# TECHNICAL REPORT



First edition 2018-08

# Robotics — Safety design for industrial robot systems —

Part 1: End-effectors

Robotique — Conception de sécurité pour les systèmes de robots **iTeh** STANDARD PREVIEW Partie 1: Organe terminal effecteur (standards.iteh.ai)

<u>ISO/TR 20218-1:2018</u> https://standards.iteh.ai/catalog/standards/sist/66fb6f33-0d50-4b4f-8334-9774801e967c/iso-tr-20218-1-2018



Reference number ISO/TR 20218-1:2018(E)

# iTeh STANDARD PREVIEW (standards.iteh.ai)

<u>ISO/TR 20218-1:2018</u> https://standards.iteh.ai/catalog/standards/sist/66fb6f33-0d50-4b4f-8334-9774801e967c/iso-tr-20218-1-2018



## **COPYRIGHT PROTECTED DOCUMENT**

#### © ISO 2018

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office CP 401 • Ch. de Blandonnet 8 CH-1214 Vernier, Geneva Phone: +41 22 749 01 11 Fax: +41 22 749 09 47 Email: copyright@iso.org Website: www.iso.org

Published in Switzerland

## Contents

Page

Introduction    v      1    Scope    1      2    Normative references    1      3    Terms and definitions    1      4    Risk assessment    2      4.1    General    2      4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.2    Protective devices and safety related functions    5      5.2.3    Robit application design    7      5.2.4    Risk reduction measures    5      5.2.3    Robit application design    7      5.4.4    Risperied control System performance    7      5.4.1    General    10      5.4.2    Workpress for hand-effectors    7      5.4	Forew	ord		iv	
1    Scope    1      2    Normative references    1      3    Terms and definitions    1      4    Risk assessment    2      4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.2    Protective devices and safety related functions    5      5.2.3    Robit application design    7      5.2.4    Risk reduction measures    5      5.2.2    Protective devices and safety related functions    7      5.4.4    Risp replet represent performance    7      5.4.5    Safety-related control system performance    7      5.4.4    Gripper end-effectors    9      5.5.4.2.10    Restaptrepresentenconsectoffectors    9 <t< td=""><td>Introd</td><td>uction</td><td></td><td>V</td></t<>	Introd	uction		V	
2    Normative references    1      3    Terms and definitions    1      4    Risk assessment    2      4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk reduction    5      5.6    Residual risks    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Risk reduction measures inplemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    10      5.5.4    Risk reduction    9      5.5.4    Gripper sinderksist of obto 3-0450-454-8334-    8      5.4.3    Yacuum	1	Scope		1	
3    Terms and definitions    1      4    Risk assessment    2      4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.2    Protective devices and safety related functions    5      5.2.3    Robiot application design    7      5.2.4    Risk reduction measures    5      5.2.3    Softot application design    7      5.4.4    Gripper end effectors    7      5.4.4    Gripper end effectors    7      5.4.3    Vacuum grippers    8      5.4.4    Magent grippers    8      5.4.3    Vacuum grippers    8      5.4.3    Vacuum grippers    9	2	Norma	ative references	1	
4    Risk assessment    2      4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robor application design    7      5.4.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4.4    Torge type groppers indexises (66663-0456-04564-8334-    8      5.4.2    Wazum grippers    8    5.4.4      5.4.4    Magnet grippers    8    5.4.4    Magnet grippers      5.5.1    General    9    5.5.2    Examples of appli	3	Terms	and definitions	1	
4.1    General    2      4.2    Limits of the end-effector(s)    3      4.3    Hazardi dentification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.5    Risk extimation    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.4    Risk reduction measures, upplemented by the user    7      5.3    Safety-related control system performance    7      5.4    Grapper end-effectors    7      5.4.1    General    10      5.4.2    Grapper sudards/sist/66/63-0406-464-8334-    8      5.4.3    Vacuum grippers!    9	4	Risk a	Rick accessment		
4.2    Limits of the end-effector(s)    3      4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk estimation    4      4.6    Residual risks    5      Safety requirements and risk reduction    5      5.1    General    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control System performance    7      5.4.1    General    ISO/IR 2018-12018    7      5.4.2    Protective devices one safety set/6616-03-0450-464-8334-    8      5.4.3    Vacuum grippers/storkack/sst/6616-03-0450-464-8334-    7      5.4.4    Magnet grippers    8    5.4.3    Nagnet grippers      5.5    Application-specific end-effectors    9    9    5.5.1    General <td< td=""><td>т</td><td>4.1</td><td>General</td><td></td></td<>	т	4.1	General		
4.3    Hazard identification    4      4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    150/tR 2018-12018      7    5.4.1    General    7      5.4.1    General    7      5.4    Application-specific end-effectors    7      5.4.1    General    7      5.4.2    Imperase of applications    9		4.2	Limits of the end-effector(s)	3	
4.3.1    General    4      4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    5      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    7      5.4.2    Topper subsection devises of 6603-0450-04548334-    8      5.4.3    Vacuum grippers    8      5.4.4    Magnet grippers    8      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Relevel end-effectors    9		4.3	Hazard identification	4	
4.3.2    Examples of hazards from end-effectors and workpieces    4      4.4    Risk estimation    4      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.2    through application design    7      5.4.3    General    7      5.4    Gripper end-effectors    7      5.4.2    through applications    7      5.4.2    through apple apples structure intervalue assist collabeles    7      5.4.2    through apple apples    8      5.4.3    Vacuum grippers    8      5.4.4    Magnet grippers    8      5.5    Application-specific end-effectors    9      5.5.1    General    10			4.3.1 General	4	
4.4    Risk estimation    4      4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.2.3    Robot application design    7      5.2.4    Gripper end-effectors    7      5.4.1    General    50      5.4.1    General    7      5.4.4    General    8      5.4.4    Magnet grippers    8      5.4.3    Vacuum grippers    8      5.4.4    Magnet grippers    8      5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    10			4.3.2 Examples of hazards from end-effectors and workpieces	4	
4.5    Risk evaluation    5      4.6    Residual risks    5      5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures in plemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    7      5.4.2    Propertive devices and safety related control system performance    7      5.4.1    General    7      5.4.2    Gripper end-effectors    7      5.4.3    Vacuum grippers    8      5.4.4    Magnet grippers    8      5.5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.2    Examples of applications    10		4.4	Risk estimation	4	
4.0    Restural Tisks    3      5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    1SOTR 2018-12018      5.4.3    Vacuum grippers/standards/stofob03-0450-4b4F8334-    8      5.4.4    Magnet grippers    8      5.5.4    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.5.4    General    10      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10		4.5	RISK evaluation	5 E	
5    Safety requirements and risk reduction    5      5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    7      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4.1    General    ISO/TR 20218-1/2018    7      5.4.1    General    ISO/TR 20218-1/2018    7      5.4.1    General    ISO/TR 20218-1/2018    8      5.4.4    General    SO/TR 20218-1/2018    8      5.4.4    Magnet grippers    8    8      5.5    Application-specific end-effectors    9    9      5.5.1    General    9    5.5.2    Examples of applications    9      5.5.2    Examples of applications    9    5.5.3    Risk reduction    10      5.6    End-effectors for hand-guiding robots    10    10    5.6.2    Risk reduction    11		4.0	Residual HSKS	5	
5.1    General    5      5.2    Risk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    5      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.2.3    Robot application design    7      5.4    Risk reduction measures implemented by the user    7      5.4    Gripper end-effectors    7      5.4.1    General    SO/R 20218-12018    7      5.4.1    General    SO/R 20218-12018    7      5.4.2    Urr Grasp- type grippers    Safety-related control system performance    7      5.4.3    Vacuum grippers    Safety-related control system performance    7      5.4.4    Magnet grippers    8    8    5.4.4    Magnet grippers    8      5.5.1    General    9    5.5.2    Examples of applications    9    5.5.2    Examples of applications    9      5.6.2    Risk reduction    10    5.6.2    Risk reduction    10      5.7.5    <	5	Safety requirements and risk reduction			
5.2    Nisk reduction measures    5      5.2.1    Shape and surfaces    5      5.2.2    Protective devices and safety related functions    5      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    ISO/TR 20218-12018    7      5.4.2    Impersor type prippers/standards/sat/660613-0450-4644-8334-    8      5.4.3    Vacuum grippers/standards/sat/660613-0450-4644-8334-    8      5.4.4    Magnet grippers    8      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.5.4    General    10      5.5.5    Examples of applications    9      5.5.2    Examples of applications    10      5.6    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7.1    General    11      <		5.1	General	5	
5.2.1    Protective devices and safety related functions.    5      5.2.3    Robot application design    7      5.2.4    Risk reduction measures implemented by the user.    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    ISO/IR 20218-1-2018    7      5.4.1    General    ISO/IR 20218-1-2018    7      5.4.2    Import of the grippers    7    5.4.4    Gripper end-effectors/stochologia-0d50-4b4F8334-    8      5.4.3    Vacuum grippers/stochologia-tochol		5.2	F 2.1 Shape and surfaces	5 E	
5.2.2    Robot application design    7      5.2.4    Risk reduction measures inplemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    ISO/TR 20218-12018    7      5.4.1    General    ISO/TR 20218-12018    7      5.4.1    General    ISO/TR 20218-12018    7      5.4.2    http://firstage-type.grippers.standards/sist/66b/613-0d50-4b4F 8334-    8      5.4.3    Vacuum grippers    8    8      5.4.4    Magnet grippers    8    8      5.5.4    Application-specific end-effectors    9    9      5.5.1    General    9    9    5.5.2    Examples of applications    9      5.5.2    Examples of applications    9    10    5.6.1    General    10      5.6.2    Risk reduction    10    10    5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11    11    11      7    Information for use    11    11    11			5.2.1 Shape and surfaces and safety-related functions <b>x x</b>	J 5	
5.2.4    Risk reduction measures implemented by the user    7      5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    1SO/TR 20218-12018      5.4.2    Informative grippers, standards/sist/66b6f3-0d50-4b4F8334    8      5.4.3    Vacuum grippers, standards/sist/66b6f3-0d50-4b4F8334    8      5.4.4    Magnet grippers    8      5.4.4    Magnet grippers    8      5.4.4    Magnet grippers    8      5.5.4    General    9      5.5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.6.3    Risk reduction    10      5.6.4    General    10      5.6.5    End-effector s for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.7<			5.2.2 Robot application design	5	
5.3    Safety-related control system performance    7      5.4    Gripper end-effectors    7      5.4.1    General    ISO/TR 20218-12018      5.4.2    Htp Grasp-type grippers/standards/sist/661663-0d50-db4f-8334-    7      5.4.3    Vacuum grippers/standards/sist/661663-0d50-db4f-8334-    8      5.4.4    Magnet grippers    8      5.4.4    Magnet grippers    8      5.5.4    Application-specific end-effectors    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.6.4    General    10      5.6.2    Risk reduction    10      5.6.3    General    10      5.6.4    General    10      5.6.5    Find-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.6.3    Isk reduction    11      7    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    Instructions			5.2.4 Risk reduction measures implemented by the user	7	
5.4    Gripper end-effectors    7      5.4.1    General    ISO/TR 20218-1:2018    7      5.4.2    Imp Grasp-type grippers    8    5      5.4.3    Vacuum grippers    8    5      5.4.4    Magnet grippers    8    8      5.4.3    Vacuum grippers    8    5      5.4.4    Magnet grippers    8    5      5.5.1    General    9    9      5.5.2    Examples of applications    9    9      5.5.2    Examples of applications    9    9      5.6.6    End-effectors for hand-guiding robots    10    10      5.6.1    General    10    10      5.6.2    Risk reduction    10    10      5.6.3    Risk reduction    10    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    General    11		5.3	Safety-related control system performance	7	
5.4.1GeneralISO/IR 20218-1201875.4.2http Grasp- type grippers standards/six/66/b6/B3-0d50-4b4F8334-85.4.3Vacuum grippers85.4.4Magnet grippers85.5.4Application-specific end-effectors95.5.1General95.5.2Examples of applications95.5.3Risk reduction95.6End-effectors for hand-guiding robots105.6.2Risk reduction105.6.3Sikk reduction105.6.4Risk reduction105.7End-effector exchange systems (tool changers)116Verification and validation117Information for use117.1General117.2Instructions117.3Informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex D (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24		5.4	Gripper end-effectors	7	
5.4.2 mp Grasp-type grippers/station/stotopis-000-0404-8334-    8      5.4.3 Vacuum grippers/1000-tr-20218-1-2018    8      5.4.4 Magnet grippers    8      5.5 Application-specific end-effectors    9      5.5.1 General    9      5.5.2 Examples of applications    9      5.5.3 Risk reduction    9      5.6 End-effectors for hand-guiding robots    10      5.6.1 General    10      5.6.2 Risk reduction    10      5.7 End-effector exchange systems (tool changers)    11      7 Information for use    11      7.1 General    11      7.2 Instructions    11      7.2 Instructions    11      7.3 General    11      7.4 General    11      7.5 Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Examples of gripper designs and their safety performance    18      Annex D (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24			5.4.1 General <u>ISO/IR 20218-1:2018</u>	7	
5.4.3    Vacuum grippers    8      5.4.4    Magnet grippers    8      5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.6.3    Risk reduction    10      5.6.4    General    10      5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    General    11      7.2    Instructions    11      7.3    General    11      7.4    General    11      7.5    Instructions    11      7.1    General    11			5.4.2 http://Grasp-type.grippers/standards/sist/06106153-0030-4041-8334-	8	
5.4.4    Magnet grippers    8      5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.6.3    Risk reduction    10      5.6.4    General    10      5.6.5    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Examples of gripper designs and their safety performance    18      Annex D (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24			5.4.3 Vacuum grippers	8	
5.5    Application-specific end-effectors    9      5.5.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    General    11      7.5    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Examples of gripper designs and their safety performance    18      Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22			5.4.4 Magnet grippers	8	
5.3.1    General    9      5.5.2    Examples of applications    9      5.5.3    Risk reduction    9      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    General    11      7.5    Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Practical examples for end-effector risk assessment    13      Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24		5.5	Application-specific end-effectors	9	
5.5.3    Risk reduction    9      5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Examples of gripper designs and their safety performance    18      Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24			5.5.1 General	9 Q	
5.6    End-effectors for hand-guiding robots    10      5.6.1    General    10      5.6.2    Risk reduction    10      5.7    End-effector exchange systems (tool changers)    11      6    Verification and validation    11      7    Information for use    11      7.1    General    11      7.2    Instructions    11      7.3    General    11      7.4    General    11      7.5    Informative) Practical examples for end-effector risk assessment    13      Annex A (informative) Practical examples for end-effector risk assessment    13      Annex B (informative) Examples of pripper designs and their safety performance    18      Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24			5.5.2 Examples of applications	9	
5.6.1    General		5.6	End-effectors for hand-guiding robots		
5.6.2Risk reduction105.7End-effector exchange systems (tool changers)116Verification and validation117Information for use117.1General117.2Instructions11Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24			5.6.1 General	10	
5.7End-effector exchange systems (tool changers)116Verification and validation117Information for use117.1General117.2Instructions11Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24			5.6.2 Risk reduction	10	
6Verification and validation117Information for use117.1General117.2Instructions11Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24		5.7	End-effector exchange systems (tool changers)	11	
7Information for use117.1General117.2Instructions117.2Instructions11Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24	6	Verific	ation and validation	11	
7.1    General    11      7.2    Instructions    11      Annex A (informative) Practical examples for end-effector risk assessment    13      Annex B (informative) Examples of gripper designs and their safety performance    18      Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24	7	Information for use			
7.2Instructions11Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24	-	7.1	General		
Annex A (informative) Practical examples for end-effector risk assessment13Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24		7.2	Instructions	11	
Annex B (informative) Examples of gripper designs and their safety performance18Annex C (informative) Examples of hazards, their potential origins and consequences19Annex D (informative) Examples of hazards by function of the end-effector22Bibliography24	Annex	A (info	rmative) Practical examples for end-effector risk assessment	13	
Annex C (informative) Examples of hazards, their potential origins and consequences    19      Annex D (informative) Examples of hazards by function of the end-effector    22      Bibliography    24	Annex	Annex B (informative) Examples of gripper designs and their safety performance			
Annex D (informative) Examples of hazards by function of the end-effector 22 Bibliography 24	Annex	<b>C</b> (info	rmative) Examples of hazards, their potential origins and consequences	19	
Bibliography 24	Annex	<b>D</b> (info	rmative) Examples of hazards by function of the end-effector	22	
8F>	Biblio	24			

## ISO/TR 20218-1:2018(E)

## 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 <a href="https://www.iso.org/directives">www.iso.org/directives</a>).

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 <a href="https://www.iso.org/patents">www.iso.org/patents</a>).

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 <u>www.iso</u> .org/iso/foreword.html. (standards.iteh.ai)

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 0-4b4f-8334-

9774801e967c/iso-tr-20218-1-2018

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 <u>www.iso.org/members.html</u>.

## 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.

# iTeh STANDARD PREVIEW (standards.iteh.ai)

ISO/TR 20218-1:2018 https://standards.iteh.ai/catalog/standards/sist/66fb6f33-0d50-4b4f-8334-9774801e967c/iso-tr-20218-1-2018

# iTeh STANDARD PREVIEW (standards.iteh.ai)

<u>ISO/TR 20218-1:2018</u> https://standards.iteh.ai/catalog/standards/sist/66fb6f33-0d50-4b4f-8334-9774801e967c/iso-tr-20218-1-2018

## 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 <u>https://www.iso.org/obp</u>

— 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.

## ISO/TR 20218-1:2018(E)

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

## iTeh STANDARD PREVIEW

*end-effector* (3.3) designed for grasping(workpieces rds.iteh.ai)

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

ISO/TR 20218-1:2018

[SOURCE: ISO 8373:2012, Bil4/modified and 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;) ARD PREVIEW
- b) space limits:

# (standards.iteh.ai)

- end-effector changing station;
- movement of the end-effector and workpiece/66fb6f33-0d50-4b4f-8334-
- movement gapsisterkaresite
- 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: **STANDARD PREVIEW**
- g) dismantling or disabling.

(standards.iteh.ai)

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

https://standards.iteh.ai/catalog/standards/sist/66fb6f33-0d50-4b4f-8334-

While hazards are similar for collaboratives and fine-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 <u>Annex D</u>.

## 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. <u>Annex A</u> 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 <u>Clause 7</u>.

## 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. <u>ISO/TR 20218-1:2018</u>

**5.2** Risk reduction measures 774801e967c/iso-tr-20218-1-2018

## 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 endeffector 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;

- b) end-effector path planning:
  - if certain orientations of the gripper result in crush points and/or sharp edges being present (e.g. a screw pointing towards a hole into which the robot screws it), robot movement in that direction can be minimized and movement speed can be decreased to reduce risks; safety-rated soft axis and space limiting functions can be used to monitor robot motion and end-effector orientation and poses;

NOTE 1 ISO 13854 contains information about the minimum gaps to avoid crushing of parts of the human body.

- c) grip force:
  - where the maximum grip force of the end-effector exceeds the risk assessment safety limits, the grip force applied by the end-effector is reduced and monitored not to exceed acceptable levels in accordance with ISO/TS 15066:2016;
- d) speed monitoring:
  - the robot speed for which the gripper is intended to be used is considered in the design of the gripper;
  - guidance is provided in ISO/TS 15066:2016 for collaborative applications;
  - if the end-effector movement is controlled separately from the robot, the stop monitoring is considered in addition to the robot system stopping;
    iTeh STANDARD PREVIEW
- e) presence sensing:
  - a sensor (e.g. proximity, motion, image) can be used to detect a workpiece that has the potential to initiate a sequence that could cause an injury to the operator;
  - to reduce risk associated with contact to the moving end-effector during collaborative operation, sensing means can be used to eg74fisable end-effector actuation when it is being touched or when the operator is within a detection zone around the end-effector;
  - these devices comply with the applicable parts of IEC 61496; integration of these devices is in accordance with ISO 10218-2:2011, 5.2;
- f) compliant link (e.g. a pliable link between the robot mechanical flange and the end-effector):
  - compliant linkages and mechanisms in the gripper can absorb energy of contact; the transferred force, motion, or energy achieved through compliant links are dissipated in a manner that reduces the risk and does not introduce new risks;
  - a sensor or safety function can be used to initiate a protective stop;
  - for PFL robot applications, the effective force for initiating a protective stop is in accordance with ISO/TS 15066:2016, 5.5.5;
    - NOTE 2 Collision protection devices, energy absorbing materials, springs can be used.
  - the force or torque which an end-effector can apply to the environment can be limited, e.g. by mechanical couplings that yield when a certain force or torque level is reached;
- g) functional safety requirements:
  - functional safety requirements in accordance with ISO 13849-1 are derived through the risk reduction process;
  - end-effector safety-related functions are designed in accordance with ISO 10218-2:2011, 5.2;

NOTE 3 Safety-related functions of the end-effector can be provided by either the robot or the end-effector.