DRAFT INTERNATIONAL STANDARD
ISO/DIS 18646-4

ISO/TC **299** Secretariat: **SIS**

Voting begins on:
2020-01-31

Voting terminates on:
2020-04-24

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

Part 4:
Lower-back support robots

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

ICS: 25.040.30

This document is circulated as received from the committee secretariat.

Reference number
ISO/DIS 18646-4:2020(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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

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

ISO 18646-4 is intended to facilitate understanding of performance of lower-back support robots. This standard defines the important performance characteristics, describes how they shall be specified, and recommends how they should be tested.

The characteristics for which test methods are given in this International Standard are those considered to affect robot performance significantly. The user of this International Standard selects which performance characteristics are to be tested, in accordance with the specific requirements.

The performance criteria specified in this part of International Standard should not be interpreted as the verification or validation of safety requirements. The verification and validation of safety requirements will be specified in other standards developed by ISO TC 299.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this part of ISO 18646 can involve the use of patents concerning the test machines of the performance of wearable robots for lower-back support referred to throughout the document. ISO takes no position concerning the evidence, validity, and scope of these patents.

The holders of these patents have assured ISO that they are willing to grant free licences or negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patents right are registered with ISO.

Robotics — Performance criteria and related test methods for service robots — Part 4: Lower-back support robots

1 Scope

This International Standard describes methods of specifying and evaluating the performance of lower-back support robots.

This standard applies regardless of the purpose and application of lower-back support robots and the driving methods (e.g. electric, hydraulic, pneumatic, etc.). This standard does not apply to medical robots, although the test methods specified in this standard can be utilized for medical robots.

This International Standard is not intended for the verification or validation of safety requirements.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8373:2012, ISO 13482:2014 and the following 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, moving within its environment, to perform intended tasks

Note 1 to entry: A robot includes the control system and interface of the control system.

Note 2 to entry: The classification of robot into industrial robot or service robot is done according to its intended application.

[SOURCE: ISO 8373:2012, 2.6, modified to add “programmed” and removed mention of axes]

3.2
wearable robot
robot that supplements or augments of personal capabilities while attached to a human during use

Note 1 to entry: Wearable robots are referred to as restraint-type physical assistant robots in ISO 13482:2014.

3.3
lower-back support robot
wearable robot to reduce the load in the lower back of the user by its assistive force or torque

3.4
user
person wearing a wearable robot to his/her body and directly receives its assistive force or torque

[SOURCE: ISO 13482:2014, 3.26, modified]

3.5
operator
person designated to make parameter and program changes, and to start, monitor, and stop the intended operation of the wearable robot

Note 1 to entry: An operator may be the same person as a user.

[SOURCE: ISO 13482:2014, 3.25, modified]

3.6
attach
fastening of the wearable robot on the user to start using the robot

3.7
detach
unfastening of the wearable robot from the user when finished using the robot

3.8
restraint part
part of the wearable robot binding a corresponding attached body part of the user to transmit an assistive force or torque

3.9
assistive torque
output torque of the wearable robot to assist a user to perform required tasks

3.10
attached body part
part of the user's body attached to the restraint part of the wearable robot

3.11
input method
interface allowing the user to control the assistive force or torque of the wearable robot by an appropriate input signal

3.11.1
biological input
input method where biological signals that are in correlation to the force or torque the user exerts at his/her body part intended for assistance are used as the input

Note 1 to entry: Biological signals include bioelectrical signals.

3.11.2
kinematic input
input method where movement and/or posture of the user's body parts intended for assistance are used as the input

3.11.3
command input
any other input method different from biological input or kinematic input

Note 1 to entry: Command input includes the use of commanding devices, breath switches or voice input.

Note 2 to entry: Command input includes the use of biological signals that are not in correlation to the force or torque the user exerts at the body part intended for assistance.

Note 3 to entry: Command input includes movement and/or posture of the user's body parts not intended for assistance.

3.12
assistive torque index
ATI
measure of how much the output torque of the user is reduced when the user performs a specific movement during a specific time range using the lower-back support robot

3.13
lumbar compression reduction
LCR
measure of how much the compressive force on the user's lumbar disks is reduced when the user performs a specific movement during a specific time range using the lower-back support robot

4 Test conditions

4.1 General

The lower-back support robot shall be completely assembled, sufficiently charged and operational. All self-diagnostic tests shall be satisfactorily completed. It should also be ensured that the robot operates in a safe manner throughout the test.

The tests shall be preceded by the preparations for operation as specified by the manufacturer.

All conditions specified in Clause 4 should be satisfied for the tests described in this standard, unless it is stated otherwise in the specific clauses.

Each test described in each clause of this standard may have different test configurations which require separate test procedures. For each test configuration, multiple trials can be conducted, if specified in the test procedure.

4.2 Environmental conditions

The following environmental conditions shall be maintained during all tests.

— Ambient temperature: 10 – 30 degrees in Celsius

— Relative humidity : 0 – 80%

If the environmental conditions specified by the manufacturer are outside the given conditions, then it shall be declared in the test results.

4.3 Operating conditions

All performance shall be measured under normal operating conditions. When the performance is measured in other conditions, it shall be declared together with the test results.

5 Test method for assistive torque index and lumbar compression reduction

5.1 Purpose

This clause describes the methods of specifying and evaluating the performance of lower-back support robots.

Note: Theoretical backgrounds and validation experiments are provided in [6].

5.2 Relevant characteristics

5.2.1 General

Two performance indices are introduced for this test method: Assistive torque index (ATI) and Lumbar compression reduction (LCR).

By assistive torque of the robot, user's extension force of hip joints and/or trunk would be reduced and then compressive force on his/her lumbar disks might be reduced. Ideally, lumbar compression should be proportional to the extension force of user's hip joint and the posture of the trunk. And the extension force can be reduced by the assistive torque of the robot. Therefore, for the robot with such characteristics, lumbar compression is not needed to be measured because lumbar compression can be inferred from assistive torque and the posture.

For some robots for which lumbar compression could be increased because of robot's mechanical structure, mass and mass distribution above the lumbar joint and/or actuation method (e.g. artificial muscles on user's back skin), lumbar compression should be measured together with assistive torque.

Note: According to [1], compressive force on his/her lumbar disks might be the major cause of back injury and, therefore, often used as an index to estimate the risk of back injury. Based on this background, LCR is introduced as a performance indication of the robot.

5.2.2 Assistive torque index (ATI)

The Assistive Torque Index (ATI) consists of 5 representative values $\mathrm{ATI}_{1000}^{\mathrm{Lower}}$, $\mathrm{ATI}_{200}^{\mathrm{Lower}}$, $\mathrm{ATI}_{1000}^{\mathrm{Hold}}$, $\mathrm{ATI}_{1000}^{\mathrm{Raise}}$ and $\mathrm{ATI}_{200}^{\mathrm{Raise}}$, which are calculated by the following equations with t_1 and t_2 specified in Table 1. The superscript and the subscript of ATI indicate a phase of reference movement and a time duration in milliseconds, respectively.

$$\mathrm{ATI}_{t_2-t_1} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \psi\left(\tau^{\mathrm{ref}}(t), \tau(t)\right) dt$$

where

$$\psi(x, y) = \begin{cases} x - y & \text{if } x \geq 0 \\ -(x - y) & \text{if } x < 0 \end{cases},$$

$\tau^{\mathrm{ref}}(t)$ is the actual output torque of the hip joints of the test machine (see 5.3.1) during the reference movements without robot;

$\tau(t)$ is the actual output torque of the hip joints of the test machine (see 5.3.1) during the reference movements with the robot.

Note 1: In general, assistive torque of the robot interferes the duration of the movement and the necessary force or torque of the user. This is a source of instability of the test results. Therefore, this standard adopts a time average within a specific time range during the reference movements.

Note 2: Because the reference movements defined in 5.3.2 are antigravity movements, $\tau^{\mathrm{ref}}(t)$ is expected always negative and the relationship $\psi(x, y) = -(x - y)$ always applies. However, this standard defines ψ in a more general form to make ψ positive when the necessary torque for the reference movement and the torque of the robot are in the same direction.

Note 3: When ψ is positive, the torque of the robot in the antigravity direction (extension) can reduce the necessary torque of the user to achieve the reference movements. Or, in some cases, the user has to output the torque in the gravity direction (flexion) to resist the torque of the robot. When ψ is negative, the torque of the robot in the gravity direction (flexion) can increase the necessary torque of the user to achieve the reference movements.

5.2.3 Lumbar compression reduction (LCR)

The Lumbar Compression Reduction (LCR) consists of 5 representative values $\mathrm{LCR}_{1000}^{\mathrm{Lower}}$, $\mathrm{LCR}_{200}^{\mathrm{Lower}}$, $\mathrm{LCR}_{1000}^{\mathrm{Hold}}$, $\mathrm{LCR}_{1000}^{\mathrm{Raise}}$ and $\mathrm{LCR}_{200}^{\mathrm{Raise}}$, which are calculated by the following equations with t_1 and t_2 specified in Table 1. The superscript and the subscript of LCR indicate a phase of reference movement and a time duration in milliseconds, respectively.

$$\mathrm{LCR}_{t_2-t_1} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \psi\left(F^{\mathrm{ref}}(t), F(t)\right) dt$$

where

$$\psi(x, y) = \begin{cases} x - y & \text{if } x \geq 0 \\ -(x - y) & \text{if } x < 0 \end{cases},$$

$$F^{\mathrm{ref}}(t) = \phi\left(M_y^{\mathrm{ref}}(t)\right) + F_z^{\mathrm{ref}}(t),$$

$$F(t) = \phi\left(M_y(t)\right) + F_z(t),$$

$$\phi(x) = \begin{cases} x/0.05 & if\ x \geq 0 \\ -x/0.1 & if\ x < 0 \end{cases},$$

$F_z^{\mathrm{ref}}(t)$ is the actual lumbar compressive force of the test machine in z-axis direction during the reference movements (without robot);

$F_z(t)$ is the actual lumbar compressive force of the test machine in z-axis direction during the reference movements (with robot);

$M_y^{\mathrm{ref}}(t)$ is the actual lumbar bending moment of the test machine around y-axis during the reference movements (without robot);

$M_y(t)$ is the actual lumbar bending moment of the test machine around y-axis during the reference movements (with robot).

Note 1: In general, assistive torque of a robot interferes the duration of the movement and the compressive force on the lumbar disks of the user. This is a source of instability of the test results. Therefore, this standard adopts a time average within a specific time range during the reference movements.

Note 2: A human would stiffen his/her muscles to resist the change of posture by the lumbar bending moment around the y-axis. This tension of the muscles is known as a source of compressive force on lumbar disks. On the other hand, the test machine does not have muscles and its mechanical structure of back does not allow any change of posture unlike the spine. Because of this, the equation for LCR uses the corrected lumbar compressive force $F(t)$ and $F^{\mathrm{ref}}(t)$ under the assumption that $M_y(t)$ and $M_y^{\mathrm{ref}}(t)$ are all supported by virtual erector spinae muscles and virtual abdominal rectus muscles. This standard adopts a 0.05 m moment arm from the L5/S1 lumbar disk to the virtual erector spinae muscles and a 0.1 m moment arm to the virtual abdominal rectus muscles [4][5].

Note 3: During the reference movement, the weight of the upper body of the test machine is expected to always compress the fixed lumbar joint and $\psi(x, y) = x - y$ always applies. However, this standard defines ψ in a more general form to be applicable to tensile forces and to be consistent to the equation of ATI.

Note 4: When ψ is positive, the lumbar stress of the user is expected to be reduced during the reference movement. When ψ is negative, the lumbar stress of the user is expected to be increased during the reference movement.