
**Robotics — Performance criteria
and related test methods for service
robots —**

**Part 3:
Manipulation**

*Robotique — Critères de performance et méthodes d'essai
correspondantes pour robots de service —*

Partie 3: Manipulation

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

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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.

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).

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 www.iso.org/patents).

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 www.iso.org/iso/foreword.html.

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

A list of all parts in the ISO 18646 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document defines characteristics for the manipulation performance of service robots and describes how to specify and test them. It is intended that the reader of this document selects which performance characteristics to test, in accordance with the specific requirements.

The performance criteria specified in this document are not intended to be interpreted as the verification or validation of safety requirements. The verification and validation of safety requirements are specified in safety related standards developed by ISO/TC 299.

Tests for position and path accuracy of manipulators, which can be useful in addition to the tests specified in this document, are provided in ISO 9283.

Tests for locomotion of mobile robots, such as rated speed and stopping characteristics are provided in ISO 18646-1. Tests for pose accuracy and pose repeatability for mobile robots are also provided in ISO 18646-2.

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Robotics — Performance criteria and related test methods for service robots —

Part 3: Manipulation

1 Scope

This document describes methods of specifying and evaluating the manipulation performance of service robots, notably:

- grasp size;
- grasp strength;
- grasp slip resistance;
- opening a hinged door; and
- opening a sliding door.

There are other grasping characteristics and use cases for manipulation of service robots. It is expected that these will be included in a future revision.

This document deals with the indoor environment only. However, the depicted tests can also be applicable for robots operating in outdoor environments.

This document is not applicable for the verification or validation of safety requirements.

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 9379:2005, *Operating forces — Test method — Doors*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

robot

programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning

Note 1 to entry: A *robot* includes the control system.

EXAMPLE *Manipulator, mobile platform, and wearable robot.*

[SOURCE: ISO 8373:2012, 2.6, modified — The phrase “actuated mechanism programmable in two or more axes” is replaced with “programmed actuated mechanism”, the phrase “moving within its environment, to perform intended tasks” is replaced with “to perform locomotion, manipulation or positioning”, note 1 to entry is modified, note 2 is removed, and EXAMPLES are added]

3.2

service robot

robot that performs useful tasks for humans or equipment excluding industrial automation applications

Note 1 to entry: Industrial automation applications include, but are not limited to, manufacturing, inspection, packaging, and assembly.

Note 2 to entry: While articulated *robots* used in production lines are industrial *robots*, similar articulated *robots* used for serving food are *service robots*.

[SOURCE: ISO 8373:2012, 2.10]

3.3

mobile platform

assembly of all components of the mobile *robot* which enables locomotion

Note 1 to entry: A *mobile platform* can include a chassis which can be used to support a load.

Note 2 to entry: Because of possible confusion with the term “base”, it is advisable not to use the term “mobile base” to describe a *mobile platform*.

[SOURCE: ISO 8373:2012, 3.18]

3.4

manipulator

mechanism usually consisting of a series of segments, connected to one another by joints, for the purpose of grasping and/or moving objects usually in several degrees of freedom

Note 1 to entry: A *manipulator* does not include an *end-effector*.

[SOURCE: ISO 8373:2012, 2.1, modified — The phrase “machine in which the mechanism usually consists of” is replaced with “mechanism usually consisting of”, the phrase “jointed or sliding relative to one another” is replaced with “connected to one another by joints”, the phrase “(pieces or tools)” is removed, and note 1 is removed]

3.5

end effector

device specifically designed for attachment to the mechanical interface to enable the *robot* to perform its task

EXAMPLE *Gripper*, nut runner, welding gun, spray gun.

[SOURCE: ISO 8373:2012, 3.11]

3.6

gripper

end effector designed for seizing and holding

[SOURCE: ISO 8373:2012, 3.14]

3.7

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.

[SOURCE: ISO 14539:2000, 4.2.1.2]

3.8**normal operating conditions**

range of environmental conditions and other parameters within which the *robot* is expected to perform as specified by the manufacturer

Note 1 to entry: Environmental conditions include, for example, temperature and humidity.

Note 2 to entry: Other parameters include electrical supply instability, electromagnetic fields, etc.

[SOURCE: ISO 8373:2012, 6.1, modified — The phrase “which can influence robot performance (such as electrical supply instability, electromagnetic fields) within which the performance of the robot (2,6) specified by the manufacturer is valid” is replaced with “within which the robot is expected to perform as specified by the manufacturer”, and note 2 to entry is added]

3.9**autonomous mode**

operational mode in which the *robot* function accomplishes its assigned task without direct human intervention

[SOURCE: ISO 13482:2014, 3.24.2, modified — The word “mission” is replaced with “task” and the EXAMPLE has been removed.]

3.10**test configuration**

particular arrangement of test objects

3.11**trial**

single instance of test procedure performed under identical *test configuration*

Note 1 to entry: A trial can be repeated multiple times.

4 Test conditions**4.1 General**

The service robot, hereafter referred to as robot, shall be completely assembled, configured with a mobile platform, if applicable, a manipulator and a gripper, sufficiently charged and operational. If there are any diagnostic tests that have to be performed before the normal operation, they shall be satisfactorily completed. Appropriate precautions should be taken to protect the personnel during the test. The tests shall be preceded by the preparations for operation as specified by the manufacturer.

All performance shall be measured under normal operating conditions and these conditions shall be included in the test report.

All sensors used in the test specified in this document shall be calibrated prior to performing any tests.

The robot may use any sensors and recognition means to identify the object for each test, as long as they are reported in the test report.

All conditions specified in this clause should be satisfied for the tests described in this document, unless it is stated otherwise in the specific subclauses.

4.2 Operational mode

Each test described in this document shall be carried out in the autonomous mode of the service robot.

4.3 Test configuration and trial

Each test described in this document can have multiple test configurations which require separate test procedures. For each test configuration, multiple trials shall be conducted, if specified in the test procedure.

5 Grasping characteristics

5.1 General

The goal of the tests described in this clause is to confirm the performance for the grasping characteristics, partially derived from Falco, et al., 2019^[4] and Falco et al., 2015^[5]. Three characteristics are addressed in this clause, but additional grasping characteristics exist. It is expected that more grasping characteristics and detailed test methodologies will be introduced in a future revision.

5.2 Grasp size

5.2.1 Purpose

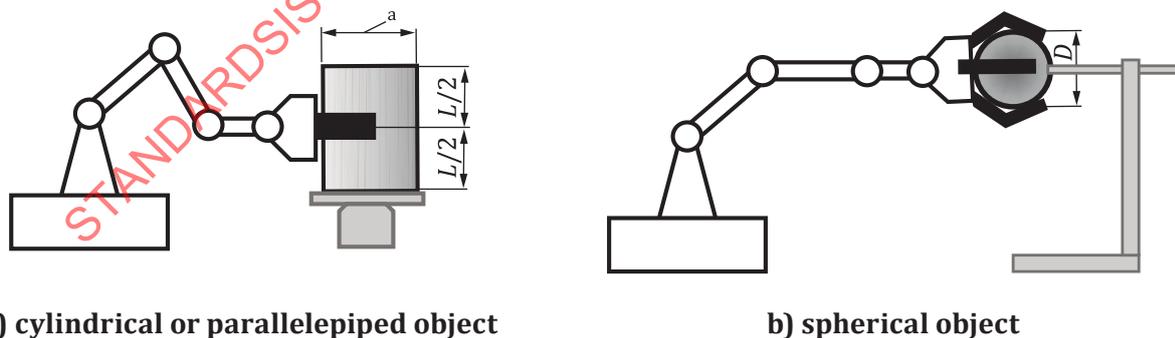
The purpose of this test is to confirm that the robot can grasp and move the objects of maximum and minimum sizes.

5.2.2 Test facility

The setup for this test is shown in [Figure 1](#). Three test objects of cylindrical, parallelepiped, and spherical type, shown in [Table 1](#), are used for this test. The test objects should be made of PVC (Polyvinyl Chloride). If the manufacturer chooses a material other than PVC, the substituted material's name and physical properties (e.g. weight) shall be recorded in the test report.

The maximum and minimum sizes of each object, specifically D for cylindrical and spherical objects and W for parallelepiped object, are tested. These sizes can be provided by the manufacturer of robot or the tester, considering the size of the gripper.

Cylindrical and parallelepiped test objects shall have a length, L , longer than the lateral width of the gripper. For cylindrical and parallelepiped objects, the gripper shall hold the object along the longitudinal direction, meaning that grasping the object by two end faces (see [Table 1](#)) is not allowed.

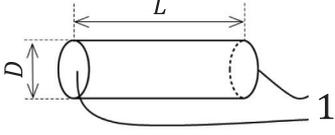
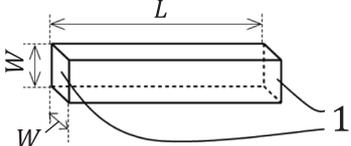
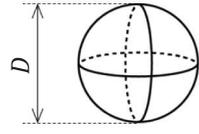


Key

^a D or W .

Figure 1 — Test setup for grasp size

Table 1 — Test objects for grasping characteristics

Name	Geometry	Description
Cylindrical object		L: Length D: Diameter
(Square) Parallelepiped object		L: Length W: Width
Spherical object		D: Diameter
<p>The test objects may have a hollow part so that the total weight of the gripper and test object is within the maximum load of the robot. In this case, the shape, dimensions, and weight of the test objects shall be declared in the test report.</p> <p>Key</p> <p>1 end face</p>		

The object should be placed so that the number of contacts between the gripper and the test object is maximized. For example, the contact with the palm of the gripper is encouraged to hold the test object securely, if possible.

A support or fixture may be used to ensure the stable vertical position of the test object, as shown in [Figure 1](#).

The robot shall be able to hold the object without dropping during the test. Manufacturer or tester shall decide the designated velocity and acceleration of the motions in the test.

5.2.3 Test procedure

This test consists of six test configurations of the cylindrical, parallelepiped and spherical objects with the maximum and minimum sizes.

Each trial shall follow the following procedure:

- A robot configured with the proper manipulator and gripper is placed at the initial pose where the gripper is around the geometric centre of the test object ([Figure 1](#)).
- The gripper grasps the test object and then the robot moves 100 mm upward at the designated velocity and acceleration (Pose A).
- The robot moves to the worst-case pose declared by the manufacturer (Pose B) at the designated velocity and acceleration and maintains this pose for 1 s. Pose B should be located sufficiently far away from Pose A as to enable the designated velocity to be attained during the movement.

NOTE If the manufacturer does not provide a “worst-case” pose for the gripper, for the purpose of this test, Pose B can be assumed to be such that the gripper’s aperture opening is pointed downward such that gravity is pulling the test object toward that opening.

- The robot moves back to Pose A at the designated velocity and acceleration.
- The robot returns to its initial pose and releases the test object.

The trial is repeated 10 times for each test object and size. The test is a success if the test object is held without dropping for all 10 trials. Otherwise, the test fails.

When this test is failed for any test configurations, the test may be repeated with the modified maximum or minimum sizes.

5.2.4 Test result

The results of the test shall be declared in the test report. This report shall include the test object sizes evaluated, and the specified test conditions, including test object weight, robot poses, and whether the test was a success or a failure. An example format is given in [Table 2](#).

Table 2 — Test report for grasp size

Object	Material	Grasp size	Dimensions	Weight	Success/Failure
Cylindrical object		Maximum	L: D:		
		Minimum	L: D:		
Parallelepiped object		Maximum	L: W:		
		Minimum	L: W:		
Spherical object		Maximum	D:		
		Minimum	D:		

The information for Pose A, Pose B, and the designated velocity and acceleration shall be provided.

5.3 Grasp strength

5.3.1 Purpose

The purpose of this test is to determine the grasp strength of a gripper. This test measures the maximum force a gripper can exert on an object. A high grasp strength is correlated with the gripper’s payload, as well as its ability to resist external forces during grasp operations.

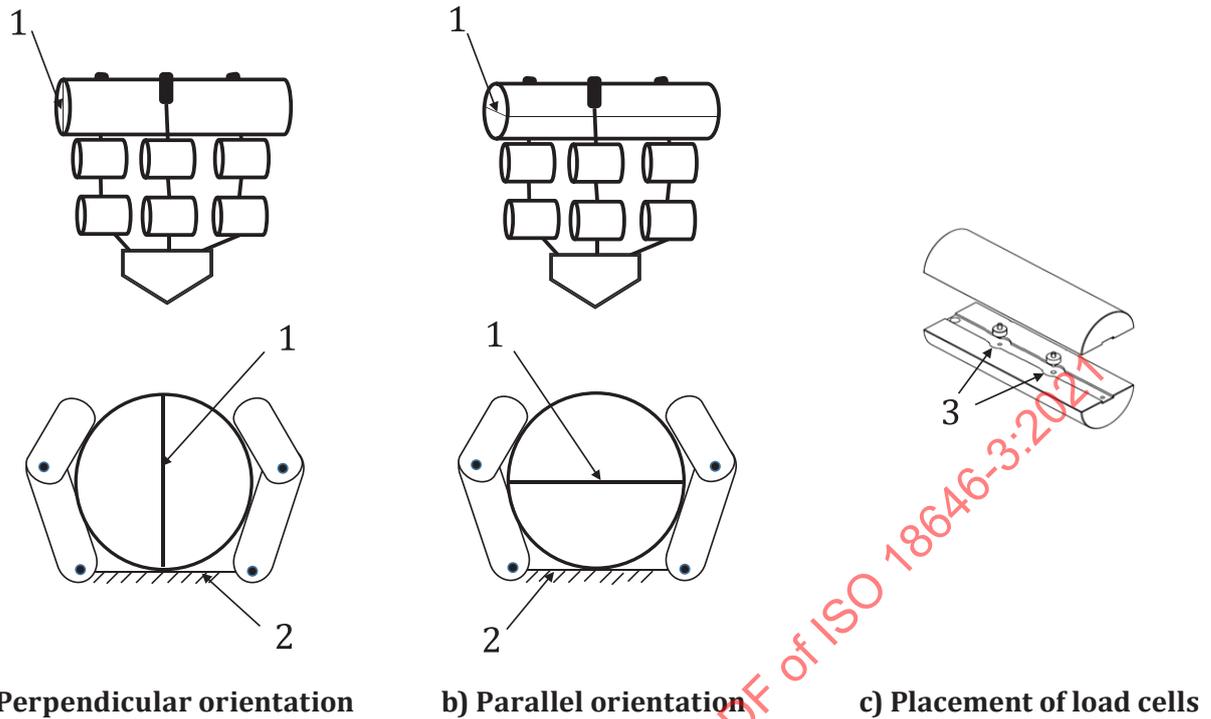
5.3.2 Test facility

The setup for this test is shown in [Figure 2](#). Cylindrical test objects, shown in [Table 1](#), with the maximum and median grasp size of the gripper, as obtained by [5.2](#), shall be used to measure the grasp strength. The test object’s length, *L*, shall be longer than the lateral width of the gripper.

NOTE The median grasp size, not the minimum grasp size, is used in this test since the minimum grasp size can be too small to implement this test. The median grasp size is defined as (maximum grasp size + minimum grasp size)/2.

The cylinder is divided into two half cylinders as shown in [Figure 2c](#)), where two load cells are installed in the centre of the facing plane of two half cylinders. The sensors are located at 1/3 and 2/3 of the length of the cylinder. The sum of the two values measured by the load cells is used as a measurement value.

The cylinder shall be placed either in the perpendicular orientation or the parallel orientation as shown in [Figure 2](#). In the perpendicular orientation, the facing plane is perpendicular to the palm of the gripper. In parallel orientation, the facing plane is parallel to the palm of the gripper.

**Key**

- 1 facing plane
- 2 palm
- 3 load cells

Figure 2 — Test setup for grasp strength

5.3.3 Test procedure

This test consists of four test configurations of the cylindrical test objects of maximum and median grasp sizes with the perpendicular orientation and the parallel orientation.

Each trial shall follow the following procedure:

- a) A robot configured with the proper manipulator and gripper is placed at the initial pose, where the gripper is around the geometric centre of the test object of the designated grasp size. The test object with the designated orientation is placed horizontally over the gripper.
- b) The gripper grasps the cylindrical test object with the maximum strength.
- c) After the gripper reaches its maximum sustained force, the force of each load cell is measured for 10 seconds. The average force is obtained after adding all sampled values of forces over the period of 10 seconds divided by number of samples. The grasp strength is determined as the sum of two average values of load cells.
- d) The gripper releases the test object.

The trial is repeated 30 times for each specified size and orientation. The mean and standard deviation from these 30 trials shall be calculated.

NOTE The selection of 30 repetitions is given to establish statistical significance. As the number of samples approaches 30, the Student's t-distribution of the samples approaches normality with a confidence interval of 95 %. As more samples are measured the confidence in the robot's grasping performance increases.

5.3.4 Test result

The results of the test shall be declared in the test report. This report shall include the test object’s size, weight, the robot’s pose, and the measurement results from the test object, along with statistical data. An example format is given in [Table 3](#).

Table 3 — Test report for grasp strength

Object	Material	Grasp sizes	Dimensions	Weights	Orientations	Grasp strength	
						Mean	Standard deviation
Cylindrical object		Maximum	L: D:		Perpendicular		
					Parallel		
		Median	L: D:		Perpendicular		
					Parallel		

The information of the initial pose of the robot shall be provided.

5.4 Grasp slip resistance

5.4.1 Purpose

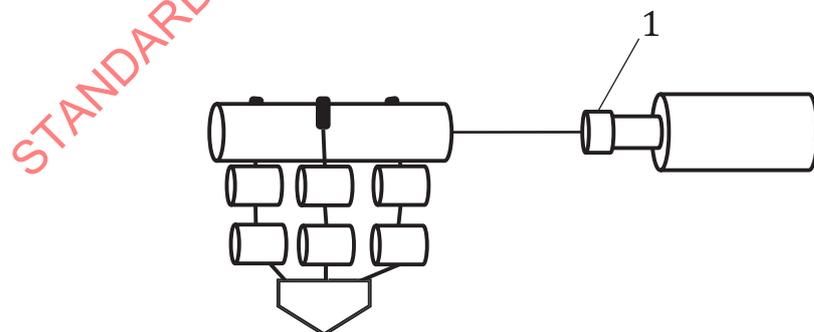
The purpose of this test is to determine the slip resistance of a gripper to hold a cylindrical object.

5.4.2 Test facility

The setup for this test is shown in [Figure 3](#). Cylindrical test objects, shown in [Table 1](#), with the maximum and median grasp size of the gripper, as obtained by [5.2](#), shall be used to measure the grasp slip resistance. The test object’s length, L, shall be longer than the lateral width of the gripper.

NOTE The median grasp size, not the minimum grasp size, is used in this test since the minimum grasp size can be too small to implement this test. The median grasp size is defined as (maximum grasp size + minimum grasp size)/2.

The cylindrical test object is connected to the fixture by metal wire. The metal wire shall be strong enough to withstand the maximum expected force during the test. A load cell should be installed either at the fixture or at the test objects to measure the pulling force. The travel path of the cylindrical test object shall be along the line connecting the cylinder and the fixture, as shown in [Figure 3](#). The pulling of wire can be accomplished either by the motion of the robot or by the motion of the fixture.



Key

- 1 fixture with a load cell

Figure 3 — Test setup for grasp slip resistance

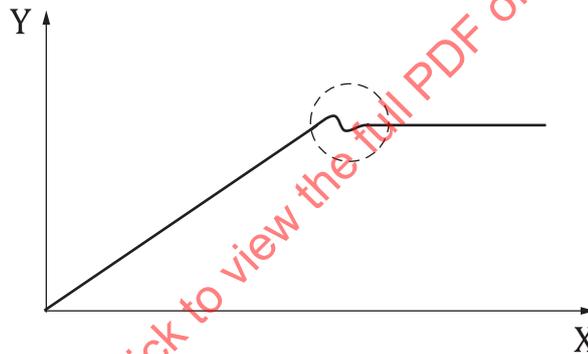
5.4.3 Test procedure

This test consists of two test configurations of the maximum grasp size and the median grasp size using a cylindrical test object held by the gripper.

Each trial shall follow the following procedure:

- a) A robot configured with the proper manipulator and gripper is placed at the initial pose, where the gripper is around the geometric centre of the test object placed horizontally over the gripper.
- b) The robot gripper grasps the cylindrical test object with the maximum grasp strength.
- c) The recording of the force measurement starts. Then, either the robot or the fixture moves along the line so that the cylindrical test object is pulled out.
- d) After the slip is indicated clearly, the motion stops and the recording is finished.
- e) From the analysis of the profile of the recorded force measurement, the slip resistance is determined as the stabilized force after flattening as shown in [Figure 4](#).

The trial is repeated 30 times for measuring the slip resistance specified in Newtons for each grasp size. The mean and standard deviation from these 30 trials shall be calculated.



Key

- X time (s)
- Y force (N)

Figure 4 — Observed slip event marked by dotted circle

5.4.4 Test result

Grasp slip resistance along with the specific test conditions, such as the diameter and weight shall be recorded in the test report. The coefficient of friction, calculated as (grasp slip resistance/grasp strength obtained in [5.3](#)), shall also be reported. An example format is given in [Table 4](#).

Table 4 — Test report for grasp slip resistance

Object	Material	Coefficient of friction	Grasp sizes	Dimensions	Weights	Slip resistance	
						Mean	Standard deviation
Cylindrical object			Maximum	L: D:			
			Median	L: D:			

The information of the grasp strength should be provided.

6 Use cases

6.1 General

The goal of the tests described in this clause is to confirm the manipulation performance of typical use cases of the service robot. The items are currently limited only to the handling of doors. It is expected that the tests for advanced use cases will be introduced in a future revision.

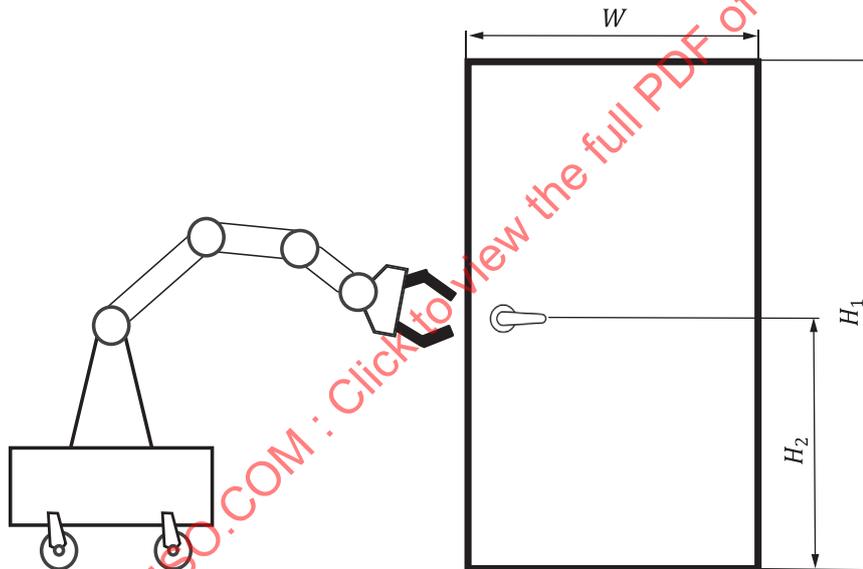
6.2 Opening a hinged door

6.2.1 Purpose

The purpose of this test is to determine the capability of the manipulator and gripper of a service robot to open a hinged door. This test may be performed relying on motion of the mobile platform.

6.2.2 Test facility

The setup for this test is shown in [Figure 5](#). Sensors may be installed within the test environment to measure the movement of the door.



Key

- W width of the door
- H_1 height of the door
- H_2 height of the door handle

Figure 5 — Test setup for a hinged door

The door should have a height, H_1 , between 1 800 mm and 2 400 mm, a width, W , between 850 mm and 1 200 mm, and a thickness, T , between 30 mm and 60 mm. The height of a handle from the bottom of door, H_2 , should be between 800 mm and 1 200 mm. The robot may be provided with the information about the door dimensions in advance of the test. This data can be used in the task program for this test.

The door shall have a dynamic opening force of 0,5 N or more in accordance with ISO 9379:2005, 7.3.

The lever type door handle shall have an operating torque of 10 Nm or more, in accordance with ISO 9379:2005, 7.2. The door handle shall be made of metal material. The length of lever for the lever type door handle should be between 100 mm and 200 mm.

6.2.3 Test procedure

This test consists of one test configuration of a pull type hinged door with a lever type handle.

Each trial shall follow the following procedure:

- a) The door is closed but not locked. A robot configured with the manipulator and the gripper is placed at an initial pose in front of the door, where the gripper is positioned to grasp the door handle.
- b) The gripper grasps the door handle and the robot turns the door handle to an unlatched position.
- c) The robot opens the door 90°.
- d) The robot releases the door handle.
- e) Measure the angle of the door opening.

The trial is repeated 10 times. The test is a success if the measured angle of the hinged door is $(90 \pm 5)^\circ$ for all 10 trials. Otherwise, the test fails.

6.2.4 Test result

The results of the test shall be declared in the test report. This report shall include the specified test conditions, including dynamic opening force and the dimension of the door, and whether the test was a success or a failure. The test conditions of the operating torque and range of turning for door handle shall also be declared. An example format is given in [Table 5](#).

Table 5 — Test report for opening a hinged door

Door type	Material	Dimensions	Dynamic opening force	Door handle		Success /failure
				Operating torque	Range of turning	
Pull type hinged door		H_1 : H_2 : W : T :				

6.3 Opening a sliding door

6.3.1 Purpose

The purpose of this test is to determine the capability of the manipulator and gripper of a service robot to open a sliding door. This test may be performed relying on motion of the mobile platform.

6.3.2 Test facility

The setup for this test is shown in [Figure 6](#). Sensors may be installed within the test environment to measure the movement of the door.

The door should have a height, H_1 , between 1 800 mm and 2 400 mm, a width, W , between 850 mm and 1 200 mm, and a thickness, T , between 30 mm and 60 mm. The height of a handle from the bottom of door, H_2 , should be between 800 mm and 1 200 mm. The robot may be provided with the information about the door dimensions in advance of the test. This data can be used in the task program for this test.

The door shall have a dynamic opening force of 0,5 N or more in accordance with ISO 9379:2005, 7.3.