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BSI Standards Publication

Machine tools safety — Machining centres, Milling machines, Transfer machines

Part 1: Safety requirements

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Full document details: BS EN ISO 16090-1:2022

National foreword

This British Standard is the UK implementation of EN ISO 16090-1:2022. It is identical to ISO 16090-1:2022. It supersedes BS EN ISO 16090-1:2018 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MTE/1/1, Machine tools - Safety.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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European foreword

This document (EN ISO 16090-1:2022) has been prepared by Technical Committee ISO/TC 39 "Machine tools" in collaboration with Technical Committee CEN/TC 143 “Machine tools - Safety” the secretariat of which is held by SNV.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2023, and conflicting national standards shall be withdrawn at the latest by June 2023.

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

This document supersedes EN ISO 16090-1:2018.

Any feedback and questions on this document should be directed to the users’ national standards body/national committee. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Endorsement notice

The text of ISO 16090-1:2022, Corrected version 2023-10 has been approved by CEN as EN ISO 16090-1:2022 without any modification.

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 10, *Safety*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 143, *Machine tools — Safety*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16090-1:2017), which has been technically revised.

The main changes are as follows:

— update and addition of safety functions in Annex J,

— revision of operating modes and change of designation from MSO (mode of safe operation) to MO (mode of operation),

— former MSO 3 (optional special mode for manual intervention under restricted operating conditions), in the current addition referred to as MO 3 (manual intervention under restricted operating conditions), has been revised in a way, that the usage of an enabling device is necessary in any case, i.e. dispensing of the enabling device is no longer possible.

A list of all parts in the ISO 16090 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This corrected version of ISO 16090-1:2022 incorporates the following corrections:

— Figure 2 has been modified so that the measurement *Y* is taken from the lower part of the moving band and not from the centre of the axis of the roller.

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Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Machining centres, milling machines and transfer machines present a wide range of hazards. Protection of operators and other persons from contact with moving cutting tools, especially when being rapidly rotated in the spindle or being swung from a tool magazine to the spindle during power-operated tool changing, or from contact with fast–moving workpieces, is of great importance.

When power-operated mechanisms are provided for workpiece transfer, they can also create hazardous situations during loading/unloading and workpiece alignment, clamping or releasing of the workpiece.

The significant hazards covered by this document 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 measures are found in 5.17.

Figures D.1 to D.8 are examples only and are not intended to illustrate the only interpretation of the text.

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Machine tools safety — Machining centres, milling machines, transfer machines —

Part 1: Safety requirements

1 Scope

This document specifies the technical safety requirements and protective measures for the design, construction and supply (including installation and dismantling, with arrangements for transport and maintenance) of:

— milling machines (see 3.1.1), including machines capable of performing boring operations (see 3.1.2);

— machining centres; and

— transfer machines (see 3.1.3)

designed for continuous production use, which are intended to cut cold metal and other non-combustible cold materials, except wood or materials with physical characteristics similar to those of wood as defined in ISO 19085-1 and glass, stone and engineered/agglomerated materials as defined in EN 14618.

This document covers the following machines (referred to as "machines" in this document):

a) manually, without numerical control, operated boring and milling machines (see 3.2.1, Group 1), e.g. knee and column type milling machines (see Figures C.1 and C.2);

b) manually, with limited numerical control, operated boring and milling machines (see 3.2.2, Group 2), e.g. profile and contouring milling machines (see Figures C.3 and C.4);

c) numerically controlled milling machines and machining centres (see 3.2.3, Group 3), e.g. automatic milling machines and milling centres, e.g. multi-spindle milling machines, gear-milling machines (see Figures C.5 to C.7);

d) transfer and special-purpose machines (see 3.2.4, Group 4), which are designed to process only pre-specified workpieces or limited range of similar workpieces by means of a predetermined sequence of machining operations and process parameters (see Figures C.8 to C.13).

e) machines fitted with the following devices/facilities, whose hazards have been dealt with:

— tool magazine(s);

— tool changer(s);

— workpiece handling mechanism(s);

— powered workpiece clamping mechanism(s);

— swarf/chip conveyor(s);

— power-operated door(s);

— moveable operator cabin(s);

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— additional equipment for turning;

— additional equipment for grinding.

This document deals with all significant hazards, hazardous situations and events relevant to this type of machinery which can occur during transportation, assembly and installation, setting, operation, cleaning and maintenance, troubleshooting, dismantling or disabling according to ISO 12100, when the machinery is used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer (see Clause 4).

This document presumes accessibility to the machine from all directions and specifies access conditions to operator positions. It also applies to workpiece transfer devices including transport devices for loading/unloading when they form an integral part of the machine.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 230-5:2000, *Test code for machine tools — Part 5: Determination of the noise emission*

ISO 3744:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 3746:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 4413:2010, *Hydraulic fluid power — General rules and safety requirements for systems and their components*

ISO 4414:2010, *Pneumatic fluid power — General rules and safety requirements for systems and their components*

ISO 4871:1996, *Acoustics — Declaration and verification of noise emission values of machinery and equipment*

ISO 9355-1:1999[1)], *Ergonomic requirements for the design of displays and control actuators — Part 1: Human interactions with displays and control actuators*

ISO 9355-2:1999, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

ISO 9355-3:2006, *Ergonomic requirements for the design of displays and control actuators — Part 3: Control actuators*

ISO 11202:2010, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions applying approximate environmental corrections*

ISO 11204:2010, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

1) Now withdrawn.

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ISO 13850:2015, *Safety of machinery — Emergency stop function — Principles for design*

ISO 13851:2019, *Safety of machinery — Two-hand control devices — Principles for design and selection*

ISO 13855:2010, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 13856-1:2013, *Safety of machinery — Pressure-sensitive protective devices — Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors*

ISO 13856-2:2013, *Safety of machinery — Pressure-sensitive protective devices — Part 2: General principles for design and testing of pressure-sensitive edges and pressure-sensitive bars*

ISO 13857:2019, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs*

ISO 14118:2017, *Safety of machinery — Prevention of unexpected start-up*

ISO 14119:2013, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

ISO 14120:2015, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

ISO 14738:2002, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery*

ISO 15534-1:2000, *Ergonomic design for the safety of machinery — Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery*

ISO 15534-2:2000, *Ergonomic design for the safety of machinery — Part 2: Principles for determining the dimensions required for access openings*

ISO 15641:2001, *Milling cutters for high speed machining — Safety requirements*

ISO 16156:2004, *Machine-tools safety — Safety requirements for the design and construction of work holding chucks*

ISO 19353:2019, *Safety of machinery — Fire prevention and fire protection*

ISO 23125:2015, *Machine tools — Safety — Turning machines*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60825-1:2014, *Safety of laser products — Part 1: Equipment classification and requirements*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test*

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) — Part 4-4: Testing and measurement techniques — Electrical fast transient/burst immunity test*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments*

EN 614-1+A1:2009, *Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles*

EN 1005-1+A1:2008, *Safety of machinery — Human physical performance — Part 1: Terms and definitions*

EN 1005-2+A1:2008, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

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EN 1005-3+A1:2008, *Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation*

EN 1005-4+A1:2008, *Safety of machinery — Human physical performance — Part 4: Evaluation of working postures and movements in relation to machinery*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and ISO 13849-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
milling machine
machine tool using geometrically defined rotary cutters to remove material in order to produce plane or formed surfaces on a workpiece while advancing (i.e. feeding) the tool or the workpiece in a certain direction (axis movement) or certain directions (axes movements)

3.1.2
boring machine
machine tool for boring holes in which the principal motion is a rotating cutter against a non-rotating workpiece along a feed axis and the diameter of the hole is adjusted by a different axis which is usually perpendicular to the feed axis

Note 1 to entry: This definition does not include machines exclusively used for drilling.

3.1.3
transfer machine
special purpose machine
machine designed to process only a pre-specified workpiece or family of workpieces, by means of a predetermined sequence of machining operations and process parameters

3.1.4
boring operation
machining process of enlarging a hole that has already been produced (e.g. drilled or cast), by means of a single-point cutting tool or a boring head which contains several such tools

3.1.5
numerical control
NC
automatic control of a process performed by a device that makes use of numeric data introduced while operation is in progress

[SOURCE: ISO 2806:1994, 2.1.1]

3.1.6
computerized numerical control
CNC
realization of *NC* (3.1.5) using a computer to control the machine functions

[SOURCE: ISO 2806:1994, 2.1.2]

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3.1.7
manual data input
MDI
mode of operation of a CNC system in which the part program is generated by inputting data manually at the machine

3.1.8
electro-sensitive protective equipment
ESPE
assembly of devices and/or components working together for protective tripping or presence-sensing purposes comprising a sensing device, controlling monitoring devices, output devices and all interconnecting wiring

[SOURCE: IEC 61496-1:2012, 3.5]

3.1.9
active opto-electronic protective device
AOPD
device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiation, generated within the device, by an opaque object present in the specified detection zone

Note 1 to entry: IEC 61496-2 gives detailed provisions on AOPD. For applications, see IEC/TS 62046.

3.1.10
pressure sensitive protective device
PSPD
sensor(s) that responds to the application of pressure, a control unit and one or more output signal switching device(s) and equipment for detecting persons or parts of persons which generates an appropriate signal to the control system to reduce risk to the persons detected

Note 1 to entry: ISO 13856-1, ISO 13856-2 and ISO 13856-3 give detailed provisions.

Note 2 to entry: Safety-related control system associated with the PSPD or the PSPD itself can further include a secondary switching device, start interlock, re-start interlock, etc.

3.1.11
safe operating stop
SOS
function that prevents motor from deviating more than a defined amount from the stopped position by providing energy to the motor to enable it to resist external forces

Note 1 to entry: The SOS function prevents the motor from deviating from the stop position by more than a specified value. The power drive system supplies the motor with energy so that it can withstand external forces; see also IEC 61800-5-2.

Note 2 to entry: This safety function corresponds to a controlled stop category 2 of IEC 60204-1, where torque, speed or rotation positions are maintained and monitored.

3.1.12
safe stop 1
SS1
function which:

a) initiates and controls the motor deceleration rate within set limits to stop the motor and initiates the *STO* (3.1.14) function when the motor speed is below a specified limit;

b) initiates and monitors the motor deceleration rate within set limits to stop the motor and initiates the STO function when the motor speed is below a specified limit; or

c) initiates the motor deceleration and initiates the STO function after an application specific time delay

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Note 1 to entry: This safety function corresponds to a controlled stop in accordance with stop category 1 of IEC 60204-1.

3.1.13
safe stop 2
SS2
function which:

a) initiates and controls the motor deceleration rate within set limits to stop the motor and initiates the safe operating stop function when the motor speed is below a specified limit;

b) initiates and monitors the motor deceleration rate within set limits to stop the motor and initiates the safe operating stop function when the motor speed is below a specified limit; or

c) initiates the motor deceleration and initiates the safe operating stop function after an application specific time delay

Note 1 to entry: This safety function corresponds to a controlled stop in accordance with stop category 2 of IEC 60204-1.

3.1.14
safe torque off
STO
function which ensures that no energy is applied to the motor that can cause rotation or motion (in the case of a linear motor)

Note 1 to entry: The power drive system (PDS) does not provide energy to the motor which can generate torque or force (in the case of a linear motor), see also IEC 61800-5-2:2016, 4.2.3.2.

Note 2 to entry: This safety function corresponds to an uncontrolled stop in accordance to stop category 0 of IEC 60204-1.

Note 3 to entry: This safety function may be used where power removal is required to prevent an unexpected start-up.

Note 4 to entry: In circumstances where external influences (e.g. falling of suspended loads) are present, additional measures (e.g. mechanical brakes) may be necessary to prevent any hazardous situation.

Note 5 to entry: Electronic means and electric contactors are not adequate for protection against electric shock and additional measures for isolation may be necessary.

3.1.15
direction control
positive actuation device to select and maintain a movement

Note 1 to entry: A direction control can be a soft key, touch key, push button control or a rotary type button, e.g. for opening or closing a door or for a movement for clockwise or counter-clockwise.

3.1.16
non-combustible cold material
material, excluding wood, with PCS ≤ 3,0 MJ/kg (ISO 1716) or $\Delta T \leq 50$ °C and $\Delta m \leq 50$ % and $t_f \leq 20$ s (ISO 1182), which withstand surface flame attacks and edge flame attacks with 30 s exposure time without flame spread in excess of 150 mm vertically from the point of application of the test flame within 60 s from the time of application (ISO 11925-2)

3.1.17
short presence
dwelling time of a person staying in the hazard zone less than an accumulated time of 1 h, but never more than 10 min per single exposition, during an 8 h shift

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3.1.18
minimum quantity lubrication
MQL
process of using a little quantity lubrication on cutting point by external spray or through-tool systems

Note 1 to entry: The amount to be used depends on the machining process and type of MQL delivery system.

Note 2 to entry: Minimum quantity lubrication is sometimes referred to as microlubrication.

3.1.19
manual reset
manual reset function
function within the SRP/CS used to restore manually one or more safety functions before restarting a machine

Note 1 to entry: Examples are to reset light curtains, open doors, etc.

3.1.20
open guard
all possible guard positions that are not fully closed

3.1.21
teleservice
machine diagnosis (including troubleshooting), software update and *telecontrol* (3.1.22) from a remote service site

3.1.22
telecontrol
control of the machine movements from a remote service site

3.1.23
emergency stop device
manually actuated control device used to initiate an emergency stop function

[SOURCE: ISO 13850:2015, 3.3]

3.2 Groups of machines

With regard to the applications and the relevant hazards, machines are subdivided into four different groups.

3.2.1
Group 1 machine: Manually controlled boring and milling machine without numerical control
machine where axis motion is controlled by actuation of a mechanical handwheel or where powered single-axis motion is controlled by mechanical, electrical or other means but without the capability for programmed multiple axes movement

Note 1 to entry: For an illustration, see Figures C.1 and C.2.

3.2.2
Group 2 machine: Manually controlled boring and milling machine with limited numerical controlled capability
machine that can be operated like a Group 1 machine by the use of mechanical or electronic handwheels or as a machine with limited NC capabilities which are not capable of automatic program start, automatic initiated tool change, unlimited rapid axis movement and automatic workpiece change or bar feed system

Note 1 to entry: For an illustration, see Figures C.3 and C.4.

Note 2 to entry: This group of machines can be equipped with some or all of the features of Group 1 machines (manual machines without NC) and a limited numeric control system (NC) that enables the machine to provide:

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— a constant surface speed (CSS);

— an axis interpolation (i.e. copying/predefined profiling);

— thread cutting cycles.

3.2.3
Group 3 machine: Numerically controlled boring-, milling machine and machining centre
numerically controlled machine capable of performing programmed multiple axis movements

Note 1 to entry: For an illustration, see Figures C.5, C.6, and C.7.

Note 2 to entry: Such machines may incorporate facilities for manual control in varying degrees.

Note 3 to entry: Machining centres can accommodate different machining processes, e.g. turning, grinding, etc.

3.2.4
Group 4 machine: Numerical controlled transfer and special purpose machine
numerically controlled machine capable to process only pre-specified workpieces or family of workpieces by means of a pre-determined sequence of machining operations

Note 1 to entry: For illustration, see Annex C, Figures C.8 to C.13 and Figures D.7 to D.8.

3.3 Parts of machines

3.3.1
station
<transfer machine> zone which is processing in each operation of the transfer machine working cycle also including the fixtures, units, spindle heads and other mechanisms associated with the process performed at a particular station

Note 1 to entry: See Figures C.11, C.12 and C.13.

Note 2 to entry: Stations are normally identified by sequential numbering, e.g.:

station 1: Load station

station 2: Machining station

station 3: Gauging station

station 4: Idle station

station xx: Unload station

3.3.2
electronic handwheel
manual pulse generator
MPG
manually operated control device which initiates and maintains an axis movement by pulse generation input to the *numerical control* (3.1.5) during its rotation

3.3.3
workpiece setting station
machine area in which the workpiece is loaded/unloaded

3.3.4
workpiece transfer device
unit typically found on Group 3 and Group 4 machines, which swaps the workpiece located in the work zone with a second workpiece

Note 1 to entry: A typical workpiece transfer device is a pallet changer.

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3.3.5
workpiece load/unload mechanism
mechanism that delivers workpieces to, or removes them from, the machine

3.3.6
feed axis
axis for feeding a cutting tool or a workpiece

Note 1 to entry: "Feed axis" may be driven by one or more feed drives.

3.3.7
work zone
zone where the cutting process is taking place

3.3.8
accessible hazard zone
hazard zone of a machine where a stationary standing position with access for the whole body is required with its intended use (e.g. accessible work zone)

3.3.9
spindle
drive system for rotating a cutting tool (tool spindle)

3.3.10
workholding spindle
drive system for rotating a workpiece

3.3.11
counter spindle
spindle which is constructed of two workholding spindles facing each other and those spindles can be rotated synchronously

Note 1 to entry: The counter spindle is a component within the machine which is arranged opposite the main spindle. It allows two-sided machining of a workpiece in which the workpiece is transferred from the main spindle to the counter spindle. The counter spindle moves on the same guideways as the main spindle.

3.4 Mode of operations

3.4.1
mode of operation
MO
provides a defined amount of machine functions under predefined protective measures

Note 1 to entry: Mode of operation is not a function itself. The functions summarized under the term mode of operation can only be used when that particular mode of operation has been activated.

Note 2 to entry: See Clause 5 for safety requirements and measures relating to modes of operation.

3.4.2
mode of operation selection system
MO selection system
facility for manual selection of the machine mode of operation, to which only an authorized group of persons have access

3.4.2.1
mode of operation access device
MO access device
facility which limits access to an authorized group of persons and prevents accidental or abusive actuation of the selection system

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3.4.2.2
mode of operation selection device
MO selection device
facility which allows changing the mode of operation of a machine

Note 1 to entry: The selection device can be integrated into the MO access device, e.g. in a key switch (mode of operation selector switch).

3.4.2.3
mode of operation activation device
MO activation device
device that activates a selected mode of operation

3.4.3
mode of operation 0
MO 0
operation of the machine by the operator with non-automatic multi-axis operation, where the operator has control over the machining process without the use of pre-programmed multiple axes operations

Note 1 to entry: MO 0 can also be referred to as manual mode.

Note 2 to entry: The motion of axes can be controlled by direction control or other means.

3.4.4
mode of operation 1
MO 1
automatic, programmed, sequential operation mode of the machine with the facility for manual or automatic loading/unloading of workpieces and tools, until stopped by program or operator

Note 1 to entry: MO 1 can also be referred to as automatic mode.

Note 2 to entry: The automatic mode can include an operational interruption for loading/unloading of workpieces and tools.

3.4.5
mode of operation 2
MO 2
operation mode in which adjustments and preparations for the following machining process are performed by the operator(setter) with the possibility that guards are open and/or protective devices suspended

Note 1 to entry: MO 2 is also be referred to as setting mode.

Note 2 to entry: Assessments of tool or workpiece position (e.g. by touching the workpiece with a probe or tool in single step mode) are procedures of the setting mode (see 5.2.4.5).

3.4.6
mode of operation 3
MO 3
limited automatic mode (fixed sequence of separate consecutive steps) started by the operator, which allows manual control or numerically controlled operation of the machine, with guards opened and/or protective devices suspended

Note 1 to entry: MO 3 can also be referred to as optional mode for manual intervention under restricted operating conditions.

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3.4.7
service mode
MO service
operation mode for service and maintenance tasks while guards are open and/or protective devices suspended

Note 1 to entry: Examples for service and maintenance tasks are checking the accuracy of positioning of an axis by laser systems, circular interpolation testing, spindle error analysis, vibration analysis, etc.

3.5 Maximum permissible spindle speed and feed rate

3.5.1
maximum spindle speed
maximum permissible rotational speed for a tool spindle specified and set as a machine parameter by the machine manufacturer

3.5.2
safely limited speed
SLS
function to prevent the motor from exceeding the specified speed limit

Note 1 to entry: The SLS function prevents the motor from exceeding the specified speed limit, see IEC 61800-5-2 and also safety functions in Table J.17 (17.3, 17.4).

4 List of significant hazards

4.1 General

This clause contains all the significant hazards, hazardous situations and events identified by risk assessment as significant for this type of machinery and which require action to eliminate or reduce risk.

4.2 Main hazard zones

The main hazard zones are the following:

a) work zones with moving spindle(s) and workpiece(s), clamping components for workpiece and tool clamping, copying unit(s), setting places for workpiece(s) and tool(s), coolant under high pressure, special measuring devices (e.g. laser);

b) handling devices for workpiece loading/unloading;

c) tool magazines and tool changers;

d) area surrounding the swarf and chip conveyor (if integrated);

e) exposed gear box;

f) exposed cam mechanisms;

g) lead screw;

h) feed screw;

i) ball screw;

j) linear and rotary drives.

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4.3 Significant hazards and hazardous situations covered by this document

The significant hazards covered by this document are listed in Table 1.

Table 1 — List of significant hazards and hazardous situations

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas	Possible consequences	Relevant subclause in this document
1	**Mechanical hazards**			
1.1	Approach of a moving element to a fixed part	Manual operations between the area of tool and parts of the machine, for milling application, especially the workpiece support or between tool and workpiece Manual operations between the areas of changing mechanisms, e.g. tool changer / workpiece changer or pallet changer	Crushing hazard Shearing hazard Drawing-in or trapping hazard	5.1 5.2
		Feed motion of tool to the workpiece	Crushing hazard Shearing hazard Ejected parts	5.1 5.2
		Manual operations near to the workpiece or machine spindle	Entanglement hazard	
		Clamping of tools and workpieces	Crushing hazard Shearing hazard	5.2.5
1.2	Moving elements	Operations in the near area of moving axes and in the area of automatic loading/ unloading devices during processing, setting, maintenance, repair Operations on tool changer/ workpiece changer/ pallet changer Operations in the area of operating platforms	Impact hazard Drawing-in or trapping hazard Crushing hazard Shearing hazard	5.1 5.2
1.3	Rotating elements	Unintended contact with the rotating tool or rotating workpiece or tool cleaning device	Drawing-in or trapping hazard Friction or abrasion hazard	5.1 5.2
1.4	Cutting parts, sharp edges	Unintended contact with sharp edges of machine elements, workpiece or tool	Stabbing or puncture hazard Friction or abrasion hazard	5.1 5.2

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Table 1 *(continued)*

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas	Possible consequences	Relevant subclause in this document
1.5	Falling or ejected objects	Ejection or fall of work material and chips during machining, machine setting, tool changing, maintenance, or shut down — falling workpiece; — tool break; — ejected broken machine element(s) at or near machine	Crushing hazard Impact hazard Stabbing or puncture hazard	5.1 5.2 5.8 5.11 Annex A, Annex B
1.6	Gravity	Falling of moving machine elements during machine setting, e.g. during tool changing or workpiece changing and weight loaded axes Breakage during operation Dropping or falling of machine elements during transport or setup, e.g. activities in the vicinity of gravity-loaded axes Operations in the area of operating platforms or pits	Crushing hazard Shearing hazard Impact hazard	5.2.5.5 5.2.5.6 Annex G
1.7	Height in relation to the floor	Fall from high situated work places	Impact hazard Slip, trip, and fall hazards	5.14
1.8	High pressure	At hydraulic elements during stay at or near machine, especially during installation of the machine Start-up and working on coolant systems	Penetration or impact of media under pressure into the skin/eyes	5.8.1 b) 5.8.1 c)
1.9	Lack of stability	Unrestrained machine or machine part falls or overturns during stay at or near machine	Impact hazard Crushing hazard Shearing hazard	5.12
1.10	Rough, slippery surface	Operations on ground and in the area of stairs around the machine, as well as work at height due to: — ejection or spillage of metal cutting fluid, lubricants or hydraulic fluid; — residuals, contained in ejected fluids; — insufficient railing or other restraining facilities, especially at places where a fall hazard exists	Slip, trip, and fall hazards	5.13 5.14
2	**Electrical hazards**			
2.1	Live parts	Contact with live parts	Electric shock hazard	5.3
2.2	Parts which have become live under fault	Contact with parts which are live by fault	Electric shock hazard	5.3

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Table 1 *(continued)*

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas	Possible consequences	Relevant subclause in this document
3	**Thermal hazards**			
3.1	Objects or materials with high/low temperature	Ejection of hot swarf or workpieces during milling operation during stay at and/or near machine, and hot/cold surfaces	Burn hazard Frostbite hazard	5.6
3.2	Explosion		Burn, fall, and bump hazards	5.6 Annex E Annex F
3.3	Flame		Burn hazard	5.6 Annex E Annex F
4	**Noise hazards**			
4.1	Manufacturing process and moving elements	Vibration of tool and/or work material while processing, drive and transmission elements, during stay at or near machine blowing air for cleaning	Permanent hearing loss All further (e.g. mechanical, electrical) problems due to Interference with speech communication or acoustical signals	5.4
5	**Vibration hazards**			
5.1	Vibrating elements	Transfer of vibrations from the milling process to the operator	Discomfort Neurological disorder	5.7
6	**Radiation hazards**			
6.1	Low- and high-frequency electromagnetic radiation	At electrical equipment, especially during setup or maintenance	Burn hazard	5.5
6.2	Optical radiation (infrared, visible and ultraviolet), including laser	At measuring equipment especially during setup or maintenance	Eye and skin injuries	5.5
7	**Material/Substance hazard**			
7.1	Biological or microbiological substance (viral or bacterial)	Contact with contaminated coolant during stay at and/or near machine	Infection hazard	5.6
7.2	Fluid	Skin contact with coolant, during stay at and/or near machine	Skin damage	5.6
7.3	Mists and vapour	Inhalation and ingestion of substances used or generated during operation (e.g. coolant) during stay at and/or near machine	Difficulties of breathing, poisoning	5.6
7.4	Combustible dust	Operating with: — combustible dust, e.g. aluminium-, titan-, magnesium swarf, and/ or — flammable coolant, e.g. oily coolant	Fire Explosion hazard, burns	5.6 Annex E Annex F

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Table 1 *(continued)*

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas	Possible consequences	Relevant subclause in this document
8	**Ergonomic hazards**			
8.1	Design or location of visual display units	Misinterpretation of displayed information at work place of operator	All further (e.g. mechanical, electrical) problems due to human errors	5.7
8.2	Design, location or identification of control devices	Maloperation of the machine at work place of operator		5.7
8.3	Excessive effort	At control devices and during handling Inadequate consideration of anatomy of hand/arm or foot/leg during workpiece or tool changing Inadequate consideration of body posture during maintenance tasks	Fatigue	5.7
8.4	Body posture		Musculoskeletal disorders	5.7
8.5	Repetitive activities		Fatigue, Motivation for defeating of safeguarding equipment	5.7
8.6	Visibility, local lighting	Operations during handling/positioning of work material and the tool, during loading/unloading, during machine setting, tool changing and maintenance	Judgement and accuracy of manual actions impaired Fatigue Human errors	5.7
8.7	Human error/human behaviour	Reasonably foreseeable misuse of the machine Incorrect work material and milling tool handling and setting Insufficient design of work place and/or organization of the machining process Inadequate consideration of anatomy of hand/arm or foot/leg Faulty mounting	All above listed hazards	5.10
9	**Hazards related to the operational environment of the machine**			
9.1	Electromagnetic interference	Uncontrolled movements (including changes in speed, unintentional, unexpected start-up)	Crushing, shearing, trapping, entanglement hazards	5.8.8

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Table 1 *(continued)*

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas	Possible consequences	Relevant subclause in this document
10	**Combination of hazards**			
10.1	Failure of the power supply	Fall or ejection of moving machine elements or clamped workpiece or tool Failure of stopping moving elements	Crushing hazard Shearing hazard Impact hazard Cutting or severing hazard Entanglement hazard Drawing-in or Trapping hazard Stabbing or puncture hazard Friction and abrasion hazard	5.8 5.9
10.2	Restoration of energy supply after an interruption	Uncontrolled movements (including change of velocity) unintended/unexpected start-up		5.8 5.9
10.3	Failure/disorder of the control system	Fall or ejection of moving machine elements or clamped workpiece or tool Failure of stopping moving elements Uncontrolled movements (including change of velocity) Unintended/unexpected start-up Other hazardous situations due to failure or inadequate design of the control system		5.8 5.9

5 Safety requirements and/or protective/risk reduction measures

5.1 General requirements

5.1.1 General

In addition to the requirements of this clause, machinery shall be designed according to the principles of ISO 12100 for relevant but not significant hazards, which are not dealt with in this document.

The selected cutting speed of the machine shall not exceed the maximum permissible cutting speed of the tool in use.

Applicable safety functions for hazardous movements in work zone shall fulfil requirements listed in Table J.18.

Applicable safety functions for hazardous movements in the maintenance area shall fulfil requirements listed in Table J.19.

Applicable safety functions for interface to load/unload applications shall fulfil requirements listed in Table J.20.

5.1.2 Guards requirements

5.1.2.1 General

Guards shall be in accordance with ISO 14120.

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5.1.2.2 Fixed guards

The requirements are the following.

a) Where fixed guards are floor-mounted (e.g. perimeter fencing), they shall have at least a height of 1 400 mm and a distance in accordance with ISO 13857:2019, Table 2, to prevent access to the hazard zone. Any opening between the bottom of the guard and the floor shall not exceed 200 mm according to ISO 11161:2007, 8.5.2.

b) Access to mechanical power transmission drives (e.g. chains and sprocket wheels, gears, feed screws, ball screws, etc.) shall be prevented by fixed guards in accordance with ISO 14120:2015, or the structures of the machine act as fixed guards. Openings in the guards and their distance to the hazardous area shall be designed in accordance with ISO 13857:2019.

5.1.2.3 Manually operated moveable interlocked guards

The requirements are the following.

a) Movable interlocked guards shall be interlocked with or without guard locking in accordance with ISO 14119:2013 in order to prevent access to hazardous areas where hazardous machine movements take place. It shall be ensured that the hazard zone cannot be reached when opening an interlocking guard before the hazardous machine motion has stopped in accordance with ISO 13855:2010, Clause 9. The selection of interlocking devices shall be in accordance with ISO 14119:2013, Clause 6. Safety function for the release of the guard locking shall fulfil the requirements in Table J.17 (17.2).

b) A detected failure in the interlocking device, i.e. function or arrangement, shall result in a stop of the machine initiated by a safety related stop function according to Annex J. Only for control with integrated safety technology, SOS in accordance with IEC 61800-5-2 satisfies the above-mentioned requirements (SS2). This measure does not apply in all cases, where the stop itself is also afflicted by error (e.g. energy loss).

c) The opening of a guard shall cause the safety requirements of the selected MO to be initiated.

d) If prolonged movement (e.g. coast of spindle) is to be expected after a power failure, access to the machine shall be prevented by guard locking device in de-energized state.

e) Measures to minimize possible defeat of interlocking device(s) shall be taken (see ISO 14119:2013, Clause 7).

f) Interlocking guards with a start function (control function) shall only be used if all requirements of ISO 12100:2010, 6.3.3.2.5, are fulfilled.

5.1.2.4 Power-operated moveable interlocked guards

5.1.2.4.1 General

Closing of the guard can be used as a start command for the machine, if the guard system meets the requirements of ISO 12100:2010, 6.3.3.2.5.

Movements of gravity loaded power-operated guards shall not result in any hazardous situation when power loss takes place, e.g. by non-return valves, blocking or clamping devices or brakes.

Power operated movable guards for user access can be realized as automatic power operated movable guards or manually controlled power operated movable guards.

All applicable safety functions listed in Table J.13 shall be fulfilled.

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5.1.2.4.2 Power-operated moveable interlocked guards where motion is maintained automatically by the control system

a) Machines without accessible hazard zone

Power-operated moveable interlocked guards shall be in accordance with ISO 12100:2010, 6.3.3.2.6 and ISO 14120:2015, 5.2.5.4 and shall be equipped with a protective device to avoid shearing hazards at the front edge or shall be provided with round edges with a radius of at least 2 mm for each edge and a combined radius value (sum of the two radii) of at least 6 mm. If one side is a flat surface, this side shall have a width of more than 30 mm and the other side shall have a minimum radius of 6 mm.

— If pressure-sensitive edges are provided, they shall be fitted on the total length of the front edge up to a maximum height of 2 700 mm above the floor or platform (ISO 13857:2019, 4.2.1.2). The pressure-sensitive edge shall be in accordance with ISO 13856-2. While opening there shall be no hazards posed by crushing and shearing edges.

— If reduced forces are used, the force to prevent the guard from closing shall not exceed 75 N and the kinetic energy of the guard shall not exceed 4 J. When the guard is fitted with a protective device which automatically initiates reopening of the guard on actuation, this may be a maximum of 150 N and the kinetic energy a maximum of 10 J.

Limitation of energy and forces shall be done according to ISO 14120 and length of time period according to EN 16005.

NOTE 1 The force can be measured e.g. with a device consisting of a piston provided with a scale acting on spring, a smooth sleeve making it possible to measure the extreme point of movement at the moment of impact. A simple calculation can be used to determine the scale that corresponds to the specified limit values (see EN 81-1:1998+A3:2009, 7.5.2.1.1.2).

b) Machines with accessible hazard zone

In addition to 5.1.2.4.2 a), further additional measures according to 5.2.3.2 b) shall be provided to prevent entrapment in the hazard zone and a start command for closing of the power operated moveable guard shall only be possible from outside the accessible hazard zone.

NOTE 2 The requirements of 5.1.2.4.2 are also applicable where motions of power-operated movable interlocked guards are initiated by a push button, softkey, M-Function, touch screen, etc.

5.1.2.4.3 Manually controlled power-operated moveable interlocked guards

For manually controlled power-operated movable guards, one of the following protective measures shall be provided:

a) manual operation of the power-operated guard by means of two-hand control (ISO 13851). The control panel of the operator shall be fixed in case of movement of the power-operated guard and the actuating mechanisms of the two-hand control shall be located at a sufficient distance to the hazard area according to ISO 13855:2010, Clause 8: at least 100 mm with adequate shrouding with the two buttons B1 (first hand) and B2 (second hand) of a two-hand control;

b) manual operation of the power-operated guard by means of enabling device (see ISO 12100) and direction control:

— a minimum distance to the hazard area is not mandatory for the operator;

— enabling device and direction control are mounted on a control panel or on a portable manual control panel to ensure full visibility to the hazard area for the operator;

— as long as there is only an impact hazard (gap >300 mm), travel speed up to 25 m/min is allowed;

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— when the gap between the movable power-operated guard and the fixed guard is less than 300 mm presenting a shearing or crushing hazard, a maximum travel speed of only 5 m/min is allowed;

— by releasing the enabling device (first hand) or the direction control device (second hand), the drive shall decelerate to a standstill initiated by a safety related stop function for the enabling device, depending on the mode of operation; or

c) manual operation of the power-operated guard by means of a hold-to-run device. The location of the hold-to-run control device shall be at least 2,10 m from the edge of the guard or safeguarding measures as described in 5.1.2.4.2 a) shall be in place. By releasing the hold-to-run device, the drive shall decelerate to a standstill initiated by a safety related stop function.

5.1.3 Requirement for gravity loaded axes

Means shall be provided to prevent hazardous movement of vertical or slant axes under gravity, e.g. redundant restrain system, brakes, counter balance as given in Annex G. For requirements concerning safety functions, e.g. control function, to prevent unintended descent of vertical or slant axes (see Table J.3)

5.2 Specific requirements resulting from mechanical hazards

5.2.1 Protective measures for Group 1 machines

The following requirements for safeguarding of Group 1 machines shall be fulfilled.

a) To inhibit access to the cutting tool (see Figure D.1) adjustable guard(s) shall be provided. Guards shall be in accordance with ISO 14120, interlocking shall be in accordance to ISO 14119:2013.

b) Regarding handwheels, the hazard of entrapment, trapping and impact resulting from power rotation of handwheels shall be prevented, e.g. by automatic disengagement or by using plain solid (no spokes) handwheels with either no pegs or sprung to safe position pegs.

c) Protective clothing and training are important. As the operator is not completely protected from ejection hazards in the work zone, special attention shall be given to the documentation, i.e. the instructions for use, to ensure that the operator has the required qualification and uses the personal protective equipment (PPE), e.g. safety glasses, tight fitted clothing, etc. [see instructions in 6.3.1 q)].

d) Continuous powered axis feed rate shall not exceed 2 m/min and/or a hold-to-run controlled rapid traverse axis speed not exceeding 5 m/min.

If Group 1 machines provide continuous powered axis feed speed exceeding 2 m/min and/or hold-to-run controlled rapid traverse axis speed exceeding 5 m/min, then the requirements of 5.2.2 for Group 2 shall also apply to Group 1 machines.

5.2.2 Protective measures for Group 2 machines

The characteristics of guards and specific requirements for Group 2 machines are the following.

a) The work zone shall be guarded with fixed and/or interlocked movable guard(s) (see Figure D.2). Guards shall be in accordance with ISO 14120, interlocking shall be in accordance with ISO 14119:2013. Guard locking (see ISO 14119) shall be provided when opening of the interlocked movable guard provides access to any hazards during deceleration (i.e. run-down) (see ISO 13855:2010, Clause 9).

b) Any machine movements (except in case of 5.2.2. c) shall only be possible when the interlocked movable guard(s) are/is closed. Opening of an interlocked movable guard shall cause the hazardous movements to stop and to be inhibited. The stop shall be in category 0 or category 1 according to

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IEC 60204-1:2016, 9.2.3.3. For control with integrated safety technology, SOS, SS2, SS1, and STO in accordance with IEC 61800-5-2 satisfy the above-mentioned requirements.

c) When powered machine movements are required with the movable guard open (e.g. for setting), these movements shall only be permitted under the following restrictions:

1) axis feed moving speed shall be limited to 2 m/min and initiated and maintained with a hold-to-run control device (ISO 12100:2010, 3.28.3);

2) spindle rotation shall be initiated and maintained by one of the following means:

— a hold-to-run control device;

— a spindle start device together with an enabling device. When a manual data input (MDI) followed by command "cycle start" is carried out, the axis and spindle movement shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according to Annex J. For control with integrated safety technology, SOS, SS1, SS2, and STO in accordance with IEC 61800-5-2 satisfy this requirement;

3) the rotational speed of the spindle shall be limited by the capability to stop the rotation, while the moveable guard is open, and the safety functions are effective. After a stop command, the spindle shall stand still within 2 revolutions without tool. In case of power loss or errors in the control or the power elements, coast of spindle drive is permissible.

d) To prevent access to moving machine elements, fixed and/or interlocked movable guard(s) shall be provided when

— impact hazards exist and the linear speed exceeds 15 m/min; or

— crushing, shearing or trapping hazards exist and linear speed exceeds 2 m/min.

The safety distances for guards to prevent the operator or other exposed persons from reaching into the hazard zone shall be according to ISO 13857:2019, Tables 4 to 7.

5.2.3 Protective measures for Group 3 and Group 4 machines

5.2.3.1 Access to the work zone

Safeguards shall be provided to reduce the risks listed in Table 1 (e.g. entanglement, crushing, shearing, etc.) by preventing access to dangerous parts/areas of the machines (see Clause 4). General guidance for the selection of safeguards, where the hazards from moving parts cannot be avoided by design, is given in 5.1.2 and in ISO 12100:2010, 6.3. For features of guards used to minimize the hazards of ejection, see 5.11.

The work zone shall be enclosed where reasonably practicable by fixed and/or interlocked movable guards during machining operations.

When using ESPE or PSPD, protective equipment for detecting access to the work zone shall be in accordance with the following standards:

— for ESPE: IEC 61496-1, IEC 61496-2, IEC 61496-3;

— for PSPD: ISO 13856-1:2013, ISO 13856-2:2013, ISO 13856-3.

NOTE See 3.1.8 for ESPE and 3.1.10 for PSPD.

Distances between the protective device (e.g. AOPDs) and the work zone shall be in accordance with ISO 13855 regarding the approaching speed.

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5.2.3.2 Characteristic of guards

The characteristics of guards and specific requirements for Group 3 and Group 4 machines are the following.

a) Where routine observation of the machine operation is required (i.e. more than once per shift), means (e.g. windows) shall be provided so that this can be achieved without the need to open, remove or suspend any work zone guarding or other protective device(s) (see also Table 1, 8.6 on visibility and local lighting).

b) Interlocking of guards: When persons can have whole body access or can remain in the hazardous zone(s) without being visible to the operator, means to inhibit restart shall be provided. These means can be:

— presence-sensing protective equipment;

— door closure inhibition by technical means (e.g. secured by interlock blocking device like padlocks);

— double acknowledgement (inside and outside the protective device);

NOTE One method of accomplishing a special reset solution is to use a second reset actuator. In this case, the reset function will be initiated within the danger zone by the first actuator in combination with a second reset actuator located outside the danger zone (near the safeguard). This reset procedure is realized within a limited time before the safety-related parts of the control system accept a separate restart command (see ISO 11161:2007, 8.9).

— acknowledgement from a position that allows viewing the hazardous area (direct activation of the guard locking device);

— unintended closing of the guards and trapping of persons shall be prevented e.g. by gravity, spring operated or hole for padlock.

c) When interlocking devices with guard locking are used locking shall be power-on released (ISO 14119:2013, 4.3.3, Figure 5 a) c)). If there is an accessible hazard zone an escape release (ISO 14119:2013, 5.7.5.2) in combination with manual reset of the interlocking device shall be provided if power-on released according to ISO 14119:2013, 4.3.3, Figure 5 a) is used.

d) Alternatives to enclosures: Where enclosure is not reasonably practicable (e.g. due to the size of the workpiece, its geometry, other special characteristics of the machine or its application), operators and other exposed persons shall be safeguarded by a combination of other means (e.g. protected operator position by a cabin, perimeter fence, other protective devices). For example, where external equipment (e.g. crane) is used to load/unload workpiece to a large size machine, cabin and perimeter fence are more practical safeguards than an enclosure. See 5.15 for more information on operator cabins and perimeter fencing.

5.2.4 Mode of operation (MO)

5.2.4.1 General requirements

Table 2 assigns the various, in this document standardised, modes of operation (MO) to the machine groups defined in this document (Group 1 to Group 4 machines). Standardized modes of operation may be:

— inherent: the MO is, due to technical limitations or lack of automatic control capability, the only possible mode of operation;

— mandatory: the MO shall be provided;

— optional: the MO may be provided; or

— not allowed: the MO shall not be provided to operate a machine belonging to a particular group.

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Table 2 — Overview of machine groups and modes of operation

Mode of operation (MO)	**Group 1** Manually controlled boring and milling machines without numerical control	**Group 2** Manually controlled boring and milling machines with limited numerical controlled capability	**Group 3** Numerically controlled boring-, milling machines and machining centres	**Group 4** Numerically controlled transfer and special purpose machines
MO 0 Manual	Inherent	Mandatory	N/A [b]	N/A [b]
MO 1 Automatic	N/A	Mandatory see 5.2.2	Mandatory	Mandatory
MO 2 Setting [a]	N/A	Optional	Mandatory	Mandatory
MO 3 Manual intervention under restricted operating conditions	N/A	N/A	Optional	Optional
MO Service[a] Service mode	N/A	Optional	Optional	Optional

[a] In order to allocate access authorization, it may be necessary to provide different key switches (or other appropriate access means) for one machine.

NOTE 1 Example of implementation:

Key 1: Access to setting mode (and automatic mode) for setting staff [see 6.3.1 a) 3)];

Key 2: Access to NC program code and user related NC-parameter modifications for adequately trained staff [see 6.3.1 a) 3)].

Key 3: Access to mode of operation 3 for adequately trained an authorized staff [see 6.3.1 a) 3)].

Key 4: Access to service mode for trained service staff of the machine user [see 6.3.1 a) 3)].

NOTE 2 In most applications, key switch 1 (setting mode) and key switch 2 (NC program code access) can be identical.

[b] Manual machining without NC capability is possible in MO 1, see 5.2.4.4.

If a machine provides more than one mode of operation, the machine shall be equipped with a MO selection system.

The selected MO shall be displayed on the machine according to 6.2.2.

5.2.4.2 Requirements for MO selection system (Group 2, Group 3 and Group 4 machines only)

The selection of a MO shall be done according to Figure 1.

The MO selection system consists of a security system (named Security in Figure 1) and a safety system [named Safety (SRP/CS) in Figure 1]. The sole purpose of the security system is the prevention of unauthorized access to the safety system, which contains the actual MO selection device and the MO activation device. The security system itself is not a safety related part of the control system (SRP/CS).

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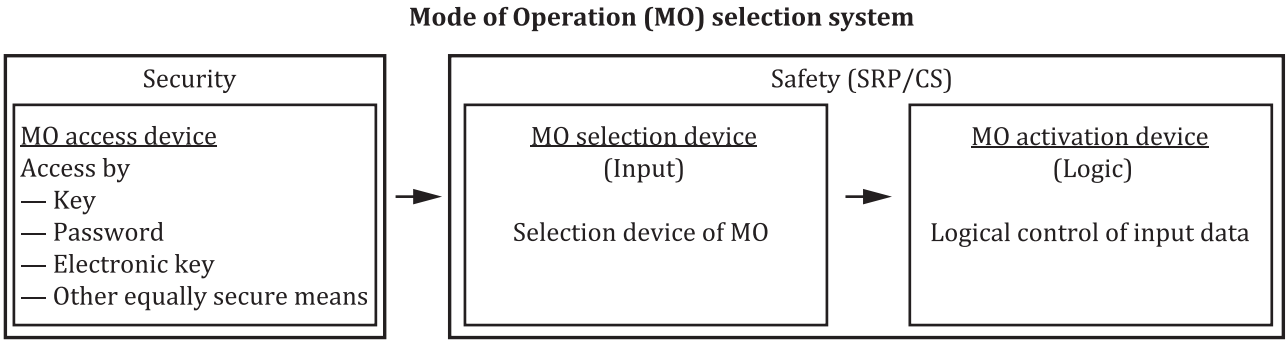

Figure 1 — Border between security system and safety system

The MO selection device (safety) and the associated control system arrangements (SRP/CS) shall ensure that only one MO is selected and enabled at any time.

All applicable safety functions listed in Table J.15 shall be fulfilled.

The selection of a MO shall only be permitted from outside the hazardous areas.

The safety relevant part of the MO selection system shall be capable of being locked. Mode selection by itself shall not initiate machine operation. The following requirements shall be fulfilled for the selection of MO.

a) If more than one location (control console) is available for MO selection at a hazard zone of several machines or interacting partial machines and a different mode of operation than MO 1 is selected from an arbitrary control console of a dedicated hazard zone, the automatic cycle shall be interrupted for this particular hazard zone before access to this hazard zone is enabled.

b) Every selected MO shall be indicated visually [e.g. by visual display on the control panel, by coloured signal lamps or a text on the user interface (HMI – human machine interface)]. See also 6.2.2, Table 6. In special cases, if necessary, audible signals can also be used (see ISO 11161:2007, 8.10).

c) Dynamic mode selection is not permitted when the machine is running. A dynamic transition between MO 1 and MO 3 is applicable to Group 3 and Group 4 machines only (see 5.2.4.6).

5.2.4.3 Mode of operation 0: Manual (MO 0)

When MO 0 is selected, the following requirements apply.

a) If interlocked moveable guards are provided, the spindle rotation shall only be initiated manually by a control device provided for that purpose when these guards are closed. Movement of spindle with these guards open shall only be initiated and maintained with the enabling device actuated. Releasing the enabling device shall initiate a safety related stop function of the spindle rotation.

b) Axis feed movements shall be possible with interlocked moveable guards closed, and traverse movement speed shall be limited to 5 m/min. Axis feed movement with open interlocked moveable table guards shall be manually selectable and shall only be possible by hold-to-run control with 2 m/min limited speed.

c) Rapid traverse movements shall be manually selectable and shall only be possible by hold-to-run control.

d) With controllable power-driven feed axes, only one feed axis movement is allowed at a time. The spindle is permitted to rotate at the same time. Releasing the enabling device stops the spindle and feed motion initiated by a safety related stop function.

e) Applicable safety functions listed in Table J.17 (17.7, 17.8) shall be fulfilled.

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5.2.4.4 Mode of operation 1: Automatic (MO 1)

MO 1 is the standard mode for production and can use the full performance of the machine. Manual movement of the machine axes and machining with running spindle drive is permitted with all safeguards active and guards closed. When MO 1 (automatic mode) is selected, the following conditions apply before the machine is started.

a) Moveable interlocked guards which give access to the work zone shall be closed and the protective devices shall be active to permit and maintain operation in automatic mode.

b) If whole body access to the hazardous area is possible, it shall be ensured that no persons are present in that area. If it cannot be ensured that persons can be seen from the position where the control devices for start/restart are located, requirements from 5.2.3.2 b) shall be fulfilled.

c) Where multiple main control cycle start devices are provided and the operators can therefore put each other in danger, only one shall be enabled at any time [see ISO 12100:2010, 6.2.11.8 e)]. If it is possible to start the same hazardous element by means of several controls, the control circuit shall be arranged that only one control is effective at any given time.

d) For start/restart in MO 1, the following requirements shall be fulfilled:

   — the start/restart shall only be initiated from a control station where no hazard exists;

   — protective devices relevant for this mode of operation including their safety related functions shall be properly arranged and active;

   — the control device(s) for start/restart shall be located to allow a clear and unobstructed view to persons within the hazardous area.

   Movements only associated with loading/unloading of tools/workpieces in MO 1 with guards open shall be possible with specific requirements stated in 5.2.5.1 (machine with tool magazine), 5.2.5.2 (machine with tool changer), 5.2.5.3 (machine with workpiece handling mechanism), 5.2.5.4 (machine with workpiece setting station) and 5.2.5.5 (machine with workpiece clamping mechanism).

5.2.4.5 Mode of operation 2: Setting (MO 2)

5.2.4.5.1 Basic specifications

MO 2 is a mode of operation which allows the operator to perform adjustments for the following machining process with movable interlocked guards open and/or protective devices suspended. Assessment of the tool and workpiece position, e.g. by touching the workpiece with a probe or tool, is part of the setting mode.

When changing to MO 2 from any other MO, the working cycle shall firstly be interrupted and then access to the work zone can be enabled (e.g. by unlocking the interlocked guard with guard locking).

When a hold-to-run control device or electronic handwheel is used, single movement and spindle rotation shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according Annex J. An enabling device is not required if the hold-to-run control device or electronic handwheel complies with the safety requirements according to 5.8.6.

When a manual data input (MDI) followed by command 'cycle start' is carried out, single axis and spindle movement shall be initiated and maintained only while the enabling device is actuated.

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5.2.4.5.2 Range of functions

When any interlocked movable guard is open, and/or a protective device is suspended, hazardous powered machine movements shall only be permitted under the following conditions:

a) singular linear feed movements:

— shall be limited to a maximum of 2 m/min (for safety function, see Table J.2 (2.4), Table J.4 (4.10), Table J.18 (18.5)); or

— the movement shall be in steps with a maximum increment of 10 mm;

b) for rotary axes (including workpiece and workholding spindle):

— peripheral speeds shall be limited to 15 m/min (for safety function, see Table J.2 (2.4), Table J.4 (4.10), Table J.18 (18.5); and

— rotation speed shall be limited to 50 min^{-1} (see ISO 23125:2015, 5.2.4.4.1 d);

c) spindle speed shall be limited by its braking ability. After a stop command the spindle shall stand still within two revolutions without tool;

NOTE The number of two revolutions only refers to the displacement/angle covered by the deceleration procedure. Response time of the operator is not included, e.g. releasing the enabling device and control are not included.

d) the limits of rotational speed or axis feed movements or incremental distance [defined in a), b) and c) above] shall be monitored (see 5.8.7 and speed limit control in Table J.17 (17.3, 17.4). A stop shall be initiated when the speed limit is exceeded. The stop function of the movement shall be initiated by a safety related stop function according to Annex J;

e) unguarded swarf/chip conveyor movements shall only be initiated and maintained by a hold-to-run control device or an enabling device (first hand) in conjunction with a direction control (second hand) (see J.11.2 to J.11.3) but not in conjunction with feed axes and spindle movement;

f) for group 3 and group 4 machines only: Automatic tool- and workpiece changing mechanisms shall remain inhibited in case of pending operations within the work zone. Initiation of their automatic movement shall only be possible by reselection of MO 1. Manually controlled single movements of tool- and workpiece changing mechanisms are permitted in conjunction with an enabling device. Every movement shall be initiated by a start command. This can be achieved, for example, by MDI;

g) releasing the enabling device or the hold-to-run control device (see 5.8.6. a) shall initiate a safety related function according Annex J (marked as SF07-1 and SF07-2);

h) high pressure coolant shall be inhibited (see Table J.12).

5.2.4.6 Mode of operation 3: Manual intervention under restricted operating conditions (MO 3)

5.2.4.6.1 Basic specifications

MO 3 is an optional mode of operation, which permits the operation of the machine under manual or numerical control while guards are open and/or protective devices suspended.

This mode of operation is only permitted to group 3 and group 4 machines.

MO 3 may only be provided if the work task requires the opening of guard(s) and/or suspension of other protective devices.

Typical work tasks and applications for MO 3 with enabling device are the following:

— cleaning of workpiece, e.g. removal of chips to prevent surface scratching;

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— CNC/NC program tests, especially cycle test with higher speeds of axes and/or spindles than permitted in MO 2 and direct observation with guard open is necessary;

— use of contact-type centring tools on hidden parts that cannot be seen from the front or on the back side of the workpiece, such as "edge finder"(observation of contact point by manual pulse handle feed in the rotated state).

NOTE The limited range of functions (see 5.2.4.6.2) provided in MO 3 give a motivation to switch back to the higher performance of MO 1.

When selecting the modes of operation MO 1 or MO 3, the following sequences shall be implemented.

— The change from MO 1 to MO 3: First the operating conditions of MO 1 shall be reduced to those demanded in MO 3 and shall be monitored. Then the relevant safety requirements (e.g. the possibility for opening of guards or the interruption of protective devices) shall be allowed.

— The change from MO 3 to MO 1: First the higher safety requirements of MO 1 (e.g. movable guards closed, or light curtain activated) shall be activated, then the higher values of the operating conditions of MO 1 shall be allowed.

5.2.4.6.2 Range of functions

When any interlocked movable guard is open, and/or a protective device is suspended, hazardous powered machine movements shall only be permitted under the following conditions:

a) Singular linear axis feed movements shall be:

   — limited to 5 m/min; or

   — in steps with a maximum increment of 10 mm.

b) For rotary axes (including workpiece and workholding spindle):

   — peripheral speeds shall be limited to 15 m/min; and

   — rotation speed shall be limited to 50 min^{-1} [see ISO 23125:2015, 5.2.4.4.1 d)].

c) Spindle speed shall be limited by its braking ability. After a stop command the spindle shall stand still within five revolutions without tool.

   NOTE The number of five revolutions only refers to the displacement/angle covered by the deceleration procedure. Response time of the operator is not included, e.g. releasing the enabling device and control are not included.

d) The limits of rotational speed or axis feed movements or incremental distance [as defined in a), b) and c)] shall be monitored [see 5.8.7 and speed limit control in Table J.17 (17.3, 17.4)].

e) Non-programmed movements shall be achieved as follows.

   1) Spindle rotation shall be initiated by a spindle start control device together with an enabling device and maintained by the enabling device.

   2) Axis movements shall be initiated and maintained by one of the following means:

      — a hold-to-run device;

      — an electronic handwheel; or

      — manual data input (MDI) followed by cycle start together with an enabling device.

f) Execution of a program shall be initiated by a cycle start control device in conjunction with an enabling device and maintained by the enabling device.

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g) Unguarded swarf/chip conveyor movements shall only be initiated and maintained by a hold-to-run control device or an enabling device (first hand) in conjunction with a direction control (second hand) (see J.11.2 to J.11.3) but not in conjunction with feed axes and spindle movement.

h) Automatic tool and workpiece changing mechanisms shall remain inhibited in case of pending operations within the work zone. Initiation of their automatic movement shall only be possible by reselection of MO 1. Manually controlled single movements of tool and workpiece changing mechanisms are permitted in conjunction with an enabling device. Every movement shall be initiated by a start command. This can be achieved, for example, by MDI.

i) Releasing the enabling device or the hold-to-run control device (see 5.8.6 a) shall initiate a safety related function according Annex J (marked as SF07-1 and SF07-2).

j) high pressure coolant shall be inhibited (see Table J.12).

NOTE In certain machining processes, e.g. with complex workpieces in single-part production, it can be necessary for the operator to observe the machining process when the guards are open and/or to take corrective action via the control device. Therefore, it is possible that the use of an enabling device over a longer period of time is not practicable for ergonomic reasons or that the setting of several parameters on the control device prevents the continuous actuation of the enabling device. In this case, an additional mode of operation can be provided using further protective measures. Due to the variety of possible machining processes that can require an additional operating mode, it is not possible within this document to standardise a corresponding operating mode. A technical report on this document with examples for the application of additional operating modes is being prepared.

5.2.4.7 Service mode (MO Service)

This mode of operation is intended for service tasks, such as calibration measurement, troubleshooting, diagnostic and checking of machine functions and performance. Therefore, MO Service enables restricted functionality of the machine or parts of it, at which guards of the individual work zone can be opened.

MO Service shall only be provided to service staff, who is trained by the manufacturer/supplier of the machine.

a) The following restrictions for automatic functionalities are required to provide this mode.

   1) Simultaneous rotation of the spindle and axis motion is allowed only for measurement and calibration tasks.

   2) Feed axis/axes can be moved under to following restrictions:

      — with enabling device (PLr = d, Cat. 3) in conjunction with a hold-to-run control device;

      — with enabling device (PLr = d, Cat. 3) in conjunction with a start command (PLr = b) and actuated override selection device; or

      — if axes speed is lower than 15 m/min and safely limited in PLr = d, Cat. 3 (SLS) in conjunction with a start command (PLr = b) and actuated override selection device, an enabling device is not required.

   3) Spindle rotation shall be initiated and maintained under the following restrictions:

      — with an enabling device (PLr = d, Cat. 3) in conjunction with a hold-to-run control device; or

      — with an enabling device (PLr = d, Cat. 3) in conjunction with a start command (PLr = b) and actuated override selection device.

   4) Spindle speed shall be limited by its braking ability. After releasing the enabling device or the hold-to-run device the spindle shall stand still within five revolutions without tool.

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NOTE The number of five revolutions only refers to the displacement/angle covered by the deceleration procedure. Response time of the operator is not included, e.g. releasing the enabling device and control are not included.

5) If movement of tool changer and/or tool magazine is foreseen, automatic tool changing movements or tool magazine movement shall be initiated by a hold-to-run control device. It shall be possible to initiate the individual steps successively.

6) If the pressure of coolant is higher than 0.5 MPa an enabling device (PLr = d, Cat. 3) in conjunction with a permanently actuated hold-to-run control device is required to initiate and maintain the coolant supply.

7) Pneumatic or hydraulic movements of machine parts shall be initiated and maintained with an enabling device (PLr = d, Cat. 3) in conjunction with a permanently actuated hold-to-run device.

8) Tool measuring using laser-based methods are not permitted.

9) Movements of the chip conveyor shall be initiated and maintained with an enabling device (PLr = d, Cat. 3) in conjunction with a permanently actuated hold-to-run device.

b) More than one feed axis can be moved.

c) Movements of automatic workpiece changing mechanisms shall, if applicable, be carried out with reduced speeds. The individual steps shall be initiated in succession.

5.2.5 Optional or additional equipment for machines

5.2.5.1 Additional requirements for tool magazine(s)

If the machine is equipped with tool magazine(s), the following requirements shall be fulfilled.

a) Access to the tool magazine shall be prevented by fixed and/or interlocked movable guards. Where routine observation of the tool magazine is required, means (e.g. windows) shall be provided.

b) When the interlocked movable guards are opened or the protective devices according to 5.2.3.1 suspended, the tool magazine drive(s) shall be stopped, and further movements shall be inhibited.

c) Access openings shall be in accordance with ISO 15534-1:2000 and ISO 15534-2:2000.

d) For any accessible hazard zone of the tool magazine, the same requirements as for the work zone shall be applied. Powered movements of the tool magazine with guards open/protective devices according to 5.2.3.1 suspended are permitted when carried out in accordance with the following:

— an enabling device together with direction control; In this case, movement shall be at a reduced speed of a maximum of 15 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min; or

— a two-hand-control.

The requirements of ISO 13851:2019 type II or type III B shall be fulfilled. However, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two hand devices with one hand, for example by two independent knob type switches or rotary type switches.

NOTE Types of switches, rotary type and knob type, are described in EN 894-3+A1:2008.

The distance requirements of ISO 13855:2010, Clause 8, apply (at least 100 mm).

e) No machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards are open (see IEC 60204-1:2016, 10.1.4).

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f) Means shall be provided to prevent movements of vertical or slant axes under gravity, e.g. brakes (see Annex G).

g) All applicable safety functions listed in Table J.10 shall be fulfilled.

5.2.5.2 Additional requirements for tool changer(s)

If the machine is equipped with tool changer(s), the following requirements shall be fulfilled.

a) Access to hazardous movements of the tool changer(s) from any direction shall be prevented by fixed and/or interlocked movable guards.

b) When the safeguarding measures are suspended, the tool changer drive(s) and other hazardous movements shall be stopped, and further movements shall be inhibited.

c) Powered movements of the tool changer with guards open/protective devices according to 5.2.3.1 suspended and no whole-body access are permitted when carried out in accordance with the following:

   — an enabling device together with direction control; In this case, movement shall be at a reduced speed of a maximum of 15 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min; or

   — a two-hand-control.

   Releasing the enabling device or one of the two hand control devices shall initiate a safety related stop function according to Annex J.

   The requirements of ISO 13851 type II or type III B shall be fulfilled. However, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two hand devices with one hand, for example by two independent knob type switches or rotary type switches.

   NOTE Types of switches, rotary type and knob type, are described in EN 894-3+A1:2008.

   The distance requirements of ISO 13855:2010, Clause 8, apply (at least 100 mm).

d) For any accessible hazard zone of the tool changer, information about the residual danger due to the presence of persons shall be provided in the documentation. The same requirements as for the work zone shall also be fulfilled.

e) No hazardous movements of the tool changer shall be initiated from the actuation of any sensor or feedback device while the interlocked guards are open (see IEC 60204-1:2016, 10.1.4).

f) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity, e.g. brakes (see Annex G).

g) Measures shall be taken to prevent hazards from ejected falling tools under all operating conditions and/or failure of power supply when the interlocked guard is open by securing the tools into the tool changer.

h) All applicable safety functions listed in Table J.9 shall be fulfilled.

5.2.5.3 Additional requirements for workpiece handling mechanisms

If the machine is equipped with automatic workpiece handling mechanisms, the following requirements shall be fulfilled.

a) The positions for operators at workpiece load/unload mechanisms shall be located outside the work zone and away from other hazardous machine movements.

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b) Access to hazardous movements from any direction of the workpiece handling mechanisms shall be prevented by fixed and/or interlocked movable guards (ISO 14119:2013, Clause 7 and Annexes A to D).

c) When the interlocked movable guards are open, the workpiece handling mechanism drive(s) and other dangerous movements shall be stopped, and further movements shall be inhibited.

d) Powered movements with movable interlocked guards open and/or protective devices according to 5.2.3.1 suspended shall be initiated and maintained in a position with sufficient distance from the hazard area either by:

— an enabling device together with direction control; In this case, movement shall be at a reduced speed of a maximum of 5 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min; or

— a two-hand control. Releasing the enabling device or one of the two-hand control devices shall initiate a safety related stop function according to Annex J.

The requirements of ISO 13851 type II or type III B shall be fulfilled. However, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two-hand devices with one hand, for example by two independent knob type switches or rotary type switches.

NOTE Types of switches, rotary type and knob type, are described in EN 894-3+A1:2008.

The distance requirements of ISO 13855:2010, Clause 8, apply (at least 100 mm).

e) For any accessible hazard zone of the handling mechanism, the same requirements as for the work zone shall be fulfilled.

f) No hazardous machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2016, 10.1.4).

g) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity, e.g. brakes (see Annex G).

h) All applicable safety functions listed in Table J.6 shall be fulfilled.

5.2.5.4 Additional requirements for workpiece setting stations

If the machine is equipped with workpiece setting stations, the following requirements shall be fulfilled.

a) If powered movement of the workpiece setting station is required (e.g. to rotate a pallet with workpiece) while interlocked guards are open or protective devices are suspended (e.g. to clean the workpiece or to carry out measurements) then this shall be possible by using either:

— an enabling device together with a direction control; In this case, movement shall not exceed the maximum of 15 m/min, if only an impact hazard exists. Where crushing, shearing or trapping hazards exist also, the movement shall be able to be stopped within a travel distance of 4 mm or the maximum travel speed shall not exceed 5 m/min; or

— a two-hand control. In this case, the requirements of ISO 13851 type II or type III B shall be fulfilled. However, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two-hand devices with one hand, for example by two independent knob type switches or rotary type switches. The distance requirements of ISO 13855:2010, Clause 8, apply (at least 100 mm).

NOTE Types of switches, rotary type and knob type, are described in EN 894-3+A1:2008.

b) For any accessible hazard zone of the workpiece setting station, the requested requirements as for work zones shall be fulfilled.

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c) No hazardous machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2016, 10.1.4).

d) All applicable safety functions listed in Annex J, Table J.6 shall be fulfilled.

The distance requirements of ISO 13855:2010, Clause 8, apply (at least 100 mm).

5.2.5.5 Additional requirements for powered workpiece clamping mechanisms

If the machine is equipped with powered workpiece clamping mechanisms, the following requirements shall be fulfilled.

a) General requirements

1) Measures shall be taken to prevent unintended loosening of workpieces due to gravity, e.g. by clamps or support devices.

2) The state of the powered workpiece clamping mechanism shall be monitored when connected and if the required actuating force, e.g. monitored by pressure, current, etc., (indirect measuring is possible) is not reached the start of operation shall be prevented, or a stop command shall be initiated if operation has already commenced [see Table J.4 (4.2, 4.3)].

3) No hazardous movement of workpiece clamping device shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2016, 10.1.4).

4) All applicable safety functions listed in Table J.4 shall be fulfilled.

b) Movement of power operated workpiece clamping device while movable interlocked guards are open shall be:

1) restricted to

i) less than 4 mm clamping stroke (see ISO 13857:2019, 4.2.4.1, Table 4), or

ii) clamping stroke between 4 mm and 20 mm initiated and maintained by means of a safety function see Table J.4, 4.1

2) initiated and maintained by means of an enabling device together with a direction control, where clamping devices are visible;

3) initiated and maintained by means of two-hand control (for two-hand controls, the requirements of ISO 13855:2010, Clause 8, and ISO 13851 for type II, shall be fulfilled); or

4) if it is required to support the workpiece by hand for fixation or adjustment, the movement shall be controlled by a three-step footswitch (category 3) and reduced speed of maximal 5 m/min. The compression of the three-step footswitch leads to an emergency stop or the activation of the movement in the release direction.

c) For magnetically operated workpiece clamping mechanisms, the following requirements shall be fulfilled:

1) the requirements of 5.2.5.5 a) 1) and b) shall be fulfilled;

2) connection via plug and socket.

When the electrical control system is connected to the magnetic clamping plate by means of an electrical plug connection, the workpiece shall be released or clamped by actuating a control device while the control system is connected. The generated clamping force or its nominal value calculated by indirect measurement shall be displayed on the electrical control device prior to disconnection. Axis movements are only permitted after verification that the displayed clamping force meets or exceeds the application requirements and that the clamping

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device has been unplugged. Once disconnected, the magnetic clamping force shall remain in the clamping plate. Confirmation that the clamping force continues to meet or exceed the application requirements shall be done at specified intervals according to the manufacturer's specifications by reconnecting the device. Specifications shall be given in the instruction for use (see 6.3.1).

NOTE A safety function according to ISO 13849-1 is not definable for these clamping devices because once they are unplugged, there is no connection to the clamping device.

3) Continuous connection

When the electrical control system is permanently connected to the magnetic clamping plate, the workpiece shall be released or clamped by actuating a control device. The generated clamping force or its nominal value calculated by indirect measurement shall be displayed on the electrical control device. Axis movements are only permitted after verification that the displayed clamping force meets or exceeds the application requirements. Confirmation that the clamping force continues to meet or exceed the initial application requirements shall be done at specified intervals according to the manufacturer's specifications. Specifications shall be given in the instruction for use (see 6.3.1).

4) Connection via sliding contacts

When the electrical control system is permanently connected to the magnetic clamping plate by sliding contacts or brushes, the workpiece is released or clamped by actuating a control device. This method allows multi-purpose applications for milling and turning operations. The requirements of 5.2.5.5 c) 3) are applicable.

The magnetically operated workpiece clamping mechanism can be used without performance level (PL).

NOTE For the time being, there is no performance level available from the manufacturers.

d) For workpiece clamping mechanisms operating with vacuum, the following requirements shall be fulfilled.

1) The requirements of 5.2.5.5 a) and b) shall be fulfilled.

2) For these clamping devices, the safety functions for workpiece clamping mechanisms in Table J.4 (4.2 and 4.3) shall be implemented.

e) It shall be possible to run the machine without workpiece(s) in the fixture in automatic mode of operation with guards closed. In that case, the monitoring of the workpiece clamping may be disabled. The muting function shall have the same safety level as the detection of an incorrectly clamped workpiece [see Table J.4 (4.3)]. The warm up cycle shall be done in MO 1.

5.2.5.6 Additional requirements for workpiece clamping mechanisms in case of turning operation

The general conditions are as follows.

a) Workpiece clamping devices, except collets, shall be clearly marked with their maximum permissible speed. The work table shall be such that manual clamping devices, primarily positive fitting, can be mounted. Mounting of clamping devices which are guided in slots shall primarily be done in such a way that the slots are closed in outside direction or bolts are fitted to open slots to prevent loose clamping devices from being ejected. Design of viewing panels and steel sheets (also roof sections) for jaws with a mass of maximum 2,5 kg shall be in accordance with ISO 23125.

b) When the workpiece is rotating, it shall not be possible to loosen the workpiece clamping device by manual operation, regardless of how the workpiece is clamped. Unclamping shall only be possible during a standstill under safe speed monitor (SSM, n = 0 r/min; see ISO 61800-5-2:2008, 4.2.3.14). Non-return valves shall be provided when hydraulic or pneumatic clamping devices are used.

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c) For machines equipped with clamping devices other than collets and where programmable workholding spindle speed is available, a program shall not run in automatic mode unless the following conditions are fulfilled.

1) Machines shall have facilities for entering and/or validating the maximum workholding spindle speed (milling/turning table) taking into account the maximum permissible speed of the workpiece clamping device.

2) Rotary movement shall only be initiated when at least one of the following conditions are fulfilled:

i) clamping device is designed for the maximum permissible speed of the worktable; or

ii) when the requested rotary speed is higher than the speed limit of the clamping device, the maximum permissible rotational speed shall be limited [see Table J.4 (4.9)].

3) The clamping device shall be designed such that necessary clamping forces and torques can be transferred to the workpiece.

4) An actuating force (e.g. by monitoring hydraulic or vacuum pressure) sufficient for the safe clamping of the workpiece shall be maintained until the workholding spindle (milling/turning table) has come to rest, in accordance with ISO 16156:2004, 5.2.1, e.g. by non-return valves on the hydraulic system or a self-locking workpiece clamping device.

5) Means shall be provided to monitor the workpiece clamping device actuating force (e.g. by monitoring hydraulic or vacuum pressure) of power-operated workpiece clamping devices.

6) For power operated clamping systems, the following applies:

i) if the required actuating force of power operated clamping device is not reached, initiation of rotary movement shall be prevented. In case of chucks additionally, the jaw stroke(s) of chucks shall be monitored to ensure that there is a sufficient stroke available once the component is clamped. If the actuating force is not reached or the necessary remaining stroke is insufficient, starting the workholding spindle drive shall be prevented. If the monitoring of jaw stroke is not possible, other safety measures shall be provided, e.g. a direct measuring of the force on the workpiece (measuring jaws);

ii) if the workholding spindle (milling/turning table) drive is running and the actuating force falls below a pre-set value, or any other monitoring system of the workpiece clamping is activated, movement shall stop initiated by a safety related stop function according to Table J.4 (4.2). If a clamping device cannot be monitored during machining, alternative protective measures shall be provided, e.g. unbalance detection, additional workpiece retaining device, workpiece present monitoring.

d) For machines with counter workholding spindles that transfer the workpiece to another spindle while both spindles are rotating with the same speed, it shall be possible to run a spindle without workpiece in the workholding spindle in automatic mode of operation with guards closed. In this case, the monitoring of the workpiece clamping in either the main spindle or the counter spindle may be disabled. Means shall be provided to ensure that at least one of the spindles is running with an activated monitoring of the workpiece clamping.

e) No hazardous movements of the workpiece clamping device shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2016, 10.1.4).

f) All applicable safety functions listed in Table J.4 shall be fulfilled.

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5.2.5.7 Additional requirements for swarf/chip conveyor and removal system with hazardous moving parts

If the machine is equipped with swarf/chip collection and removal system, the following requirements shall be fulfilled.

a) Access to hazardous moving parts of swarf/chip collection systems shall be prevented by means of fixed guards. Where operators have a need to access more frequently than once per shift, interlocked movable guards shall be provided. Guards shall be in accordance with ISO 14119:2013 and ISO 14120.

b) Opening an interlocked movable guard, which provides access to hazardous moving parts of a swarf/chip collection and removal system, shall initiate a safety related function according to Table J.11, 11.1, 11.4.

c) If movement of a swarf/chip system with an interlocked guard open is essential (e.g. for cleaning purposes), the movement shall only be:

   1) permitted by means of a hold-to-run control device according to 5.8.6;

   2) permitted by means of an enabling device together with a start device and reduced peripheral speed of maximum 5 m/min. The movement shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related function according to Table J.11, 11.2, 11.3; or

   3) initiated and maintained by means of two-hand control. For two-hand controls, the requirements of ISO 13851:2019, Clause 7, shall be fulfilled. Distance requirements of ISO 13855:2010, Clause 8, (at least 100 mm) shall be fulfilled. The movement shall be initiated and maintained only while the two-hand control device is actuated. Releasing the two-hand control device shall initiate a safety related function according to Table J.11, 11.2, 11.3.

d) For the swarf/chip discharge area (removal area), the following applies.

   1) Design and safety distances for guards according to ISO 13857:2019, Table 3, where any other additional measures are not provided.

   2) Figure 2 shows a design example with a fixed guard structure for a conveyor that fulfils this requirement. If the measure *Y* in Figure 2 is shorter than 850 mm, additional measures shall be taken to prevent reaching into the hazardous movement of the chip conveyor. The following measures shall be done:

      — funnel dimensions *Y* (see Figure 2) shall be at least 150 mm;

      — design to minimize the chance of chips being held up in the funnel;

      — provide a lockable device to switch off the movement of the chip conveyor with direct visibility at the chip discharge area (see ISO 12100:2010, 6.2.2.1);

   3) The chip conveyor shall be marked as described in 6.2.1 c) 2).

   As stated in 6.2, a yellow and a black marking shall be placed on the floor.

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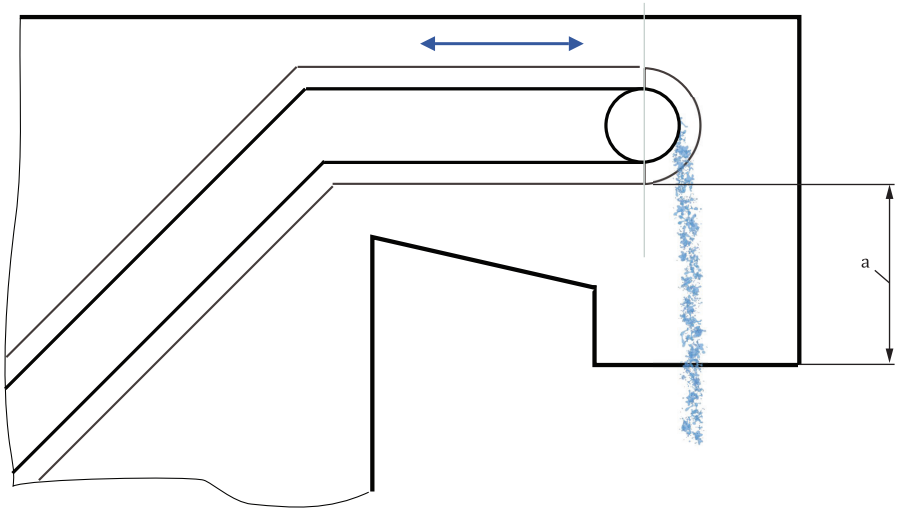

a $Y \geq 150$ mm.

Figure 2 — Discharge chute of a chip conveyor

e) Information regarding operating/handling the chip conveyor and container shall be provided in the instruction for use [see 6.3.1 d)].

f) For Group 4 machines only: Means shall be provided to enable the collection and removal of swarf/chips without the need to remove guards (e.g. fixture design to promote swarf/chip shedding, directed flows of metal working fluid).

g) All applicable safety functions listed in Table J.11 shall be fulfilled.

5.2.5.8 Additional requirements for pits

If the machine construction includes pits, the following requirements shall be fulfilled.

a) Pits shall be covered (e.g. floor grids) or secured against persons falling into them. If coverage is not possible, one of the following alternatives in given priority order shall be installed to prevent persons from falling into the pit:

   1) railings in accordance with ISO 14122-1 to ISO 14122-4;

   2) cables with roll-up devices or barrier chains, tapes or cables with a warning sign located at least 1 m, but no more than 2 m in front of the hazardous area.

b) Where access to pits is necessary for observation, maintenance or adjustment purposes, entry into the pit shall be possible via movable guards which prevent machine movement. Where powered machine movements are necessary, machine elements may be moved under the conditions set out in 5.2.4, 5.2.5.3 and 5.2.5.4.

NOTE ISO 13854 contains requirements for minimum distances to prevent crushing.

5.2.5.9 Additional requirements for machines equipped with tailstock

If the machine is equipped with tailstock device(s), the following requirements apply.

a) For the tailstock device(s), the same requirements as for the work zone shall be applied.

b) All applicable safety functions listed in Table J.5 shall be fulfilled.

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5.2.5.10 Additional requirements for machines equipped with bar feed

If the machine is equipped with bar feed devices, the following requirements apply.

a) For the bar feed device, the same requirements as for the work zone shall be applied.

b) All applicable safety functions listed in Table J.7 shall be fulfilled.

5.2.5.11 Additional requirements for compressed air for cleaning and measuring processes

If the machine is equipped with compressed air, the applicable safety functions listed in Table J.22 shall be fulfilled.

5.2.5.12 Additional requirements for pallet clamping and movements on machines with milling and turning operation

If the machine is equipped with pallet clamping and movements, the applicable safety functions listed in Table J.8 shall be fulfilled.

5.3 Specific requirements resulting from electrical hazards

a) Direct contact with electrical equipment

   1) Electrical equipment shall be in accordance with IEC 60204-1, unless otherwise specified in this document.

   2) The following requirements apply:

      i) IEC 60204-1:2016, Clause 7, for protection of equipment, against short circuit, feeder circuit excluded and overloading. The machine manufacturer shall provide the user with information on how to provide the protection against short circuit of the feeder circuit (see 6.3.8);

      NOTE The protection against short circuit of the feeder circuit is not up to the machine manufacturer.

      ii) IEC 60204-1:2016, Clause 8, for equipotential bonding;

      iii) IEC 60204-1:2016, Clause 12, for conductors and cables;

      iv) IEC 60204-1:2016, Clause 13, for wiring practices;

      v) IEC 60204-1:2016, Clause 14, for electrical motors and associated equipment.

   3) Electrical enclosures shall not be exposed to the risk of damage from the ejection of tools and/or workpieces. The access to live parts shall only be possible under the conditions of IEC 60204-1:2016, 6.2.2). The risk of fire is not considered significant for machines where power circuits are protected against over current (see IEC 60204-1:2016, 7.2.2).

b) For indirect contact with electrical equipment, the machine manufacturer shall provide the protective bonding system of the machine up to the PE terminal. It shall also provide the user with information on how to complete protection against electrical shock due to indirect contact (see 6.3.8).

   NOTE See IEC 60204-1:2016, 3.1.34, for the definition of “indirect contact”.

c) The protection of all electric components against ingress of foreign objects, liquids, dust, coolants, lubricants and swarf shall be adequate taking into account the external influences under which the machine is intended to operate (in accordance with IEC 60204-1 and IEC 60529).

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5.4 Specific requirements resulting from noise hazards

When designing the machine, the available information and technical measures to reduce noise at its source shall be taken into account (see, for example, ISO/TR 11688-1, ISO/TR 11688-2). The design shall take into account noise from every possible source. Appropriate technical measures for reducing noise at the main sound sources of machines are listed below:

a) usage of low-noise machine components;

b) transmission noise by gearbox damping;

c) pneumatic exhaust through silencers;

d) power generation sounds by damping or absorption;

e) noise during cutting process by damping or absorption inside the work zone enclosure;

f) during workpiece/tool change by damping or absorption inside the work zone enclosure.

The above list is not exhaustive. Alternative technical measures for noise reduction with identical or greater efficiency may be used.

Where noise levels shall be reduced beyond those achievable by design at source, the machine shall be provided with protective measures (e.g. noise enclosures, screens fitted to the machinery, silencers).

Operating conditions for noise measurement shall be in accordance with Annex K. The determination of the noise emission shall be in accordance with ISO 230-5. The declaration of the noise emission values shall be in accordance with 6.3.6.

5.5 Specific requirements resulting from radiation hazards

a) For low-frequency radiation, high-frequency and microwaves radiation, see 5.8.8. See also IEC 61000-6-2:2016 and IEC 61000-6-4 for more information.

b) Built-in laser feedback systems shall be designed to prevent exposure to beam paths or specular reflections in accordance with IEC 60825-1:2014.

c) Strong magnetic fields, which may be encountered at e.g. linear drives, can cause irreversible injuries. Through constructive measures, e.g. guards, direct access during normal operation shall be prevented.

Warning signs according to ISO 7010 to emphasize the residual risk shall be attached in a position where the operator can see them.

NOTE Persons particularly at risk are those with cardiac stimulator and prostheses which react to magnetic fields.

5.6 Specific requirements resulting from material or substance hazards

5.6.1 Combustible coolants

Machinery designed to make usage of combustible coolants shall be equipped with devices which minimize the risk from the production of combustible mixtures or an ignition source, especially in MO 1.

a) Dimension of coolant circuit shall be such (pipe cross section, reservoir, pumps, nozzle forms and positioning, etc.) that a sufficient and continuous amount of coolant supply is ensured at processing site.

b) Preventing start-up of machines working cycle, when coolant supply is not functioning properly.

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c) In case of a coolant supply not functioning properly, the machining process shall automatically be brought to a stop in an appropriate manner, e.g. separation of workpiece and tool and shut-off of tool drives.

d) Use of adequate exhaust systems

The suction power shall be as such that at least a negative pressure (below the atmospheric pressure) in the work zone is maintained to securely prevent coolant vapours and aerosols from escaping the work zone.

In case of an incorrectly functioning exhaust system, start-up of a machines working cycle shall be prevented or a currently running machining process shall automatically be brought to a stop in an appropriate manner, e.g. separation of workpiece and tool and shut-off of tool drives. For safety functions, see Table J.14.

Piping of exhaust systems shall be designed so that fluids flow back into the machine, so that the pipes are empty.

All metal parts within the work zone including pipes of exhaust system shall be fully connected to the protective bonding circuit to prevent electrostatic charge.

Vents within the work zone shall be as such that swarf/chips or greater amounts of fluid cannot be sucked in.

If fire and explosion risks cannot be excluded by these systems, additional measures for limiting the consequences of fire and explosion events shall be provided in accordance with ISO 19353:2019 and EN 1127-1.

These include the following measures:

— pressure-resistant enclosure of the work zone including windows and, if necessary, pressure relief in a direction not dangerous to personal;

— preventing flames and hot gases from work zone escaping into the operating area outside the work zone and vicinity of the machine, e.g. flame arresting labyrinth seals on movable parts of the guards (circumferential). For examples, see F.2;

— adequate fire extinguishing devices;

— the machine, including the control system, shall be designed so that connecting fire detecting devices, e.g. fire extinguishing systems, fire alarm, pressure relief valves, etc., are possible according to the manufacturer's recommendations (interface description).

For accessible machines and use of fire extinguishing devices with oxygen suppressing quenching gases, mechanical interlocking capability for the quenching gas supply shall be provided. Additional measures shall be taken to prevent personnel from being trapped within the work zone, e.g. possibility for unlocking the door from the inside without the need of power supply by means of a guard locking device with an escape release (see ISO 14119:2013). In addition, the extinguishing system shall be provided with a release button which shall be actuated only from outside the work zone. The automatic extinguishing system is only activated after the release button has been actuated and can only be set after a sensor signal has been triggered, in a condition where quenching gas can stream into the work zone.

NOTE 1 It can otherwise be possible to unintentionally close and lock the door from the inside while the machine is switched off and quenching gas can perhaps stream inside.

NOTE 2 For further information, see also Annex E.

For machines which are intended to be connected to a central exhaust system, measures or devices shall be provided, which in case of fire:

— prevent fire from spreading into the central exhaust;

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— prevent further air flow into the work zone; and

— prevent exhaust of extinguishing agent, e.g. flame arresters (see example in F.3), butterfly valve for exhaust air.

Integrated decentralized exhaust systems shall automatically shut off in case of fire or explosion.

e) All applicable safety functions listed in Table J.14 shall be fulfilled.

NOTE 1 Further measures of risk reduction depend on the actual conditions of use of the machine and need to be considered individually.

NOTE 2 Accumulation of fluid and dried materials and contact with hot swarf/chips within the piping can cause a fire.

5.6.2 Minimum quantity lubrication (MQL)

For minimum quantity lubrication, the risk of fire and explosion is primarily determined by the amount of flammable swarf/chips and dusts.

The flashpoint of minimum quantity lubricant used shall be considered. In principle, lubricants with a flashpoint of at least 150 °C shall be used. When used in accordance with its intended use, evolution of a dangerous explosive air/vapour mixture is not likely to occur if the consumption rate remains below 100 ml/(m^3/h). If this is not ensured, a machine extraction system is mandatory.

5.6.3 Dry processing and combustible dust

A mechanical interface for an air-extraction system is mandatory [see 6.3.1 r) for documentation requirements].

An explosion risk shall be considered for accumulations of combustible dust (for example, for graphite dust) and especially for light metal dusts, e.g. aluminium, titanium and magnesium. Dispersion of deposited combustible dust can lead to a hazardous explosive atmosphere. If ignition by aluminium, titanium and magnesium dust is to be expected during the intended use of the machine, suitable gases or dry powders such as CO_2 or inert gas shall be used in the extinguishing system.

A higher risk of fire exists in areas in which great amounts of combustible swarf/chips and dusts emerge and accumulate. In addition to the work zone of the encapsulated system, the pipes and filter area of the exhaust system in which fine dust can be separated and dispersed shall also be considered. If fine dry combustible dust particles are cleaned up or dispersed, a possible risk of explosion exists. In these areas, it is not permitted to use compressed air as this causes dispersion of the dust particles during machining (see Annex F).

Machining shall be stopped in case of failure of the swarf/chip removal or exhaust within sealed machines.

5.6.4 Requirements for biological or microbiological hazards

The following are the requirements for biological or microbiological hazards:

a) the total content of the metalworking fluid systems shall be circulated in normal use so that no stationary volume within the reservoir exists except where settlement is required by design;

b) to avoid stagnant areas remaining within the machine, metalworking fluid shall drain under gravity from the machine towards the reservoir. Otherwise, elevating pumps with level monitoring shall be provided to pump the metalworking fluid from the machine back into the reservoir;

c) discharge pipework shall have a sufficient diameter and slope to minimize sludge settlement;

d) the metalworking fluid system shall be provided with filtration;

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e) when sediment build-up occurs, the design shall facilitate cleaning (e.g. rounded corners in reservoirs). Cleaning shall not require drainage of the whole system, see ISO 14159;

f) the inside of reservoirs shall not contribute to the growth of bacteria (e.g. smooth, unpainted surfaces);

g) metalworking fluid reservoirs shall have covers designed to prevent the ingress of foreign matter;

h) contamination of the metalworking fluid by oil or grease from external sources such as lost machine lubrication shall be avoided or means shall be provided for their systematic removal. It shall be possible to add a separation or removal system for oil or grease, if necessary;

i) where a machine is provided with enclosed guards used with metal removal fluid (coolant), that enclosure shall be designed to provide an interface between the guard enclosure and an extraction system. The positioning of the interface shall take into consideration the internal airflows generated by the machine when in normal operation to enable effective operation of the extraction system;

j) provision shall be made to empty metalworking fluid reservoirs completely;

k) means shall be provided to enable, with the least possible exposure of operator to the fluid:

   — fluid samples to be taken;

   — sumps and pipework to be cleaned; and

   — filters to be changed.

5.7 Specific requirements resulting from neglect of ergonomic principles hazards

Machines shall be designed in accordance with the ergonomic principles given in:

— EN 614-1+A1;

— ISO 12100;

— ISO 14738:2002;

— ISO 15534-1;

— ISO 15534-2;

— EN 1005-1+A1:2008, EN 1005-2+A1:2008, EN 1005-3+A1:2008 and EN 1005-4+A1:2008.

a) The requirements for unhealthy posture or excessive efforts (repetitive strain) include the design of machines in accordance with ergonomic principles to avoid excessive effort, unhealthy posture or fatigue during use and in particular:

   1) workpieces, tooling and accessories shall be easy to move. For requirements on lifting equipment, see 6.3.1 i);

   2) where work handling equipment, hoists or lifting devices are required, provision shall be made for their installation and operation (e.g. by making work zone access possible through the top of the machine when movable guards are partially open);

   3) where parts are manually loaded, their fixtures, tool pockets or tool holders shall be positioned to prevent excessive reaching into the machine (see ISO 9241-400, ISO 9241-410, EN 1005-2+A1 and EN 1005-3+A1);

   4) control devices to operate clamping or gripping devices (e.g. drawbars, chucks) shall be positioned to avoid excessive reaching while supporting the weight of the tool or workpiece (e.g. application of foot controls) (see ISO 9355-3:2006, Clause 4);

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5) moveable guards shall be power-operated where use of them will lead to repeated excessive effort (see also ISO 12100:2010, 4.2.2).

b) For adequate consideration of hand-arm or foot-leg anatomy, the positioning of control devices and points for observation or service, such as those for filling and draining of reservoirs, shall be chosen to satisfy the ergonomic principles given in EN 614-1+A1:2009, ISO 9241-400, ISO 9241-410; ISO 9355-1:1999, ISO 9355-2:1999, ISO 9355-3, EN 1005-2 and ISO 13855.

c) Work zone lighting shall be provided with at least 500 lx at the tip of the tool.

d) For design location or identification of manual controls, input devices (e.g. keyboards, keypads and push buttons) shall be in accordance with ISO 9355-1:1999 and ISO 9355-3.

e) For design or location of visual display units, screen displayed information shall be clear and unambiguous. Reflections and glare shall be minimized (see ISO 9241, ISO 9355-1:1999 and ISO 9355-2:1999.

f) Equipment and accessories indicated in the instruction handbook and not readily available, shall be provided for adjusting and maintaining the machine.

5.8 Specific requirements resulting from failure or disorder of the control system

5.8.1 General

The requirements are the following:

a) Electrical control systems and SRP/CS shall be designed in accordance with:

— IEC 60204-1;

— ISO 13849-1; and

— ISO 13849-2:2012.

NOTE Designing the electrical control system according to IEC 62061 can generally achieve the same safety level of any safety function in Annex J as the application of ISO 13849-1.

b) pneumatic systems shall be in accordance with ISO 4414;

c) hydraulic systems shall be in accordance with ISO 4413;

d) safety-related software shall be protected against unauthorized reconfiguration. It shall not be possible for the user to suspend the operation of safety function (including interlocked guards) by means of sequences inserted in or called up by the part program. This may be achieved using a password, key switch or adequate access device.

5.8.2 Starting

The requirements for starting are the following.

a) Requirements for starting are described in 5.2.4 depending on active Operating Mode. Where multiple main control cycle start devices are provided and the operators can therefore put each other in danger, only one shall be enabled at any time [see ISO 12100:2010, 6.2.11.8 e)]. If it is possible to start the same hazardous element by means of several controls, the control circuit shall be arranged that only one control is effective at any given time (see Table J.15, 15.2 for switching control sovereignty).

b) In MO 1 (automatic mode), machining shall only be started or restarted when the guards are closed and protective devices active by actuation of the start device provided for that purpose, or if the requirements for guards with start function in accordance with ISO 12100:2010, 6.3.3.2.5, are fulfilled, the closure of a movable interlocked guard can result in a restart of moving machine parts.

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c) Unexpected start-up of hazardous movements shall be prevented in accordance with ISO 14118:2017, Clause 6, when the interlocked movable guards are open.

5.8.3 Normal stop

a) Machinery shall be fitted with a control device whereby the machinery is be brought to a complete stop in cat 0 or cat 1 (for machines group 1 and 2, Table J.17, 17.8 and for group 3 and 4 machines see Table J.17, 17.6).

b) Machines shall have a stop function according to IEC 60204-1:2016, 9.2.2.

c) The machinery's stop control shall have priority over the start control.

5.8.4 Emergency stop

Each machine shall be fitted with one or more emergency stop devices. When a sequenced shutdown is required, the emergency stop functions shall be category 0 stop or category 1 stop in accordance with IEC 60204-1:2016, 9.2.3.4.2, ISO 12100:2010, 5.5.2 and ISO 13850:2015.

An emergency stop function shall be initiated by one emergency stop device or more which shall be in accordance with IEC 60204-1:2016, 10.7, and ISO 13850. An emergency stop device shall be provided at each operator's position including:

a) the main control panel;

b) each portable control panel(s) (if provided); and

c) inside the tool magazine or workpiece setting station, where whole body access to the enclosure is possible, but it can be omitted if presence is short (see 3.1.17) and it is possible for a person to release oneself from inside the enclosure.

Where emergency stop devices are detachable, the requirements of ISO 13850:2015, 4.3.8, shall be followed.

Safety functions listed in Table J.16 shall be fulfilled.

5.8.5 Manual reset function

After a stop command has been initiated e.g. by a safeguard, the stop condition shall be maintained until safe conditions for restarting exist.

The re-establishment of the safety function by resetting of the safeguard cancels the stop command. This cancellation of the stop command shall be confirmed by a manual, separate and deliberate action (manual reset).

The manual reset function shall

— be provided through a separate and manually operated device within the SRP/CS,

— only be achieved if all safety functions and safeguards are operative,

— not initiate motion or a hazardous situation by itself,

— be by deliberate action,

— enable the control system for accepting a separate start command,

— only be accepted by edge detection of the input signal from the actuator (see Table J.17, 17.10).

The reset actuator shall be situated outside the danger zone and in a safe position from which there is good visibility for checking that no person is within the danger zone.

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