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

*Robots manipulateurs industriels — Systèmes de changement automatique
de terminal — Vocabulaire et présentation des caractéristiques*



Reference number
ISO 11593:1996(E)

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Foreword

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

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

International Standard ISO 11593 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 2, *Robots for manufacturing environment*.

Annex A of this International Standard is for information only.

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Introduction

ISO 11593 is one of a series of standards dealing with the requirements of manipulating industrial robots. Other documents cover such topics as terminology, general characteristics, coordinate systems, performance criteria and related test methods, safety, robot programming languages, and robot companion standards to MMS. It is noted that these standards are interrelated and also related to other International Standards.

Automatic exchange systems for end effectors increase in importance for handling devices. This International Standard contains the vocabulary and presentation of characteristics, e.g. forces, moments (torques), and exchange times, for end effector exchange systems. This International Standard does not contain any details for the development and design of these systems.

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

1 Scope

This International Standard defines terms relevant to automatic end effector exchange systems used for manipulating industrial robots operated in a manufacturing environment.

The terms are presented by their symbol, unit, definition and description. The definition includes applicable references to existing standards.

Annex A provides a format for the presentation of automatic end effector exchange systems characteristics.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8373:1994, *Manipulating industrial robots — Vocabulary*.

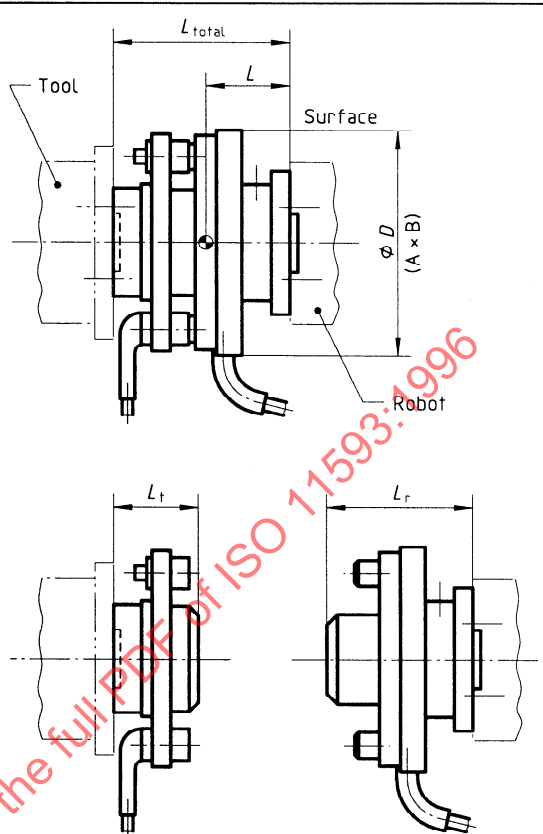
ISO 9409-1:1996, *Manipulating industrial robots — Mechanical interfaces — Part 1: Plates (form A)*.

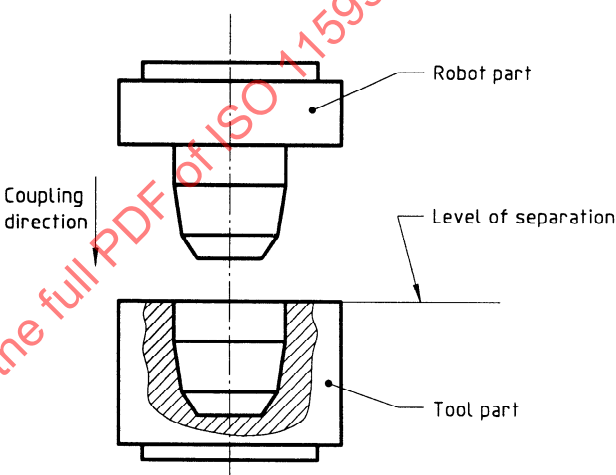
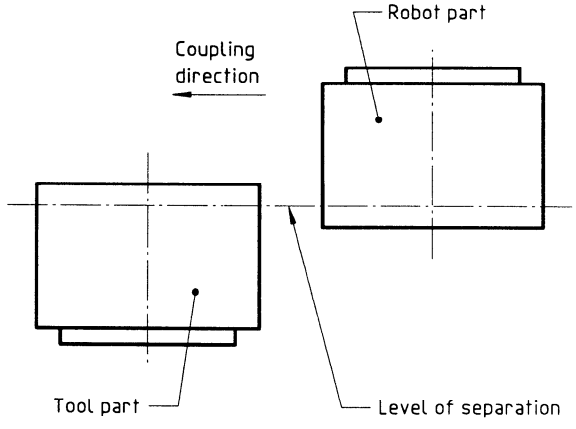
ISO 9409-2:1996, *Manipulating industrial robots — Mechanical interfaces — Part 2: Shafts (form A)*.

ISO 9787:1990, *Manipulating industrial robots — Coordinate systems and motions*.

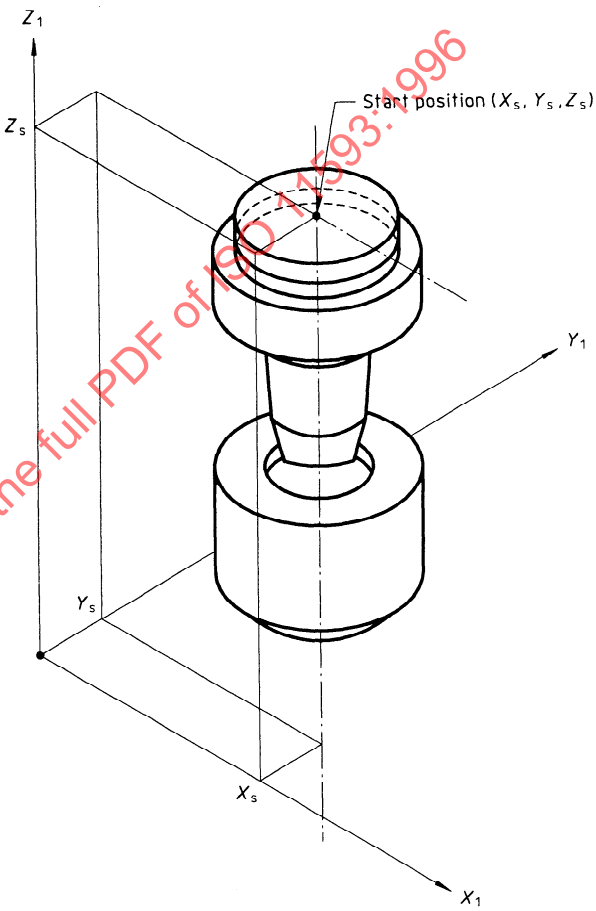
3 Terms and definitions

For the purposes of this International Standard, the definitions given in ISO 8373 apply.

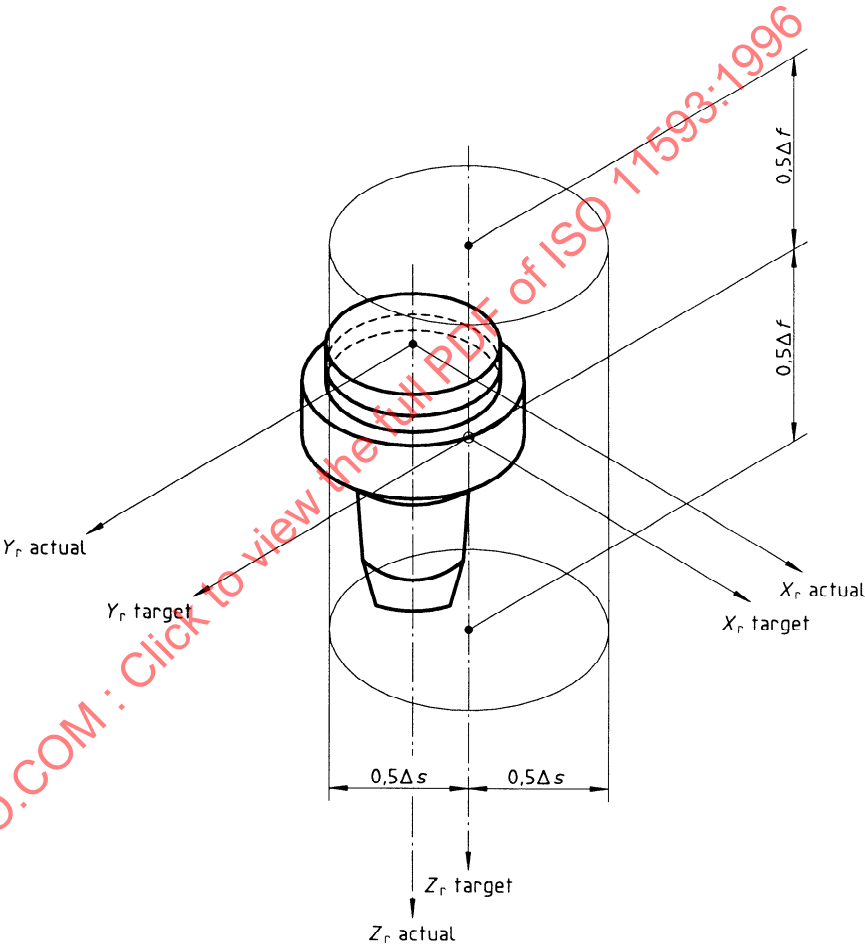
No.	Term	Symbol	Unit	Definition and description
3.1 External shape and main dimensions of the exchange system				
3.1.1	structural shape	D A B L_r L_t	mm mm mm mm mm	 Overall dimensions of device: - external diameter (for circular shape) - width } (for other) - depth } - length of the individual robot-mounted part - length of the individual tool-mounted part
3.1.2	face-to-face dimension	$L_{total} \pm \Delta$ $L_{cr} \pm \Delta$ $L_{ct} \pm \Delta$	mm mm mm	Distance measured from the robot interface to the tool interface: - length of the coupled systems; - coupling length of the robot part; - coupling length of the tool part. The tolerance of the length L_{cr} and L_{ct} has a significant effect on the pose accuracy of the complete system when using different tools.
3.1.3	centre of gravity in the coupled system	L_g	mm	Distance of the centre of gravity in the coupled system from the reference plane of the mechanical interface of the robot.
3.1.4	moment of inertia of the coupled system	I	kg·m ²	Moment of inertia of the coupled system about the Z_m axis.
3.1.5	mass	m_r m_t	kg kg	Mass of the robot part. Mass of the tool part.
3.1.6	interface for robot side and tool side			Description and marking for robot part and tool part according to ISO 9409-1 and ISO 9409-2.

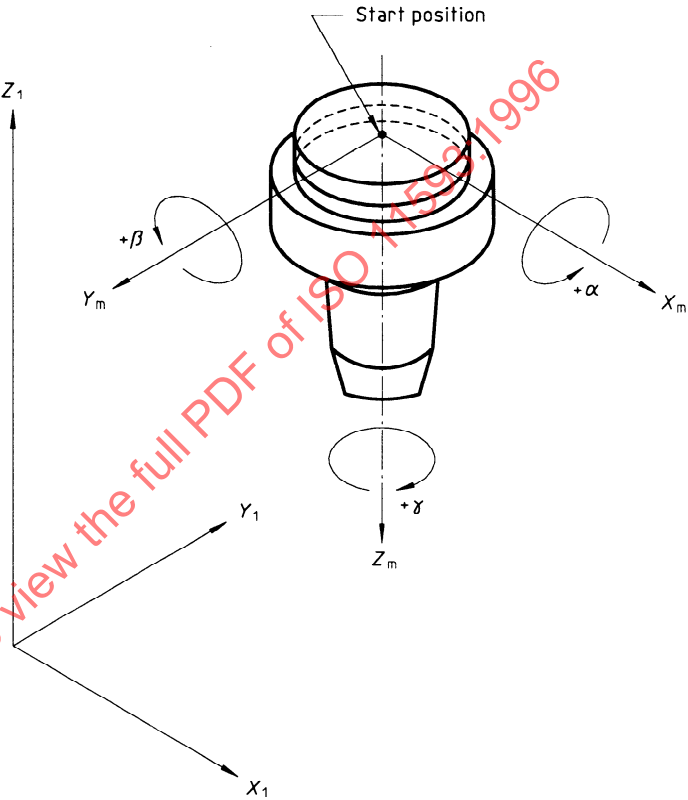
No.	Term	Symbol	Unit	Definition and description
3.1.7	cable routing			Position and dimension of routing and tracking of cable for robot part and tool part in one drawing.
3.2 Positioning and orientation in coupling procedures				
3.2.1	coupling direction			The coupling direction is the direction in which the robot-mounted and/or the tool-mounted part are moved to each other. Kinds of coupling direction: On axial coupling direction the motion of coupling runs vertical to the level of separation of the interface.  On lateral coupling direction the motion of coupling runs parallel to the level of separation of the interface. 

No.	Term	Symbol	Unit	Definition and description
3.2.2	length of the approach distance	L_a L_{a1} L_{a2} L_{a3}	mm mm mm mm	The length of the approach distance shows the total distance of operation of the robot-mounted (and/or tool-mounted) part in coupling direction until the complete coupling of both parts. The approach distance results from the total of the following single coupling distances: distance of operation for precentring; distance of operation for centring; distance of operation thereafter until the complete coupling $L_a = L_{a1} + L_{a2} + L_{a3}$. On axial coupling direction the approach distance runs vertical to the reference plane, on lateral coupling direction it runs parallel to the reference plane. Example for axial coupling direction:

No.	Term	Symbol	Unit	Definition and description
3.2.3	start position	X_s Y_s Z_s	mm mm mm	The start position represents the position of the robot-mounted part of the exchange device in relation to the tool-mounted part shortly before the coupling process begins. If the start position is related to a typical kind of arrangement, the start position can be defined in the cartesian coordinate system X_1, Y_1, Z_1 of the robot (according to ISO 9787) as X_s, Y_s, Z_s. Example for axial coupling direction: 

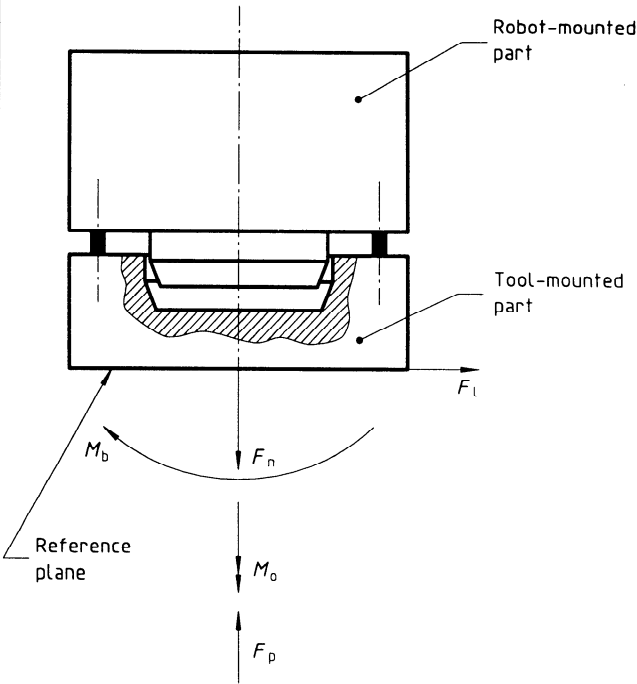
No.	Term	Symbol	Unit	Definition and description
3.2.4	position tolerance in the start position	s f	mm mm	To permit the assembly of both parts of the exchange system, the start position must be fixed with a defined accuracy. The position tolerance in the start position is fixed by the attained pose within a cylindrical space. The command start position represents the centre of thus tolerancing space, which is marked by the diameter s in circular direction and the height f in axial direction. Example for axial coupling direction:



No.	Term	Symbol	Unit	Definition and description
3.2.5	orientation tolerance in the start position			The orientation tolerance must be fixed with a precise accuracy. All values concerning the orientation tolerance are related to the mechanical interface coordinate system X_m, Y_m, Z_m. The command value for the orientation is given by the alignment X_m, Y_m, Z_m, A, B, C.
				
				NOTE — The orientation tolerance is defined from the two measures "limit value of the misalignment" and "limit value of distortion".
3.2.6	limit value of the misalignment	$\pm 0,5 \alpha$ $\pm 0,5 \beta$	rad or degree rad or degree	The limited deviations of the attained pose from the command pose according to the X_m and Y_m axis (rotations $\pm \alpha$ and $\pm \beta$ respectively) 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 (see the figure in 3.2.5).
3.2.7	limit value of the distortion	$\pm 0,5 \gamma$	rad or degree	The deviation of the attained pose from the command pose according to the Z_m axis is represented as limit value of the distortion $\pm 0,5 \gamma$ (see the figure in 3.2.5).
3.2.8	tolerance of the coupling path			The deviation of the coupling path shall be within the approved position tolerance in the start position.

No.	Term	Symbol	Unit	Definition and description
3.2.9	coupling repeatability			The coupling repeatability defines the deviation between the robot part and the tool part in case of multiple coupling operations. Reference point is the centre of the interface on the robot part (according to ISO 9409-1 and ISO 9409-2) 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. The deviations will be decomposed into deviation of position — in lateral direction (s_t), — in axial direction (f_t), and deviation of orientation — misalignment (α_t, β_t), — distortion (γ_t).
		s_t	mm	
		f_t	mm	
		α_t, β_t	rad or degree	
		γ_t	rad or degree	

- command pose of the tool part of the interface after coupling
- attained pose of the tool part of the interface after coupling

No.	Term	Symbol	Unit	Definition and description
3.3 Coupling and releasing forces				
3.3.1	coupling force	F_c	N	The force to be applied by the robot in order to couple the robot-mounted part of the exchange system with the tool-mounted part. During this process the tool-mounted part is considered to be held in the tool magazine. The coupling force includes all external forces required to couple all mechanical, electrical, hydraulic or pneumatic connectors.
3.3.2	releasing force	F_e	N	The force to be applied by the robot in order to release the robot-mounted part of the exchange system from the tool-mounted part. During this process the tool-mounted part is considered to be held in the tool magazine. The releasing force includes all external forces required to release all mechanical, electrical, hydraulic or pneumatic connectors.
3.4 Load characteristics				
3.4.1	reference plane			NOTE — All permissible maximum values for the load characteristics are valid for the sum of both static and dynamic loads. All load characteristics are stated for the reference plane. The reference plane is the tool mounting surface on the tool part of the exchange system designed according to ISO 9409-1 and ISO 9409-2.  The diagram illustrates the forces and moments acting on a robot-mounted part and a tool-mounted part at the reference plane. The robot-mounted part is shown above the tool-mounted part. The reference plane is indicated by a horizontal line. Forces and moments shown include: F_l (lateral force), F_n (normal force), M_b (bending moment), M_o (oscillating moment), and F_p (pull force).

No.	Term	Symbol	Unit	Definition and description
3.4.2	maximum bending moment	M_{bmax}	N·m	Permissible bending moment, if only load of bending occurs.
3.4.3	maximum torsional moment	M_{omax}	N·m	Permissible torsional moment, if only load of torsion occurs.
3.4.4	maximum tensile force	F_{nmax}	N	Permissible tensile force, if only load of tension occurs.
3.4.5	maximum compressive force	F_{pmax}	N	Permissible compressive force, if only load of compression occurs.
3.4.6	maximum lateral force	F_{lmax}	N	Permissible lateral force, if only lateral force occurs.

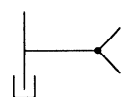
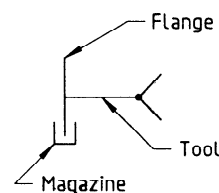
3.5 Magazine interface of the tool mounted part

NOTES

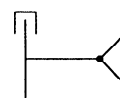
1 Performance criteria should be used in the same sense as those used in 3.2. The defined coordinate system is still valid even if the direction of insert movement into the magazine is different from the coupling direction at the exchange of the tool.

2 F_y , F_v , M_y , and M_v are forces or moments, to be produced between robot or tool on one hand and the magazine on the other hand if a tool will be laid off into the magazine or will be removed from the magazine. (Example: Force to push away safety relevant elements at the magazine that prevent the dropping 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.

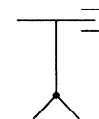
For reasons of different design the interface orientation in the magazine should be shown.



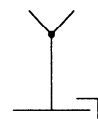
Vertical
(tool standing)



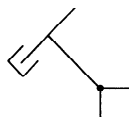
Vertical
(tool hanging)



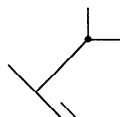
Horizontal
(tool hanging)



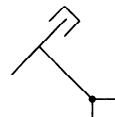
Horizontal
(tool standing)



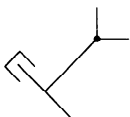
Inclined standing
(tool hanging)



Inclined standing
(tool standing)



Inclined hanging
(tool hanging)

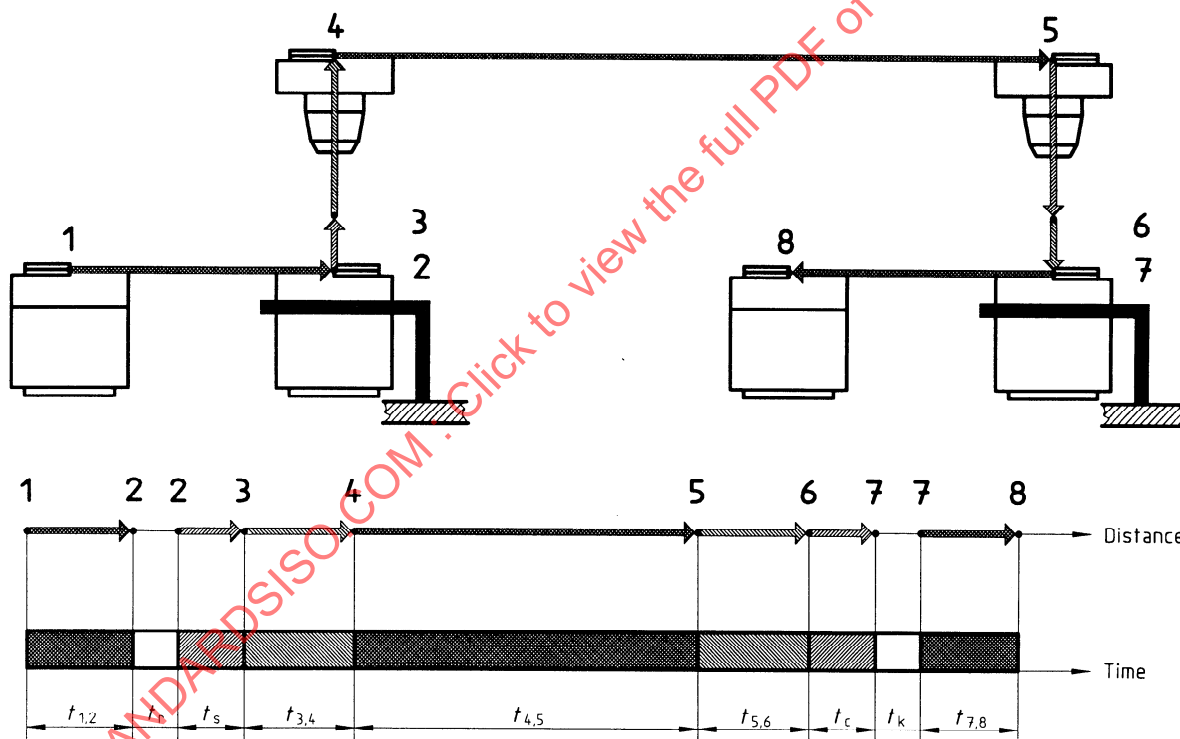


Inclined hanging
(tool standing)

No.	Term	Symbol	Unit	Definition and description
3.5.2	pose tolerance ahead of drive-in			Pose tolerance measured at the TCP at the beginning of the drive-in to the magazine. The pose must be fixed by the supplier (e.g. by drawing).
3.5.3	lay-off force	F_y	N	Force necessary for the lay-off of the tool into the magazine.
3.5.4	lay-off moment	M_y	N·m	Moment necessary for the lay-off of the tool into the magazine.
3.5.5	removal force	F_v	N	Force necessary for the removal of the tool from the magazine.
3.5.6	removal moment	M_v	N·m	Moment necessary for the removal of the tool from the magazine.

3.6 Tool exchange time

3.6.1	tool exchange time	t_{total}	s	The tool exchange time is the result of all single motions which are necessary for a complete exchange operation as described below. The tool exchange time is valid only for a specified periphery and a specified exchange cycle.
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NOTES

1 The times $t_{1,2}$, $t_{3,4}$, $t_{5,6}$ and $t_{7,8}$ are influenced by the way of magazing the tool-mounted part and by the resulting demands of the safety distance and the approved velocities. These times are specific for a particular periphery.

2 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.

3.6.2	drive-in time	$t_{1,2}$	s	Drive-in of the robot-mounted and coupled tool-mounted part into the magazine with reduced velocity (from position 1 to position 2).
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No.	Term	Symbol	Unit	Definition and description
3.6.3	releasing time	$t_{2,2} = t_r$	s	Releasing of the exchange system by unlocking the locking elements to allow the separation between the robot-mounted part and the tool-mounted part (at position 2).
3.6.4	separation time	$t_{2,3} = t_s$	s	Separation of the robot-mounted part and the tool-mounted part in the magazine by operation along the approach distance L_a contrary to the coupling direction (from position 2 to position 3).
3.6.5	drive-away time	$t_{3,4}$	s	Drive of the robot-mounted part with reduced velocity to the intermediate position 4 near the tool-mounted part (from position 3 to position 4).
3.6.6	convey time	$t_{4,5}$	s	Drive to a second intermediate position 5 near the tool-mounted part (appropriate on the top of the start position). The time $t_{4,5}$ is relevant to the distance between the position of the tool-mounted part laid off and the position of the tool-mounted part to be coupled and is specific to the periphery, magazine and the exchange cycle (from position 4 to position 5).
3.6.7	bring-on time	$t_{5,6} = t_{3,4}$	s	Drive of the robot-mounted part with reduced velocity to the start position of the coupling action with the tool-mounted part to be coupled (from position 5 to position 6).
3.6.8	coupling time	$t_{6,7} = t_c$ $= t_{2,3}$	s	Coupling of robot-mounted part and tool-mounted part along the approach distance L_a in the coupling direction (from position 6 to position 7).
3.6.9	locking time	$t_{7,7} = t_k$	s	Locking of the end effector exchange system by using the locking elements to connect the robot-mounted part with the tool-mounted part (at position 7).
3.6.10	drive-off time	$t_{7,8} = t_{1,2}$	s	Drive-off of the end effector exchange system from the magazine with reduced velocity (from position 7 to position 8).
3.6.11	system-specific exchange time	$t_x = t_r + t_s$ $+ t_c + t_k$	s	The system specific exchange time is the total of all specific exchange system time items of the total exchange time.

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Annex A
(informative)

Format for the presentation of automatic end effector exchange systems characteristics

This annex provides a format for the presentation of the information to describe different automatic end effector exchange systems. These details are not intended to be used for the development or design of these systems.

A.1 General information

A.1.1 Product (supplier/distributor) and model

A.1.2 Graphical presentation

simple pictures with main dimensions

as follows



A.2 External shape and main dimensions of the exchange system

A.2.1	robot part	☐
A.2.1.1	circular shape	☐
A.2.1.1.1	external diameter	<i>D</i> _____ mm
A.2.1.2	rectangular or squared shape	☐
A.2.1.2.1	width	<i>A</i> _____ mm
A.2.1.2.2	depth	<i>B</i> _____ mm
A.2.2	tool part	☐
A.2.2.1	circular shape	☐
A.2.2.1.1	external diameter	<i>D</i> _____ mm
A.2.2.2	rectangular or squared shape	☐
A.2.2.2.1	width	<i>A</i> _____ mm
A.2.2.2.2	depth	<i>B</i> _____ mm

A.2.3	length measured from the robot interface to the tool interface	
A.2.3.1	length of the coupled system	L_{total} ____ mm
A.2.3.2	length of the individual robot mounted part	L_r ____ mm
A.2.3.3	length of the individual tool mounted part	L_t ____ mm

A.3 Load characteristics

The approved maximum values for the load characteristics are valid for the total of both static and dynamic loads and are to be supplied by the supplier/distributor of the automatic exchange system. All load characteristics are stated for the reference plane.

A.3.1	mass, robot part	M_r ____ kg
A.3.2	mass, tool part	M_t ____ kg
A.3.3	maximum bending moment	M_{bmax} ____ N·m
A.3.4	maximum torsional moment	M_{omax} ____ N·m
A.3.5	maximum tensile force	F_{rmax} ____ N
A.3.6	maximum compressive force	F_{pmax} ____ N
A.3.7	maximum lateral force	F_{lmax} ____ N

A.4 Pitch circle and shaft diameter

A.4.1	pitch circle diameter according to ISO 9409-1	
A.4.1.1	plate, robot mounted	d_1 ____ mm
A.4.1.2	plate, tool mounted	d_1 ____ mm
A.4.1.3	other _____	
A.4.2	shaft diameter according to ISO 9409-2	
A.4.2.1	shaft	d_1 ____ mm
A.4.2.2	slot	yes ☐ no ☐
A.4.2.3	other _____	