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Robots and robotic devices — Safety requirements for industrial robots —

Part 2: Robot systems and integration

Robots et dispositifs robotiques — Exigences de sécurité pour les robots industriels —

Partie 2: Systèmes robots et intégration

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Foreword

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

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

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

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

ISO 10218-2 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 2, *Robots and robotic devices*.

ISO 10218 consists of the following parts, under the general title *Robots and robotic devices — Safety requirements for industrial robots*:

— *Part 1: Robots*

— *Part 2: Robot systems and integration*

Introduction

This part of ISO 10218 has been created in recognition of the particular hazards that are presented by industrial robot systems when integrated and installed in industrial robot cells and lines.

Hazards are frequently unique to a particular robot system. The number and types of hazards are directly related to the nature of the automation process and the complexity of the installation.

The risks associated with these hazards vary with the type of robot used and its purpose and the way in which it is installed, programmed, operated, and maintained.

For the purpose of understanding requirements in this part of ISO 10218, a word syntax is used to distinguish absolute requirements from recommended practices or suggested actions. The word “shall” is used to identify requirements necessary for compliance with this part of ISO 10218. Such requirements have to be accomplished unless an alternative instruction is provided or a suitable alternative is determined by a risk assessment. The word “should” is used to identify suggestions, recommended actions or possible solutions for requirements, but alternatives are possible and the suggested actions are not absolute.

In recognition of the variable nature of hazards with the application of industrial robots, this part of ISO 10218 provides guidance for the assurance of safety in the integration and installation of robots. Since safety in the use of industrial robots is influenced by the design of the particular robot system, a supplementary, though equally important, purpose is to provide guidelines for the design, construction and information for use of robot systems and cells. Requirements for the robot portion of the system can be found in ISO 10218-1.

Providing for a safe robot system or cell depends on the cooperation of a variety of “stakeholders” – those entities that share in a responsibility for the ultimate purpose of providing a safe working environment. Stakeholders may be identified as manufacturers, suppliers, integrators and users (the entity responsible for using robots), but all share the common goal of a safe (robot) machine. The requirements in this part of ISO 10218 may be assigned to one of the stakeholders, but overlapping responsibilities can involve multiple stakeholders in the same requirements. While using this part of ISO 10218, the reader is cautioned that all of the requirements identified may apply to them, even if not specifically addressed by “assigned” stakeholder tasks.

This part of ISO 10218 is complementary and in addition to ISO 10218-1, which covers the robot only. This part of ISO 10218 adds additional information in line with ISO 12100 and ISO 11161, International Standards for requirements to identify and respond in a type-C standard to unique hazards presented by the integration, installation and requirements for use of industrial robots. New technical requirements include, but are not limited to, instructions for applying the new requirements in ISO 10218-1 for safety-related control system performance, robot stopping function, enabling device, programme verification, cableless pendant criteria, collaborating robot criteria and updated design for safety.

This part of ISO 10218 and ISO 10218-1 form part of a series of standards dealing with robots and robotic devices. Other standards cover such topics as integrated robotic systems, coordinate systems and axis motions, general characteristics, performance criteria and related testing methods, terminology, and mechanical interfaces. It is noted that these standards are interrelated and also related to other International Standards.

For ease of reading this part of ISO 10218, the words “robot” and “robot system” refer to “industrial robot” and “industrial robot system” as defined in ISO 10218-1.

Figure 1 describes the relationship of the scope of machinery standards used in a robot system. The robot alone is covered by ISO 10218-1, the system and cell is covered by this part of ISO 10218. A robot cell may include other machines subject to their own C level standards, and the robot system can be part of an integrated manufacturing system covered by ISO 11161 which in turn can also make reference to other relevant B and C level standards.

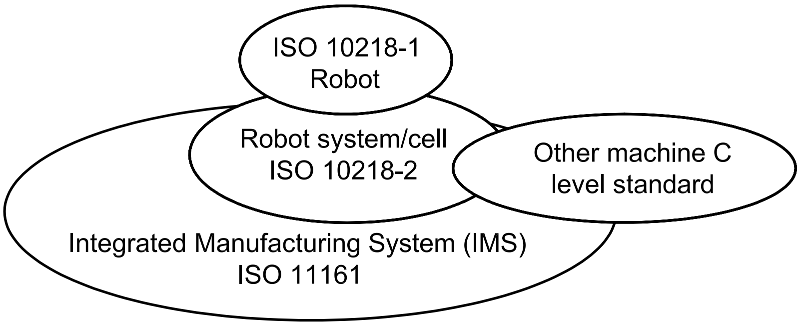

Figure 1 — Graphical view of relationships between standards relating to robot system/cell

Robots and robotic devices — Safety requirements for industrial robots —

Part 2: Robot systems and integration

1 Scope

This part of ISO 10218 specifies safety requirements for the integration of industrial robots and industrial robot systems as defined in ISO 10218-1, and industrial robot cell(s). The integration includes the following:

a) the design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or cell;

b) necessary information for the design, manufacturing, installation, operation, maintenance and decommissioning of the industrial robot system or cell;

c) component devices of the industrial robot system or cell.

This part of ISO 10218 describes the basic hazards and hazardous situations identified with these systems, and provides requirements to eliminate or adequately reduce the risks associated with these hazards. Although noise has been identified to be a significant hazard with industrial robot systems, it is not considered in this part of ISO 10218. This part of ISO 10218 also specifies requirements for the industrial robot system as part of an integrated manufacturing system. This part of ISO 10218 does not deal specifically with hazards associated with processes (e.g. laser radiation, ejected chips, welding smoke). Other standards can be applicable to these process hazards.

2 Normative references

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

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

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

ISO 8995-1, *Lighting of work places — Part 1: Indoor*

ISO 9946, *Manipulating industrial robots — Presentation of characteristics*

ISO 10218-1, *Robots and robotic devices — Safety requirements for industrial robots — Part 1: Industrial robots*

ISO 11161, *Safety of machinery — Integrated manufacturing systems — Basic requirements*

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

ISO 13849-1:2006, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

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

ISO 13854, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

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

ISO 13856 (all parts), *Safety of machinery — Pressure-sensitive protective devices*

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

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

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

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

ISO 14122 (all parts), *Safety of machinery — Permanent means of access to machinery*

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

IEC 61496-1, *Safety of machinery — Electro-sensitive protective equipment — Part 1: General requirements and tests*

IEC 61800-5-2, *Adjustable speed electrical power drive systems — Part 5-2: Safety requirements — Functional*

IEC/TS 62046, *Safety of machinery — Application of protective equipment to detect the presence of persons*

IEC 62061:2005, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10218-1 and ISO 12100 and the following apply.

3.1
application
intended use of the robot system, i.e. the process, the task and the intended purpose of the robot system

EXAMPLE Spot welding, painting, assembly, palletizing.

3.2
collaborative robot
robot designed for direct interaction with a human within a defined **collaborative workspace** (3.3)

3.3
collaborative workspace
workspace within the safeguarded space where the robot and a human can perform tasks simultaneously during production operation

3.4
control station
part of the robot system which contains one or more control devices intended to activate or deactivate functions of the system or parts of the system

NOTE The control station can be fixed in place (e.g. control panel) or movable (e.g. control pendant).

3.5
distance guard
guard that does not completely enclose a danger zone, but which prevents or reduces access by virtue of its dimensions and its distance from the danger zone

EXAMPLE Perimeter fence or tunnel guard.

3.6
integration
act of combining a robot with other equipment or another machine (including additional robots) to form a machine system capable of performing useful work such as production of parts

NOTE This act of machine building can include the requirements for the installation of the system.

3.7
integrator
entity that designs, provides, manufactures or assembles robot systems or integrated manufacturing systems and is in charge of the safety strategy, including the protective measures, control interfaces and interconnections of the control system

NOTE The integrator can be a manufacturer, assembler, engineering company or the user.

3.8
integrated manufacturing system
IMS
group of machines working together in a coordinated manner, linked by a material-handling system, interconnected by controls (i.e. IMS controls), for the purpose of manufacturing, treatment, movement or packaging of discrete parts or assemblies

[ISO 11161:2007, definition 3.1]

3.9
industrial robot cell
one or more robot systems including associated machinery and equipment and the associated safeguarded space and protective measures

3.10
industrial robot line
more than one robot cell performing the same or different functions and associated equipment in single or coupled safeguarded spaces

3.11
safe state
condition of a machine or piece of equipment where it does not present an impending hazard

3.12
simultaneous motion
motion of two or more robots at the same time under the control of a single control station and which may be coordinated or synchronous using a common mathematical correlation

3.13
space
three dimensional volume

3.13.1
operating space
operational space
portion of the **restricted space** (3.13.2) that is actually used while performing all motions commanded by the task programme

NOTE Adapted from ISO 8373:1994, definition 4.8.3.

3.13.2
restricted space
portion of the maximum space restricted by limiting devices that establish limits which will not be exceeded

NOTE Adapted from ISO 8373:1994, definition 4.8.2.

3.13.3
safeguarded space
space defined by the perimeter safeguarding

3.14
validation
confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled

3.15
verification
confirmation by examination and provision of objective evidence that the requirements have been fulfilled

4 Hazard identification and risk assessment

4.1 General

4.1.1 The operational characteristics of robots can be significantly different from those of other machines and equipment, as follows:

a) robots are capable of high energy movements through a large operational space;

b) the initiation of movement and the path of the robot arm are difficult to predict and can vary, for example due to changing operational requirements;

c) the operating space of the robot can overlap a portion of other robots' operating space or the work zones of other machines and related equipment;

d) operators can be required to work in close proximity to the robot system while power to the machine actuators is available.

4.1.2 It is necessary to identify the hazards and to assess the risks associated with the robot and its application before selecting and designing appropriate safeguarding measures to adequately reduce the risks. Technical measures for the reduction of risk are based upon the following fundamental principles:

a) the elimination of hazards by design or their reduction by substitution;

b) preventing operators coming into contact with hazards or controlling the hazards by achieving a safe state before the operator can come into contact with it;

c) the reduction of risk during interventions (e.g. teaching).

4.1.3 The realization of these principles can involve:

a) designing the robot system to allow tasks to be performed from outside the safeguarded space;

b) the creation of a safeguarded space and a restricted space;

c) provision of other safeguards when interventions have to occur within the safeguarded space.

4.1.4 The type of robot, its application and its relationship to other machines and related equipment will influence the design and the selection of the protective measures. These shall be suitable for the work being done and permit, where necessary, teaching, setting, maintenance, programme verification and troubleshooting operations to be carried out safely.

4.2 Layout design

The design of the robot system and cell layout is a key process in the elimination of hazards and reduction of risks. The following factors shall be taken into account during the layout design process.

a) Establishing the physical limits (three dimensional) of the cell or line, including other parts of a larger cell or system (integrated manufacturing system):

   1) scale and origin for modelling the layout in design drawings;

   2) location and dimensions of the components within available facilities (scale).

b) Workspaces, access and clearance:

   1) identifying the maximum space of the robot system, establishing restricted and operating spaces, and identifying the need for clearances around obstacles such as building supports;

   2) traffic routes (pedestrian aisles, visitor routes, material movement outside the perimeter safeguarding of the cell or line);

   3) access and safe pathway to support services (electricity, gas, water, vacuum, hydraulic, ventilation) and control systems;

   4) access and safe pathway for service, cleaning, troubleshooting and maintenance purposes;

   5) cables/other hazards for slips, trips and falls;

   6) cable trays.

c) Manual intervention – the layout should be designed to allow tasks requiring manual intervention to be performed from outside the safeguarded space. Where this is not practicable and when the intervention requires powered movements of the machine(s), appropriate enabling devices shall be provided. The enabling devices may be designed to control:

   1) the whole robot cell;

2) a zone in the robot cell;

3) a selected machine or equipment within the cell.

NOTE See ISO 12100 for more information.

d) Ergonomics and human interface with equipment:

1) visibility of operations;

2) clarity of controls;

3) clear association of controls with robot;

4) regional control design traditions;

5) position of workpiece relative to the operator;

6) foreseeable misuse;

7) collaborative operation.

e) Environmental conditions:

1) ventilation;

2) weld spark.

f) Loading and unloading the workpieces/tool change.

g) Consideration of perimeter safeguarding.

h) Requirements for and location of emergency stop devices and possible zoning of the cell (e.g. local stops or full cell stop).

i) Requirements for and location of enabling devices.

j) Attention to the intended use of all components.

The risk assessment shall determine the additional space required beyond the restricted space to define the safeguarded space.

4.3 Risk assessment

4.3.1 General

Because a robot system is always integrated into a particular application, the integrator shall perform a risk assessment to determine the risk reduction measures required to adequately reduce the risks presented by the integrated application. Particular attention should be paid to instances where safeguards are removed from individual machines in order to achieve the integrated application.

Risk assessment enables the systematic analysis and evaluation of the risks associated with the robot system over its whole lifecycle (i.e. commissioning, set-up, production, maintenance, repair, decommissioning).

Risk assessment is followed, whenever necessary, by risk reduction. When this process is repeated, it gives the iterative process for eliminating hazards as far as practicable and for reducing risks by implementing protective measures.

Risk assessment includes:

— determination of the limits of the robot system (see 4.3.2);

— hazard identification (see 4.4);

— risk estimation;

— risk evaluation.

4.3.2 Limits of the robot system

The integration of a robot system begins with the specification of its intended use and limits described in ISO 12100, ISO 11161 and other applicable C level standards. This specification should include, for example:

a) use limits:

   1) description of functions, intended use and reasonably foreseeable misuse;

   2) description of the different user modes;

   3) analysis of process sequences including manual intervention;

   4) description of interfaces, tooling and equipment;

NOTE 1 It is advisable that the relevant C level standards for these devices be taken into account.

   5) utility connections;

   6) information supplied by the manufacturer, which is derived from the use of ISO 10218-1, including applied measures for risk reduction;

   7) required power supply and their appliances;

   8) required or anticipated user skills (competency);

b) space limits (see 5.5 describing layout):

   1) required machine movement range;

   2) required space for installation and maintenance;

   3) required space for operator tasks and other human intervention;

   4) reconfiguration capabilities (ISO 11161);

   5) required access (see 5.5.2);

   6) foundations;

   7) required space for supply and disposal devices or equipment;

c) time limits:

   1) intended life limit of the machinery and its components (wear parts, tools, etc.);

   2) process flow charts and timings;

   3) recommended service intervals;

d) other limits:

1) environmental (temperature, use indoors or outdoors, tolerance to dust and moisture, etc.);

2) required cleanliness level for the intended use and environment;

3) properties of processed materials;

4) hazardous environments;

5) lessons learned, i.e. study and comparison, including available accident and incident reports, of similar operations and systems.

NOTE 2 Other national standards and local codes can also provide important information on sources of power and requirements for safe handling and installation.

4.4 Hazard identification

4.4.1 General

The list of significant hazards for robot and robot systems contained in Annex A is the result of hazard identification and risk assessment carried out as described in ISO 12100.

Further hazards (e.g. fumes, gases, chemicals and hot materials) can be created by specific applications (e.g. welding, laser cutting, machining) and by the interaction of the robot system with other machines (e.g. crushing, shearing, impact). These hazards shall be addressed on an individual basis with a risk assessment for the specific application.

4.4.2 Task identification

In order to determine the potential occurrence of hazardous situations it is necessary to identify the tasks that are to be carried out by operators of the robot system and its associated equipment. The integrator shall identify and document these tasks. The user shall be consulted to ensure that all reasonably foreseeable hazardous situations (task and hazard combinations) associated with the robot cell are identified, including indirect interactions (e.g. persons having no tasks associated with the system but having exposure to hazards associated with the system). These tasks include, but are not limited to:

a) process control and monitoring;

b) workpiece loading;

c) programming and verification;

d) brief operator intervention not requiring disassembly;

e) set-up (e.g. fixture changes, tool change);

f) troubleshooting;

g) correction of malfunction(s) (e.g. equipment jams, dropped parts, event recovery and abnormal conditions);

h) control of hazardous energy (including fixtures, clamps, turntables and other equipment);

i) maintenance and repair;

j) equipment cleaning.

4.5 Hazard elimination and risk reduction

Having identified the hazards, it is necessary to assess the risks associated with the robot system before applying appropriate measures to adequately reduce the risks. Measures for the reduction of risk are based upon these fundamental principles:

a) the elimination of hazards by design or the reduction of their risk by substitution;

b) safeguarding to prevent operators coming into contact with hazards or to ensure the hazards are brought to a safe state before the operator can come into contact with them;

c) the provision of supplementary protective measures such as information for use, training, signs, personal protective equipment, etc.

The requirements contained in Clause 5 have been derived from the iterative process of applying risk reduction measures, in accordance with ISO 12100, to the hazards identified in Annex A. The integrator shall ensure that the risks identified in the risk assessment are adequately reduced by applying the requirements of Clause 5. If risks are not adequately reduced, further risk reduction measures shall be applied until they are adequately reduced.

5 Safety requirements and protective measures

5.1 General

The integration of robot systems and cells shall comply with the requirements of this part of ISO 10218. In addition, the robot cell or robot line shall be designed according to the principles of ISO 12100 for relevant hazards that are not specifically dealt with by this part of ISO 10218 (e.g. sharp edges). The design of the robot system should follow ergonomic principles to ensure that it is easy to operate and maintain. The robot system shall be designed to avoid exposing personnel to hazards.

NOTE 1 Not all of the hazards identified by this part of ISO 10218 apply to every robot system, nor will the level of risk associated with a given hazardous situation be the same from robot system to robot system.

NOTE 2 Recommended methods of verification of various requirements in this clause are found in Clause 6.

5.2 Safety-related control system performance (hardware/software)

5.2.1 General

Safety-related control systems (electric, hydraulic, pneumatic and software) shall comply with 5.2.2, unless the results of the risk assessment determine that an alternative performance criterion as described in 5.2.3 is appropriate. The safety-related control system performance of the robot system and any furnished equipment shall be clearly stated in the information for use.

NOTE 1 Safety-related control systems can also be called SRP/CS (safety-related parts of control systems).

For the purposes of this part of ISO 10218, safety-related control system performance is stated as:

— Performance Levels (PL) and categories as described in ISO 13849-1:2006, 4.5.1;

— Safety Integrity Levels (SIL) and hardware fault tolerance requirements as described in IEC 62061:2005, 5.2.4.

Those two standards address functional safety in similar but different methods. Requirements in those standards should be used for the respective safety-related control systems for which they are intended. The designer may choose to use either of the two standards. The data and criteria necessary to determine the safety-related control system performance shall be included in the information for use.