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Robotics — Safety design for industrial robot systems —

Part 1: **End-effectors**

Robotique — Conception de sécurité pour les systèmes de robots industriels —

Partie 1: Organe terminal effecteur

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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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This document was prepared by Technical Committee ISO/TC 299, *Robotics*.

A list of all parts in the ISO 20218 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.

Introduction

This document applies to industrial robot systems as described in ISO 10218-2:2011 and ISO/TS 15066:2016.

This document provides guidance for end-effectors in robot systems, including collaborative applications where a robot system and operators share the same workspace. In such collaborative applications, the end-effector design is of major importance, particularly characteristics such as shapes, surfaces and application function (e.g. clamping forces, residual material generation, temperature).

A comprehensive risk assessment is required by ISO 10218-2:2011. This document provides additional guidance specific to end-effectors that can be helpful when performing the risk assessment in accordance with ISO 10218-2:2011.

Robotics — Safety design for industrial robot systems —

Part 1: **End-effectors**

1 Scope

This document provides guidance on safety measures for the design and integration of end-effectors used for robot systems. The integration includes the following:

— the manufacturing, design and integration of end-effectors;

— the necessary information for use.

This document provides additional safety guidance on the integration of robot systems, as described in ISO 10218-2:2011.

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 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 11593, *Manipulating industrial robots — Automatic end effector exchange systems — Vocabulary and presentation of characteristics*

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

ISO 14539:2000, *Manipulating industrial robots — Object handling with grasp-type grippers — Vocabulary and presentation of characteristics*

ISO/TS 15066:2016, *Robots and robotic devices — Collaborative robots*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100, ISO/TS 15066:2016, ISO 10218-1:2011, ISO 10218-2:2011, ISO 14539:2000, ISO 11593 and the following apply.

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

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

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

3.1
compliant
exhibiting deformation of material or mechanism when subjected to a force

EXAMPLE Compliant linkage, compliant surface.

Note 1 to entry: The reciprocal of compliant is stiff.

Note 2 to entry: Compliance is defined in ISO 8373:2012.

3.2
mechanical interface
end-effector (3.3) flange mounting surface at the end of the manipulator to which the end-effector is attached

[SOURCE: ISO 8373:2012, 3.10, modified — The words "end-effector flange" have been added at the start of the definition and the Note to entry has been deleted.]

3.3
end-effector
device specifically designed for attachment to the *mechanical interface* (3.2) to enable the robot to perform its task

EXAMPLE *Gripper* (3.4), welding gun, spray gun.

Note 1 to entry: In this document, the term refers to end-effectors in robot systems.

Note 2 to entry: End-effectors are sometimes known as end-of-arm tooling (EOAT).

[SOURCE: ISO 8373:2012, 3.11, modified — The words "nut runner" have been deleted from the Example and the Notes to entry have been added.]

3.4
gripper
end-effector (3.3) designed for grasping workpieces

Note 1 to entry: Grip, grasp, grasping and releasing are defined in ISO 14539:2000.

[SOURCE: ISO 8373:2012, 3.14, modified — The words "seizing and holding" have been replaced by "grasping workpieces" in the definition and the Note to entry has been added.]

3.5
fixture
device used to fixate an item as part of the handling or assembling process in a robot system, but not as an *end-effector* (3.3)

3.6
robot application
system comprising an industrial robot system [industrial robot, *end-effectors* (3.3), workpieces and any machinery, equipment, devices, external auxiliary axes or sensors supporting the robot performing its task] and any obstacle or object within the robot system workspace that has influence on the risk assessment of the workspace

[SOURCE: ISO 10218-1:2011, 3.11, modified — Adapted from definition for "industrial robot system".]

4 Risk assessment

4.1 General

This clause describes the actions and factors particularly relevant for the parts of a risk assessment that address end-effectors in a robot application. In accordance with ISO 10218-2:2011, 4.3.1, the risk assessment considers the risks for the entire robot application, including the robot, end-effector, workpieces and fixture(s), over its whole lifecycle.

According ISO 10218-2:2011, the initial risk is assessed on the assumption that no risk reduction measures have been applied. This includes modifications to existing robot applications.

Potential contact situations (both intended and unintended) and the expected accessibility of a person to interact with the end-effector(s) are considered.

The integrator consults with the user during the risk assessment and design of the workspace, in accordance with ISO 10218-2:2011, 4.4.2. The purpose of this consultation is 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). The integrator is responsible for coordinating this participation and for selecting the appropriate end-effector(s) based on the requirements of the application.

The results of the risk assessment are documented in accordance with ISO 12100:2010, 5.1 and Clause 7.

4.2 Limits of the end-effector(s)

The limits of the end-effector(s) should be considered when determining the limits for the robot application as a whole (see ISO 10218-2:2011, 4.3.2). Some specific considerations for end-effectors can include, but are not limited to the following:

a) use limits (description of functions, intended use and reasonably foreseeable misuse):
   - automatic or manual;
   - hand-guiding;
   - collaborative or non-collaborative;

b) space limits:
   - end-effector changing station;
   - movement of the end-effector and workpiece;
   - variation in dimensions of the end-effector and workpieces;

c) time limits:
   - expected life for end-effector or parts of the end-effector or the grasped tool;
   - end-effector exchange system exchange time;

   NOTE 1 Deviations in the end-effector exchange time can indicate a fault in the robot system or the end-effector exchange system.

d) other end-effector limits:
   - acceptable workpiece shape/geometry;
   - centre of gravity of workpiece(s);
   - maximum/minimum payload;
   - maximum/minimum grasping force (see ISO 14539:2000, 3.1.5);
   - maximum/minimum suction of vacuum cup(s);
   - maximum/minimum magnetic attraction properties;
   - minimum friction between grasping surface (e.g. gripper fingers) and the workpiece;
   - physical properties of workpiece, e.g. maximum/minimum size, compliance;
   - maximum speed and/or acceleration;

— environmental data, e.g. maximum/minimum temperature.

4.3 Hazard identification

4.3.1 General

In accordance with ISO 10218-2:2011, Clause 4, the risk assessment should identify all hazards related to the intended use and the reasonably foreseeable misuse of the end-effector(s). End-effector hazards are identified by a task-based risk assessment (see ISO 10218-2:2011, 4.4). In consultation with the user, the integrator identifies all the tasks associated with the end-effector(s). These tasks could be associated with an operating mode. End-effector usage is identified. In accordance with ISO 12100, examples of factors which should be taken into consideration include but are not limited to the following:

a) transport;

b) assembly and installation or commissioning, e.g. process observation and monitoring;

c) setting, e.g. teaching and testing the robot program;

d) operation, e.g. routine operator intervention not requiring disassembly such as load/unload operations, operator intervention such as clearing jams or similar simple corrections;

e) cleaning or maintenance, e.g. extended interaction with operator such as an adaptive fixture for variable presentation of work piece or assembly;

f) fault-finding or troubleshooting;

g) dismantling or disabling.

An understanding of the interaction between end-effectors and other parts of the robot application is needed for hazard identification.

While hazards are similar for collaborative and non-collaborative applications, the exposure of the operator to these hazards can vary greatly. Consequently, the most relevant risks to consider can differ depending upon whether the end-effector is used in a collaborative application or whether it is solely operating in a non-collaborative environment.

4.3.2 Examples of hazards from end-effectors and workpieces

Examples of hazards that could be caused by end-effectors and workpieces include, but are not limited to, those shown in Annex D.

4.4 Risk estimation

Risk is defined in ISO 12100:2010 as the combination of the probability of harm and the severity of that harm. Annex A gives practical examples of risks associated with end-effectors.

Hazards associated with end-effectors and workpieces can be more or less severe than hazards associated with the motion of the robot. Depending on the estimation of the risks associated with the hazards of the end-effector and workpiece, safety functions used to control these hazards have a safety performance level (PL) or a safety integrity level (SIL) in accordance with ISO 10218-2:2011, 5.2.

The risk level also depends upon whether the application uses a type of collaborative operation as described in ISO 10218-2:2011, 5.11. The exposure of the operator is considered accordingly. The hazards are the same for collaborative and non-collaborative applications, although the exposure can vary greatly.

In accordance with ISO 12100, exposure is carefully considered for the design of the end-effector for both collaborative and non-collaborative applications.

NOTE 1 ISO/TR 14121-2 gives examples of risk estimation tools.

4.5 Risk evaluation

In accordance with ISO 12100, risk evaluation should be performed after risk estimation to verify whether risks have been adequately reduced.

4.6 Residual risks

In accordance with ISO 10218-2:2011, 7.1, information about identified residual risks is included in the information for use. See Clause 7.

5 Safety requirements and risk reduction

5.1 General

In accordance with ISO 10218-2:2011, end-effectors:

— are designed and constructed to comply with ISO 10218-2:2011, 5.3.10;

— comply with ISO 10218-2:2011, 5.2, for any safety-related control functions.

If intended for use in a power and force limited (PFL) collaborative application, a means to establish the threshold limit values is provided in ISO/TS 15066:2016, Annex A.

NOTE 1 Power and force limited robots and robot systems are described in ISO 10218-1:2011, 5.10.5, and ISO 10218-2:2011, 5.11.5.5. ISO/TS 15066:2016 contains additional information. The information contained in this clause provides detailed guidance for designers of generic end-effectors, integrators selecting end-effectors for robot applications as well as integrators designing end-effectors for specific robot applications.

NOTE 2 ISO 10218-2:2011 requires an end-effector to undergo a risk assessment for its specific application.

5.2 Risk reduction measures

5.2.1 Shape and surfaces

End-effector and fixture designs can incorporate design measures that reduce sharp edges to reduce human contact forces or pressures (e.g. using smooth and compliant surfaces). End-effector mass can be as low as practicable to minimize the forces or pressures associated with a transient contact (e.g. minimizing momentum and kinetic energy). Padding and cushioning materials, as well as deformable components, can reduce impact energy transfer.

Risk reduction measures are taken to minimize risks posed by sharp edges and prevent motion where edges can result in unacceptable contact force(s) or pressure(s). Protective measures, such as increasing edge radius, increasing surface area, modifying edge profiles (e.g. chamfer), or using different surface materials, can be implemented. ISO/TS 15066:2016 provides further information on collaborative robot applications.

The end-effector can also be designed to provide protection from hazards associated with the workpiece(s).

5.2.2 Protective devices and safety-related functions

Protective devices and safety-related control systems built into, or associated directly with, the end-effector can be used in some robot applications to reduce risk. Protective devices and safety control systems can be, but are not limited to, the following:

a) force sensing (e.g. enhanced force sensing that is more sensitive than force sensing of the robot arm):

   — measurement of applied forces on the surface(s) of the end-effector and corresponding monitoring of the end-effector and/or robot as a safety function;

