INTERNATIONAL STANDARD

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Mechanical vibration — Rotor balancing —

Part 21: **Description and evaluation of balancing machines**

Vibrations mécaniques — Équilibrage des rotors —

Partie 21: Description et évaluation des machines à équilibrer

Reference number
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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 21940-21 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 21940-21 cancels and replaces ISO 2953:1999, of which it constitutes an editorial revision. The main change is that for all definitions, reference is made to ISO 1925. Additionally, the Scope has been reworded in order to exactly reflect what this part of ISO 21940 is dealing with. Furthermore, some rough rounding in the numbers given in the Tables has been smoothened, and some Figures drawn more exactly.

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]

[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 + Cor.1:2005, *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 + Cor.1:2000, *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*

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

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

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

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

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

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

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*

Mechanical vibration — Rotor balancing —

Part 21:
Description and evaluation of balancing machines

1 Scope

This part of ISO 21940 specifies requirements for evaluating the performance of machines for balancing rotating components by the following tests:

a) test for minimum achievable residual unbalance, U_{mar} test;

b) test for unbalance reduction ratio, URR test;

c) test for couple unbalance interference on single-plane machines;

d) compensator test.

These tests are performed during acceptance of a balancing machine and also later, on a periodic basis, to ensure that the balancing machine is capable of handling the actual balancing tasks. For periodic tests, simplified procedures are specified. Tests for other machine capacities and performance parameters, however, are not contained in this part of ISO 21940.

For these tests, three types of specially prepared proving rotors are specified, covering a wide range of applications on horizontal and vertical balancing machines. An annex describes recommended modifications of proving rotors prepared in acccordance with ISO 2953:1985.[2]

Moreover, this part of ISO 21940 also stresses the importance attached to the form in which the balancing machine characteristics are specified by the manufacturer. Adoption of the format specified enables users to compare products from different manufacturers. Additionally, in an annex, guidelines are given on the information by which users provide their data and requirements to a balancing machine manufacturer.

This part of ISO 21940 is applicable to balancing machines that support and rotate rotors with rigid behaviour at balancing speed and that indicate the amounts and angular locations of a required unbalance correction in one or more planes. Therefore, it is applicable to rotors with rigid behaviour as well as to rotors with shaft-elastic behaviour balanced in accordance with low-speed balancing procedures. It covers both soft-bearing balancing machines and hard-bearing balancing machines. Technical requirements for such balancing machines are included; however, special features, such as those associated with automatic correction, are excluded.

This part of ISO 21940 does not specify balancing criteria; such criteria are specified in ISO 1940-1[1] and ISO 11342[3] (only low-speed balancing procedures apply).

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*[11)]

3 Terms and definitions

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

4 Capacity and performance data of the balancing machine

4.1 General

The manufacturer shall specify the data listed in 4.2 for horizontal or 4.3 for vertical balancing machines, as applicable, and in a similar format.

NOTE Information provided by the user to the balancing machine manufacturer is summarized in Annex A.

4.2 Data for horizontal balancing machines

4.2.1 Rotor mass and unbalance limitations

4.2.1.1 The maximum mass of a rotor, m, which can be balanced shall be stated over the range of balancing speeds (n_1, n_2, ...).

The maximum moment of inertia of a rotor with respect to the shaft axis, $m\,r^2$, where m is the rotor mass and r is the radius of gyration, which the machine can accelerate in a stated acceleration time shall be given for the range of balancing speeds (n_1, n_2, ...) together with the corresponding cycle rate (see Table 1).

4.2.1.2 Production efficiency (see Clause 7) shall be stated, as follows.

4.2.1.2.1 Time per measuring run:

a) Time for mechanical adjustment: .... s

b) Time for setting indicating system: .... s

c) Time for preparation of rotor: .... s

d) Average acceleration time: .... s

e) Reading time (including time to stabilize): .... s

f) Average deceleration time: .... s

g) Relating readings to rotor: .... s

h) Other necessary time: .... s

i) Total time per measuring run [a) to h) in the preceding]: .... s

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[11)] To become ISO 21940-2 when revised.

4.2.1.2.2 Unbalance reduction ratio, URR, for inboard rotors: .... %

4.2.1.2.3 Unbalance reduction ratio for outboard rotors: .... %

Table 1 — Data for horizontal balancing machines

Manufacturer:		**Model:**					
Balancing speeds or speed ranges (see also 4.2.3.1)			n_1	n_2	n_3	n_4	…
Rotor mass (see Note 1)	kg	maximum, m_{max}					
		minimum					
Occasional overload force per support (see Note 1)	N						
Maximum negative force per support (see Note 1)	N						
Maximum rotor moment of inertia with respect to the shaft axis (see Note 2)	kg·m^2						
Cycle rate (see Note 2)							
Maximum unbalance (see Note 3)	g·mm/kg or g·mm	measurable					
		permissible					
a) For inboard rotors Minimum achievable residual specific unbalance, e_{mar} (see Note 4 and Clause 6)	g·mm/kg	maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					
Corresponding deflection of analogue amount-of-unbalance indicator, mm or Number of digital units (see Note 4)		maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					
b) For outboard rotors Minimum achievable residual specific unbalance, e_{mar} (see Note 4 and Clause 6)	g·mm/kg	maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					
Corresponding deflection of analogue amount-of-unbalance indicator, mm or Number of digital units (see Note 4)		maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					

NOTE 1 The occasional overload force is only stated for the lowest balancing speed. It is the maximum force per support that can be accommodated by the machine without immediate damage.

The negative force is the static upward force resulting from a rotor having its centre of mass outside the bearing support.

NOTE 2 Cycle rate for a given balancing speed is the number of starts and stops which the machine can perform per hour without damage to the machine when balancing a rotor of the maximum moment of inertia.

NOTE 3 In general, for rotors with rigid behaviour with two correction planes, one-half of the stated value pertains to each plane; for disc-shaped rotors, the full stated value holds for one plane.

NOTE 4 Limits for soft-bearing machines are generally stated in gram millimetres per kilogram (specific unbalance, g·mm/kg), since this value represents a measure of rotor displacement and, therefore, motion of the balancing machine bearings. For hard-bearing machines, the limits are generally stated in gram millimetres (g·mm), since these machines are usually factory calibrated to indicated unbalance in such units (see Clause 6). For two-plane machines, this is the result obtained when the minimum achievable residual unbalance is distributed between the two planes.

4.2.2 Rotor dimensions

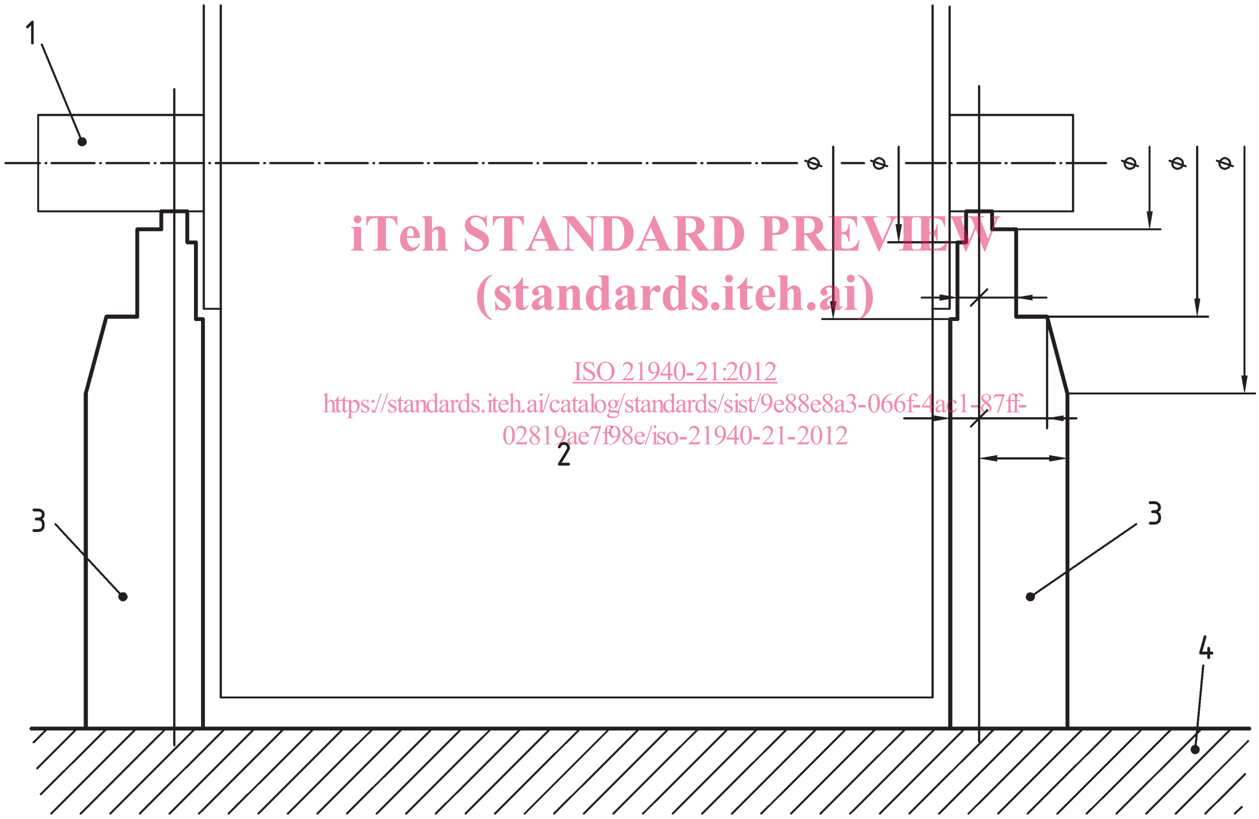
4.2.2.1 Adequate envelope drawings of the pedestals and of other obstructions, such as belt-drive mechanism, shroud mounting pads, thrust arms and tie bars, shall be supplied to enable the user to determine the maximum rotor envelope that can be accommodated and the tooling or adaptors required.

A combination of large journal diameter and high balancing speed can result in an excessive journal peripheral speed. The maximum journal peripheral speed shall be stated.

When belt drive is supplied, balancing speeds shall be stated for both the maximum and minimum diameters over which the belt can drive, or other convenient diameter.

The manufacturer shall state if the axial position of the drive can be adjusted.

4.2.2.2 Rotor envelope limitations shall be stated (see Figure 1).



Key

1 shaft

2 rotor

3 support

4 bed

If the left-hand support is not a mirror image of the right-hand support, separate dimensions shall be shown.

The profile of the belt-drive equipment shall be shown, if applicable.

Figure 1 — Example of a machine support drawing illustrating rotor envelope limitations

4.2.2.3 Rotor diameter:

a) Maximum diameter over bed: .... mm

b) Maximum diameter over which belt can drive: .... mm

c) Minimum diameter over which belt can drive: .... mm

4.2.2.4 Distance between journal centrelines:

a) Maximum: .... mm

b) Minimum: .... mm

c) Maximum distance from coupling flange to centreline of farthest bearing: .... mm

d) Minimum distance from coupling flange to centreline of nearest bearing: .... mm

4.2.2.5 Journal diameter:

a) Maximum: .... mm

b) Minimum: .... mm

Maximum permissible peripheral journal speed .... m/s

4.2.2.6 Correction plane limitations (consistent with the statements in 5.4) shall be stated.

4.2.2.7 Correction plane interference ratios (consistent with the statements in 5.4 and based on the proving rotor) shall be stated.

4.2.3 Drive

4.2.3.1

	Balancing speed r/min	Rated torque on rotor N·m
n_1	....	....
n_2	....	....
n_3	....	....
n_4	....	....
n_5	....	....
n_6	....	....
n_7	....	....
n_8	....	....
	or	or
	steplessly variable	steplessly variable
from	....	....
to	....	....

4.2.3.2 Torque:

a) Zero-speed torque: .... % of rated torque on rotor

b) Run-up torque adjustable from .... % to .... % of rated torque on rotor

c) Peak torque .... % of rated torque on rotor

NOTE In most cases, maximum torque is required for accelerating a rotor. However, in the case of a rotor with high windage or friction loss, maximum torque can be required at balancing speed. When there is axial thrust, it is necessary that provisions be made to take this into account.

4.2.3.3 Type of drive to rotor: ....

EXAMPLES End drive by universal joint driver, end drive by band, belt drive, magnetic field, driven bearing rollers, air jet.

4.2.3.4 Prime mover (type of motor): ....

a) Rated power: .... kW

b) Motor speed: .... r/min

c) Power supply, voltage/frequency/phase: .... / .... / ....

4.2.3.5 Brake

a) Type of brake: ....

b) Braking torque adjustable from .... % to .... % of rated torque

c) Can the brake be used as a holding device? Yes / No

4.2.3.6 Motor and controls in accordance with the following standard(s): ....

4.2.3.7 Speed regulation provided:

Accurate or constant within .... % of .... r/min, or .... r/min

4.2.4 Couple unbalance interference ratio: .... g·mm/(g·mm^2)

NOTE This value is only applicable for single-plane balancing machines. It describes the influence of couple unbalance in the rotor on the indication of resultant unbalance.

4.2.5 Air pressure requirements: .... Pa, ... m^3/s.

4.3 Data for vertical balancing machines

4.3.1 Rotor mass and unbalance limitations

4.3.1.1 The maximum mass of a rotor, m, which can be balanced shall be stated over the range of balancing speeds (n_1, n_2, ...).

The maximum moment of inertia of a rotor with respect to the shaft axis, $m\,r^2$, where m is the rotor mass and r is the radius of gyration, which the machine can accelerate in a stated acceleration time shall be given for the range of balancing speeds (n_1, n_2, ...) together with the corresponding cycle rate (see Table 2).

Table 2 — Data for vertical balancing machines

Manufacturer:			**Model:**				
Balancing speeds or speed ranges (see also 4.3.3.1)			n_1	n_2	n_3	n_4	…
Rotor mass (see Note 1)	kg	maximum, m_{max}					
		minimum					
Occasional overload force up to (see Note 1)	N						
Maximum rotor moment of inertia with respect to the shaft axis (see Note 2)	$kg \cdot m^2$						
Cycle rate (see Note 2)							
Maximum unbalance (see Note 3)	g·mm/kg or g·mm	measurable					
		permissible					
Minimum achievable residual specific unbalance, e_{mar} (see Note 4 and Clause 6)	g·mm/kg	maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					
Corresponding deflection of analogue amount-of-unbalance indicator, mm or Number of digital units (see Note 4)		maximum mass, m_{max}					
		0,2 m_{max}					
		minimum mass					

NOTE 1 The occasional overload force is only stated for the lowest balancing speed. It is the maximum force that can be accommodated by the machine without immediate damage.

NOTE 2 Cycle rate for a given balancing speed is the number of starts and stops which the machine can perform per hour without damage to the machine when balancing a rotor of the maximum moment of inertia.

NOTE 3 In general, for rotors with rigid behaviour with two correction planes, one-half of the state value pertains to each plane; for disc-shaped rotors, the full stated value holds for one plane.

NOTE 4 Limits for soft-bearing machines are generally stated in gram millimetres per kilogram (specific unbalance, g·mm/kg), since this value represents a measure of rotor displacement and, therefore, motion of the balancing machine bearings. For hard-bearing machines, the limits are generally stated in gram millimetres (g·mm), since these machines are usually factory calibrated to indicated unbalance in such units (see Clause 6). For two-plane machines, this is the result obtained when the minimum achievable residual unbalance is distributed between the two planes.

4.3.1.2 Production efficiency (see Clause 7) shall be stated, as follows.

4.3.1.2.1 Time per measuring run:

a) Time for mechanical adjustment: .... s

b) Time for setting indicating system: .... s

c) Time for preparation of rotor: .... s

d) Average acceleration time: .... s

e) Reading time (including time to stabilize): .... s

f) Average deceleration time: .... s

g) Relating readings to rotor: .... s

h) Other necessary time: .... s

i) Total time per measuring run [a) to h) in the preceding]: .... s

4.3.1.2.2 Unbalance reduction ratio, URR: .... %

4.3.2 Rotor dimensions

4.3.2.1 If the machine is equipped with two or more speeds, the information on rotor dimensions shall be stated for each speed. If the machine is equipped with steplessly variable balancing speeds, then the information shall be given in the form of a table, formula or graph.

Adequate drawings of the support surface of the spindle or mounting plate and of obstructions, such as drill heads and electrical control cabinets, above the mounting plate shall be supplied to enable the user to determine the maximum rotor envelope that can be accommodated and the tooling or adaptors required.

4.3.2.2 Maximum diameter: .... mm

4.3.2.3 Rotor height:

a) Maximum overall height: .... mm

b) Maximum height of centre of gravity: .... mm

at 100 % of maximum mass: .... mm

at 50 % of maximum mass: .... mm

at 25 % of maximum mass: .... mm

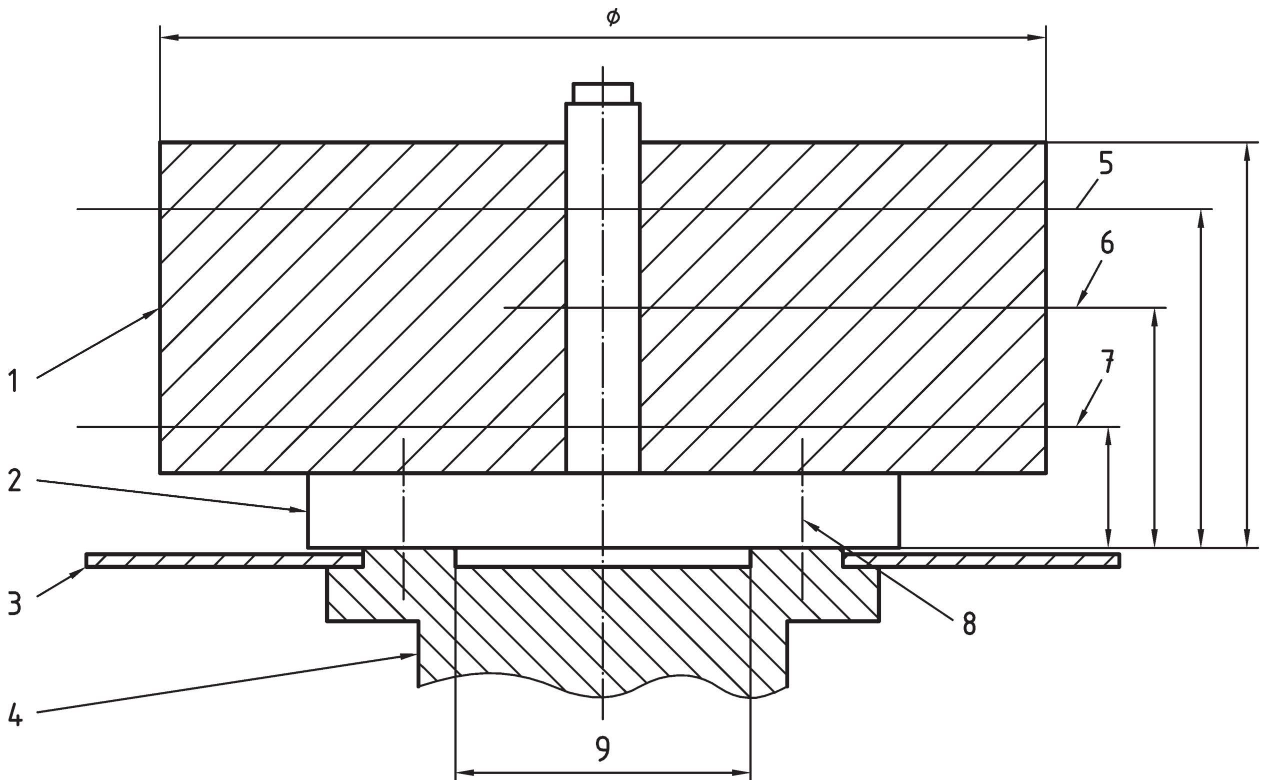
4.3.2.4 Rotor envelope limitations, including machine spindle or mounting plate interface, shall be stated (see Figure 2).

4.3.2.5 Correction plane limitations (consistent with the statements in 5.4) shall be stated.

4.3.3 Drive

4.3.3.1

	Balancing speed r/min	Rated torque on rotor N·m
n_1	....	....
n_2	....	....
n_3	....	....
n_4	....	....
n_5	....	....
n_6	....	....
n_7	....	....
n_8	....	....



Key

1 rotor
2 adaptor
3 protractor
4 spindle
5 upper correction plane
6 centre of mass plane
7 lower correction plane
8 mounting holes for adaptor
9 spigot diameter

Figure 2 — Example of vertical machine mounting interface illustrating rotor envelope limitations

4.3.3.2 Torque:

a) Zero-speed torque: .... % of rated torque on rotor

b) Run-up torque adjustable from .... % to .... % of rated torque on rotor

c) Peak torque: .... % of rated torque on rotor

NOTE In most cases, maximum torque is required for accelerating a rotor. However, in the case of rotors with high windage or friction loss, maximum torque can be required at balancing speed.

4.3.3.3 Prime mover (type of motor): ....

a) Rated power: .... kW

b) Motor speed: .... r/min

c) Power supply, voltage/frequency/phase: .... / .... / ....

4.3.3.4 Brake

a) Type of brake: ....

b) Braking torque adjustable from .... % to .... % of rated torque