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Service robot - Mechanical safety assessment and test method

服务机器人 机械安全评估与测试方法

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Service robot - Mechanical safety assessment and test method

1 Scope

This standard specifies terms and definitions, test conditions, mechanical safety assessment and test methods, markings, instructions, document requirements related to mechanical safety of service robots.

This standard applies to all types of service robots, which mainly include personal/household service robots and public service robots.

Special robots can refer to this standard.

Note: In the case of presence of relevant standards on special product's mechanical safety, the product standard takes precedence over this standard.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) is applicable to this standard.

GB 6675.2-2014 Safety of toys - Part 2: Mechanical and physical properties

GB/T 12643-2013 Robots and robotic devices - Vocabulary

GB/T 16855.1-2018 Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design

GB/T 16855.2-2015 Safety of machinery - Safety-related parts of control systems - Part 2: Validation

GB/T 18029.13-2008 Wheelchair - Part 13: Determination of friction of test surface

GB/T 23821-2009 Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs

GB/T 36008-2018 Robots and robotic devices - Collaborative robots

knowledge or skills, nor requiring special training or qualifications.

[GB/T 37283-2019, definition 3.3]

3.3

Public service robot

Service robots, which are used for public or commercial tasks.

Examples: hotel service robots, banking service robots, venue service robots, catering service robots.

Note: Public service robots are usually operated by appropriately trained personnel.

[GB/T 37283-2019, definition 3.4]

4 Test conditions

4.1 Test sample

Service robots mainly include personal/household service robots AND public service robots.

The service robot shall be assembled and operated, in accordance with the manufacturer's instructions. All necessary preparations (such as functional tests, etc.) shall be completed before the test. Before the test, it shall record the condition information and usage history of the tested sample.

Note: Condition information may include model/name, software version, accessories (if any).

All tests shall be performed on the same service robot AND its accessories (if any). For the tests, which are performed to simulate the stress that the service robot may be subjected to, during normal use, it may cause damage to the service robot; thereby, it requires additional replaceable parts AND recording the replaced parts.

4.2 Working conditions for test

4.2.1 Operating conditions

The installed software shall not be modified or changed during a set of tests.

The safety facilities on the test site shall be in normal working condition.

4.2.2 Environmental conditions

- C: Measurement (comparing the measured actual value with the required limit);

- D: Observe during operation [under normal or abnormal conditions of the service robot, use the inspection method A during operation to check (such as carrying out under rated load)];

- E: Analyze related design drawings [structural analysis or roughly browse circuit diagram design (including electrical, pneumatic, hydraulic, etc.) and related instructions].

5.2 Verification of structural design

5.2.1 Verification of edge and corner

5.2.1.1 Test procedure

If the function of the service robot requires touchable edges and corners, whether they are qualification or not, is determined through actual tests.

If the function of the service robot does not require touchable edges and corners, whether they are qualification or not, is determined through the related tests in Appendix A.

For service robots that may be used by children, in addition to the above procedures, it shall also carry out the relevant tests of 5.8 and 5.9 in GB 6675.2-2014.

Note: See A, B, D of 5.1 for inspection methods.

5.2.1.2 Qualification criteria

If the function of the service robot requires touchable edges and corners, THEN:

a) They do not cause injury but may be painful; or

b) They may cause injury.

Note 1: "Do not cause injury" means that, based on experience and/or basic safety standards, it does not require emergency treatment by doctor or hospital.

Note 2: "May cause injury" means that, based on experience and/or basic safety standards, a doctor or hospital may be required to provide emergency treatment.

If the function of the service robot requires that, there are edges and corners that do not cause injury but may cause pain and may cause injury, THEN:

a) Any possible exposure shall not be life-threatening; and

Measure the safety distance of dangerous moving parts.

Note: See A, B, C, D of 5.1 for inspection methods.

5.2.3.2 Qualification criteria

Adequate protective measures shall be provided around the gap, to ensure that external objects cannot touch the internal circuit or conductive parts.

The safety distance from hazardous moving parts shall meet the requirements of GB/T 23821-2009.

5.2.4 Position limit

5.2.4.1 Test procedure

Through visual inspection and measurement, the service robot runs to the maximum or minimum stroke position, at rated load and maximum speed, without any braking measures.

Note: For inspection methods, see A, B, D, E of 5.1.

5.2.4.2 Qualification criteria

For the use and operation of the service robot, the range of motion shall not exceed the safe range.

Mechanical limit devices (such as mechanical stops) shall not cause unacceptable risks after a collision; meanwhile it can be restored to their original form. For the electromechanical limit device (such as proximity switch), its control circuit shall meet the electrical performance requirements. The service robot's control and task program shall not change the settings of the electromechanical limit device.

The soft limit range shall be smaller than the hard limit range. If the soft limit can be set, THEN, the soft limit setting shall be restricted by personnel authorization, meanwhile it will always be active after the service robot system is powered on.

5.2.5 Evacuate after failure

5.2.5.1 Test procedure

Through visual inspection, actual test, observation in operation, simulate a failure of the service robot under normal working conditions.

Note 1: Evacuation from manned service robot's service space after failure: The service robot restrains people in the service space. If the manned service robot's

The accessibility of moving parts is checked by visual inspection. If necessary, make verification in accordance with the test method in Appendix A.

Note 1: If function of the robot requires a level 2 mechanical energy source (MS2) moving parts, that are accessible to general personnel, or a level 3 mechanical energy source (MS3) moving parts, that are accessible to general personnel or trained personnel, THEN:

- Any exposure shall not be life-threatening; and
- When exposed, moving parts shall be obvious; and
- Take as much protection as possible for moving parts; and
- Indicative safety protection shall be used; and
- For MS3, the manually triggered stop device shall be clearly visible, AND placed in a prominent position, within 750 mm of its vicinity.

For the following MS3 moving parts:

- They are only accessible to skilled technicians; and
- MS3 moving parts are not obvious (for example, intermittent motion devices).

Note 2: For the definition of MS2 and MS3, see 8.2 in IEC 62368-1:2018.

Note 3: For inspection methods, see A, B, D of 5.1.

5.3.2 Qualification criteria

Instructive safety protection shall be provided, to reduce the possibility of unintentional contact with moving parts.

The elements of indicative safety protection shall include the following:

- For moving fan blades, or for other moving parts;
- As applicable, "moving parts" or "moving fan blades" or similar words;
- As applicable, "body parts are kept away from moving parts" or "body parts are kept away from fan blades" or "body parts are away from motion path" or similar words.

Under normal maintenance conditions, if the safety protection against contact with the MS2 moving parts needs to be disabled or bypassed, an indicative safety protection shall be provided, to remind the following:

- Disconnect the power supply before failing or bypassing the safety

- Verification of anti-drop function (5.4.7);

- Verification of singularity restriction (5.4.8);

- Verification of wireless control (5.4.9).

The safety functions, which are involved in this article, are common safety functions of the service robot. If the control function of the service robot is not within the scope, it shall follow the GB/T 16855.1-2018 and Appendix A, to judge the performance requirements of the safety-related control system, meanwhile meet the corresponding performance criteria.

5.4.1.2 The required performance level (PL_r) of the safety-related components of the control system of typical service robot

For the safety-related components of the control system of a typical service robot, the minimum required performance level (PL_r) is as shown in Table 1.

Mobile service robots (wheeled, footed, crawler, etc.):

- Type 1.1: Light-weighed AND slow type AND is expected to be used in non-crowded places;

- Type 1.2: Medium-weighted AND slow type AND is expected to be used in non-crowded places;

- Type 1.3: Heavy-weighted OR fast type OR is expected to be used in crowded places.

Stationary service robot:

Type 2.1: For the quasi-static contact and/or transient contact BETWEEN the moving part AND the person, the force and pressure value is less than or equal to the threshold;

- Type 2.2: For the quasi-static contact and/or transient contact BETWEEN the moving part AND the person, the force and pressure value exceed the threshold.

Note 1: "Light-weighted" refers to product mass ≤ 7 kg; "Medium-weighted" refers to product mass > 7 kg and ≤ 25 kg; "Heavy-weighted" refers to product mass > 25 kg.

Note 2: "Slow type" refers that, the product's maximum moving speed is lower than or equal to the normal walking speed of the predetermined user group, which is determined through the risk assessment; "fast type" refers that, the product's maximum moving speed is higher than the normal walking speed of the predetermined user group, which is determined through the risk assessment.

shall meet the requirements of 6.5.2.2 in GB/T 36530-2018. After the collision between the human and the service robot, the service robot shall not have the risk, which is caused by insufficient stability.

5.4.3 Verification of stop function

5.4.3.1 Verification of emergency stop

5.4.3.1.1 Test procedure

Through visual inspection, actual test, observation in operation, under normal working conditions of the service robot, press the emergency stop button OR runs the software with stop function. Based on the results of the risk assessment, determine the emergency stop category of the service robot product (category 0 stop or category 1 stop).

Note: See A, B, D of 5.1 for inspection methods.

5.4.3.1.2 Qualification criteria

The service robot shall not cause secondary injury to the personnel, after the emergency stop, meanwhile there are measures to make the personnel out of the dangerous state.

The emergency stop device shall comply with IEC 60204-1:2016 or ISO 13850.

If the emergency stop function of the service robot is realized by a safety-related control system, the safety-related components of the control system shall meet the level requirements in 5.4.1.

If the service robot has an emergency stop function, every instruction device, that can trigger the service robot to move or other dangerous conditions, shall have a function to manually trigger emergency stop:

- Take priority over other controlled execution of service robot; and
- Stop all controlled risks; and
- If the service robot is in a safe state, remove the driving source of the service robot's actuator; and
- Able to control the danger of the system manipulation of service robot; and
- It can only be reset manually, meanwhile it will not cause the service robot to restart after resetting.

If the command device does not have an emergency stop button (such as a voice interface, a computer screen based on remote applications), it shall be

5.4.4.3.1 Body restrictions

It shall meet the requirements of 6.3 of GB/T 36530-2018 on the restrictions of operating space.

Note 1: For the service robots, that do not have the ability to move or motion, this requirement does not apply.

Note 2: For the service robots, which have special operating capabilities, such as window cleaning service robots, cooking service robots, etc., during the normal operation of the service robot, it shall use protective measures or auxiliary facilities, or in conjunction with the service robot's safe use manual, to ensure the safe use of service robot.

5.4.4.3.2 Space restrictions

Service robots are not allowed to be used in unforeseen spaces and environments.

In the service robot's use information, the operating space and use environment of the service robot shall be clearly defined, including: the size of the operating space, the use object, the temperature and humidity of the use environment, etc.

5.4.5 Safety-related speed control test

5.4.5.1 Test procedure

Use the risk assessment to determine the safety-related speed limit of the service robot. Operate the service robot in the most unfavorable situation, to verify whether its safety-related speed control is qualified.

Note 1: The most unfavorable situation is determined through consultation with the supplier.

Note 2: For inspection methods, see A, B, C, D in 5.1.

5.4.5.2 Qualification criteria

The overall speed of the service robot shall be controlled within a certain range, to ensure that the moving parts do not exceed the safety-related speed limit. The design and manufacture of safety-related speed control shall ensure that, when an error occurs, the speed of the end effector and other parts of the operating machine, will not exceed the safety-related speed limit; meanwhile when an error occurs, it shall activate a safe state.

If the function of the service robot is realized through a safety-related control system, the safety category of the safety parts of the control device shall

autonomous motion mode, which is specified in the manual.

Note: See A, B, D of 5.1 for inspection methods.

5.4.7.2 Qualification criteria

During the test, the service robot shall meet the following requirements:

- The service robot shall not fall outside the test area;

- The service robot can detect this height difference, take some evasive measures (such as braking, backing up, detouring, etc.).

5.4.8 Verification of singularity limitation

5.4.8.1 Test procedure

For service robots with singularities in the process of movement, estimate the state of singularities according to the structural characteristics of the service robot, that is, the position of each axis of the service robot's operating arm. The end effector of the service robot moves along a straight line; the straight-line movement shall include the estimated state. Observe the movement of the service robot.

Note 1: For the movement of the service robot through the singularities, it may take one or more of the following measures:

a) Control the movement through the singularity to avoid danger;

b) Service robots shall avoid singularities, for example, achieved by adjusting path planning;

c) Stop the movement of the service robot and issue a warning before the service robot passes the singularity OR avoid it during coordinated movement.

Note 2: For inspection methods, see A, B, D of 5.1.

5.4.8.2 Qualification criteria

The service robot shall not have unforeseen movement conditions (including irregular shaking, sudden stop of movement, etc.). It is necessary to deal with the singularity problem, during the operation of the service robot, through the essential design of the control program, including the processing of the Jacobian matrix, speed limit, etc., to ensure that the service robot shall not cause unpredictable movement speed and direction, due to the singularity.

5.4.9 Verification of wireless control

structure.

Example: If it needs to use casters and support devices during the normal operation of a service robot, it shall place the casters and support devices in the most unfavorable position, so that the wheels and similar devices are locked or blocked. However, if the casters are only used to carry the service robot AND the installation instructions require the support device to be lowered after installation, THEN, during the test, use the support device (not the casters) AND place the support service robot in the most unfavorable position, which is consistent with the natural level of service robot.

Note 1: After evaluation, if the service robot does not have the wheels locked during the expected use, it is not necessary to lock the wheels in the subsequent test.

Note 2: This article only applies to service robots, that are expected to be used on the ground.

Where applicable, the following tests are used to check whether it is qualified; each test shall be carried out separately:

1) Slope stability

Place the service robot on the slope, which is specified by the manufacturer, in the most unfavorable direction; arrange it in the above manner; visually inspect it.

2) Horizontal stability

- For a service robot, which has a mass equal to or greater than 25 kg, at a height of no more than 2 m from the ground, apply a force, which is equal to 20% of the service robot's weight, but not more than 250 N, in any direction (except the upward direction), to the service robot. At the same time, all doors and drawers, which are scheduled to be opened by the operator or maintenance personnel, shall be placed in the most unfavorable position, according to the installation instructions;

- For service robots used on the ground, at a height of up to 1 m from the ground, apply a constant downward force of 800 N to any point, that can generate the maximum moment, on any level planes, which have a length and width of at least 125 mm × 200 mm, THEN, the service robot shall not tip over. During this test, doors, drawers, etc. shall be closed tightly. The 800 N force may be applied by a suitable test tool, which has a plane of approximately 125 mm × 200 mm. The entire plane of the test tool is brought into contact with the equipment under test (EUT), to apply a downward force. The test tool does not have to be in full contact with uneven surfaces, for example, grooved or curved surfaces.

For the various hazards of the service robot, it shall, through risk assessment, determine whether it is necessary to stick markings to the corresponding location where the hazard occurs OR to a conspicuous location nearby. The style of the markings shall comply with ISO 7010.

Note: Refer to Appendix F for the identification of various hazards of service robots.

6.2 Durability of marking

Any marking required by Chapter 6 shall be durable and eye-catching. When considering the durability of the marking, it shall take into consideration of the effect on the marking during normal use.

Check whether it is qualified by checking and wiping the mark. When wiping the mark, use a cotton cloth, which was dipped in distilled water, to wipe it by hand for 15 s. THEN, use a cotton cloth, which was dipped in solvent oil, to wipe it by hand for 15 s. After the test in this article, the mark shall still be clear; the marking nameplate shall not be easily peeled off; there shall be no curling.

The volume fraction of the maximum aromatic hydrocarbon content of the aliphatic hydrocarbon hexane solvent of the refined mineral spirits, which are used for the test, is 0.1%. The kauri butanol (dissolved solution) value is 29. The initial boiling point is about 65 °C. The drying point is about 69 °C. The mass per unit volume is about 0.7 kg/L.

As an alternative, a minimum of 85% reagent grade hexane is allowed as n-hexane.

Note: The name n-hexane is the chemical term "normal" or linear hydrocarbon. This solvent oil may later be recognized as a certified ACS (American Chemical Society) reagent grade hexane.

7 Documentation requirements

7.1 Instruction manual

Information related to machinery safety shall be in the user manual or other written instructions (such as the instructions on the packaging).

7.2 Documents in packing box

The following documents (can be combined for printing) shall be included in the packaging box of the service robot:

a) Packing list;

b) Instructions for use (it shall include size and weight);

Appendix A

(Normative)

Determination of accessible parts

A.1 Accessible parts of service robots

A.1.1 Basic requirements

The accessible parts of the service robot are parts, that can be touched by the human body. In order to determine the accessible parts, one or more specific test tools are used to represent the body parts.

Accessible parts of the service robot may include rear parts, such as doors, panels, removable covers, that can be opened without tools.

Accessible parts do not include those parts, that become accessible when a floor-standing service robot, with a mass of more than 40 kg, is tilted.

For service robots that are scheduled to be embedded or rack-mounted, OR for components that are scheduled to be installed in large-scale service robots, the accessible parts do not include those parts, that are inaccessible, after the service robot or components are installed, according to the installation method specified in the installation manual.

If it needs to touch a part, according to the instructions or signs, the part is considered to be accessible. There is no need to test in this situation; meanwhile it does not consider whether it is accessible by the use of tools.

A.1.2 Test method 1 - Use hinged test tool to test the surface and opening

For the surface and opening, the following articulated test tools shall be applied to the surface and opening of the service robot, without any obvious force AND in any possible orientation:

- For service robots that may be touched by children, the test tool as shown in Figure A.1;

Note 1: Service robots, which are scheduled to be used in homes, schools, public places and similar places, are generally considered service robots accessible to children.

- For service robots that cannot be touched by children, the test tool as shown in Figure A.2.

Appendix C

(Normative)

Static and dynamic stability test of service robot

C.1 Static stability test of service robot

The static stability test of the service robot is as follows:

1) Hard test platform: A platform that can accommodate the tested sample; the flatness error is not more than 5 mm;

2) Regulating device: A device used to adjust the angle of the inclined plane of the test platform.

Note 1: If the increase in the inclination of the test platform is stepless, when approaching the tilt angle, the increase in the inclination shall not be greater than 1°/s. If the increase in the slope of the test platform is progressive, each level shall not be too large, so as not to affect the accuracy of the measured tilt angle.

3) Anti-rolling device: A device, which is used to prevent the service robot from rolling on an inclined surface, during the test. It does not affect the service robot to freely rotate AND tilt around the corresponding axis.

4) Anti-slip device: A device, which is used to prevent the service robot from sliding on an inclined surface, during the test. It does not affect the free rotation AND tipping of the contact point between the service robot and the test surface.

Note 2: When the wheels at the lower end of the inclined plane are braked, the method of placing a stop under these wheels is inappropriate, because this will change the tipping point of rotation.

5) Device to limit the degree of tilting: A device, which is used to limit the degree of tilt of the service robot on the test platform. This device does not affect the stability of the service robot, BUT only restricts the service robot from over-tilting or deforming.

6) Device for measuring angle: A device for measuring the angle BETWEEN the test platform AND the horizontal plane, which has a measurement accuracy of ± 0.2°.

C.2 Dynamic stability test of service robot

The dynamic stability test of the service robot is as follows:

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