SLOVENSKI STANDARD
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Kmetijski stroji in traktorji - Varnost delno avtomatiziranih, polavtonomnih in avtonomnih strojev - 4. del: Metode preverjanja in načela validacije (ISO/DIS 18497 -4:2022)

Agricultural machinery and tractors - Safety of partially automated, semi-autonomous and autonomous machinery - Part 4: Verification methods and validation principles (ISO/DIS 18497-4:2022)

Landmaschinen und Traktoren - Sicherheit von teilautomatisierten, halbautonomen und autonomen Maschinen - Teil 4: Verifizierungsmethoden und Validierungsgrundsätze (ISO/DIS 18497-4:2022)

Tracteurs et matériels agricoles - Sécurité des machines partiellement automatisées, semi-autonomes et autonomes - Partie 4: Méthodes de vérification et principes de validation (ISO/DIS 18497-4:2022)

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Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery —

Part 4:
Verification methods and validation principles

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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 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 144, *Tractors and machinery for agriculture and forestry,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 18497-4, together with ISO 18497-1[1)], ISO 18497-2[1] and ISO 18497-3[1], cancels and replaces ISO 18497:2018, which has been technically revised.

The main changes compared to the previous edition are as follows:

— Verification methods and validation principles were made its own part (ISO 18497-4) and substantially revised to account for the wide range of functionality and use cases within agricultural machines and tractors

A list of all parts in the ISO 18497 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.

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Introduction

This document is a type-B1 standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

In addition, this document is intended for standardization bodies elaborating type-C standards.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The structure of safety standards in the field of machinery is as follows:

— Type-A standards (basis standards) give basic concepts, principles for design, and general aspects that can be applied to machinery;

— Type-B standards (generic safety standards) deal with one or more safety aspects or one or more types of safeguards that can be used across a wide range of machinery:

  — Type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);

  — Type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards);

— Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

The purpose of this standard is to establish general design principles for partially automated, semi-autonomous and autonomous (see ISO 18497-1[2)]) functions of agricultural machinery and tractors.

Manual non-automated functions are addressed in existing agricultural machinery and tractor safety standards. Due to the potential number of different functions of agricultural machinery and tractors and the mixed type and mode to which these functions can exist, it is necessary to establish general design principles. In this way, the combination, operator location, and types of interaction of these functions can be guided so that further type-C safety standards can be developed consistently and explicitly to address the mitigation of risk of injury to operators and bystanders. This is the primary focus of safety standards. Attempting to define risk mitigation requirements based on combinations of

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type and mode of functions alone cannot be accomplished accurately for all agricultural machinery and tractors due to the wide variety of the machinery and variety of functionality.

Therefore, the familiar representation of SAE J3016[1] with six levels of automation was deliberately not chosen as a basis for this standard and it is necessary to develop more specific type-C safety standards, using the general design principles of this document, to adequately account for the risks of agricultural machinery and tractors used in a specified way with various types of partially automated, semi-autonomous and autonomous functions.

When requirements of this document for partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors are different from those which are stated in a machine-specific type-C standard dealing with partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors, the requirements of the machine-specific standard take precedence over the requirements of this document.

Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery —

Part 4: Verification methods and validation principles

1 Scope

This International standard specifies principles for verification methods and validation principles of agricultural machinery and tractors that are used in agricultural applications and that have partially automated, semi-autonomous and autonomous functions.

The purpose of this document is to assist in the provision of more specific safety requirements, means of verification and information for use to ensure an appropriate level of safety for agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions used in a specified way.

This document deals with all the significant hazards, hazardous situations and events, relevant to agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions when used as intended and under the conditions of misuse foreseeable by the manufacturer during normal operation and service.

Applicability of the design principles and any additional requirements, for design, verification, validation or information for use are outside the scope of this document. When risk assessment concludes that hazards are not significant hazards, the principles of this document do not apply.

NOTE Safety requirements for specific non-automated functions of agricultural machinery and tractors can be available in machine-specific type-C standards.

This document is not applicable to:

— forestry applications;

— operations on public roads including relevant requirements for braking and steering systems.

This document is not applicable to agricultural machinery and tractors which are manufactured before the date of its publication, or to systems applied to agricultural machinery and tractors put into use before the date of its publication.

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 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO 18497-1[3)], *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 1: Machine design principles and vocabulary*

ISO 18497-2[3], *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 2: Design principles for obstacle protective systems*

ISO 18497-3[3], *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 3: Design principles for autonomous operating zones*

ISO 25119-1:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development*

ISO 25119-1:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development — Amendment 1*

ISO 25119-2:2019, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 2: Concept phase*

ISO 25119-3:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software*

ISO 25119-3:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software — Amendment 1*

ISO 25119-4:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes*

ISO 25119-4:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes — Amendment 1*

3 Terms and definition

For the purposes of this document, the terms and definitions given in ISO 18497-1[3] 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 https://www.electropedia.org/

4 Verification methods and validation principles

4.1 General

Design of machine systems, obstacle protective systems and autonomous operating zones of agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions (see Figure 1) shall comply with ISO 18497-13, ISO 18497-2[3], and ISO 18497-3[3] respectively.

For ensuring an appropriate level of safety the verification methods of 4.2 and validation principles of 4.3 shall be applied for protective or risk reduction measures of significant hazards when used in the machine design.

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<table>
<tr><td></td><td>Manual Non-Automated (see ISO 18497-1[4], 3.1)</td><td>Partially Automated (see ISO 18497-1[4], 3.2)</td><td>Semi-Autonomous (see ISO 18497-1[4], 3.3)</td><td>Autonomous (see ISO 18497-1[4], 3.4)</td></tr>
<tr><td rowspan="2">Functions (see ISO 18497-1[4], 3.5)</td><td colspan="3">Non-Automated (see ISO 18497-1[4], 3.6)</td><td></td></tr>
<tr><td></td><td colspan="3">Automated (see ISO 18497-1[4], 3.7)</td></tr>
<tr><td rowspan="2">Modes</td><td colspan="3">Manual Mode (see ISO 18497-1[4], 3.9)</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="2">Autonomous Mode (see ISO 18497-1[4], 3.10)</td></tr>
</table>

Figure 1 — Terms used for combinations of functions and modes (see ISO 18497-1[4])

4.2 Verification methods

4.2.1 Verification shall be carried out by the collection of data and results from the verification methods listed in this clause. Table 1 below provides the minimum verification methods for each part of ISO 18497. Depending on the design and implementation of the protective or risk reduction measures, other verification methods may also be used. More detailed verification methods for a specific use case or type of machine may be given in type-C standards.

a) Inspection/observation – visual and/or audible evaluation without any specialized equipment

b) Measurement – evaluation of physical values of components or systems of the machine to specified values or limits

c) Test – evaluation of components or systems of the machine under normal and abnormal conditions

   — Functional tests (e.g. fault injection testing)

   — Cyclic tests (e.g. endurance testing)

   — Performance tests (e.g. braking, steering, persons and/or obstacle detection tests)

d) Simulation – virtual evaluation of functions and performance of components or systems of the machine with anticipated environmental and operating stresses

e) Analysis – evaluation of inspection/observation, measurement, test and simulation methods in addition to the design and its specifications through qualitative and quantitative means

   — Failure modes and effects analysis (FMEA)

   — Fault tree analysis (FTA)

   — Estimation / prediction by simulation models (e.g. Markov models, reliability models)

   — Formal design review

NOTE 1 Annex A gives information regarding physical properties of objects and humans for use in development of test and simulation verification methods.

NOTE 2 Annex B gives information regarding environmental influences for use in development of test and simulation verification methods.

NOTE 3 Annex C gives information regarding test objects for use in development of test and simulation verification methods.

NOTE 4 Annex D gives information regarding examples of test procedures.

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Table 1 — List of verification methods of protective or risk reduction measures

ISO 18497	Subclause	Inspection / observation	Measurement	Test	Simulation	Analysis
ISO 18497-1[a]	4.2.1.1; 4.2.1.2 a), b)	X		X		
ISO 18497-1[a]	4.2.2.1 a); 4.2.2.2 a), b)	X			X	
ISO 18497-1[a]	4.2.3.1 a)	X				
ISO 18497-1[a]	4.2.3.1 b)	X			X	
ISO 18497-1[a]	4.2.3.1 c), d)	X		X		
ISO 18497-1[a]	4.2.3.2 a)	X				
ISO 18497-1[a]	4.2.3.2 b), c), d), e), f), h)	X			X	
ISO 18497-1[a]	4.2.3.2 g)	X		X		
ISO 18497-1[a]	4.2.4.1 a)	X				
ISO 18497-1[a]	4.2.4.2 a), b), c), d)	X				
ISO 18497-1[a]	4.2.5.1 a)	X				
ISO 18497-1[a]	4.2.5.2 a), b), c), d)	X				
ISO 18497-1[a]	4.2.6.1 a), b)	X		X		
ISO 18497-1[a]	4.2.6.2 a), b)	X		X		
ISO 18497-1[a]	4.2.7.1 a), b), c)	X		X		
ISO 18497-1[a]	4.2.8.2 a)	X				
ISO 18497-1[a]	4.2.8.2 b)	X			X	
ISO 18497-1[a]	4.2.9.1; 4.2.9.2; 4.2.9.3 a); 4.2.9.4 a), b)				X	X
ISO 18497-1[a]	4.3.1; 4.3.2.1.1	X				
ISO 18497-1[a]	4.3.2.1.2; 4.3.2.1.3, 4.3.2.1.4	X	X			
ISO 18497-1[a]	4.3.3.1.1; 4.3.3.1.2; 4.3.3.1.3; 4.3.3.1.4	X				
ISO 18497-1[a]	4.4; 4.5	X				X
ISO 18497-2[a]	4.2.2.1 a)			X	X	
ISO 18497-2[a]	4.2.2.1 b)	X			X	
ISO 18497-2[b]	4.2.2.1 c)			X		X
ISO 18497-2[b]	4.2.3.1	X		X		
ISO 18497-2[b]	4.2.4.1; 4.2.5.1; 4.2.6.2	X				
ISO 18497-2[b]	4.2.7.1; 4.2.7.2; 4.2.7.3				X	X
ISO 18497-2[b]	4.3; 4.4	X				X
ISO 18497-3[b]	4.2.2.1 a)			X	X	
ISO 18497-3[b]	4.2.2.1 b)	X			X	
ISO 18497-3[b]	4.2.2.1 c)			X		X
ISO 18497-3[b]	4.2.2.2 a)			X	X	
ISO 18497-3[b]	4.2.2.2 b)	X			X	
ISO 18497-3[b]	4.2.2.2 c)			X		X
ISO 18497-3[b]	4.2.3.1; 4.2.3.2	X		X		
ISO 18497-3[b]	4.2.4	X				

[a] Under preparation

[b] Under preparation

Table 1 *(continued)*

ISO 18497	Subclause	Inspection / observation	Measurement	Test	Simulation	Analysis
ISO 18497-3[b]	4.2.5.1; 4.2.5.2; 4.2.5.3				X	X
ISO 18497-3[b]	4.3; 4.4	X				X
[a] Under preparation						
[b] Under preparation						

4.3 Validation principles

Validation shall be carried out for the design objectives of protective or risk reduction measures in the machine design by applying the validation principles listed in this clause.

a) Evaluation of used verification methods from 4.2.1:

   — Appropriate tests, test methods, setup, conditions and procedures;

   — Appropriate simulations, simulation methods, setup, conditions and procedures;

   — Appropriate analysis methods

b) Evaluation of risk reduction level as intended per ISO 12100:2010

c) Evaluation of functional safety performance level as intended per ISO 25119-1:2018, ISO 25119-1:2018/AMD 1:2020 and ISO 25119-2:2019 and ISO 25119-3:2018, ISO 25119-3:2018/AMD 1:2020 and ISO 25119-4:2018, ISO 25119-4:2018/AMD 1:2020, or ISO 13849-1:2015 and ISO 13849-2:2012

d) Evaluation of information for use:

   — found in ISO 18497-1[4], 4.5;

   — found in ISO 18497-2[4], 4.4;

   — found in ISO 18497-36[5)], 4.4.

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Annex A
(informative)

Information regarding physical properties of objects and humans for use in development of test and simulation verification methods

A.1 Physical properties of objects

The physical properties of an object can include, but are not limited to:

— absorption (physical)

— absorption (electromagnetic)

— area

— capacitance

— colour

— density

— dielectric

— ductility

— elasticity

— electric charge

— electrical conductivity

— electrical impedance

— electric field

— emission

— flow rate

— fluidity

— frequency

— hardness

— inductance

— intrinsic impedance

— intensity

— irradiance

— length

— location

— luminance

— luminescence

— malleability

— magnetic field

— opacity

— permeability

— permittivity

— radiance

— reflectivity

— strength

— temperature

— thermal conductivity

— velocity

— volume

A.2 Human dimensions

The following are sources for human adult and child anthropometric data:

— ISO 7250 (all parts)([20] to[22])

— Japanese children size DATA "Report of children size Data Base for increasing safety of machinery 2008", by the Japan Machinery Federation and Research Institute of Human Engineering for Quality Life[23]

— "Physical Characteristic of Children – As related to Death and Injury for Consumer Product Design an Use", UM-HSRI-BI-75-5 Final Report Contract FDA-72-70 May 1975, https://math.nist.gov/~SRessler/anthrokids/child.html[24]

NOTE 1 CEN/CENELEC Guide 14, Annex C and D[25] is a source of information on age specific behaviour and development which can be used to help determine appropriate ages of anthropometric data to use.

A.3 Human movement

The following are values which can be used for human movement:

— Velocity representing walking of adult persons: 0 mm/s and 1 600 mm/s

NOTE 1 1 600 mm/s for velocity is in accordance with intended use of an industrial environment as defined in ISO 13855[26].

— Acceleration of adult persons: 0 mm/s^2 and 2 000 mm/s^2

NOTE 2 2 000 mm/s^2 is the acceleration of an adult person initiating normal walking speed of 1 600 mm/s according to "Temporal symmetries during gait initiation and termination in nondisabled ambulators and in people with unilateral transtibial limb loss", Journal of Rehabilitation Research and Development. 2005 Mar-Apr;42(2):175-82, https://www.researchgate.net/publication/7797294_Temporal_symmetries_during_gait_initiation_and_termination_in_nondisabled_ambulators_and_in_people_with_unilateral_transtibial_limb_loss [27]