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Robots and robotic devices — Collaborative robots

Robots et dispositifs robotiques — Robots coopératifs

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Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
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Foreword

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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).

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The committee responsible for this document is Technical Committee ISO/TC 299, *Robots and robotic devices*.

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This Technical Specification is relevant only in conjunction with the safety requirements for collaborative industrial robot operation described in ISO 10218-1 and ISO 10218-2.

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Introduction

The objective of collaborative robots is to combine the repetitive performance of robots with the individual skills and ability of people. People have an excellent capability for solving imprecise exercises; robots exhibit precision, power and endurance.

To achieve safety, robotic applications traditionally exclude operator access to the operations area while the robot is active. Therefore, a variety of operations requiring human intervention often cannot be automated using robot systems.

This Technical Specification provides guidance for collaborative robot operation where a robot system and people share the same workspace. In such operations, the integrity of the safety-related control system is of major importance, particularly when process parameters such as speed and force are being controlled.

A comprehensive risk assessment is required to assess not only the robot system itself, but also the environment in which it is placed, i.e. the workplace. When implementing applications in which people and robot systems collaborate, ergonomic advantages can also result, e.g. improvements of worker posture.

This Technical Specification supplements and supports the industrial robot safety standards ISO 10218-1 and ISO 10218-2, and provides additional guidance on the identified operational functions for collaborative robots.

The collaborative operations described in this Technical Specification are dependent upon the use of robots meeting the requirements of ISO 10218-1 and their integration meeting the requirements of ISO 10218-2.

NOTE Collaborative operation is a developing field. The values for power and force limiting stated in this Technical Specification are expected to evolve in future editions.

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Robots and robotic devices — Collaborative robots

1 Scope

This Technical Specification specifies safety requirements for collaborative industrial robot systems and the work environment, and supplements the requirements and guidance on collaborative industrial robot operation given in ISO 10218-1 and ISO 10218-2.

This Technical Specification applies to industrial robot systems as described in ISO 10218-1 and ISO 10218-2. It does not apply to non-industrial robots, although the safety principles presented can be useful to other areas of robotics.

NOTE This Technical Specification does not apply to collaborative applications designed prior to its publication.

2 Normative references

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

ISO 10218-1:2011, *Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots*

ISO 10218-2:2011, *Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration*

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

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

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

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

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10218-1, ISO 10218-2 and ISO 12100 and the following apply.

3.1
collaborative operation
state in which a purposely designed robot system and an operator work within a collaborative workspace

[SOURCE: ISO 10218-1:2011, 3.4, modified]

3.2
power
mechanical power
mechanical rate of doing work, or the amount of energy consumed per unit time

Note 1 to entry: Power does not pertain to the electrical power rating on an electronic device, such as a motor.

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3.3
collaborative workspace
space within the operating space where the robot system (including the workpiece) and a human can perform tasks concurrently during production operation

Note 1 to entry: See Figure 1.

[SOURCE: ISO 10218-1:2011, 3.5, modified]

3.4
quasi-static contact
contact between an operator and part of a robot system, where the operator body part can be clamped between a moving part of a robot system and another fixed or moving part of the robot cell

3.5
transient contact
contact between an operator and part of a robot system, where the operator body part is not clamped and can recoil or retract from the moving part of the robot system

3.6
protective separation distance
shortest permissible distance between any moving hazardous part of the robot system and any human in the collaborative workspace

Note 1 to entry: This value can be fixed or variable.

3.7
body model
representation of the human body consisting of individual body segments characterized by biomechanical properties

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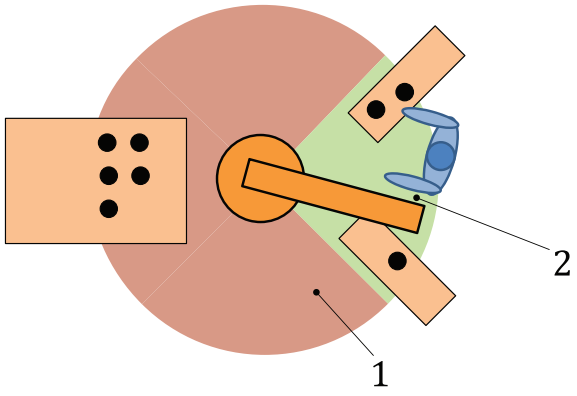
4 Collaborative industrial robot system design

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4.1 General

ISO 10218-2:2011 describes safety requirements for the integration of industrial robots and robot systems, including collaborative robot systems. The operational characteristics of collaborative robot systems are significantly different from those of traditional robot system installations and other machines and equipment. In collaborative robot operations, operators can work in close proximity to the robot system while power to the robot's actuators is available, and physical contact between an operator and the robot system can occur within a collaborative workspace. See Figure 1.

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Key

1 operating space

2 collaborative workspace

Figure 1 — Example of a collaborative workspace

Any collaborative robot system design requires protective measures to ensure the operator's safety at all times during collaborative robot operation. A risk assessment is necessary to identify the hazards and estimate the risks associated with a collaborative robot system application so that proper risk reduction measures can be selected.

4.2 Collaborative application design

A key process in the design of the collaborative robot system and the associated cell layout is the elimination of hazards and reduction of risks, and can include or influence the design of the working environment. The following factors shall be taken into consideration:

a) the established limits (three dimensional) of the collaborative workspace;

b) collaborative workspace, access and clearance:

   1) delineation of the restricted space and collaborative workspaces;

   2) influences on the collaborative workspace (e.g. material storage, work flow requirements, obstacles);

   3) the need for clearances around obstacles such as fixtures, equipment and building supports;

   4) accessibility for operators;

   5) the intended and reasonably foreseeable contact(s) between portions of the robot system and an operator;

   6) access routes (e.g. paths taken by operators, material movement to the collaborative workspace);

   7) hazards associated with slips, trips and falls (e.g. cable trays, cables, uneven surfaces, carts);

c) ergonomics and human interface with equipment:

   1) clarity of controls;

   2) possible stress, fatigue, or lack of concentration arising from the collaborative operation;

   3) error or misuse (intentional or unintentional) by operator;

   4) possible reflex behaviour of operator to operation of the robot system and related equipment;

   5) required training level and skills of the operator;

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6) acceptable biomechanical limits under intended operation and reasonably foreseeable misuse;

7) potential consequences of single or repetitive contacts;

d) use limits:

1) description of the tasks including the required training and skills of an operator;

2) identification of persons (groups) with access to the collaborative robot system;

3) potential intended and unintended contact situations;

4) restriction of access to authorized operators only;

e) transitions (time limits):

1) starting and ending of collaborative operation;

2) transitions from collaborative operations to other types of operation.

4.3 Hazard identification and risk assessment

4.3.1 General

The integrator shall conduct a risk assessment for the collaborative operation as described in ISO 10218-2:2011, 4.3. Special consideration concerning potential intended or reasonably foreseeable unintended contact situations between an operator and the robot system, as well as the expected accessibility of an operator to interact in the collaborative workspace, shall be taken into account.

The user should participate in the risk assessment and design of the workspace. The integrator is responsible for coordinating this participation and for selecting the appropriate robot system components based on the requirements of the application.

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4.3.2 Hazard identification

The list of significant hazards for robot and robot systems contained in ISO 10218-2:2011, Annex A, is the result of hazard identification carried out as described in ISO 12100. Additional hazards (e.g. fumes, gases, chemicals and hot materials) can be created by the specific collaborative applications (e.g. welding, assembly, grinding, or milling). These hazards shall be addressed on an individual basis through a risk assessment for the specific collaborative application.

The hazard identification process shall consider the following as a minimum:

a) robot related hazards, including:

1) robot characteristics (e.g. load, speed, force, momentum, torque, power, geometry, surface shape and material);

2) quasi-static contact conditions in the robot;

3) operator location with respect to proximity of the robot (e.g. working under the robot) ;

b) hazards related to the robot system, including:

1) end-effector and workpiece hazards, including lack of ergonomic design, sharp edges, loss of workpiece, protrusions, working with tool changer;

2) operator motion and location with respect to positioning of parts, orientation of structures (e.g. fixtures, building supports, walls) and location of hazards on fixtures;

3) fixture design, clamp placement and operation, other related hazards;

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4) a determination as to whether contact would be transient or quasi-static, and the parts of the operator's body that could be affected;

5) the design and location of any manually controlled robot guiding device (e.g. accessibility, ergonomic, potential misuse, possible confusion from control and status indicators, etc.);

6) the influence and effects of the surroundings (e.g. where a protective cover has been removed from an adjacent machine, proximity of a laser cutter);

c) application related hazards, including:

1) process-specific hazards (e.g. temperature, ejected parts, welding splatters);

2) limitations caused by the required use of personal protective equipment;

3) deficiency in ergonomic design (e.g. resulting in loss of attention, improper operation).

4.3.3 Task identification

In consultation with the user, the integrator shall identify and document the tasks associated with the robot cell. All reasonably foreseeable task and hazard combinations shall be identified. The collaborative tasks can be characterized by:

a) the frequency and duration of operator presence in the collaborative workspace with a moving robot system (e.g. collaborative assembly with external fixtures);

b) the frequency and duration of contact between an operator and robot system with the drive power or application-related sources of energy active (e.g. hand guiding, physical interaction with tool or workpiece);

c) transitioning between non-collaborative operation and collaborative operation;

d) automatic or manual restart of robot system motion after the collaborative operation has been completed;

e) tasks involving more than one operator;

f) any additional tasks within the collaborative workspace.

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4.3.4 Hazard elimination and risk reduction

After hazards are identified, the risks associated with the collaborative robot system shall be assessed before applying risk reduction measures. These measures are based upon these fundamental principles listed in their order of priority (see ISO 10218-2:2011, 4.1.2):

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

b) protective measures that prevent personnel from accessing a hazard or control the hazards by bringing them to a safe state (e.g. stopping, limiting forces, limiting speed) before an operator can access or be exposed to the hazards;

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

For traditional robot systems, risk reduction is typically achieved through safeguards that separate the operator from the robot system. For collaborative operation, the risk reduction is primarily addressed by the design and application of the robot system and of the collaborative workspace. Specific measures for risk reduction for collaborative operation are identified in Clause 5.

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5 Requirements for collaborative robot system applications

5.1 General

Robot systems with collaborative applications shall meet the requirements of ISO 10218-1:2011 and ISO 10218-2:2011. The information contained in this clause supplements that given in ISO 10218-1:2011, 5.10 and ISO 10218-2:2011, 5.11.

5.2 Safety-related control system performance

The safety-related control system functions shall comply with ISO 10218-1:2011, 5.4, or ISO 10218-2:2011, 5.2.

5.3 Design of the collaborative workspace

The design of the collaborative workspace shall be such that the operator can perform all intended tasks. Any risks introduced by machinery or equipment shall be sufficiently mitigated by the measures identified in the risk assessment. The location of equipment and machinery should not introduce additional hazards. Safety-rated soft axis and space limiting, as described in ISO 10218-1:2011, 5.12.3, should be used whenever practicable, to reduce the size of the restricted space.

Risks associated with whole body trapping or crushing between the robot system and, for example, parts of buildings, structures, utilities, other machines, and equipment, shall be eliminated or safely controlled. Clearance in accordance with ISO 10218-2:2011, 5.11.3 should be provided.

NOTE The clearance can be different for systems designed to comply with 5.5.4 and 5.5.5.

If other machines in the collaborative workspace present a hazard, then protective measures shall be applied in accordance with ISO 10218-2:2011, 5.11.2. Any relevant safety-related functions shall comply with the requirements of 5.2.

5.4 Design of the collaborative robot operation

5.4.1 General

The requirements for the design of the collaborative robot operation are provided in ISO 10218-2:2011, 5.11. The operating methods in 5.5 may be used singularly or in combination when designing a collaborative application.

Any detected failure in the safety-related parts of the control system shall result in a protective stop (ISO 10218-2:2011, 5.3.8.3). Operation shall not resume until reset by a deliberate restart action with the operator outside of the collaborative workspace.

5.4.2 Protective measures

All persons within the collaborative workspace shall be protected by protective measures. Safeguards used in a collaborative workspace shall meet the requirements of ISO 10218-2:2011, 5.10.

Information on active settings and configuration of collaborative safety parameters shall be capable of being viewed and documented with a unique identifier (e.g. checksum) so that changes to the configuration can be easily identified (see ISO 10218-1:2011, 5.12.3). Setting and adjusting collaborative safety parameters shall be protected against unauthorized and unintentional changes by password protection or similar security measures.

5.4.3 Stopping functions

During collaborative operation, the operator shall have the means to either stop robot motion at any time by a single action or have an unobstructed means of exiting the collaborative workspace.

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