupling. Calculations are based on SI units of the metric system. The AGMA method of computing coupling potential unbalance is provided. A guide is provided for balance class selection for purchasers who have not defined the coupling balancing requirements for their system.

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Foreword

[The foreword, footnotes and annexes, if any, in this document are provided for informational purposes only and are not to be construed as a part of ANSI/AGMA Standard 9110-A11, *Flexible Couplings – Potential Unbalance Classification (Metric Edition)*.]

This standard was developed after intensive study of existing standards, literature, design practices, and manufacturing procedures for the balancing of flexible couplings. The intent of this document is to offer designers, manufacturers and users standard criteria for the unbalance classification of flexible couplings.

The information contained within this standard does not necessarily agree with some existing specifications for other rotating components and equipment. This standard is based upon the design criteria, related to the balancing of couplings, that have evolved over many years of successful industry practice.

ANSI/AGMA 9110-A11 is a hard metric adaptation of ANSI/AGMA 9000-D11, with additional information for both standard and high performance couplings in the annexes. ANSI/AGMA 9110-A11 incorporates information from the rigid rotor standard, ISO 1940-1:2003, and how to properly apply that information to flexible coupling potential unbalance.

The first draft of ANSI/AGMA 9110-A11 was made in October, 2004. It was approved by the AGMA membership in April, 2011 and approved as an American National Standard on August 10, 2011.

Suggestions for improvement of this standard will be welcome. They should be sent to the American Gear Manufacturers Association, 1001 N. Fairfax Street, 5th Floor, Alexandria, Virginia 22314.

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American National Standard –

Flexible Couplings – Potential Unbalance Classification (Metric Edition)

1 Scope

This metric standard defines classes of flexible coupling potential unbalance, one of which the user must select in order to meet the needs of their system. The classes are established using mass and speed and system sensitivity to arrive at a mass displacement value that defines the potential unbalance. The standard defines types of unbalance, provides a method of selecting balance class, identifies contributors to potential unbalance, and provides a method of determining potential coupling unbalance. The balance classes are derived from consideration of the potential unbalance of the coupling.

The balancing requirements for a flexible coupling depend upon the rotating system into which it is mounted. Each half of the coupling is mounted on a separate rotor with the whole coupling providing the connection. Each of the connected rotors is balanced independently of the coupling and the coupling is added when the rotors are installed.

This standard is used with ISO 1940-1:2003 which applies to balance quality requirements of rigid rotors. If ISO 1940-1:2003 is used for balancing coupling components and assemblies in the balancing machine, then potential unbalances are introduced after the coupling is disassembled and reassembled either in the balancing machine or the rotor system. These potential unbalances are primarily the result of:

- balancing mounting fixture inaccuracies;
- displacement of coupling components with respect to the axis of rotation of the rotor system during disassembly and reassembly of the coupling.

1.1 Application

This standard is applicable to couplings and addresses potential unbalance which could be expected of a coupling in service. This standard accounts for issues of runout and clearances in the calculation of potential unbalance and resulting balance class. It should be noted that a flexible coupling is generally an assembly of several components having diametral clearance and eccentricities between the pilot surfaces. ISO 1940-1:2003 addresses residual unbalance as measured in the balancing machine. For an example, see annex K.

1.2 Exclusions

This standard does not take into account balance standards developed by other standards organizations (e.g., American Petroleum Institute). In addition, this standard does not address the unbalance effects caused by:

- shaft runout;
- keys that protrude beyond the hub or shaft;
- unfilled keyways or keyseats;

- coupling mounting surface clearance;
- non-homogeneous materials;
- curved datum.

1.3 Additional considerations

Balancing a coupling does not assure one of great gains in balance. The greatest gains in balance come during the manufacturing of the coupling. Controlled runouts of pilots and pilot fit clearances, provided by the coupling supplier during manufacturing, give the greatest results. Balancing of various components results in minimal gain over controlling the bore runout during re-boring. It should be noted that two perfectly balanced parts mounted eccentrically would still shake. An assembly balanced coupling, re-assembled to runouts different than those when in the balance machine, will still be out of balance (the difference between residual and potential unbalance).

Calculations of system unbalance cannot be used to determine system vibrations as stated in the introduction to ISO 1940-1:1986 [1], which reads:

“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.”

2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of the manual. At the time of publication, the editions were valid. All publications are subject to revision, and the users of this manual are encouraged to investigate the possibility of applying the most recent editions of the publications listed:

ANSI/AGMA 9000-D11, *Flexible Couplings - Potential Unbalance Classification*

ISO 1940-1:2003, *Mechanical vibration - Balance quality requirements for rotors in a constant (rigid) state - Part 1: Specification and verification of balance tolerances*

3 Definitions and symbols

The definitions of the elements of unbalance classification and the symbols used in the calculation of potential unbalance are included in this clause.

NOTE: The symbols and definitions used in this standard may differ from other AGMA Standards. The users should assure themselves that they fully understand the terms, definitions, and symbols as contained in this standard.

3.1 Balancing

A procedure by which the mass distribution of a rotating component or assembly is checked and, if necessary, adjusted in order to ensure that the vibration of the shaft journals and/or forces on the bearings at a frequency corresponding to service speed are within specified limits.

3.2 Types of unbalance

3.2.1 Static unbalance

The condition of unbalance for which the central principal axis of inertia is displaced only parallel to the shaft axis. See Figure 1.

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

3.2.2 Couple unbalance

The condition of unbalance for which the central principal axis of inertia intersects the shaft axis at the center of gravity. See Figure 2.

NOTE: 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 center of gravity and the shaft axis.

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

3.2.3 Dynamic unbalance

The condition in which the central principal axis of inertia is not parallel to and does not intersect the shaft axis at the center of gravity. See Figure 3.

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.

Dynamic unbalance is a combination of static unbalance and couple unbalance resolved into two (and in some cases more than two) transverse planes. Only the two-plane case is covered in this standard. Analytical conversion by vector analysis can be made from dynamic unbalance to static plus couple unbalance and vice versa. The correction of dynamic unbalance will achieve complete unbalance correction.

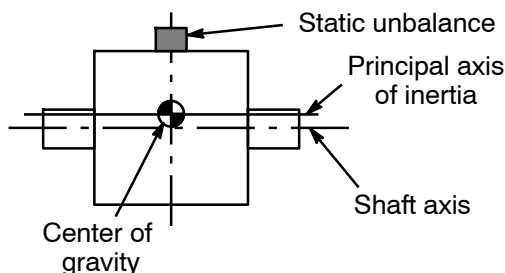


Figure 1 - Static unbalance

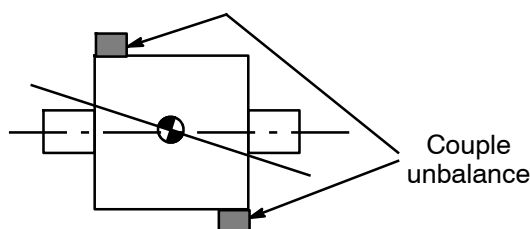


Figure 2 - Couple unbalance

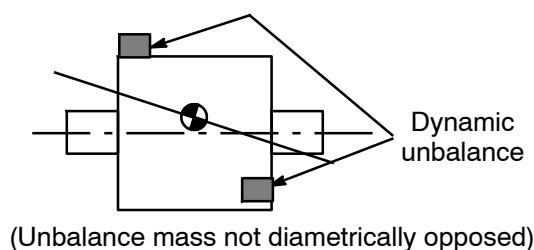


Figure 3 - Dynamic unbalance

3.2.4 Quasi-static unbalance

The condition of unbalance for which the central principal axis of inertia intersects the shaft axis at a point other than the center of gravity. See Figure 4.

NOTE: Quasi-static unbalance is a special case of dynamic unbalance where the angle of the static unbalance coincides with the angle of one of the couple unbalances.

3.3 Additional balancing definitions

3.3.1 Rigid rotor

A rotor is considered rigid when its unbalance can be corrected in any two arbitrarily selected planes and after that correction, its residual unbalance does not change significantly, relative to the shaft axis, at any speed up to maximum service speed and when running under conditions which approximate closely those of the final supporting system.

3.3.2 Axis of rotation (spin axis)

The axis of rotation is that instantaneous line about which a body rotates.

NOTE: This axis may be determined by journals, fits or other locating surfaces.

3.3.3 Principal inertia axis displacement

The displacement measured in micrometers (μm) of the principal inertia axis with respect to the axis of rotation at the balancing planes. In the case of static unbalance these two axes are parallel. In all other cases they are not parallel and are, therefore, at different distances from each other in the two balancing planes.

NOTE: 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.

3.3.4 Amount of unbalance

The 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 center of gravity from the axis of rotation. It is normally measured in gram-millimeters (g mm).

3.3.5 Potential unbalance

The maximum amount of unbalance that may exist in a coupling assembly, whether corrected or uncorrected.

3.3.6 Repeatability of unbalance

The ability of the coupling to repeat (within a specified tolerance) the unbalance reading after being disassembled and reassembled.

NOTE: An assembled coupling is frequently placed on a balancing machine to measure the unbalance. This can be performed on a component balanced coupling or an assembly balanced coupling. The machine readings thus obtained are relative to the running surface and may not accurately represent the unbalance in the installed coupling.

3.3.7 Residual unbalance

The final amount of unbalance that remains in a coupling component or assembly after balancing, prior to removal from the balancing machine.

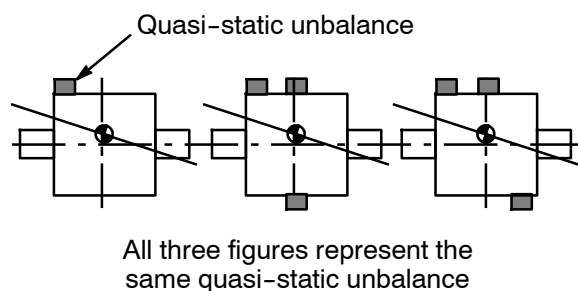


Figure 4 - Quasi-static unbalance

3.3.8 Balance class

The balance class defines the magnitude of potential unbalance (see clause 5).

3.3.9 Mandrel (arbor)

A cylindrical part on which the coupling component or assembly is mounted for balancing.

3.3.10 Mounting fixtures

Tools which adapt a component or coupling to the balancing machine.

3.3.11 Bushing

An adapter or adapter assembly used to mount the coupling components or coupling assembly on the mandrel.

3.3.12 Mandrel assembly

A mandrel with one or more bushings.

3.3.13 Mounting surface

The surface of the mandrel, bushing, or mandrel assembly on which another part of the balancing tooling, a coupling component, or the coupling assembly is mounted.

3.3.14 Rigidifying hardware

The hardware used to make the coupling rigid and aligned to its design axis.

3.3.15 Running surface

The surface used to support the coupling in the balancing machine. The running and mounting surface may be the same.

3.3.16 Unbalance correction

The amount of mass added to, or removed from, the coupling or coupling component, which brings it into specified balance tolerance.

3.3.17 Component balancing

The procedure when each piece or component of the coupling is balanced individually.

3.3.18 Balancing without a mandrel (mandrelless balancing)

A coupling assembly or component must be made rigid and placed on a balancing machine for balancing without a mandrel.

3.3.19 Indicating surface

The indicating surface establishes the axis of a part for the purpose of balancing.

3.3.20 Aligning surface

The aligning surface is used to establish the axis from which a part is located for the purpose of balancing. In some cases, the aligning and indicating surfaces are the same.

3.3.21 Assembly balancing

The procedure when the coupling is assembled and then balanced.

3.3.22 Assembly balancing using component balanced parts

The procedure when the coupling is assembled and balanced using components which have been balanced individually.

3.3.23 Balance tolerance

The maximum permissible residual unbalance, U_{per} .

3.3.24 Inherent unbalance

The unbalance of a homogeneous body caused by geometric design concentricity tolerances which result in the displacement of the center of gravity relative to the axis of rotation.

3.3.25 Pilot surface

The supporting surface of a coupling component or assembly upon which another coupling component is mounted. Examples are given in Table 1.

NOTE: A pilot surface is often referred to as a rabbet, spigot or register.

3.4 Symbols

Table 2 lists the symbols used in this standard, along with their terms, and indicates where they are first used.

Table 1 - Typical examples of coupling pilot surfaces

Component	Usual pilot surfaces
Rigid hub	Bore, rabbet diameter, bolt circle
Flex hub (gear type)	Bore, hub body outside diameter, tooth tip or root diameter
Flanged sleeve (gear type)	Tooth root or tip diameter, end ring inside diameter, rabbet diameter or bolt circle
Flanged adapter plate	Rabbet diameter or bolt circle
Flanged stub end adapter	Stub end (shaft) diameter, rabbet diameter or bolt circle
Spool spacer (gear type)	Tooth tip or root diameter
Flanged spacer	Rabbet diameter or bolt circle
Plate spacer	Rabbet diameter or bolt circle

Table 2 - Symbols and definitions

Symbol	Definition	Unit	Where first used
B	Bolt circle radius	mm	Eq 15
D	Inner diameter of outer component where the inner component will pilot	mm	8.7
d	Outside diameter of inner component where the outer component will pilot	mm	8.7
e_C	Bolt circle eccentricity	mm	Eq 14
e_{F1}	Displacement of the mass axis of the balancing fixture(s)	mm	Eq 18
e_{F2}	Eccentricity of mounting fixture	mm	Eq 19
e_{F3}	Radial clearance between mounting fixtures	mm	Eq 20
e_H	Maximum bolt to bolt hole radial clearance	mm	Eq 14
e_{mar}	Balancing machine minimum achievable residual unbalance expressed as displacement	μm	Eq 17
e_{p1}	Maximum cumulative radial eccentricity of this component relative to the axis of rotation	mm	Eq 14
e_{p2}	Maximum cumulative radial pilot clearance of this component relative to the axis of rotation	mm	Eq 22
e_{per}	Balancing tolerance in terms of displacement of mass axis	μm	Eq 16
e_1	Displacement (eccentricity) of the outer diameter axis relative to the bore axis x-x of component one	mm	Eq 2
e_2	Displacement (eccentricity) of the outer diameter axis relative to the bore axis y-y of component two	mm	Eq 5

(continued)

Table 2 (concluded)

Symbol	Definition	Unit	Where first used
e_3	Radial clearance between bore of component two and outside diameter of component one when component two is mounted on component one	mm	Eq 36
e_4	Normally zero unless a different surface is used for indicating, such as the flange outside diameter.	mm	Eq 36
L_1	Length from indicating surface to centerline of balance machine roller	mm	Eq 36
L_2	Length from centerline of roller to half coupling center of gravity	mm	Eq 36
M_{B1}	Equivalent mass of the bore of component or section one	kg	Eq 2
M_{B2}	Equivalent mass of the bore of component or section two	kg	Eq 3
M_H	Total mass of hardware set	kg	Eq 14
M_{S1}	Mass of component of section one as if it had no bore	kg	Eq 2
M_{S2}	Mass of component of section two as if it had no bore	kg	Eq 3
M_T	Mass apportioned per balancing plane	kg	Eq 16
N	Number of fasteners in the hardware set	—	Eq 14
R_1	Radius to the outside diameter of component one	mm	Figure 8
R_2	Radius to the outside diameter of component two	mm	Figure 9
r_1	Bore radius of component one	mm	Figure 8
r_2	Bore radius of component two	mm	Figure 9
TIR	Total indicator reading	mm	Eq 19
U	Contribution to unbalance of any component or portion of a component	g mm	Eq 1
U_{F1}	Residual unbalance of the mounting fixture	g mm	9.2.3.1
U_{F2}	Unbalance due to mounting fixture eccentricity	g mm	9.2.3.2
U_{F3}	Unbalance due to mounting fixture clearance	g mm	9.2.3.3
U_{H1}	Unbalance due to hardware displacement	g mm	9.1.4
U_{H2}	Unbalance due to hardware mass differences	g mm	9.1.5
U_1	Inherent unbalance of uncorrected coupling components	g mm	9.1.1
U_{11}	Inherent unbalance of uncorrected component one	g mm	Eq 2
U_{12}	Inherent unbalance of uncorrected component two	g mm	Eq 8
U_{mar}	Unbalance due to balancing machine minimum achievable residual unbalance	g mm	9.2.2
U_{P1}	Potential unbalance due to coupling pilot surface eccentricity	g mm	9.1.2
U_{P2}	Potential unbalance due to coupling pilot surface clearance	g mm	9.1.3
U_{rss}	Square root of the sum of the squares of the unbalance of all contributing sources	g mm	Eq 1
U_{per}	Balance tolerance (maximum permissible residual unbalance)	g mm	9.2.1
y_{xx}	Location of center of gravity relative to axis of rotation x-x	mm	Eq 2
y_{yy}	Location of center of gravity relative to axis of rotation y-y	mm	Eq 4
ΔM	Mass of the heaviest fastener component in a set minus the mass of the lightest similar fastener component in the set	g	Eq 15

4 Responsibility

The coupling manufacturer is responsible for supplying a coupling which meets the balance class specified by the purchaser. The successful operation of the coupling in the system is the responsibility of the purchaser.

5 Coupling balance class

The balance class of any coupling assembly is determined by the square root of the sum of the squares (rss) of the maximum displacement between the coupling principal inertia axis and the axis of rotation. Factors which contribute to these displacements are listed and defined in clauses 7 and 8. Typical examples of computation are shown in the appendices.

NOTE: It is unrealistic to assume that each contribution to potential unbalance by the coupling components and balancing tooling is arithmetically additive. The various unbalance errors are vectors and will have different angular directions and are added vectorially, not arithmetically. To determine the probable resultant error, the square root of the sum of the squares (rss) of the individual contributions is used.

5.1 Standard classes of coupling balance

The standard classes of coupling balance are given in Table 3 for maximum potential displacement of principal inertia axis from the axis of rotation at balancing planes in terms of rss micrometers.

6 Coupling balance class selection

The selection of proper coupling balance class is the responsibility of the purchaser of the coupling.

6.1 Unbalance limit

The amount of coupling unbalance that can be satisfactorily tolerated by any rotating system is dictated by the characteristics of the specific connected machines with their supporting structure and can best be determined by the manufacturers of those machines. It is recommended that each machinery manufacturer specify the proper coupling balance class for flexible couplings to be used in conjunction with the equipment. It should be noted that some couplings have different masses apportioned to each coupling half. When the coupling purchaser is unable to determine the appropriate balance class, he may refer to Table 4 as a general guide. The values suggested in Table 4 reflect typical selection practice only. Assurance is neither offered nor intended that these values are proper or appropriate for any particular system or machine. Systems that are insensitive to coupling unbalance may operate satisfactorily with values of coupling balance class lower than those suggested. Conversely, systems or machines which are unusually sensitive to coupling unbalance may require a higher balance class than those suggested.

Table 3 - Standard classes of coupling balance

AGMA coupling balance class	Maximum potential displacement (rss, micrometers)
4	Over 800
5	800
6	400
7	200
8	100
9	50
10	25
11	12.5

Table 4 - Values of coupling balance class

Selection bands (from Figure 5)	System sensitivity to coupling unbalance		
	Low	Average	High
A	5	6	7
B	6	7	8
C	7	8	9
D	8	9	10
E	9	10	11
F	10	11	
G	11		
NOTE Refer to Table 3 for standard classes of coupling balance.			

6.2 Selection bands

Where Table 4 is used as a guide for selection of coupling balance class, it is first necessary to determine the appropriate selection band from Figure 5 for the coupling net mass per coupling half and maximum service speed of the coupling. For each selection band, typical values of coupling balance classes are shown in Table 4 dependent upon the system's sensitivity to coupling unbalance.

EXAMPLE:

Coupling net mass per coupling half: 34 kg

Maximum service speed: 7500 rpm

From Figure 5, the appropriate selection band is Band "E". From Table 4, for a system estimated to have average sensitivity to coupling unbalance, the typical coupling balance class selection is Class 10.

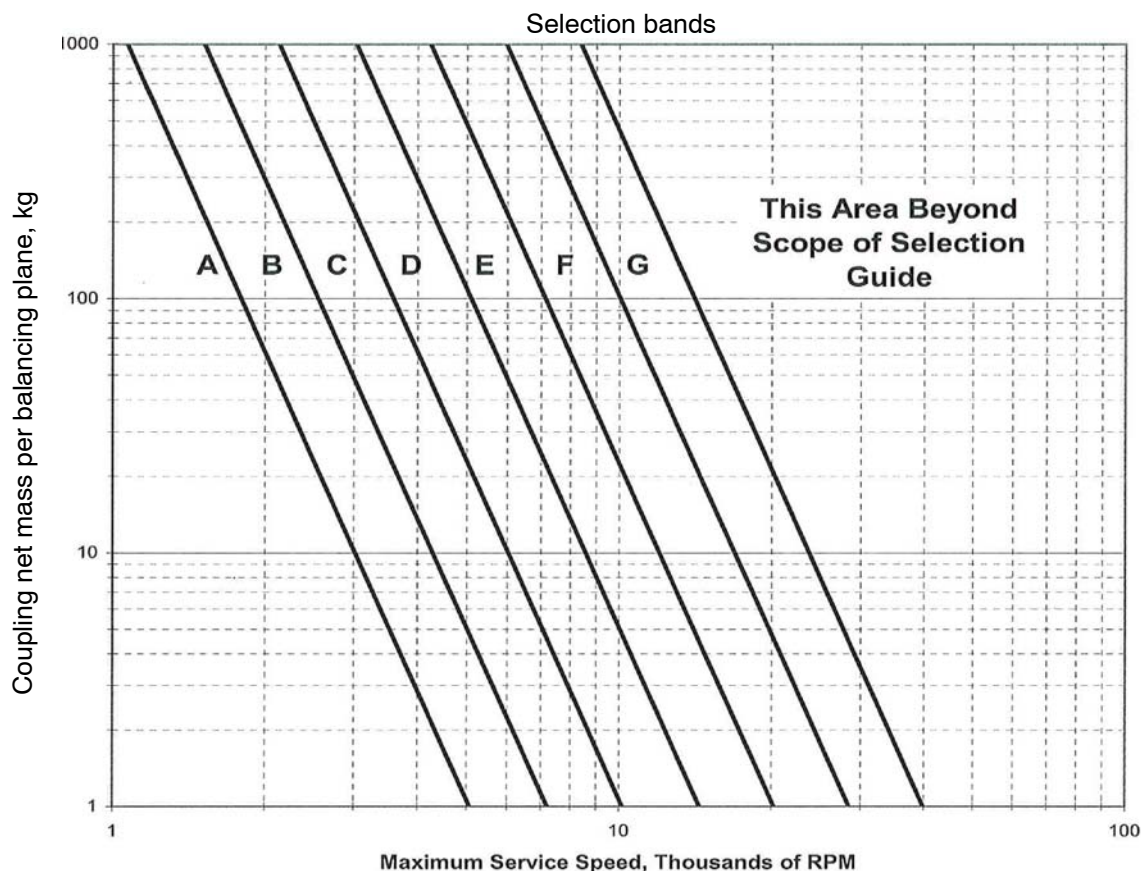


Figure 5 - Selection bands

6.3 System sensitivity factors

Factors which increase the system's sensitivity to coupling unbalance include:

- Shaft end deflection. Machines having flexible shaft extensions that produce large deflections are relatively sensitive to coupling unbalance.
- Bearing load due to coupling mass relative to total bearing load. Machines having lightly loaded bearings or bearings loaded primarily by the overhung mass of the coupling are relatively sensitive to unbalance. Machines having overhung rotors or mass are often sensitive to coupling unbalance.
- Bearing, bearing support, and foundation flexibility. Machines or systems with flexible foundations or supports for the rotating elements are relatively sensitive to coupling unbalance.
- System natural frequencies. Machines or systems operating near natural frequencies of rotor or support systems are sensitive to coupling unbalance.
- Machine separation. Systems having widely separated machines, for instance those employing floating shaft couplings, are relatively sensitive to coupling unbalance.
- Shaft extension relative to bearing span. Machines having a short bearing span relative to their shaft extensions are sensitive to static unbalance.

NOTE: Coupling mass shift can be caused by shaft runout, hub to shaft clearance and pilot clearance.

7 Factors contributing to the potential unbalance of uncorrected (not balanced) couplings

The factors which can contribute to the potential unbalance of an uncorrected coupling assembly are listed below and are defined in the following subclauses.

- inherent unbalance of uncorrected coupling components
- coupling pilot surface eccentricity
- coupling pilot surface clearance
- hardware displacement
- hardware mass differences

The method of computing the overall effect of these factors on coupling unbalance is given in clause 9. Examples of the computation are found in annexes B and F.

7.1 Inherent unbalance of an uncorrected coupling

If the coupling assembly or components are not corrected, an estimate of inherent unbalance caused by manufacturing tolerances may be based upon either:

- statistical analysis of unbalance data accumulated for couplings manufactured to the same design specifications.
- calculations of the maximum rss unbalance that could theoretically be produced by the design specification.

7.2 Coupling pilot surface eccentricity

Coupling pilot surface eccentricity is a condition which may permit relative radial displacement of the mass axis between coupling parts upon assembly or reassembly.

7.3 Coupling pilot surface clearance

Coupling pilot surface clearance is the clearance which permits relative radial displacement of the mass axis of the coupling components or subassemblies.

7.4 Hardware displacement

Hardware displacement is the combined effect of hardware clearance and bolt circle eccentricity.

7.5 Hardware mass differences

Hardware mass differences are those found in all coupling hardware, including fasteners, washers, nuts, lube plugs, seal rings, gaskets, keys, snap rings, keeper plates, thrust plates and retainer nuts.

8 Factors contributing to the potential unbalance of corrected (balanced) couplings

The factors which can contribute to the potential unbalance of a corrected coupling assembly are listed below and are defined in the following subclauses.

- balance tolerances
- balancing machine minimum achievable residual unbalance
- mandrel assembly or balancing fixture unbalance
- mandrel assembly mounting surface eccentricity
- mandrel assembly clearance(s)
- coupling pilot surface eccentricity
- coupling pilot surface clearance
- hardware displacement
- hardware mass differences
- coupling bore eccentricity to running surface

The method of computing the overall effect of these factors on coupling unbalance is given in clause 9. Examples of the computation are found in annexes C, D, E, G and H.

CAUTION: It is strongly emphasized that the potential unbalance of a coupling assembly when installed in the drive train is, in most cases, greater than the residual unbalance as measured in the balancing machine.

8.1 Balance tolerance

Balance tolerances are attributable to each balanced component.

8.2 Balancing machine minimum achievable residual unbalance

The sources of errors are:

- limitation in machine capability to indicate a sufficiently small residual unbalance
- drive errors (if applicable)

8.3 Mandrel assembly or balancing fixture unbalance

Mandrel assembly or balancing fixture unbalance is the combined residual unbalance caused by all components of the mandrel assembly or fixture, including mandrel, bushings, flanges, clamping devices, keys, set-screws, nuts and bolts.

8.4 Mandrel assembly mounting surface eccentricity

The mandrel assembly mounting surface or balancing fixture mounting surface eccentricity is the eccentricity with respect to the axis of rotation in the balancing machine.

8.5 Mandrel assembly clearance(s)

The mandrel assembly or fixture mounting surface clearance(s) are the clearance(s) in the assembly or fixture such as the bushing to bore, and mandrel to bushing clearances, where applicable.

8.6 Coupling pilot surface eccentricity

Coupling pilot surface eccentricity is a condition which may permit relative radial displacement of the mass axis between coupling parts upon assembly or reassembly subsequent to the balancing operation.

NOTE: For assembly balanced couplings, pilot surface eccentricity does not contribute to potential unbalance because the effect is corrected by balancing if the coupling is match marked.

8.7 Coupling pilot surface clearance

Coupling pilot surface clearance is the clearance which permits relative radial displacement of the mass axis of the coupling components or subassemblies on reassembly subsequent to the balancing operation. When the coupling is balanced as an assembly, the potential displacement upon re-assembly is equal to the full amount of the diametral clearance ($D - d$), see Figure 6. When the coupling is balanced as component parts, the potential displacement upon assembly is equal to one-half of the diametral clearance ($[D - d]/2$), see Figure 7.

It should be noted that the foregoing conditions also apply to coupling components piloted by bolts.

8.8 Hardware displacement

Hardware displacement is the combined effect of hardware clearance and bolt circle eccentricity.

8.9 Hardware mass differences

Hardware mass differences are those found in all coupling hardware including fasteners, washers, nuts, lube plugs, seal rings, gaskets, keys, snap rings, keeper plates, thrust plates and retainer nuts.

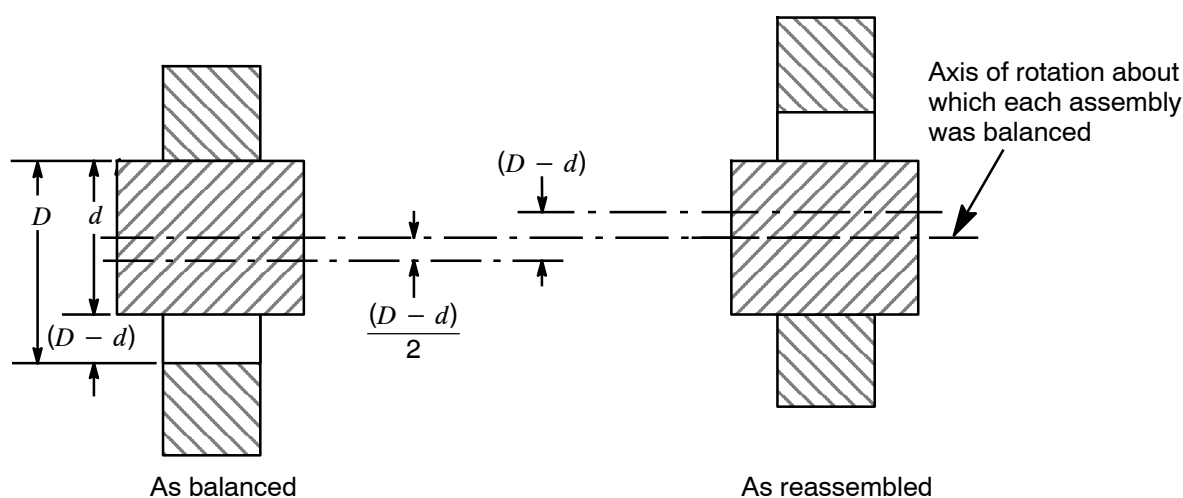


Figure 6 - Coupling pilot surface clearance - assembly balanced

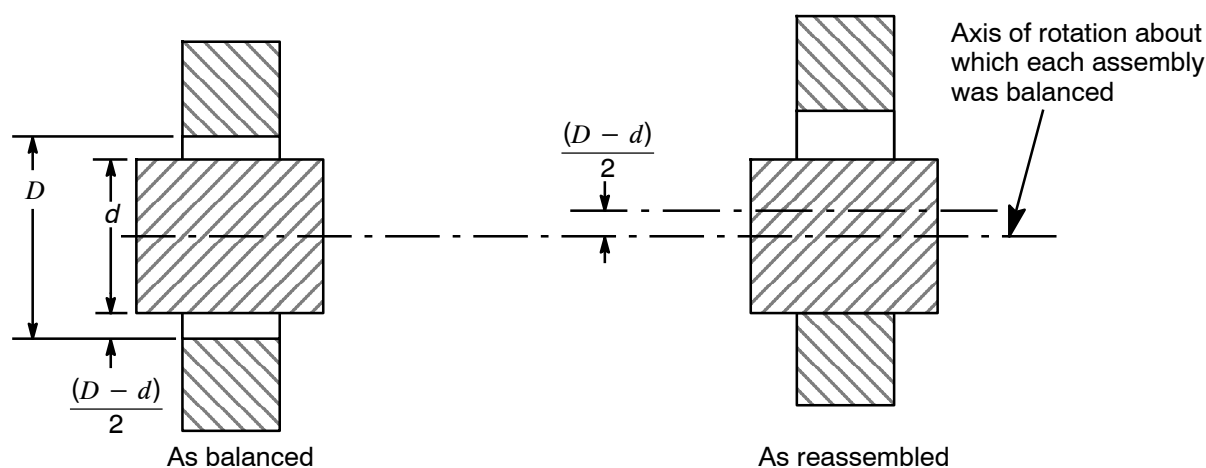


Figure 7 - Coupling pilot surface clearance - component balanced

8.10 Coupling bore eccentricity to running surface

The coupling bore eccentricity to the running surface is the displacement of the theoretical bore centerline with respect to the surface upon which the coupling is supported in the balancing machine (balanced without a mandrel).

9 Determination of coupling potential unbalance

A flexible coupling is normally treated as two separate halves with half the spacer mass assigned to each. The driver equipment is subjected to the potential unbalance of one half coupling acting through its center of gravity (see Figure E.1 and Figure H.1), and the driven equipment the other half. If a coupling is non-symmetrical, the calculation should be performed for each half separately.

The general procedure is to calculate the unbalance contributions from various sources and combine them by taking the square root of the sum of the squares of the individual contributions. Possible sources of unbalance are:

- component unbalance, whether corrected or not;
- component pilot eccentricities;
- component pilot clearances;
- fixture eccentricities, clearances and unbalance.

$$U_{\text{rss}} = \sqrt{\sum U^2} \quad (1)$$

where

U_{rss} is square root of the sum of the squares of unbalance of all contributing sources;

U is contribution to unbalance of any component or portion of a component as defined in clauses 7 and 8. Refer to annexes for examples.

9.1 Uncorrected coupling

The potential unbalance of an assembly of uncorrected components is determined by taking the rss summation of the individual component contributions to the total unbalance. Refer to annexes B and F for examples.

9.1.1 Inherent unbalance of uncorrected coupling components, U_1

The individual component contribution is determined by multiplying its mass by the maximum displacement of the center of gravity (centroid) of that component with respect to the axis of rotation.

The inherent unbalance, U_1 , of the component or portion of a component (see Figure 8) relative to the axis of rotation $x - x$ is:

$$\begin{aligned} U_{11} &= 1000 y_{\text{xx}} (M_{\text{S1}} - M_{\text{B1}}) \\ &= 1000 e_1 M_{\text{S1}} \end{aligned} \quad (2)$$

where

U_{11} is inherent unbalance of uncorrected component one, g mm (1000 g = 1 kg);

y_{xx} is location of the center of gravity relative to the axis of rotation $x - x$ (see annex A for derivation), mm;

r_1 is bore radius of component one, mm;

R_1 is radius to the outside diameter of component one, mm;

e_1 is displacement (eccentricity) of the outer diameter axis relative to the bore axis $x - x$, mm;

M_{S1} is mass of the component as if it had no bore, kg;

M_{B1} is equivalent mass of the component bore, kg.

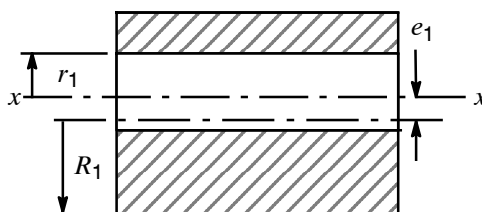


Figure 8 - Component or portion of a component

9.1.2 Unbalance due to coupling pilot surface eccentricity, U_{P1}

The calculation of the potential unbalance, U , of component 2 when mounted on component 1 whose pilot surface is eccentric to the axis of rotation $x-x$ (see Figure 9) is:

$$U = 1000 y_{xx} (M_{S2} - M_{B2}) \quad (3)$$

where

$$R_1 = r_2 \text{ (no clearance)}$$

$$y_{xx} = e_1 + y_{yy} \quad (4)$$

where

$$y_{yy} = \frac{e_2 M_{S2}}{(M_{S2} - M_{B2})} \quad (5)$$

$$U = 1000 \left(e_1 + \frac{e_2 M_{S2}}{M_{S2} - M_{B2}} \right) (M_{S2} - M_{B2}) \quad (6)$$

$$U = 1000 \left[e_1 (M_{S2} - M_{B2}) + e_2 M_{S2} \right] \quad (7)$$

$$U = U_{P1} + U_{I2} \quad (8)$$

where

U_{P1} is $1000 e_1 (M_{S2} - M_{B2})$ and is the contribution due to pilot surface eccentricity, g mm;

U_{I2} is $1000 e_2 M_{S2}$ and is the inherent unbalance of component 2 as in 9.1.1, g mm;

e_1, e_2 are eccentricities of components 1 and 2 relative to the bore axis of each component, mm;

M_{S2} is mass of component 2 with no bore, kg;

M_{B2} is mass of the bore of component 2, kg.

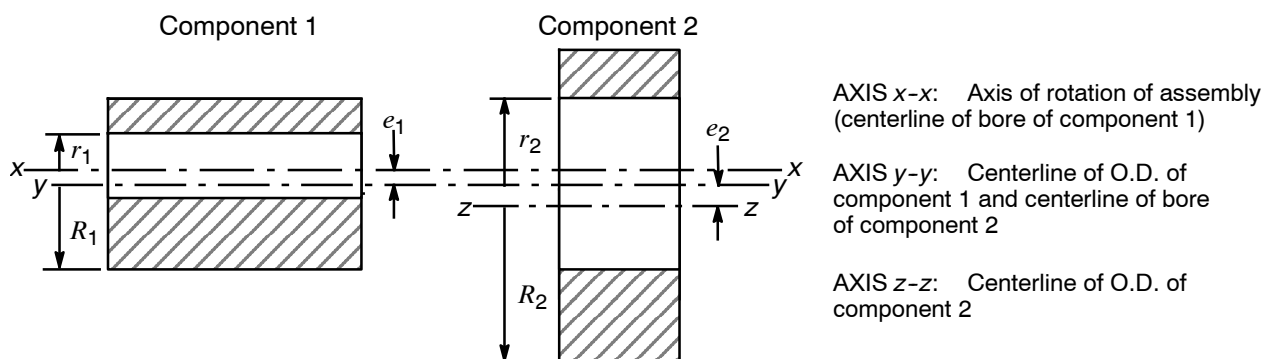


Figure 9 - Components to be assembled to each other