Manipulating industrial robots -- Object handling with grasp-type grippers -- Vocabulary and presentation of characteristics

Foreword

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International Standard ISO 14539 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.

Introduction

ISO 14539 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, mechanical interfaces and graphical user interfaces for programming. It is noted that these standards are interrelated and also related to other International Standards.
Object handling with manipulating industrial robots is steadily diversifying as robots proliferate in automated manufacturing. This standard provides the vocabulary for understanding and planning of object handling and presentation of characteristics of grasp-type grippers.

Successful object handling is achieved with the cooperation of both robots and end effectors. In some cases robot arms/wrists play major roles in positioning objects. In some other cases, however, end effectors with adaptively controlled fingers can perform flexible object handling.

1 Scope

This International Standard focuses on the functionalities of end effectors and concentrates on grasp-type grippers as defined in 4.1.2.1.

This International Standard provides terms to describe object handling and terms of functions, structures, and elements of grasp-type grippers.

Annex A, which is informative, provides formats for presenting characteristics of grasp-type grippers. This part can be used in the following ways:

a) End effector manufacturers can present the characteristics of their products to robot users.

b) Robot users can specify the requirements of end effectors they need.

c) Robot users can describe the characteristics of the objects to be handled and of handling the objects in their specific robot applications.

This International Standard is also applicable to simple handling systems which are not covered by the definition of manipulating industrial robots, such as pick-and-place or master-slave units.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.


3 Vocabulary of object handling

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

3.1 Type of handling

3.1.1 object

solid (non-fluid) body gripped, held, or manipulated by an end effector in a robot application

Note 1 to entry: An object may have various shapes and dimensions, and may be deformed during handling.

3.1.2 object handling

action on an object by an end effector, or keeping a state of an object by an end effector

3.1.3 grip

constraints of an object by an end effector

3.1.4 grasp

constraints of an object with gripper finger(s)

3.1.5 grasping

gripper’s motion to apply constraints by finger(s) to an object
3.1.6

releasing
gripper’s motion to eliminate constraints from an object

3.1.7

state

condition of constraints of an object and resulting pose of the object

SEE:  Figure 1

3.1.8

action

transition of the state of an object

SEE:  Figure 1

Note 1 to entry: Some actions complete transfer between different types of states while other actions comprise transfer within a same type of states.

3.1.9  Type of states

3.1.9.1

gripped (state 1)

state in which the object is constrained by the end effector but not by the environment

3.1.9.2

semi-gripped (state 2)

state in which the object is constrained by the end effector and by the environment

3.1.9.3

laid (state 3)

state in which the object is constrained by the environment but not by the end effector

3.1.9.4

free (state 4)

state in which the object is neither constrained by the end effector nor by the environment
Note 1 to entry: Constraints by conservative forces, such as those by gravity, are not regarded as part of constraints by the environment. Constraints by conservative forces, if any, are irrelevant in the definitions of the types of the states.

**Figure 1 — States and actions in object handling**

- **State 1** — **État 1**
  - **Gripped** (Object: constrained by end effector)
  - **Pris** (Objet: contraint par un terminal)
  - End effector constrains object
  - End effector does not constrain object

- **State 4** — **État 4**
  - **Free** (Object: neither constrained by end effector nor by environment)
  - **Libre** (Objet: aucune contrainte ni par un terminal, ni par l'environnement)
  - Environment does not constrain object

- **State 2** — **État 2**
  - **Semi-gripped** (Object: constrained by end effector and by environment)
  - **Semi-pris** (Objet: contraint par un terminal et par l'environnement)
  - Environment constrains object

- **State 3** — **État 3**
  - **Laid** (Object: constrained by environment)
  - **Placé** (Objet: contraint par l'environnement)
  - Process

**NOTE** The names of actions are for information only.
3.2 Grasps

3.2.1 Type of grasps

3.2.1.1 degrees of freedom of grasped object

degrees of freedom of motion of object in space when constrained by fingers with or without considering friction forces at contact points

Note 1 to entry: This definition assumes that there is no motion of the gripper. For cases where the gripper moves, see 4.3.3.

3.2.1.2 form closure grasp

grasp with degrees of freedom of object being 0 or less without considering friction forces at contact points

Note 1 to entry: Form closure grasp is a grasp in which only the configuration of the gripper defines the pose of the object.

3.2.1.3 force closure grasp

grasp with degrees of freedom of object being 1 or more without considering friction forces at contact points but 0 or less with considering them

Note 1 to entry: Force closure grasp is a grasp in which not only the configuration of the gripper but also the forces serve to keep the pose of the object. Forces are usually friction forces.

3.2.1.4 external grasp

outside grasp

grasp that effects on the external surface of the object

SEE: Figure 2 a)

SEE: Figure 2 d)

SEE: Figure 2 f)
3.2.1.5

internal grasp

inside grasp

grip that effects on the internal surface of the object

**Figure 2 — Typical grasps with grasp-type grippers**

a), b): one-finger type gripper
c), d), e), f): two-finger type gripper
g): multi-finger type gripper

3.2.2 Forces in grasps

NOTE Forces in grasps are all considered to be dynamic forces which include static components. These forces can be increased or decreased by external forces and/or accelerations.

3.2.2.1

contact force

force exerted from a finger to an object through a contact point, contact line, or contact plane

Note 1 to entry: See $\vec{F}_1$ or $\vec{F}_2$ in Figure 3.
Note 2 to entry: Contact forces include frictional forces as well as normal forces.

### 3.2.2.2

**manipulating force**

vector sum of all contact forces exerted from fingers to an object

Note 1 to entry: See $\vec{F}_1 + \vec{F}_2 (= -\vec{F})$ in Figure 3 a).

#### Figure 3 — Forces in grasps

![Figures a) and b) showing forces in grasps](image)

### 3.2.2.3

**gripping force**

magnitude of the contact force, defined only for grasps with two contact points under the condition that forces

and moments exerted on the object other than the contact forces result zero

Note 1 to entry: The magnitude of $\vec{F}_1 (= -\vec{F}_2)$ in Figure 3 b) is the gripping force.

Note 2 to entry: The “forces and moments exerted on the object other than the contact forces” include external, gravitational, and inertial ones as well as the moments exerted through the contact points. In this case, the magnitude of $\vec{F}_1$ is equal to that of $\vec{F}_2$.

### 3.2.3 Stable grasps

#### 3.2.3.1

**grasp stability (1)**
state in which an object restores its initial pose in the gripper after its position is slightly changed as a result of disturbance forces applied to it

3.2.3.2

grasp stability (2)

state in which the gripper fingers always keep contact with the object it is grasping without slippage when the object is exposed to disturbance forces

3.3 Coordinate systems in object handling

See Figure 4.

NOTE It is helpful for robot task programming to describe the position and orientation of objects to be handled in a chain of coordinate systems.

3.3.1 world coordinate system

stationary coordinate system referenced to earth which is independent of the robot motion, denoted by $O_0^-X_0^-Y_0^-Z_0$ (as defined in ISO 8373 and ISO 9787)

3.3.2 base coordinate system

coordinate system referenced to the base mounting surface, denoted by $O_1^-X_1^-Y_1^-Z_1$ (as defined in ISO 8373 and ISO 9787)

3.3.3 mechanical interface coordinate system

coordinate system referenced to the mechanical interface, denoted by $O_m^-X_m^-Y_m^-Z_m$ (as defined in ISO 8373 and ISO 9787)

3.3.4 tool coordinate system

coordinate system referenced to the tool or to the end effector attached to the mechanical interface, denoted by $O_t^-X_t^-Y_t^-Z_t$ (as defined in ISO 8373 and ISO 9787)
Note 1 to entry: The tool coordinate system is related to the mechanical interface coordinate system.

3.3.5
task coordinate system
coordinate system referenced to the site of the task, denoted by $O_k-X_k-Y_k-Z_k$

3.3.6
object coordinate system
coordinate system referenced to the object, denoted by $O_j-X_j-Y_j-Z_j$

3.3.7
camera coordinate system
coordinate system referenced to the sensor which monitors the site of the task, denoted by $O_c-X_c-Y_c-Z_c$

Note 1 to entry: A vision system may be installed to detect the position and orientation of arbitrarily placed objects.

Figure 4 — Coordinate systems in object handling
3.3.8

TCP

Tool Centre Point

point defined for a given application with regard to the mechanical interface coordinate system (as defined in ISO 8373)

Note 1 to entry: The TCP is the origin of the tool coordinate system (as defined in ISO 9787).

Note 2 to entry: The TCP can be considered as an important point of agreement between manufacturers and users for handling objects and for each end effector.

3.4 Sensing in object handling

Various sensing signals are used to achieve reliable or sophisticated handling tasks. Grippers may have the following sensing capabilities for feedback control of handling.

NOTE There are other sophisticated sensing functions for object handling besides those given in this subclause, such as object position/orientation sensing, contact point sensing, object contour sensing, and finger speed sensing. They should be described individually.
3.4.1
object presence detection

detection of object presence, used in the following situations:

a) to make sure the object to be gripped is properly placed;

b) to make sure the object is successfully gripped;

c) to make sure the object is successfully released

3.4.2
finger position sensing

sensing of the finger position, used in the following situations:

a) the finger control (such as servo control) needs the finger position information;

b) the object size or shape is measured by gripping

3.4.3
gripping force sensing

sensing of the gripping force exerted to objects in the following situations:

a) gripping force is specified, e.g., in handling of fragile objects;

b) finger joints are controlled for stable grasps

Note 1 to entry: Gripping force can be sensed with a force sensor or from the finger actuating current.

3.4.4
external force sensing

sensing of external forces and torques in the following situations:

a) to measure the weight of the object;

b) to check if the gripper or the gripped object gets in or loses contact with objects or obstacles in the environment;

c) the object handling control needs the contact information in such a task as inserting

Note 1 to entry: External forces and torques can be sensed with a force/torque sensor or from the finger actuating current.
3.4.5

slip detection

sensing of slip between fingers and objects in the following situations:

a) to avoid gripping and lifting too heavy objects;

b) to avoid loose and unstable grasps of objects;

c) to grip objects with a minimum force necessary to avoid slips

4 Vocabulary of grasp-type grippers

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

4.1 Type of end effectors

4.1.1
tool-type end effector

derived from itself while moved or positioned by a robot arm

Note 1 to entry: Arc welding torches, spot welding guns, sanders, grinders, deburring equipment, routers, drills, spray guns, gluing guns, automatic screw drivers, laser cutting guns, and water jet cutting guns.

4.1.2
gripper

end effector designed for seizing and holding (as defined in ISO 8373)

Note 1 to entry: A gripper, or a gripper-type end effector as compared to a tool-type end effector, is an end effector that grips objects so as to move or place them.

4.1.2.1
grasp-type gripper

gripper that handles an object with finger(s)

4.1.2.2
non-grasp-type gripper

gripper that handles an object without fingers
Note 1 to entry: Non-grasp-type grippers handle objects by scooping, hooking, piercing, or sticking, or by vacuum/ magnetic/electrostatic levitation.

4.2 Elements and mechanisms of grasp-type grippers

4.2.1 Basic mechanical elements

See Figure 5.

4.2.1.1 robot interface

interface of a gripper to the interfaces of robots

4.2.1.2 palm

solid member in the basic mechanical structure of a gripper on which the first joints of fingers are fixed

Note 1 to entry: A palm may make direct contact to objects.

4.2.1.3 finger

kinematic chain structure whose first joint is fixed on the palm

Note 1 to entry: A finger may make direct contact to objects. A finger moves primarily with respect to the palm.

4.2.1.4 actuator

power mechanism used to effect motion of fingers

EXAMPLE:

Electric motor, electromagnetic actuator, electrostatic actuator, pneumatic actuator, hydraulic actuator, ultrasonic motor, rubber actuator, shape memory alloy, piezoelectric actuator.

4.2.1.5 power transmission mechanism

mechanism for transmitting the driving power from the actuators to the fingers

EXAMPLE:
Power transmission mechanisms, linkage transmission, wire transmission, gear transmission, screw transmission, cam transmission, spring transmission, direct actuation.

**Figure 5 — Mechanical elements of gripper**

**Key**

1. Robot interface
2. Palm
3. Finger
4. First joint
5. First link
6. Second joint
7. Second link
8. Third joint
9. Third link
10. Clamping element

**4.2.1.6 clamping element**

part of finger or finger link specially designed for direct contact to objects
4.2.1.7  
sensor

device for acquiring, from the gripper and/or the objects, signals to be used for controlling the gripper in object handling

4.3  Type of grasp-type grippers

4.3.1
degrees of mobility of gripper

the number of coordinate axes of translations and rotations of the moving space of the whole fingers of a gripper with respect to its palm

SEE:  Figure 6

Note 1 to entry: The motion of a gripper can be divided into three categories: linear, planar, and spatial, depending on the degrees of mobility of grippers. The degrees of mobility of grippers shown in Figure 6 a), b), c), for instance, are 1, 3, 6, respectively.

Note 2 to entry: The first step in planning grasping tasks is to select the degrees of mobility taking the object properties into consideration.

4.3.2
degrees of freedom of gripper

the minimum number of inputs which can determine the configuration of the gripper mechanism

4.3.3
degrees of freedom of gripper with object

the degrees of freedom of a gripper with an object are obtained in the same way as the degrees of freedom of a gripper considering the object as a link and replacing the contact points, lines, or planes with equivalent joints

4.3.4
angle gripper

gripper with rotational fingers
4.3.5

parallel gripper
gripper with translational fingers that move parallel to each other

4.3.6 Type of grasping

4.3.6.1

centric grasping
grasping in which the gripper adjusts its motion so that it grasps the object in the centre of the gripper

4.3.6.2

non-centric grasping
grasping that does not have the function of centric grasping

Figure 6 — Degrees of mobility of gripper

4.3.6.3

adaptive grasping
grasping in which the gripper adjusts its configuration to fit the shape of the object

4.3.6.4

symmetrical grasping
grasping in which fingers make symmetrical motions

4.3.6.5

asymmetrical grasping
grasping in which fingers do not make symmetrical motions
4.3.6.6

**power grasping**

grasping in which not only fingers but also the palm or the arm are used to make a form closure grasp

4.4  **Type of fingers**

4.4.1

**degrees of mobility of finger**

dimensions of the moving space of a finger

4.4.2

**degrees of freedom of finger**

minimum number of inputs which can determine the configuration of a finger

4.4.3  **Type of finger movements**

4.4.3.1

**rotational finger**

finger that makes rotational motions

SEE:  [Figure 7 a)](#)

4.4.3.2

**translational finger**

finger that makes translational motions

SEE:  [Figure 7 b)](#)

4.4.3.3

**multi-joint finger**

finger with many joints

SEE:  [Figure 7 c)](#)

4.4.3.4

**inflatable finger**

pneumatically inflatable finger
4.4.3.5

**mechanically interrelated finger**

deringer whose motion is mechanically interrelated with other finger motion(s)

SEE:  Figure 8 a)

4.4.3.6

**mechanically independent finger**

deringer whose motion is mechanically independent of other finger motion(s)

SEE:  Figure 8 b)

4.5  Finger control

4.5.1

**two-value control**

control scheme in which the command is either “open” or “close”

4.5.2

**position control**

control scheme in which only the position is commanded

4.5.3

**velocity control**

control scheme in which the velocity is commanded
Figure 8 — Finger interrelation

a) Mechanically interrelated fingers

b) Mechanically independent fingers

Key

1 Gear

2 Actuator

4.5.4

force control

control scheme in which only the force is commanded

4.5.5

impedance control

compliance control
control scheme in which the position commands and the force commands are integrated through real or virtual equations of motion so that the task coordinate servo control is performed

4.5.6

hybrid control

control scheme in which the position commands and force commands on the task coordinate system are transformed into those on the joint coordinate system and are integrated through a formula of conversion so that the joint coordinate servo control is performed

4.6 Clamping elements

NOTE Clamping elements should be designed to adapt for object properties.

4.6.1 Geometrical features

See Figure 9.

4.6.1.1 conforming

clamping element whose shape is designed to fit the shape of the grasped object

4.6.2 replaceability

clamping element is replaceable if it can be changed with the same type of clamping element for grasping the same type of objects

Note 1 to entry: Clamping elements should be designed to be replaceable if they are often damaged with repeated handling of objects.

4.6.3 exchangeability

clamping element is exchangeable if it can be changed with a different type of clamping element for grasping different type of objects

Note 1 to entry: Clamping elements can be designed exchangeable to make the gripper accommodate a certain variety of geometric or physical properties of objects.
4.7 Robot interfaces

Robot interfaces should conform to the mechanical interfaces such as:

4.7.1

**mechanical interface (plate)**

[SOURCE: see ISO 9409-1]

4.7.2

**mechanical interface (shaft)**

[SOURCE: see ISO 9409-2]

4.8 Safety in grasps and grasping

4.8.1

**fail-safe**

function designed to maintain safety in case of foreseeable failure of any single component

4.8.2

**self-holding**

function of a mechanism in which passive elements keep the gripper from releasing the grasped object in case of power failure
4.8.3

self-lock

mechanical function to prevent the external forces from driving the gripper to release the grasped object in case of power failure

4.8.4

interlock

conditional enabling or inhibition of particular grasping or releasing motion

4.8.5

grasping safety

function to avoid insecure grasps

Note 1 to entry: Examples are automatic avoidance of gripping too heavy objects and automatic force control to avoid slippage of an object.

1) Clamping elements can be made of elastic materials to adapt geometrical or physical properties of objects. To handle heavy objects with smooth surfaces, clamping elements with rough surfaces should be used. Heat resistant elements should be used for handling high temperature objects. For objects with abrasive surfaces, wear resistant elements should be used. Anti-corrosive materials may be used where required for harsh environmental conditions.