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Robots for industrial environments — Automatic end effector exchange systems — Vocabulary

Robots manipulateurs industriels — Systèmes de changement automatique de terminal — Vocabulaire

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

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

This second edition cancels and replaces the first edition (ISO 11593:1996), which has been technically revised.

The main changes are as follows:

— references, terminology and drawings have been updated;

— the Scope and the Introduction have been updated;

— reference documents have been moved from the Normative references clause to the Bibliography;

— the document has been restructured and Annex A has been removed.

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 is one of a family of standards dealing with the requirements of components of robot systems for industrial environments.

This document contains the vocabulary for end-effector exchange systems. This document does not contain any details for the development and design of these systems.

For the terms related to coupling and releasing forces (see 3.4), all permissible maximum values for the load characteristics are valid for the sum of both static and dynamic loads and all load characteristics are stated for the reference plane.

For the terms related to magazine interfaces of the tool-mounted part (see 3.7), the performance criteria should be used in the same sense as those used in the terms related to the external shape and main dimensions of the exchange system (see 3.2). The defined coordinate system is still valid even if the direction of insert movement into the magazine is different from the coupling direction at the exchange of the tool. They differ in their value and their direction as well as in the force of coupling work which is required to assemble or release the tool part from the robot part of the interface.

Robots for industrial environments — Automatic end effector exchange systems — Vocabulary

1 Scope

This document defines terms relevant to automatic end-effector exchange systems used as a part of robot systems in accordance with ISO 10218-2.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1 General terms and definitions

3.1.1
automatic end-effector exchange system
coupling device between the mechanical interface and the end-effector enabling automatic exchange of end-effectors, made up of a *robot-mounted part* (3.1.2) and one or more *tool-mounted parts* (3.1.3)

Note 1 to entry: Also referred to as tool changer, quick-change device, automatic tool changer, robotic tool changer or robot coupler.

3.1.2
robot-mounted part
part of an *automatic end-effector exchange system* (3.1.1) that is attached to the mechanical interface of a manipulator

Note 1 to entry: Also referred to as master or robot side.

3.1.3
tool-mounted part
part of an *automatic end-effector exchange system* (3.1.1) that is attached to the end-effector

Note 1 to entry: Also referred to as slave or tool side.

3.1.4
couple, verb
join the *robot-mounted part* (3.1.2) to the *tool-mounted part* (3.1.3)

3.1.5
uncouple, verb
release the *tool-mounted part* (3.1.3) from the *robot-mounted part* (3.1.2)

3.1.6
lock, verb
actuate the locking elements to secure the *tool-mounted part* (3.1.3) to the *robot-mounted part* (3.1.2)

3.1.7
unlock, verb
actuate the locking elements to allow the uncoupling of the *robot-mounted part* (3.1.2) from the *tool-mounted part* (3.1.3)

3.1.8
dock, verb
couple (3.1.4) and *lock* (3.1.6) the *robot-mounted part* (3.1.2) to the *tool-mounted part* (3.1.3) when the tool-mounted part is held in the *magazine* (3.1.10)

3.1.9
undock, verb
unlock (3.1.7) and *uncouple* (3.1.5) the *tool-mounted part* (3.1.3) from the *robot-mounted part* (3.1.2) when the tool-mounted part is held in the *magazine* (3.1.10)

3.1.10
magazine
storage means of end-effectors that are *docked* (3.1.8) and *undocked* (3.1.9) from the associated *robot-mounted parts* (3.1.2)

Note 1 to entry: Also referred to as tool stand, tool storage rack or nest.

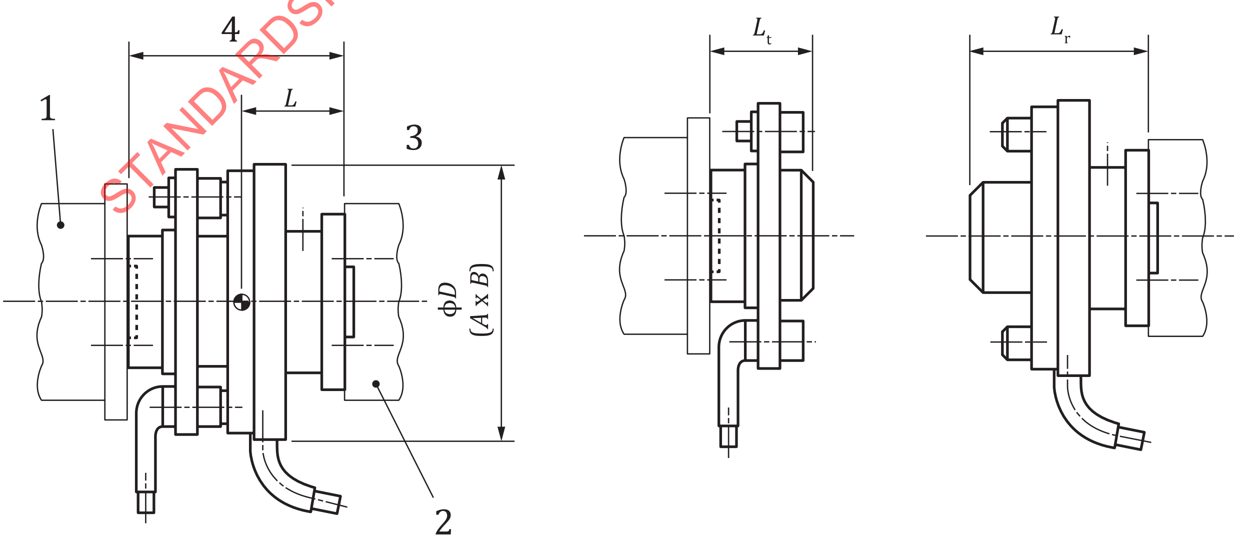
3.1.11
interface for robot side and tool side
description and marking for robot part and tool part in accordance with ISO 9409-1:2004, Clause 6, and ISO 9409-2:2002, Clause 8

3.1.12
cable routing
position and dimension of routing and tracking of cable for robot part and tool part in one drawing

3.2 Terms related to the external shape and main dimensions of the exchange system

3.2.1
structural shape
overall dimensions of device comprising external diameter (or width), depth, length of the individual *robot-mounted part* (3.1.2), and length of the individual *tool-mounted part* (3.1.3)

Note 1 to entry: See Figure 1.



a) exchange systems coupled **b) exchange systems uncoupled**

Key

1 tool-mounted part
2 robot-mounted part
3 surface
4 total length of the coupling (when coupled)

D external diameter (circular shape) (mm)
A width (for other) (mm)
B depth (for other) (mm)
L length from the robot mounting flange to the coupling flange (mm)
L_r length of the robot-mounted part (mm)
L_t length of the tool-mounted part (mm)

Figure 1 — External shape and main dimensions of the exchange system when coupled and uncoupled

3.2.2
face-to-face dimension
distance measured from the robot interface to the tool interface

Note 1 to entry: See Figure 1 a), item 4.

Note 2 to entry: The tolerance of the coupling length of the robot part (L_{cr}) and the coupling length of the tool part (L_{ct}) has a significant effect on the pose accuracy of the complete system when using different tools. The length of the coupled system is calculated as $L_{total} \pm \Delta$.

3.3 Terms related to positioning and orientation in coupling

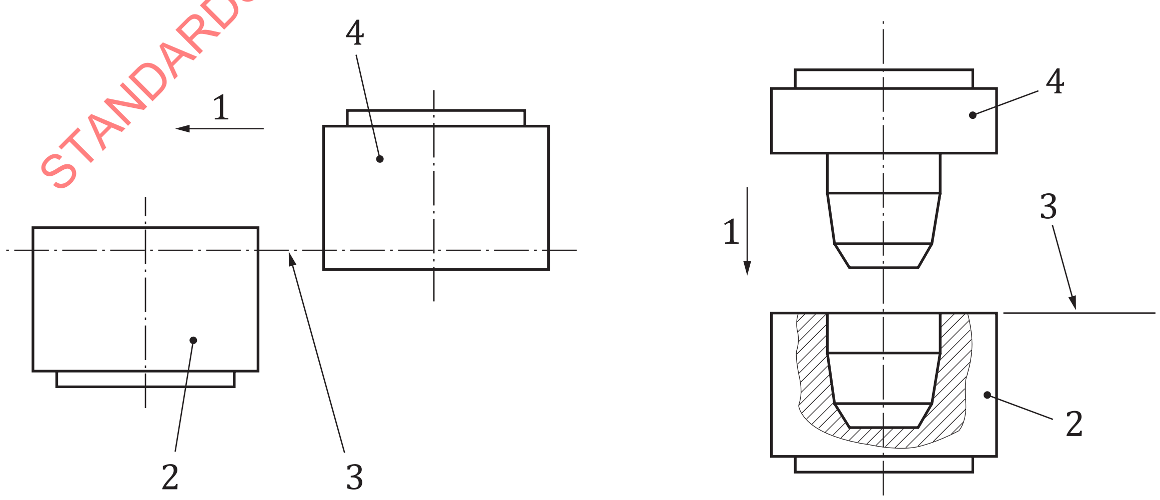
3.3.1
coupling direction
direction in which the *robot-mounted part* (3.1.2) and/or the *tool-mounted part* (3.1.3) are moved to each other

Note 1 to entry: See Figure 2.

Note 2 to entry: Couplings may be either lateral or axial:

— lateral coupling direction [see Figure 2 a)]: the motion of coupling runs parallel to the level of separation of the interface;

— axial coupling direction [see Figure 2 b)]: the motion of coupling runs vertical to the level of separation of the interface.



a) Lateral positioning and orientation in coupling **b) Axial positioning and orientation in coupling**

Key

1 coupling direction
2 tool-mounted part
3 level of separation
4 robot-mounted part

Figure 2 — Positioning and orientation in coupling

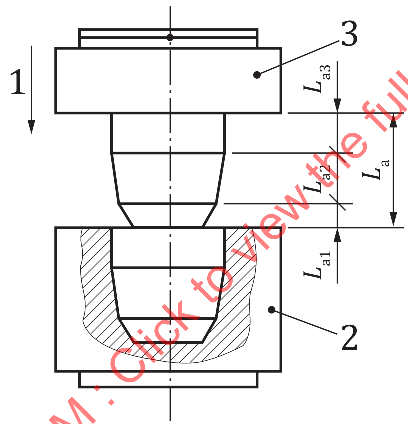
3.3.2
length of the approach distance
L_a
total distance of operation of the *robot-mounted part* (3.1.2) and/or the *tool-mounted part* (3.1.3) in the *coupling direction* (3.3.1) until the complete coupling of both parts

Note 1 to entry: L_a is expressed in millimetres.

Note 2 to entry: $L_a = L_{a1} + L_{a2} + L_{a3}$

Note 3 to entry: For axial coupling direction, the approach distance runs vertical to the *reference plane* (3.6.7). On lateral coupling direction, it runs parallel to the reference plane.

Note 4 to entry: See Figure 3.



Key

1 coupling direction
2 tool-mounted part
3 robot-mounted part

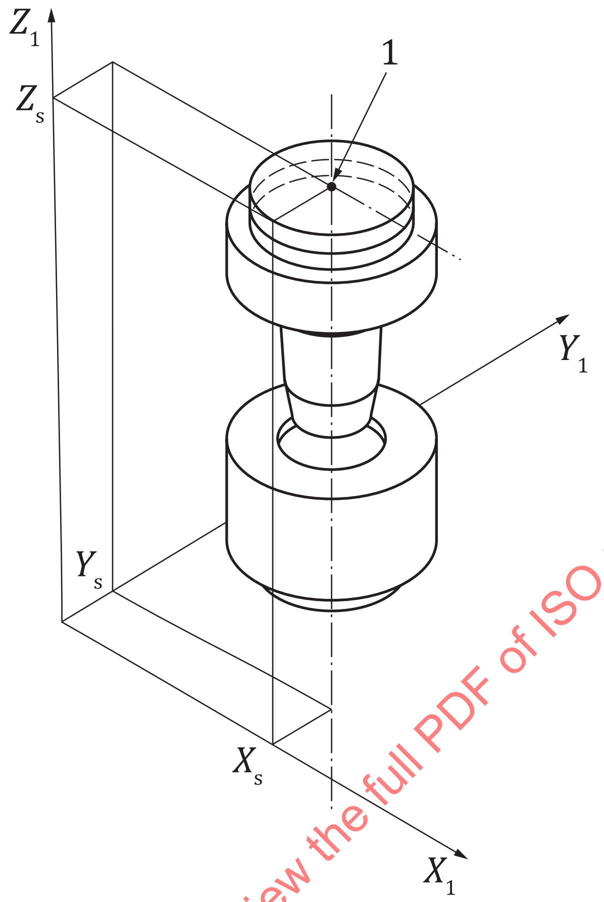
L_a length of the approach distance (mm)
L_{a1} distance of operation for precentring (mm)
L_{a2} distance of operation for centring (mm)
L_{a3} distance of operation thereafter until the complete coupling (mm)

Figure 3 — Axial coupling direction

3.3.3
start position
location of the *robot-mounted part* (3.1.2) of the exchange device in relation to the *tool-mounted part* (3.1.3) shortly before the coupling process begins

Note 1 to entry: The start position can be defined in the Cartesian coordinate system as (X_s, Y_s, Z_s).

Note 2 to entry: See Figure 4.



Key

1	start position (X_s, Y_s, Z_s)	X_1	Cartesian coordinate X axis
X_s	start X axis coordinate	Y_1	Cartesian coordinate X axis
Y_s	start Y axis coordinate	Z_1	Cartesian coordinate X axis
Z_s	start Z axis coordinate		

Figure 4 — Demonstration of axial coupling direction

3.4 Terms related to coupling and releasing forces

3.4.1
coupling force
F_c
force to be applied by the robot in order to *couple* (3.1.4) the *robot-mounted part* (3.1.2) of the exchange system with the *tool-mounted part* (3.1.3)

Note 1 to entry: F_c is expressed in Newtons.

Note 2 to entry: During this process, the tool-mounted part is considered to be held in the tool *magazine* (3.1.10). The coupling force includes all external forces required to couple all mechanical, electrical, hydraulic or pneumatic connectors.

3.4.2
releasing force
F_e
force to be applied by the robot in order to release the *robot-mounted part* (3.1.2) of the exchange system from the *tool-mounted part* (3.1.3)

Note 1 to entry: F_e is expressed in Newtons.

Note 2 to entry: During this process, the tool-mounted part is considered to be held in the tool *magazine* (3.1.10). The releasing force includes all external forces required to release all mechanical, electrical, hydraulic or pneumatic connectors.

3.4.3
maximum bending moment
M_{bmax}
permissible bending moment, if only load of bending occurs

Note 1 to entry: M_{bmax} is expressed in Newton-metres.

3.4.4
maximum torsional moment
M_{omax}
permissible torsional moment, if only load of torsion occurs

Note 1 to entry: M_{omax} is expressed in Newton-metres.

3.4.5
maximum tensile force
F_{nmax}
permissible tensile force, if only load of tension occurs

Note 1 to entry: F_{nmax} is expressed in Newtons.

3.4.6
maximum compressive force
F_{pmax}
permissible compressive force, if only load of compression occurs

Note 1 to entry: F_{pmax} is expressed in Newtons.

3.4.7
maximum lateral force
F_{lmax}
permissible lateral force, if only lateral force occurs

Note 1 to entry: F_{lmax} is expressed in Newtons.

3.5 Terms related to mass and inertia of the coupled system

3.5.1
centre of gravity in the coupled system
L_g
distance of the centre of gravity in the coupled system from the *reference plane* (3.6.7) of the mechanical interface of the robot

Note 1 to entry: L_g is expressed in millimetres.

3.5.2
moment of inertia of the coupled system
I
moment of inertia of the coupled system about the Z_m axis

Note 1 to entry: I is expressed in Newton-metres.

Note 2 to entry: For Z_m, see Figure 6.

3.5.3
mass
m
physical property of a material that defines its weight relative to the force of gravity and its resistance to changes in acceleration due to inertia

Note 1 to entry: *m* is expressed in kilogrammes.

Note 2 to entry: Mass is distinct from weight due to the force of gravity

3.5.4
mass of robot part
m_r
mass (3.5.3) of the robot-side component of the exchange system

Note 1 to entry: m_r is expressed in kilogrammes.

3.5.5
mass of tool part
m_t
mass (3.5.3) of the tool-side component of the exchange system

Note 1 to entry: m_t is expressed in kilogrammes.

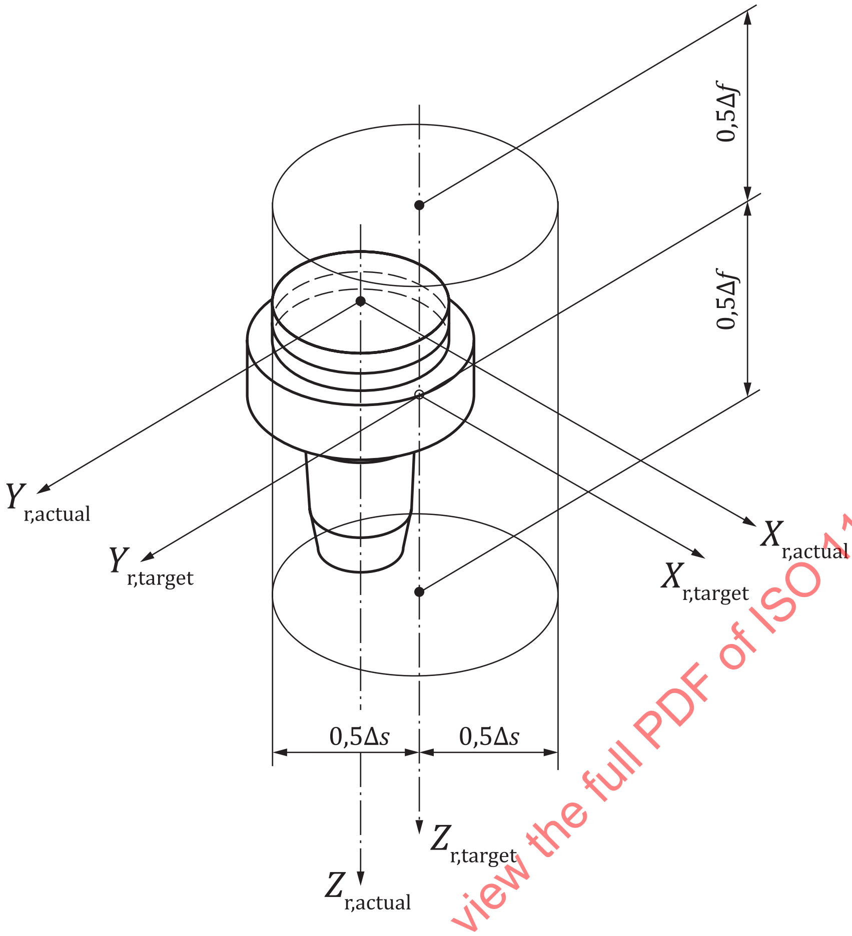
3.6 Terms related to tolerances and uncertainty

3.6.1
position tolerance in the start position
permissible uncertainty of the pose accuracy for the components of the exchange system

Note 1 to entry: To permit the assembly of both parts of the exchange system, the *start position* (3.3.3) needs to be fixed with a defined accuracy. The position tolerance in the start position is fixed by the attained pose within a cylindrical space.

Note 2 to entry: The command start position represents the centre of the tolerancing space, which is marked by the diameter *s* in the circular direction and the height *f* in the axial direction.

Note 3 to entry: See Figure 5.



Key

$X_{r,target}$	Cartesian pose in the X axis (target)	$Z_{r,target}$	Cartesian pose in the Z axis (target)
$X_{r,actual}$	Cartesian pose in the X axis (actual)	$Z_{r,actual}$	Cartesian pose in the Z axis (actual)
$Y_{r,target}$	Cartesian pose in the Y axis (target)	s	diameter of the lateral tolerance area
$Y_{r,actual}$	Cartesian pose in the Y axis (actual)	f	height of the axial tolerance

Figure 5 — Axial coupling direction, position tolerance in the start position

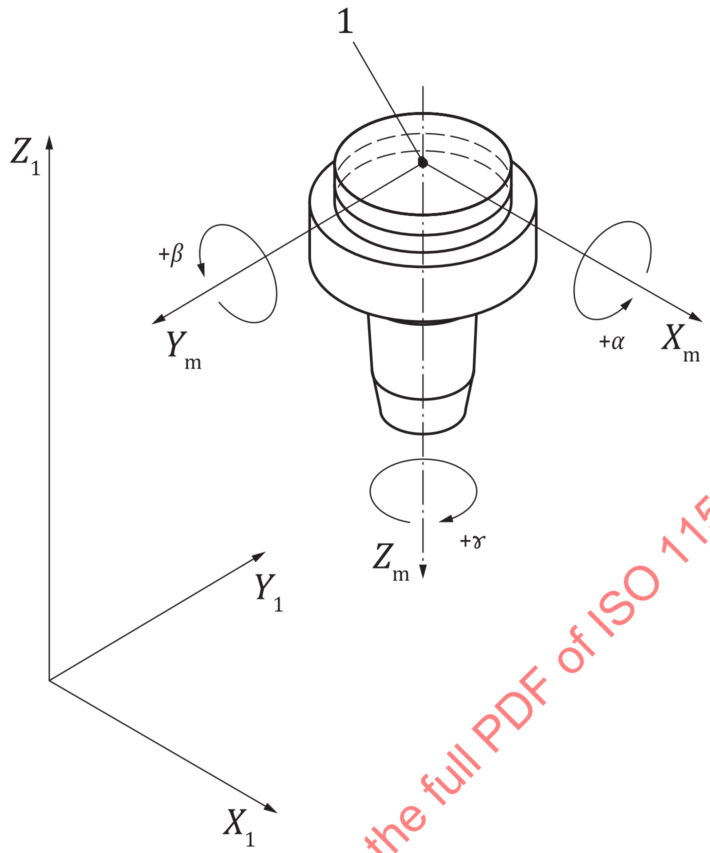
3.6.2
orientation tolerance in the start position
permissible uncertainty of the orientation accuracy for the components of the exchange system

Note 1 to entry: The orientation tolerance is fixed with a precise accuracy.

Note 2 to entry: The orientation tolerance is defined from the two measures *limit value of the misalignment* (3.6.3) and *limit value of the distortion* (3.6.4).

Note 3 to entry: All values concerning the orientation tolerance are related to the mechanical interface coordinate system X_m, Y_m, Z_m.

Note 4 to entry: See Figure 6.



Key

1	start position (X_s, Y_s, Z_s)
X_1	Cartesian coordinate X axis
Y_1	Cartesian coordinate Y axis
Z_1	Cartesian coordinate Z axis
X_m	mechanical interface X axis
α	axis of rotation along X_m
Y_m	mechanical interface Y axis
β	axis of rotation along Y_m
Z_m	mechanical interface Z axis
γ	axis of rotation along Z_m

Figure 6 — Demonstration of orientation tolerances of axial coupling direction

3.6.3
limit value of the misalignment
permissible maximum deviation of the attained pose from the command pose according to the X_m and Y_m axes (rotations $\pm\alpha$ and $\pm\beta$ respectively)

Note 1 to entry: The limit values of the misalignment can normally be regarded as identical and are represented as limit values of the misalignment $\pm 0{,}5\alpha$ and $\pm 0{,}5\beta$ respectively.

Note 2 to entry: See the *position tolerance in the start position* (3.6.1) in Figure 5 and the *orientation tolerance in the start position* (3.6.2) in Figure 6.

3.6.4
limit value of the distortion
permissible maximum deviation of the attained pose from the command pose according to the Z_m axis

Note 1 to entry: The limit value of the distortion is represented as the limit value of the distortion $\pm 0{,}5\gamma$.

Note 2 to entry: See Figure 5 and Figure 6.

3.6.5
tolerance of the coupling path
deviation of the coupling path within the approved *position tolerance in the start position* (3.6.1)

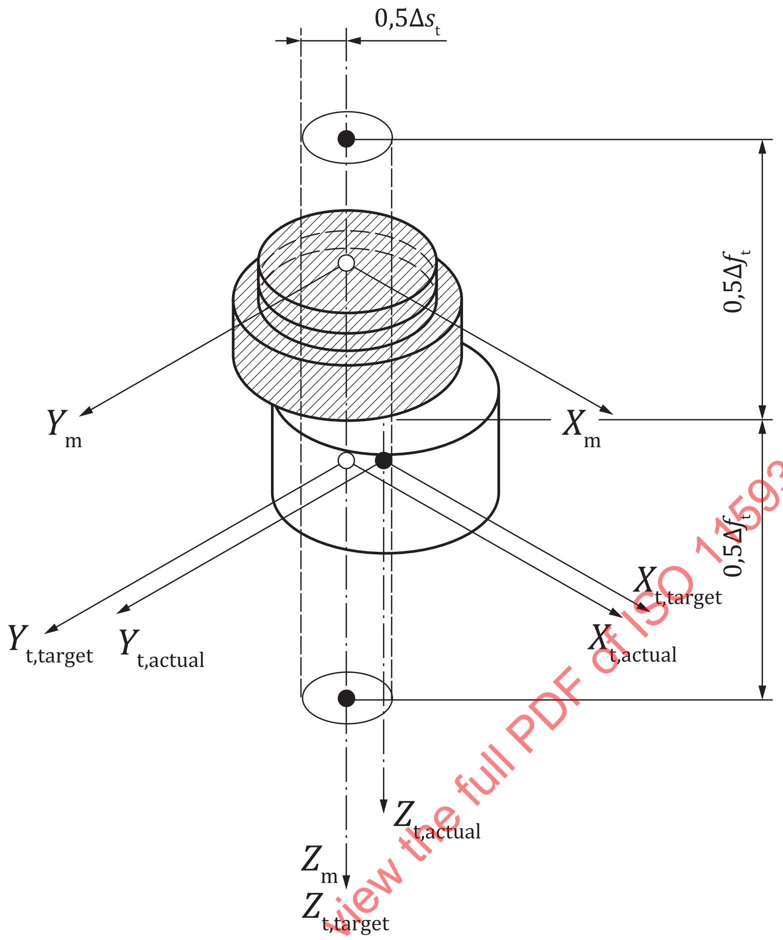
3.6.6
coupling repeatability
measured position and orientation uncertainty of the robot system's ability to perform the coupling action multiple times

Note 1 to entry: The coupling repeatability defines the deviation between the robot part and the tool part in case of multiple coupling operations. The reference point is the centre of the interface on the robot part in the mechanical interface coordinate system X_m, Y_m, Z_m, and on the tool part in the coordinate system X_t, Y_t, Z_t. The command pose is placed on the Z_m axis of the mechanical interface coordinate system X_m, Y_m, Z_m and is displaced by L_a in the direction of Z_m.

Note 2 to entry: See Figure 6 and Figure 7.

Note 3 to entry: See ISO 9409-1:2004, Clause 6, and ISO 9409-2:2002, Clause 8.

Note 4 to entry: The deviations will be decomposed into deviation of position, expressed in millimetres [in lateral direction (Δs_t); in axial direction (Δf_t)], and deviation of orientation, expressed in rad or degree [misalignment (α_t, β_t); distortion (γ_t)].



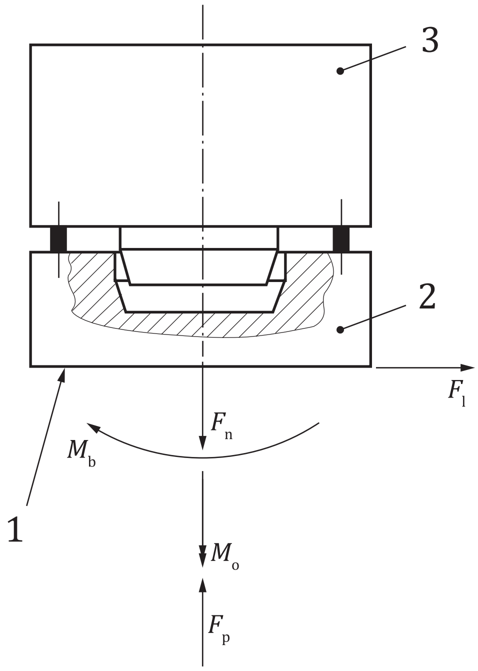
Key

X_m	mechanical interface X axis
$X_{t,target}$	tool X axis (target)
$X_{t,actual}$	tool X axis (actual)
Y_m	mechanical interface Y axis
$Y_{t,target}$	tool Y axis (target)
$Y_{t,actual}$	tool Y axis (actual)
Z_m	mechanical interface Z axis
$Z_{t,target}$	tool Z axis (target)
$Z_{t,actual}$	tool Z axis (actual)
Δf_t	deviation of position in axial direction
Δs_t	deviation of position in lateral direction
○	command pose of tool part of interface after coupling
●	attained pose of tool part of interface after coupling

Figure 7 — Demonstration of coupling repeatability

3.6.7
reference plane
tool mounting surface on the tool part of the exchange system designed in accordance with ISO 9409-1:2004 and ISO 9409-2:2002

Note 1 to entry: See Figure 8.



Key

1 reference plane
2 tool-mounted part
3 robot-mounted part

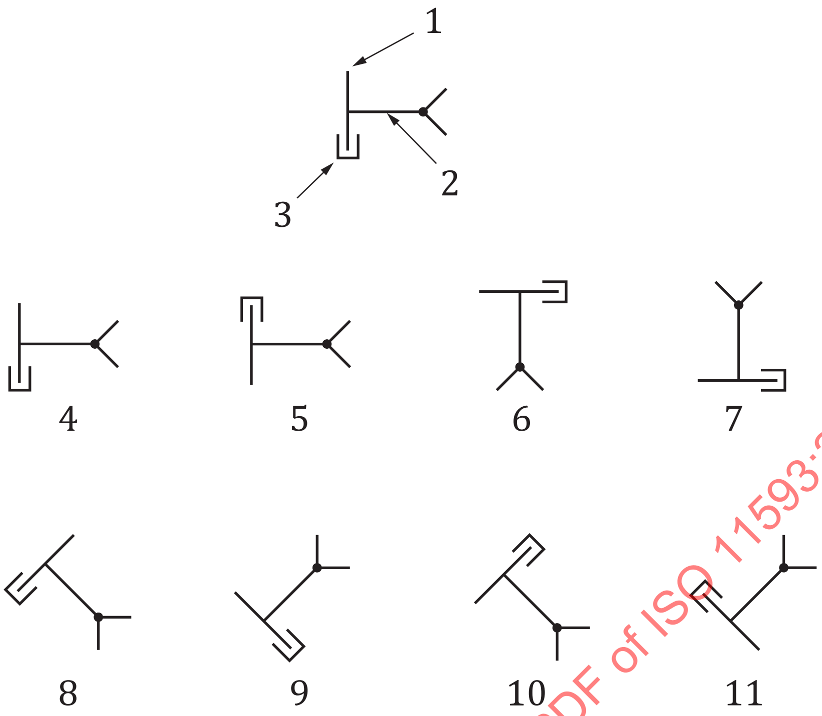
F_n tensile force (N)
F_l lateral force (N)
F_p compressive force (N)
M_b bending moment (N·m)
M_o torsional moment (N·m)

Figure 8 — Reference plane and load characteristics

3.7 Terms related to magazine interfaces of the tool-mounted part

3.7.1
interface orientation in the magazine
orientation of the exchange system and the tool as a function of how it is held by the tool changer *magazine* (3.1.10) and the orientation of the magazine itself

Note 1 to entry: See Figure 9.



Key

1 flange
2 tool
3 magazine
4 vertical (tool standing)
5 vertical (tool hanging)
6 horizontal (tool hanging)
7 horizontal (tool standing)
8 inclined standing (tool hanging)
9 inclined standing (tool standing)
10 inclined hanging (tool hanging)
11 inclined hanging (tool standing)

Figure 9 — Orientations of the tools held in the magazine

3.7.2
pose tolerance ahead of drive-in
pose tolerance measured at the TCP at the beginning of the drive-in to the *magazine* (3.1.10)

Note 1 to entry: The pose needs to be fixed by the supplier (e.g. by providing a drawing).

3.7.3
lay-off force
F_y
force necessary for the lay-off of the tool into the *magazine* (3.1.10)

Note 1 to entry: F_y is expressed in Newtons.

3.7.4
lay-off moment
M_y
moment necessary for the lay-off of the tool into the *magazine* (3.1.10)

Note 1 to entry: M_y is expressed in Newton-metres.

3.7.5
removal force
F_v
force necessary for the removal of the tool from the *magazine* (3.1.10)

Note 1 to entry: F_v is expressed in Newtons.

3.7.6
removal moment
M_v
moment necessary for the removal of the tool from the *magazine* (3.1.10)

Note 1 to entry: M_v is expressed in Newton-metres.

3.8 Terms related to tool exchange timing

3.8.1
tool exchange time
t_{total}
total time necessary to execute the combination of motions necessary for a complete exchange operation

Note 1 to entry: t_{total} is expressed in seconds.

Note 2 to entry: $t_{total} = t_{1,2} + t_r + t_s + t_{3,4} + t_{4,5} + t_{5,6} + t_c + t_k + t_{7,8}$

Note 3 to entry: See Figure 10.

Note 4 to entry: The tool exchange time is valid only for a specified periphery and a specified exchange cycle.

Note 5 to entry: The times $t_{1,2}$, $t_{3,4}$, $t_{5,6}$ and $t_{7,8}$ are influenced by the way of magazining the *tool-mounted part* (3.1.3) and by the resulting demands of the safety distance and the velocities. These times are specific for a particular periphery.

Note 6 to entry: The times t_r, t_s, t_c and t_k depend upon the kind of the end-effector exchange system and are characteristics for the used end-effector exchange system.