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Mechanical vibration — Rotor balancing —

Part 23: Enclosures and other protective measures for the measuring station of balancing machines

Vibrations mécaniques — Équilibrage des rotors —
Partie 23: Enceintes et autres mesures de protection pour le poste de mesurage des machines à équilibrer

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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ISO 21940-23 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 cancels and replaces ISO 7475:2002, which has been technically revised. The main change is deletion of protection class 0.

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)]

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

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

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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 + 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*

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*

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

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

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

In designing and operating balancing machines, efforts already are made to minimize hazards arising from the use of the machines themselves. Rising demand for still greater safety in the working environment, however, requires additional protective measures, especially with respect to the rotor to be balanced. Potential hazards to the balancing machine operator or the surrounding workshop area can exist, e.g. by personnel coming into contact with machine components or the rotor, by rotor components or unbalance correction masses detaching and flying off or by the rotor lifting from the supports or disintegrating.

Special-purpose balancing machines, e.g. those used in the mass production automotive industry, normally incorporate all necessary protective measures because the workpiece, as well as the operating conditions of the machine, are known and can be taken into account by the machine manufacturer. For multipurpose balancing machines, however, where the workpieces to be balanced are generally unknown to the machine manufacturer, and are thus beyond his control, basic protective measures are limited to obvious hazards, e.g. from end-drive or belt-drive systems. However, the balancing machine manufacturer has to provide sufficient information for the user to assess possible hazards originating from a rotor when in the balancing machine, and from the intended use of the balancing machine. Together with this information, the user of the balancing machine has to state the possible hazards originating in his rotors in order to allow the balancing machine manufacturer to supply equivalent protective measures or the user has to provide adequate protective measures on his own.

When the rotors are not known in advance, e.g. in service and repair, a good estimation is needed. Table A.2 states typical values for different balancing machine sizes. But for each individual type of rotor to be balanced, the user of the balancing machine needs to check if the protective measures cover all hazards.

Most local regulations require certain minimum protective measures to be taken. Observance of such requirements in conjunction with the recommendations contained in this part of ISO 21940 will generally provide an adequate measure of protection to the balancing machine operator and surrounding workshop personnel. There may be applications, however, in which the recommended enclosures or other protective measures are so costly, or their use so time-consuming, that other protective precautions have to be considered, such as vacating the surrounding area for a sufficient distance, remote control of the balancing machine or work outside normal hours.

The consideration of accident probability can be important if a rotor needs to be balanced or spin-tested at or above its service speed, where major rotor failure cannot be excluded with as much certainty as during low-speed balancing.

On the other hand, a rotor being balanced at low speed may consist of an assembly of several components, such as a bladed turbine wheel. It is then important to consider whether an enclosure for low-speed balancing should withstand penetration of a turbine blade or whether it is sufficient to protect against unbalance correction masses that might fly off during balancing. If the probability of blade separation is practically non-existent, a light enclosure, which just protects against correction masses, may be sufficient.

Since this part of ISO 21940 deals with balancing machines and protective measures in general, no details of the risk can be stated for specific rotor types and balancing machines. Individual investigations, based on actual rotor parameters, will probably be required in each specific case. In this connection, risk analysis of possible accidents should include the characteristics of the balancing machine itself. For the extent of the ensuing damages, it may be of decisive importance to know how much unbalance can be endured by its supports and bearings due to partial rotor failure, e.g. rotor components becoming detached.

The significant hazards covered by this part of ISO 21940 are listed in Clause 4. The safety requirements and protective measures to prevent or minimize those hazards are identified in Clause 5, and procedures for verification of these requirements and protective measures are found in Clause 6.

Mechanical vibration — Rotor balancing —

Part 23: Enclosures and other protective measures for the measuring station of balancing machines

1 Scope

This part of ISO 21940 specifies requirements for enclosures and other protective measures used to minimize mechanical hazards produced by the rotor in the unbalance measuring station of centrifugal (rotational) balancing machines. The hazards are associated with the operation of balancing machines under a variety of rotor and balancing conditions. This part of ISO 21940 defines different classes of protection that enclosures and other protective measures provide and describes the limits of applicability for each class of protection.

Devices for adjusting the mass distribution of a rotor and devices to transfer the rotor are not covered by this part of ISO 21940, even if they are combined with the measuring station.

Special enclosure features, such as noise reduction, windage reduction or vacuum (which may be required to spin bladed rotors at balancing speed), are not covered by this part of ISO 21940.

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)]

ISO 4849, *Personal eye-protectors — Specifications*

3 Terms and definitions

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

4 List of significant hazards

4.1 General

Significant hazards identified at measuring stations of centrifugal (rotational) balancing machines are listed in Table 1 together with examples of associated hazardous situations, activities and danger zones.

4.2 Risk assessment

The user of this part of ISO 21940 (i.e. the balancing machine user, designer, manufacturer or supplier) shall conduct a risk assessment. As part of the risk assessment, the user of this part of ISO 21940 shall describe the intended use of the balancing machine including manual tool loading, workpiece set-up, maintenance, repair and cleaning, together with reasonably foreseeable misuse of the machine. As part of the risk assessment, the user of this part of ISO 21940 shall also verify whether the list of hazards in Table 1 is applicable to the balancing machine under consideration.

11) To become ISO 21940-2 when revised.

Table 1 — List of significant specific hazards and examples of hazard sources associated with the measuring station of balancing machines

Item	Specific hazard	Example of hazard source	Associated activity	Related danger zone
1	**Mechanical**			
1.1	Crushing	workpiece moving	loading the workpiece	between rotor and pedestal
1.2	Shearing	workpiece rotating	check of belt drive	around drive shaft and rotor/ guide rollers
			lubrication of rollers	between journal and roller
		workpiece moving in axial direction when rotating	during process control	between rotor and pedestal, access area around machine
		power operation of clamping device	loading of rotor	between rotor and clamping device
1.3	Impact of mass	ejection of rotor	protective bracket not closed, large unbalances, high balancing speed	area around machine and remote, depending on speed and energy of masses
		ejection of rotor parts	parts loose, excessive balancing speed	
		rotor bursting		
		ejection of correction masses	masses insufficiently fixed	
1.4	Stabbing or puncture	end drive not coupled to rotor and drive actuated	start of drive	around end drive
		rotor with protruding parts rotating	checking set-up while rotor running	at rotor
1.5	Entanglement	belt drive running	check of belt drive	between belt and rotor/guide rollers
		rotor with protruding parts rotating	checking set-up while rotor running	at rotor
1.6	Slip, trip and fall	ejection of lubricant from sleeve bearing	during operation of machine	floor area around machine
1.7	Excessive vibration	mechanical vibration caused by unbalances and bending modes	balancing at high speeds, overspeeding	area around machine and remote, depending on vibration magnitude
2	**Electrical**			
2.1	High voltage	contact to live parts		
2.2	Drive power	automatic restart after power loss	during set-up of rotor	around rotor and drive
		loss of speed control during indexing activity	indexing of rotor	between rotor and clamping device
3	**Excessive noise**	balancing bladed rotors, air-drive	balancing run	near machine
4	**Neglecting ergonomic principles**			
4.1	Unhealthy postures or excessive efforts (repetitive strain)	lifting and reaching while handling workpiece and machine parts	during loading or unloading and maintenance	load and unload positions, maintenance action points
		inadequate consideration of human hand–arm or foot–leg anatomy	while operating the balancing machine	workplace
4.2	Inadequate local lighting	judgement and accuracy of manual actions during set-up and loading	during loading and set-up	at drive elements, pedestals, and load and unload positions
5	**Human error**	inadvertent operation of controls, misuse of guard-controls	measuring unbalance, during set-up	around rotor
NOTE	This list should not be considered complete.			

4.3 Access to balancing machine

The risk assessment shall assume foreseeable access to the balancing machine from all directions. Risks to both the operator(s) and other persons who may have access to the danger zones shall be identified, taking into account all hazards which may occur during the lifetime of the balancing machine. The assessment shall include an analysis of the effect of failure(s) of protective functions in the control system.

5 Safety requirements and protective measures

5.1 General requirements

5.1.1 General considerations

The balancing machine shall be securely attached to the foundation (or the floor) in such a way as to safely withstand all loads occurring from the rotor mass, the unbalance, particles or parts flying off the rotor, and the necessary movements of the enclosure while opening or closing.

During operation of a balancing machine, various potential hazards to the balancing machine operator or the surrounding workshop area can exist, e.g.:

— from personnel coming into contact with moving machine components or the rotor;

— from rotor components or unbalance correction masses detaching and flying off;

— from the rotor lifting from the supports or disintegrating.

General safety requirements therefore have to cover two areas: protection against contact with hazardous movements (mainly the rotating workpiece) and protection against particles or parts flying off the rotor.

5.1.2 Protection against contact

All rotors represent a hazard during balancing. For that reason, the work zone of a centrifugal (rotational) balancing machine shall be protected by guards (barriers, fences, enclosures and covers) to protect people from contacting the rotating workpiece and drive.

Such guards are not needed in special cases, provided that *all* of the criteria a) to f) apply.

a) The surface of the rotor shall be so smooth that contact is not dangerous, and entanglement is not possible.

b) The correction method shall be such that no particles can become detached (normally material removal).

c) The maximum rotor speed shall be such that major rotor failure is not expected.

d) The rotor shall be prevented from lifting out of the balancing machine bearings by provisions such as those mentioned in Table 3 (item 1.3) or the rotor mass and the rotational energy of the rotor at maximum balancing speed shall be so small that no damage is possible if the rotor lifts out of the machine.

e) The maximum available drive torque shall be such that the circumferential forces required to stop rotation at all relevant radii shall be less than 100 N.

f) The kinetic energy of the rotor plus drive (if coupled without the ability to slip) shall be below 20 N·m at balancing speed. For rotors with large diameter (e.g. automotive wheels), higher values may be permitted if entanglement with operator's clothes is not possible.

5.1.3 Protection against particles or parts

According to the mass and velocity of particles or parts flying off the rotor, different protective measures are needed, from personal eye-protectors (spectacles, goggles or face-shields), over machine enclosures, to burst-proof protections. In general three different criteria shall be considered.

a) Area-specific energy

This criterion is based on the case that the kinetic energy of a particle or part is concentrated with its smallest possible area on the protective device (see A.2.1). The particle or part shall not penetrate or escape from the protective device.

b) Absolute energy

This criterion is based on the case that the kinetic energy of a particle or part is loading the structure of the protective device (see A.3.1). The protective device shall not disintegrate so that a particle or part cannot escape from the protective device.

c) Impulse

This criterion is based on the case that the impulse of a particle or part is transmitted to the protective device (see A.5.1). The protective device shall not turn over and its displacement shall be reasonably limited.

5.1.4 System of protection classes

The system of protection classes on a balancing machine, as given in Table 2, can be described by two criteria:

— the area-specific energy, absolute energy, and impulse of a part which could fly off the rotor; and

— the need for a guard (e.g. barrier, fence, enclosures, and covers) for the balancing machine.

Table 2 — Balancing machine protection classes

Necessity for guards on the balancing machine	No	Yes		
Criteria	Spectacles, goggles or face-shields needed	Minimum protection required to avoid physical contact with rotating parts and no particles shall be released	Area-specific energy up to approximately 340 mN·m/mm^2 Absolute energy up to approximately 2 000 N·m Impulse up to approximately 200 kg·m/s	Area-specific energy, absolute energy or impulse values above the class C criteria
Protection class	A	B	C	D

In some cases it may be advisable to combine classes A and B, e.g. if a rotor is dangerous to contact *and* only small particles with limited energy can be ejected during balancing.

5.1.5 Mode of operation

If the machine is equipped with guards around the work zone, it shall have two modes of operation. These modes are a) and b).

a) Mode 1: Normal (production) operation: Rotation of the workpiece under manual or numerical control to achieve sequential operation with the enclosure closed and/or protective devices active (e.g. guard lock, pressure-sensitive protective device, electro-sensitive protection equipment).

b) Mode 2: Setting mode of operation: Rotation of the workpiece under manual or numerical control to validate the set-up with work zone enclosure open and the interlocks suspended.

Mode 2 shall only be provided when details of the intended application and required skill level of operators are defined in the instructions for use. Reduced balancing speed is a significant factor in the risk reduction for this mode and the maximum speed permitted shall be carefully considered and determined by a risk assessment.

The selection of the mode shall be by a key switch, access code or equally lockable means, and shall only be permitted from outside the work zone and shall not initiate start-up. For application of the modes, see Table 3.

The selected mode shall be clearly indicated.

5.1.6 Controls

The safety-related parts of control systems for interlocking, monitoring, reduced speed(s), and enabling device(s) shall be designed so that a single fault in the control shall not lead to loss of the protective function(s), and wherever reasonably practicable, the single fault shall be detected at or before the next demand upon the protective function.

Monitoring may be achieved by separate channels, automatic monitoring or other appropriate means.

An enabling device may be a two-position device in conjunction with an emergency stop device, or a three-position device.

5.2 Specific requirements

Each machine shall be designed and safeguarded in accordance with the specific requirements and protective measures listed in Table 3.

6 Verification of safety requirements and protective measures

Safety requirements and protective measures implemented in accordance with Clause 5 shall be verified using the procedures given in Table 3, rightmost column.

Table 3 — List of safety requirements and protective measures and their verification procedures

Item	Hazard source	Safety requirement and protective measure	Verification
1	**Mechanical**		
1.1	Disengagement or failure of the end-drive coupling	An enclosure around the universal joint shaft shall prevent the whipping around of the shaft if not coupled to a rotor. Alternative interlocking devices shall prevent the start of the motor if the shaft is not coupled	By visual inspection or functional test
1.2	Axial rotor movement off the machine supports	On belt drive machines, axial thrust stops shall prevent axial movement of the rotor. On end-drive machines, the drive shaft shall be able to transmit the axial load to the drive thrust bearing	By visual inspection or measurement
1.3	Rotor lifting out of the machine's open bearings	The machine shall be equipped with closed bearings or hold-down brackets. If, when balancing cardan shafts, one or all clamping devices fail, the rotor as a whole shall be caught by protective catches. Fragments of the clamping devices shall be caught by a protective device of an appropriate protection class	By visual inspection and (if necessary) by calculation

Table 3 *(continued)*

Item	Hazard source	Safety requirement and protective measure	Verification
1.4	Operator coming into contact with any part of the spinning rotor or rotor-specific drive elements	Work zones shall be guarded using fixed and/or interlocked movable guards or fences designed to prevent access to the work zone by the operator. Guard interlocking shall incorporate redundancy and monitoring. Redundancy may be by two separate switches or by a guard-closed switch and detection of guard-lock position. Measures to minimize possible defeat of interlocking shall be taken. In some applications, only part of the rotor needs to be protected, because other parts of the rotor fall into protection class A. In such cases, it is sufficient to prevent contact only with the dangerous surface(s) of the rotor (e.g. low-speed wheel balancing machines where only the clamping mechanism shall be protected or designed in such a way that entanglement of operator's clothes is not possible)	By visual inspection and practical checks
1.4.1		In mode 1 [see 5.1.5 a)], machine movements shall only be possible when the guards are closed and/or the protective devices are active. If in this mode, it is possible to open an interlocking movable guard, this shall cause the hazardous movements to cease and be inhibited. If opening of the interlocking guard gives access to hazards 1.1 to 1.6 of Table 1, guard locking shall be provided	Examination of circuit diagrams and practical checks. Check to ensure that the hazardous moving parts are not accessible when the interlocking guard is opened
1.4.2		In mode 2 [see 5.1.5 b)], powered machine movements shall be possible only when *all* of the following conditions are satisfied: a) Key or code access to this mode with program execution limited to a single block or fixed/canned cycle (see ISO 2806). b) Machine movements initiated by cycle start control in conjunction with an enabling device. c) The selection of mode 1 shall automatically reinstate all appropriate safeguarding (e.g. interlocking functions). d) Machine movements in the reinstated mode 1 shall not be possible until the cycle start control is operated	Examination of circuit diagrams and practical checks
1.5	Ejection of very small particles	Personal eye-protectors (spectacles, goggles or face-shields) shall be used, unless the impact energy of particles separating from the rotor exceeds the limits set by ISO 4849 or local regulations, in which case enclosures or other protective measures at the machine shall be provided	By calculation and check of personal eye-protector specification