INTERNATIONAL STANDARD

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Mechanical vibration — Rotor balancing —

Part 32: Shaft and fitment key convention

Vibrations mécaniques — Équilibrage des rotors —

Partie 32: Convention relative aux clavettes d'arbres et aux éléments rapportés

Reference number
ISO 21940-32:2012(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 21940-32 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

This first edition of ISO 21940-32 cancels and replaces ISO 8821:1989, of which it constitutes an editorial revision. The main change is deletion of statements relating to the implementation date, transition period and key convention usage in the past.

ISO 21940 consists of the following parts, under the general title *Mechanical vibration — Rotor balancing*:

— *Part 1: Introduction* [1)]

— *Part 2: Vocabulary* [2)]

— *Part 11: Procedures and tolerances for rotors with rigid behaviour* [3)]

— *Part 12: Procedures and tolerances for rotors with flexible behaviour* [4)]

— *Part 13: Criteria and safeguards for the* in-situ *balancing of medium and large rotors* [5)]

— *Part 14: Procedures for assessing balance errors* [6)]

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1) Revision of ISO 19499:2007, *Mechanical vibration — Balancing — Guidance on the use and application of balancing standards*

2) Revision of ISO 1925:2001, *Mechanical vibration — Balancing — Vocabulary*

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

4) Revision of ISO 11342:1998, *Mechanical vibration — Methods and criteria for the mechanical balancing of flexible rotors*

5) Revision of ISO 20806:2009, *Mechanical vibration — Criteria and safeguards for the* in-situ *balancing of medium and large rotors*

6) Revision of ISO 1940-2:1997, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 2: Balance errors*

— *Part 21: Description and evaluation of balancing machines* [7)]

— *Part 23: Enclosures and other protective measures for balancing machines* [8)]

— *Part 31: Susceptibility and sensitivity of machines to unbalance* [9)]

— *Part 32: Shaft and fitment key convention* [10)]

7) Revision of ISO 2953:1999, *Mechanical vibration — Balancing machines — Description and evaluation*

8) Revision of ISO 7475:2002, *Mechanical vibration — Balancing machines — Enclosures and other protective measures for the measuring station*

9) Revision of ISO 10814:1996, *Mechanical vibration — Susceptibility and sensitivity of machines to unbalance*

10) Revision of ISO 8821:1989, *Mechanical vibration — Balancing — Shaft and fitment key convention*

Introduction

It is often impossible or economically unreasonable to balance rotors with fitments after they have been assembled; the rotor components which also may originate from different suppliers are therefore balanced separately. An appropriate balance tolerance is applied to each component so that, when shaft and fitment(s) are coupled together, the rotor assembly meets the required balance tolerance and/or vibration limit. For coupling the fitment(s) to the shaft, different methods are applied, a very common one uses keys. If, however, a different key convention has been used when balancing the shaft than that one used for balancing the fitment(s), it is quite likely that the rotor assembly has a balance error influencing its residual unbalance.

There are three methods, or key conventions, for balancing shafts and fitments coupled together with keys:

— full-key convention;

— half-key convention;

— no-key convention.

This part of ISO 21940 unifies the key conventions used throughout the world and gives instructions on a marking of components balanced in accordance with the key convention applied. When consistently used, it results in compatibility of shafts and fitments so that they can be balanced by different suppliers and, after being assembled, the balance tolerance and/or vibration limit for the rotor assembly is met.

Mechanical vibration — Rotor balancing —

Part 32: Shaft and fitment key convention

1 Scope

This part of ISO 21940 specifies one convention for balancing the individual components (shaft and fitments) of a keyed rotor assembly. This provides compatibility of all balanced components so that when they have been assembled the overall balance tolerance and/or vibration limit for the rotor assembly is met.

This part of ISO 21940 specifies that half-keys be used when balancing the individual components of a keyed rotor assembly. It also specifies a marking of the components balanced in accordance with the key convention used.

This part of ISO 21940 applies to rotors balanced in a balancing machine, in their own bearings or *in situ*. The key convention can also be applied when measuring the residual unbalance and/or vibration of rotors with keyways, but to which fitments have not yet been assembled.

In addition to applying to keys of constant rectangular or square cross-section mounted parallel to the shaft centreline, this part of ISO 21940 also applies to keys mounted on tapered shaft surfaces, to woodruff, gibhead, dowel and other special keys. The principle of the half-key convention is applied as is appropriate to the particular shape and location of the special key.

2 Normative references

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

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*[1)]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1925 apply.

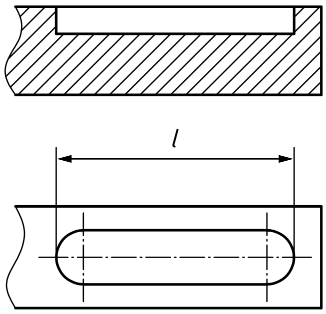
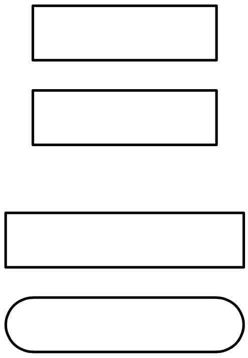
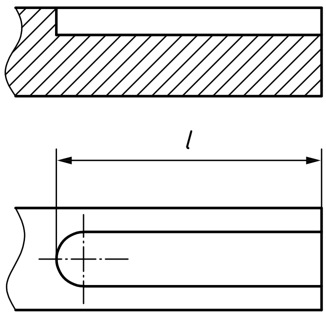
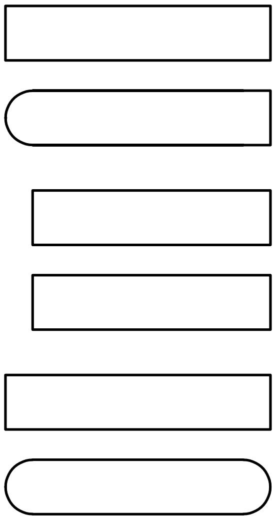
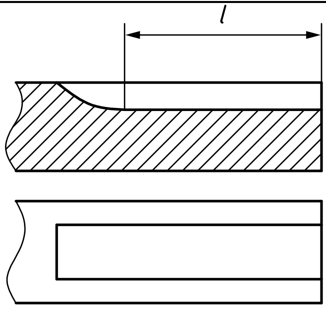
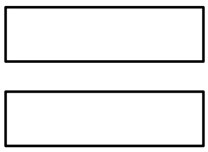
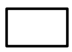
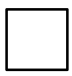
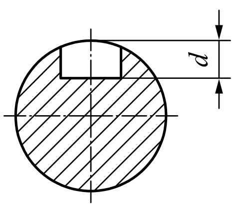
4 Half-key convention

This part of ISO 21940 specifies that the half-key convention be followed. According to this convention a half-key shall be used in the keyway of the shaft having one keyway while balancing the shaft without the fitment. A complementary half-key shall be used while balancing the corresponding fitment on a balancing mandrel, provided the mandrel has no keyways. If the mandrel has keyways, the methods described in A.1.3 shall be followed. If at one cross-section, shaft and fitment each have two keyways the methods described in A.1.4 shall be followed. The axial location of the centre of gravity of the half-key should be the same as that of the full key in the final assembly.

NOTE Table 1 shows examples of various types of shaft keyways and full keys of constant rectangular or square cross-section.

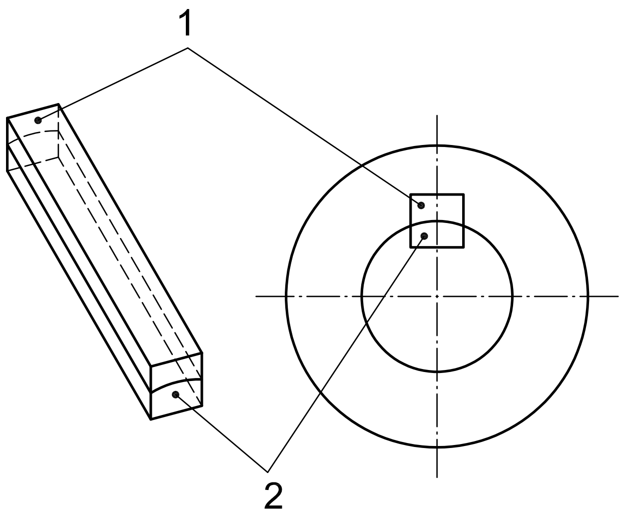
1) To become ISO 21940-2 when revised.

Table 1 — Examples of types of shaft keyways and keys

Type	Configuration of keyway	Name of keyway	Configuration of key[a]	Name of key
A		Round/round end		Square/square end Round/round end
B		Round/square end		Round/square end Square/square end Round/round end
C		Sled runner		Square/square end
a	Full-key cross-section	 Rectangular  Square		

l Length of the keyway
d Depth of the keyway

Practical considerations for making and usage of half-keys are given in Annex B. A contoured half-key set is shown in Figure 1.



Key

1 half-key for the fitment

2 half-key for the shaft

Figure 1 — Contoured half-key set

The use of the half-key convention provides a uniform method for balancing shafts and fitments joined together by keys. It eliminates balance errors and therefore unnecessary residual unbalance and/or vibration which can be caused by the use of different key conventions, and avoids the creation of an internal bending moment in the assembly (as would be caused by the use of full keys during balancing of the shaft). For more information on the differences between the key conventions, see Annex C.

5 Marking

5.1 The end face of the shaft adjacent to the keyway shall be permanently marked with the letter H to indicate that balancing was performed using the half-key convention. Permanent marking using metal stamps or vibratory engravers is recommended, but a permanent or indelible ink may also be used.

If the shaft end face is too small for marking, the bottom of the keyway may be used.

5.2 The face of the fitment adjacent to the keyway shall be permanently marked with the letter H to indicate that balancing was performed using the half-key convention. The letter should be readily visible when the fitment is joined to the shaft. Permanent marking using metal stamps or vibratory engravers is recommended, but a permanent or indelible ink may also be used.

5.3 The marking of the shaft and the fitment with the letter H may only be omitted if confusion as to which key convention was used is unlikely.

5.4 When balancing a replacement shaft or fitment, the known mating part of which has not been balanced using the half-key convention, it is permissible to balance the replacement component with the key convention of the existing mating part. In this special case, both components shall be permanently marked with an identification letter corresponding to the key convention used, as follows:

a) components balanced using the full-key convention (see C.1.2) shall be marked with the letter F adjacent to the keyway;

b) components balanced using the no-key convention (see C.1.4) shall be marked with the letter N adjacent to the keyway.

NOTE 1 For the fitment, the balancing procedures in accordance with the full-key convention and the no-key convention are identical. Marking is done as ordered.

NOTE 2 If fitments are balanced for being put on stock, these fitments may be marked either with F or with N. But since the full-key convention is in use more often, these fitments generally are marked with F.

6 Implementation of the half-key convention

All manufacturers of original parts and processed components shall comply with the half-key convention of balancing and mark each newly manufactured shaft and fitment with the letter H.

NOTE Some International Standards prescribe that the half-key convention be followed, e.g. IEC 60034-14[1].

Change-over of equipment in service to the half-key convention with proper marking of the shaft and fitment(s) during a repair balancing operation is encouraged. In any case, a marking shall be added (see Clause 5).

Annex A
(normative)

Specifications for the half-key convention

A.1 Principal specifications for the half-key convention

A.1.1 The specifications given in A.1.2 to A.1.4 apply to one cross-section.

A.1.2 For a shaft with a single keyway, a half-key is required for the keyway.

A.1.3 For a fitment with a single keyway, one of the following requirements shall be met:

a) when the mandrel has no keyway: use one half-key;

b) when the mandrel has two identical keyways 180° opposite each other: use one full key and one half-key of equal length;

c) when the mandrel has a single keyway:

— first use one half-key for balancing the mandrel, and

— then use one full key for balancing the mandrel/fitment assembly.

NOTE 1 Mandrel constructions using requirement a) or b) are preferred because they are inherently balanced.

NOTE 2 The balancing mandrel should have the same diametral tolerances as the shaft it is intended to simulate. The mandrel should also have correction planes on it to allow for unbalance correction, index balancing and biasing.

A.1.4 If a shaft or fitment is provided with two equal keyways 180° opposite each other and two keys are used in the final assembly, it is permissible to balance without keys. This is in accordance with the specifications for the half-key convention. If the two keyways are not equal or are positioned other than 180° opposite each other, two half-keys are required for balancing the shaft and two more for balancing the fitment.

A.1.5 Special keys, such as woodruff, gibhead or tapered keys, require individual consideration.

A.1.6 If a full key is shipped with the shaft, its length is obvious and therefore permits determination of the proper half-key length for balancing the fitment (see also B.4). If no key is shipped with the shaft, the length of the half-key used originally for balancing the shaft is assumed to be the same as the length of the shaft keyway (see also Table 1, dimension l).

A.1.7 Half-keys used for balancing should always be made of material having the same density as the final key. Unless specifically stated otherwise, it is to be assumed that final keys are made of steel; therefore, half-keys should also be made of steel.

A.1.8 The half-key should be held in place on the shaft by a means that introduces negligible unbalance, e.g. fibreglass tape, but prevents the half-key from accidentally separating from the keyway.

A.2 Special cases

A.2.1 If the unbalance tolerances and/or vibration limits of certain assemblies are generous enough not to be exceeded by the change in key convention, or if a manufacturer has a limited number of users who require no shaft repair by or replacement from alternative sources, it may be acceptable to retain a key convention other than the half-key convention. However, all rotor components shall be marked accordingly (see Clause 5).

A.2.2 A half-key is not used in certain couplings because they are balanced by the manufacturer without a keyway machined into the bore. The user of the coupling generally enlarges the bore and machines the keyway to his requirements without rebalancing. This method basically complies with the half-key convention, provided the final key has approximately the same length as the keyway of the coupling.

Annex B
(informative)

Practical considerations for making half-keys and usage of keys

B.1 Contoured half-keys

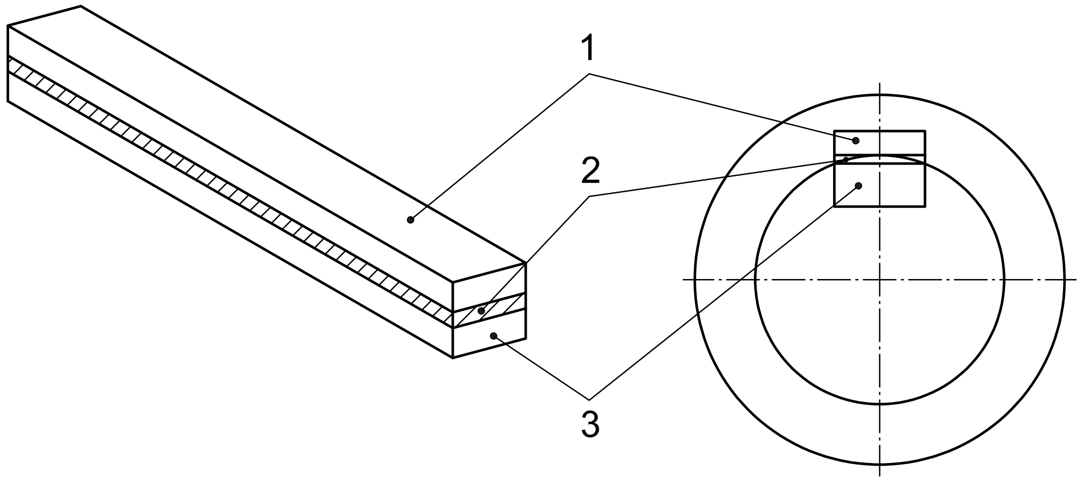
When contoured half-keys for the shaft and fitment, as shown in Figure 1, are put together, they have the same overall dimensions and mass as the full key that is used in the final rotor assembly. However, such contoured half-keys are rather expensive to manufacture and quite seldom used for balancing one-of-a-kind or small lots of shafts or fitments.

B.2 Not-contoured half-keys for shafts

Shop practice often uses half-keys of less than ideal dimensions, such as keys of (approximately) half-height or half-length (see Figures B.1 to B.3). The half-length keys are preferable because they are easier to make and provide a closer unbalance value of the ideal contoured half-key than the half-height key. In fact, for keys having a square cross-section, a half-length key cut to 48 % of the mass of the final full key generally causes an unbalance whose value is within 2 % of that of the ideal contoured half-key.

If the depth of the keyways differs between shaft and fitment, the above rule no longer holds true. Instead, the mass of the half-length key for the shaft should be 45 % of the final full key for keys up to 8 mm wide, and 54 % for wider keys. The unbalance values of these half-keys are then generally within 2 % of the ideal value.

The percentage stated above may not be accurate enough to be applicable to half-keys used for balancing shafts with flexible behaviour.



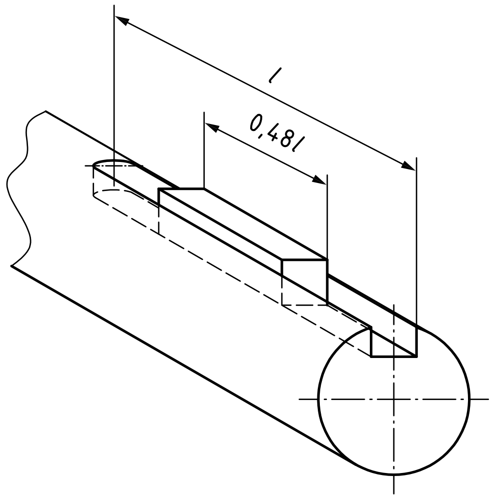
Key

1 half-key for the fitment

2 missing material due to the cut

3 half-key for the shaft

Figure B.1 — Half-height key set



Key

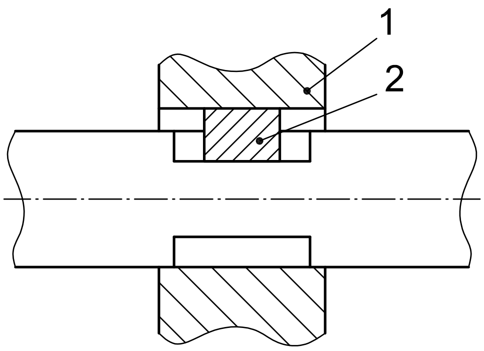
l length of the keyway

Figure B.2 — Half-length key used for balancing a shaft, its centre of gravity located in the same transverse plane as that of the full key in the final assembly

B.3 Not-contoured half-keys for fitments

For low-volume production, the not-contoured half-height key is prevalent. To compensate for the missing contoured portion facing the shaft (labelled 1 in Figure B.1), the length of the half-key should exceed the length of the final (square cross-section) full key by 4 %.

For high-volume production, a half-length key as shown in Figure B.3 may be more efficient. The key can be bolted into one of the opposing keyways of a balanced mandrel to maintain its axial position. Centre the fitment over the half-key during balancing.



Key

1 fitment

2 half-length key

Figure B.3 — Half-length key used for balancing a fitment on a balanced mandrel with two identical keyways 180° opposite each other

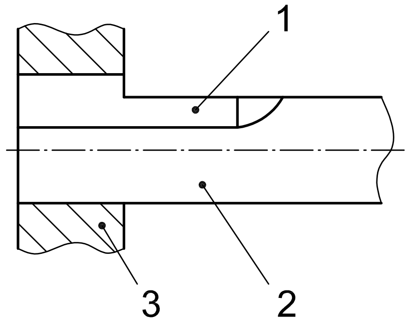
B.4 Half-key length

Key lengths are not universally standardized for given shaft diameters. Often shaft and fitment are furnished by different manufacturers, neither knowing the length of the other's keyway. In such cases, the rule is that each manufacturer uses a half-key properly dimensioned on the assumption that the final assembly key occupies the full length of the keyway (see also A.1.6).

Occasionally, an assembler of shaft and fitment is confronted with a longer keyway in the shaft than in the fitment. To avoid having to rebalance either the shaft with a half-key based on the shorter fitment keyway or the fitment with a half-key based on the longer shaft keyway, one of the following alternative solutions may be used for the assembly:

a) stepped key, machined to have two sections of different height to accommodate different keyway lengths in shaft and fitment (see Figure B.4);

b) average-length key, consisting of a full-height key cut to the average length of the shaft and fitment keyways (see Figures B.5 and B.6).



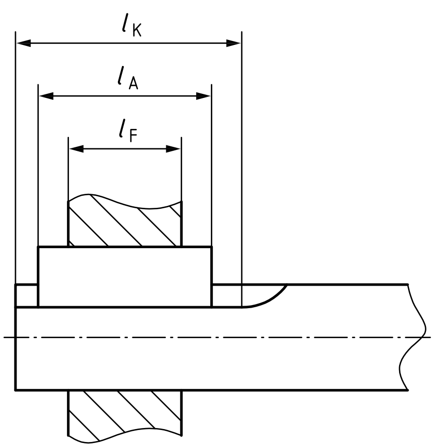
Key

1 stepped key

2 shaft

3 fitment

Figure B.4 — Stepped (final) key for a short fitment



Key

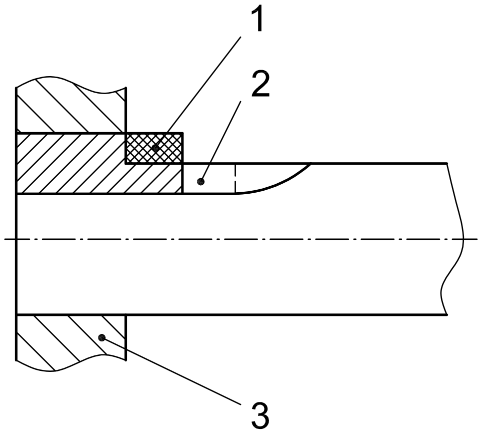
l_K length of the shaft keyway

l_F length of the fitment

l_A average length for the key

$$l_A = \frac{l_K + l_F}{2}$$

Figure B.5 — Average-length (final) key for a short fitment in the ideal axial position



Key

1 filled

2 not filled

3 fitment

Figure B.6 — Average-length (final) key for a short fitment mounted flush with the shaft end, producing balance errors

The ideal axial installation position for the average-length key is in the centre of the rectangular portion of the shaft keyway with the fitment centred on the key (see Figure B.5). Mounting the fitment in the ideal axial position, however, is seldom possible. Instead, the fitment is usually installed flush with the shaft end, as shown in Figure B.6. This, however, produces balance errors, see Clause B.5.

If the fitment keyway is longer than the shaft keyway, balance the fitment with a half-key based on the shorter shaft keyway. Alternatively, a stepped key can be made, one half of which fills the full length of the fitment keyway, the other half filling the shorter length of the shaft keyway.

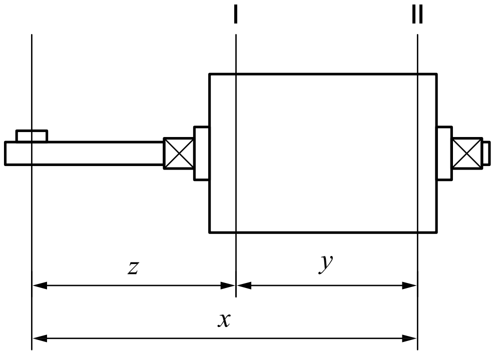
B.5 Balance errors due to keys

Half-keys can cause balance errors (and therefore influence the residual unbalance of the rotor assembly) because of keyway design clearances, machining tolerances, and deviations from the ideal shape or position. The installation shown in Figure B.6 introduces two balance errors: namely, a couple unbalance because the portion of the key marked “filled” should be in the axial position marked “not filled”, and a static unbalance because the portion of the key marked “filled” is located at a greater distance from the shaft centreline than the portion marked “not filled” where it should be located. To assess the significance of these errors, transfer them to the shaft (rotor) correction planes I and II, see e.g. Figure B.7.

Note that the balance error occurring in the plane of the key, which is a single unbalance, usually increases its effect when transferred to the tolerance planes. The shaft example in Figure B.7 illustrates this for the case that the tolerance planes are the correction planes. For plane I (the near correction plane) the error increases by the ratio x/y, and for plane II (the far correction plane) it changes by the ratio $-z/y$. The couple unbalance error occurring in two closely spaced planes, e.g. those mentioned for Figure B.6, is usually transferred to smaller unbalance values in the shaft (rotor) correction planes by the ratio of the distances between the couple unbalance planes and the correction planes.

Figure B.8 illustrates another error by showing a cross-section through a shaft and fitment assembly with key and keyway in stationary and then in operational position. Clearances permit the key to tilt slightly.

Take these and other balance errors into account when setting individual balance tolerances for the shaft and the fitment.



Key

x, y, z distances

I, II correction planes

Figure B.7 — Transfer of a single unbalance from the plane of the key to the shaft (rotor) correction planes

a) Stationary **b) Operational**

[a] Shaft torque.

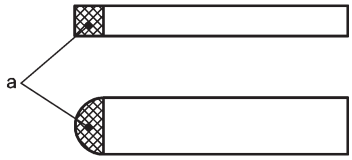
Figure B.8 — Stationary and operational key positions

B.6 Shape of keyway end

Keyways are generally machined into shafts with an end mill cutter (type A and B in Table 1) or with a key slot cutter (type C in Table 1), see Figures B.9 and B.10. If the rounded portion of the shaft keyway is not filled by the final key (it never is in type C keyways), its unbalance value needs not to be considered when calculating the size of the half-key (see also Table 1, dimension l). Instead, the small void constitutes an unbalance in the shaft and is corrected, together with the other shaft unbalances, in the shaft correction planes. The internal bending moment thereby introduced into the shaft is of no concern on rotors with rigid behaviour, but may not be acceptable on rotors with flexible behaviour.

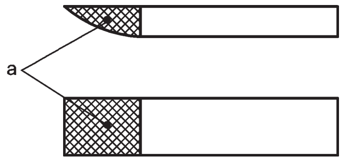
Fitment keyways are generally machined with a broach or shaper and therefore are rectangular in shape, with both ends open.

If the fitment was balanced with a half-key that filled the entire length of the keyway, and is then mounted on a shaft having a key of the same length but with one or two round ends, a small balance error results. Each round key end leaves void two small corner spaces in the fitment keyway. In most cases, this error is small enough to be absorbed by the balance tolerance of the rotor assembly. If not, correct the error by rebalancing the fitment with an appropriately dimensioned half-key.



a This part of the keyway is not to be filled by the half-key if not filled by the final key.

Figure B.9 — Shaft keyway (for types, see Table 1) machined with an end mill cutter



a This part of the keyway is never filled by the half-key or the final key.

Figure B.10 — Shaft keyway (for types, see Table 1) machined with a key slot cutter

B.7 Use of setscrews

To prevent axial movement of a fitment mounted on a shaft, frequently one or more setscrews are used. These are located in the hub of the fitment directly over the keyway.

When balancing the fitment on a mandrel, ensure that the setscrew(s) be tightened down on the key(s). This presses the mandrel against the fitment bore opposite the setscrew(s), the same as is the case in the final rotor assembly.

If the fitment has two setscrews offset by 90°, ensure that the setscrews be tightened in the same sequence each time.

By following these procedures balance errors are minimized.

Annex C
(informative)

Comparison between shaft and fitment key conventions

C.1 Description of the key conventions

C.1.1 There are three methods, or key conventions, used for balancing shafts and fitments:

- full-key convention (see C.1.2);
- half-key convention (see C.1.3);
- no-key convention (see C.1.4).

C.1.2 The full-key convention requires that a full key (usually the final key) be used in the shaft keyway during balancing. No key is used to balance the fitment on a balancing mandrel that has no keyway. If the mandrel has a keyway, it has to be balanced by itself using a full key. That same key is to remain in the mandrel during balancing the fitment. The location of the full key in the shaft should be in the same axial position that is used when the shaft and fitment are assembled.

C.1.3 The half-key convention requires that a half-key be used in the shaft keyway during balancing. A complementary half-key is used to balance the fitment on a balancing mandrel that has no keyway (other cases are dealt with in A.1.3 and A.1.4). The location of the half-key should be in the same axial position that is used when the shaft and fitment are assembled.

C.1.4 The no-key convention does not use any type of key during balancing a shaft or a fitment, even though both have keyways.

C.2 Advantages and disadvantages of the key conventions

C.2.1 General

Each of the three key conventions has certain advantages and disadvantages associated with it. The most important attributes and drawbacks of each convention are outlined in C.2.2 to C.2.4.

C.2.2 Full-key convention

C.2.2.1 Advantages

The advantages of the full-key convention are that

a) balance errors from an incorrect key mass are avoided by using the final key in the shaft and no key in the fitment;

b) no special half-keys need to be manufactured;

c) the keyway in the fitment may be of different length than the key in the shaft, without affecting the balance of the rotor assembly or requiring a stepped key;

d) the shaft balance (without the fitment) can be checked in a test laboratory or *in situ* with the final key;

e) the shaft (with full key) and the fitment (without key) both leave the manufacturer's plant in a balanced state.

C.2.2.2 Disadvantages

The disadvantages of the full-key convention are as follows.

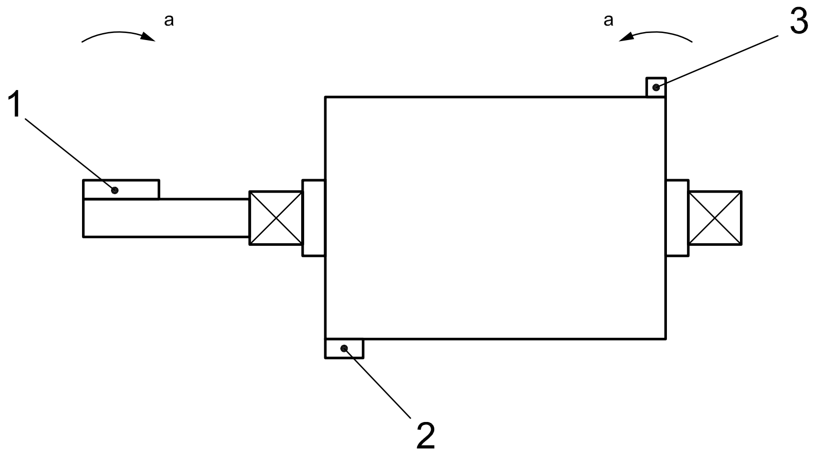
a) An additional unbalance in the shaft and in the fitment is produced which results in a correction cost not incurred with the half-key convention. Initial unbalance may exceed allowable or correctable magnitudes and thus might cause rejection of the components.

b) An internal bending moment is produced in the shaft. The protruding part of the key creates an unbalance which has to be compensated by correction masses in at least two planes on the shaft body (since it usually cannot be corrected in the plane of the key), see Figure C.1. The internal bending moment can affect the balance quality of rotors with flexible behaviour (however, it does not affect the balance quality of rotors with rigid behaviour). The internal bending moment remains in the shaft after the fitment has been attached.

c) The full-key convention can create confusion in world markets as individual manufacturers using this method nevertheless use the half-key method on larger shafts without proper marking. This results in incompatible components if they are supplied by two manufacturers using different key conventions.

d) The danger that a full key separates from the shaft keyway during balancing is greater than for a half-key since a full key has twice the mass of a half-key.

e) The full-key convention does not allow coupling manufacturers to follow the common practice of balancing their couplings before the keyways are machined.



Key

1 full key

2 correction mass 1

3 correction mass 2

a Bending moment.

Figure C.1 — Internal bending moment created when the full-key unbalance is corrected by two correction masses in two planes on the shaft body

C.2.3 Half-key convention

C.2.3.1 Advantages

The advantages of the half-key convention are that

a) no unbalance is created in either the shaft or the fitment and therefore no corresponding unbalance corrections are required;

b) no internal bending moment is produced in the shaft;

c) the half-key convention allows fitments to be balanced before the keyway is machined (this practice is commonly used by coupling manufacturers).

C.2.3.2 Disadvantages

The disadvantages of the half-key convention are as follows.

a) A special half-key is required for balancing. Balance errors may be introduced if the half-key does not have the proper mass, shape or position. Half-keys for special keys, such as woodruff, round and gibhead keys, may be difficult to manufacture.

b) The half-key may cause extra expense, particularly in *in-situ* balancing.

c) A half-key is required when determining the residual unbalance or vibration of a shaft without the fitment in a test laboratory or *in situ*.

d) If the length of the key used in the final assembly differs from the length assumed for the design of the half-keys used in balancing, an unbalance is produced in the rotor assembly which might not be acceptable.

C.2.4 No-key convention

C.2.4.1 Advantages

The no-key convention is convenient, since during balancing no keys are required either in the shaft or in the fitment.

C.2.4.2 Disadvantages

The disadvantages of the no-key convention are as follows.

a) The absence of a key produces an unbalance which needs to be corrected in both the shaft and the fitment during individual balancing.

b) Unbalance correction usually cannot be made in the plane of the shaft key — instead, it has to be made in two shaft body planes (see also Figure C.1). This creates an internal bending moment in the shaft which, in case of a rotor with flexible behaviour, can affect its balance quality (however, it does not affect the balance quality of rotors with rigid behaviour). The internal bending moment remains in the shaft after the fitment has been attached.

c) The addition of the key during assembly of the fitment to the shaft produces an unbalance. Therefore the no-key convention can only be used if the permissible residual unbalance for the rotor assembly is larger than the balance error produced by the missing key. The alternative solution of *in-situ* balancing after assembly is costly, inconvenient and sometimes not possible due to inaccessibility of the correction planes.

Bibliography

[1] IEC 60034-14, *Rotating electrical machines — Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher — Measurement, evaluation and limits of vibration severity*

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