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Mechanical vibration — Balancing machines — Enclosures and other protective measures for the measuring station

Vibrations mécaniques — Machines à équilibrer — Enceintes et autres mesures de protection pour le poste de mesurage

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7475 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 1, *Balancing, including balancing machines*.

This second edition cancels and replaces the first edition (ISO 7475:1984) and the technical corrigendum, of which it constitutes a technical revision.

Major chances to the previous edition are

— expanding the permissible particle velocity range,

— using the area-specific energy of a particle as criterion for the capability of the enclosure material to hold a particle which leaves the rotor,

— taking the absolute energy of a particle as criterion for the strength of the fastening of the whole enclosure or of its components,

— considering the impulse of a particle when it hits a free-standing enclosure, and

— adding other safety aspects that are intrinsic to balancing machines and are related to the integrity of the operator.

This International Standard follows the rules for drafting and presentation of a machinery-related safety standard as they are mandatory in European Standards, and gives verification procedures for the safety requirements.

Annex A constitutes a normative part of this International Standard. Annexes B and C are for information only.

Introduction

In designing and using balancing machines, efforts 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 protection, especially with respect to the rotor to be balanced. Potential hazards to the balancing machine operator or the surrounding workshop area may exist, for example, 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. These potential hazards may theoretically increase with rotor size and balancing speed, but they are generally minimized by appropriate rotor design and balancing instructions.

Special-purpose balancing machines, for example 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, for example end-drive coupling and/or drive belt covers. Therefore 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 these 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 rotor to be balanced, the user should 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 International Standard will generally provide an adequate measure of protection to the balancing machine operator and surrounding workshop personnel. There may be applications, however, where the recommended enclosures or other protective measures are so costly, or their use so time-consuming, that other protective precautions, such as vacating the surrounding area for a sufficient distance, remote control of the balancing facility, or work outside normal hours, etc., have to be considered.

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. Maximum service and spin-test speeds are generally well below the speed where major rotor failure can be expected.

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 International Standard deals with balancing machines and protective measures in general, no details of the risk can be stated for specific rotor types and balancing facilities. 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, for example rotor components becoming detached.

The significant hazards covered by this International Standard are those listed in clause 4. The safety requirements and/or protective measures to prevent or minimize those hazards identified in Table 1 and procedures for verification of these requirements or protective measures are found in clause 5.

Mechanical vibration — Balancing machines — Enclosures and other protective measures for the measuring station

1 Scope

This International Standard 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 International Standard 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 International Standard, 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 International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*

ISO 2041, *Vibration and shock — Vocabulary*

ISO 2806, *Industrial automation systems — Numerical control of machines — Vocabulary*

ISO 4849, *Personal eye-protectors — Specifications*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 1925 and ISO 2041 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 International Standard (i.e. the user, designer, manufacturer or supplier) shall conduct a risk assessment. As part of the risk assessment, the user of this International Standard 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

International Standard shall also verify whether the list of hazards in Table 1 is exhaustive and applicable to the balancing machine under consideration.

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/or 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 whilst opening or closing.

During operation of a balancing machine, various potential hazards to the balancing machine operator or the surrounding workshop area can exist, for example,

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

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

— from the rotor lifting from the supports or disintegrating.

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

5.1.2 Protection against contact

Many rotors represent a hazard during balancing due to the surface (e.g. bladed rotors) or due to the rotational energy stored. For that reason the work zone of a dynamic balancing machine shall be protected by guards (barriers, fences) to protect people from contacting the rotating workpiece and drive.

Such guards are not needed in special cases, provided that all of the following criteria apply.

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

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 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 drive torque shall be be low to ensure that the circumferential forces stay below 100 N at all relevant radii [for moments of inertia, see f)].

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.

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

Item	Specific hazard	Examples 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
		workpiece rotating	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	
		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
2	**Electrical**			
2.1	High voltage	contact to live parts		
2.2	Drive power	automatic re-start 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/ unloading and maintenance	load/unload position; maintenance action points
4.2		inadequate consideration of human hand-arm or foot-leg anatomy	while operating the balancing machine	workplace
4.3	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/unload position
5	**Human errors**	inadvertent operation of controls, misuse of guard-controls	measuring unbalance during set-up	around rotor
NOTE This list should not be considered complete.				

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 protection [see A.2.1 and equation (A.1)]. The particle or part shall not penetrate or escape from the protection.

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 protection [see A.3.1 and equation (A.6)]. The protection shall not disintegrate so that a particle or part cannot escape from the protection.

c) Impulse

This criterion is based on the case that the impulse of a particle or part is transmitted to the protection [see A.5.1 and equation (A.10)]. The protection 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 may fly off the rotor; and

— the need for a guard (e.g. barrier, fence) for the balancing machine (see Table 2).

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

Table 2 — Protection classes, specified by the necessity for guards for the balancing machine and resistance against particles or parts

<table>
<tr><th colspan="2">Necessity for guards
(barriers, fences)</th><th colspan="2">No</th><th colspan="3">Yes</th></tr>
<tr><td rowspan="3">Resistance to particles or parts</td><td>Area-specific energy</td><td rowspan="3">below the necessity for spectacles, goggles or face-shields</td><td rowspan="3">spectacles, goggles or face-shields needed</td><td rowspan="3">below the necessity for spectacles, goggles or face-shields</td><td>above class B, up to ≈ 340 mN·m/mm^2</td><td rowspan="3">above the values of class C</td></tr>
<tr><td>Absolute energy</td><td>above class B, up to ≈ 2 000 N·m</td></tr>
<tr><td>Impulse</td><td>above class B, up to ≈ 200 kg·m/s</td></tr>
<tr><td colspan="2">Protection class</td><td>0</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

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 as follows.

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 protection 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 needs to be carefully considered and determined by risk assessment.

The selection of the mode shall be by either 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/or protective measures listed in Table 3.

6 Verification of safety requirements and/or protective measures

Safety requirements and/or protective measures implemented in accordance with clause 5 shall be verified using the recommended procedures given in Table 3, last column.