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Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture —

Part 2: Testing of satellite-based auto-guidance systems during straight and level travel

Tracteurs et matériels agricoles et forestiers — Modes opératoires d'essai des systèmes de positionnement et de guidage utilisés en agriculture —

Partie 2: Essai des systèmes d'autoguidage satellitaires lors de déplacements droits et horizontaux

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 12188-2 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

ISO 12188 consists of the following parts, under the general title *Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture*:

— *Part 1: Dynamic testing of satellite-based positioning devices*

— *Part 2: Testing of satellite-based auto-guidance systems during straight and level travel*

Introduction

This part of ISO 12188 provides detailed information for the dynamic testing of satellite based positioning devices or complex navigation systems (automatic steering systems) used in agriculture. The dynamic testing relies on metering geographic positioning quality when tested devices and systems are in motion resembling their use in agriculture. Various professionals need comparable and detailed information on the behaviour of such systems based on standardised test procedures. Potential users include developers and manufacturers of agricultural equipment and positioning or navigation components as well as farmers or other end users.

Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture —

Part 2:
Testing of satellite-based auto-guidance systems during straight and level travel

1 Scope

This part of the ISO 12188 specifies the process for evaluating and reporting the performance of agricultural vehicles equipped with automated guidance systems (AGS) based on a global navigation satellite system (GNSS) when operating in an automatic steering mode.

The main performance criterion is the lateral deviation of a representative point on the vehicle from a desired trajectory for that point. This performance criterion integrates the uncertainties associated with the performance of all components of the vehicle guidance system including the positioning device(s), automated steering components, and vehicle mechanisms and dynamics.

This part of ISO 12188 focuses on steady-state tracking performance of the automated guidance system while travelling on straight paths over a level surface.

2 Terms and definitions

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

2.1 General terms

2.1.1
positioning device
PD
instrument that is capable of determining and reporting the position of its antenna center point in geographic coordinates and in real time using satellite-based radio-navigation signals

2.1.2
differential correction
means of accounting for predictable geographic positioning errors in real time

2.1.3
automatically guided vehicle system
AGVS
AGS-equipped agricultural vehicle

2.1.4
representative vehicle point
RVP
fixed point relative to a vehicle or implement used to represent the location of the AGVS

2.1.5
test course
repeatable route of travel comprised of one or more test course segments typical of an agricultural field operation

2.1.6
test course segment
clearly defined continuous part of the test course that is used to estimate tracking errors of the AGVS

2.1.7
tracking sensor
instrument or instrument system designed to produce horizontal distance measurements required for error calculations that are at least ten times more accurate than the accuracy of the AGVS being tested

2.1.8
test run
one complete passage along the test course in one direction of travel

2.1.9
complete test
combination of several identical test runs performed at different times

2.1.10
A–B line
imaginary line passing through two arbitrary selected locations (A and B) used by most automated guidance systems to establish field traffic geometry

2.1.11
operator
individual operating or monitoring the AGVS being tested

2.2 Error terms

2.2.1
relative cross-track error
XTE
lateral deviation of the RVP from the desired path determined from previous paths of the RVP when guided along the same test course

2.2.2
revisit time
time elapsed between two RVP position recording events used to calculate relative XTE; e.g., measurements made in the same location along a test course during two different test runs

2.2.3
pass-to-pass error
anticipated short-term XTE with less than 15 min revisit time

2.2.4
long-term guidance error
anticipated XTE with a revisit time greater than 1 h

3 Test description

3.1 Surface conditions

The test course shall be established on a concrete pavement surface. Alternative surface conditions, e.g., agricultural field surfaces, may also be tested but must be clearly described in the test report.

3.2 Test course location

The test course location and geometry shall be documented with appropriate details to allow exact replication. The course shall have a change in elevation of no greater than 1 m. There shall be no obstructions visible from any point on the test course at the elevation of the PD antennae higher than

10 degrees above a horizontal horizon that could interfere with or block satellite signals. There shall be no metallic or other surfaces within 50 m of the course that could cause multipath interference.

3.3 Test course

The test course shall include one or more test course segments. The configuration of the test course shall allow the tested AGVS to enter and exit each designated test course segment at the test velocity and in the direction of the "test path". The test course shall allow rapid turns at the ends to maximize the ratio of time travelling through the test course segment(s) to the total test run sequence time. Each test course segment shall be at least one 100 m long preferably oriented between 35 and 55 degrees from true north.

3.4 Determination of RVP relevant position

Measurements performed by the tracking sensor shall be sufficient to determine XTE along each test course segment. Reference to the tracking sensor specifications and calibration process shall be available and cited in the test report.

3.5 Vehicle selection

Vehicle selection should be done to provide the most representative AGVS option available to producers. For every vehicle, an RVP shall be selected so that the estimated guidance error is related to the amount of skips and overlaps when performing an actual field operation. Unless specified otherwise, RVP should be a point on the ground directly between the rear wheels for tractors to be used with 3-point hitch-mounted implements, a specified drawbar pivoting point for tractors to be used with towed implements, a point on the ground directly below the midpoint of the boom for self-propelled sprayers, and a point specified distance in front of the front wheels for combines.

3.6 Test preparation

Prior to testing, all components of the AGS shall be properly installed. All firmware and user configurable settings shall be reset to default. Changes to user-configurable settings are permitted after this reset and shall be made before the initialization period and then not altered throughout an entire test. All modified settings shall be explicitly documented.

Operation manuals and other user-oriented instructions from the manufacturer shall be used to ensure full compliance with manufacturer recommendations. This requirement applies to all components of the AGVS, including the agricultural vehicle and AGS. Any significant deviation from these recommendations (e.g. reduced accuracy of differential correction service, degraded vehicle stability, non-recommended instrumentation settings, and other scenarios of special interest) require a separate complete test.

3.7 Test procedure

The following listing describes the test run sequences.

— The A–B line shall be established at least 1 h prior to the first test run sequence by manually driving the test vehicle along the test course or by entering specified geographic coordinates. Points A and B shall represent approximate beginning and end of the longest test course segment.

— Each complete test for a given travel speed shall consist of a minimum of three test run sequences performed with different configurations of GNSS constellation during two consecutive days. The start time for each test run sequence shall be assigned randomly. To ensure diversified quality of GNSS positioning, consecutive test run sequences shall be separated by more than 1 h. In addition, two test run sequences shall not be conducted when the GNSS constellation is repeated due to the satellite orbiting cycle (24 ± 1 h for GPS). More than a 24 h time period is required between the first and the last test run sequences.

— Each test run sequence shall consist of a combination of test runs that provide an evenly spread distribution of revisit time for RVP position pairs that can be used to calculate pass-to-pass error values. This should be accomplished by travelling for at least 7,5 min in one direction, turning around and travelling 7,5 min back to the start. The horizontal distance between RVP positions, recorded when travelling in opposite direction, shall represent XTE for every discrete portion of test course segments. Repeating the first pass after turning around will allow two independent estimates of pass-to-pass error for every value of revisit time under 15 min.

— In case a test course combines more than one test course segment and/or requires a significant portion of a test run to occur outside the designated test course segments, the distribution of revisit time for valid RVP position records shall not have more than a 25 % data gap (revisit time with no corresponding data), and no such gaps are allowed between 12 min and 15 min as greater errors could be observed with longer revisit times.

— Each test run sequence shall be performed at a constant travel speed when moving forward with constant engine speed setting (as performing field operations). No operator actions are allowed while travelling through a test course segment where test data are being recorded. For tractors, it is recommended to use three different speeds: slow (0,1 ± 0,05 m/s or the minimum recommended for the vehicle in use), medium (2,5 ± 0,2 m/s), and fast (5 ± 0,2 m/s). If travelling at 0,1 m/s with automatic steering mode engaged is not feasible, the lowest possible travel speed shall be used and a corresponding note shall be provided in the report. Test data corresponding to each travel speed as well as optional travel in reverse shall be processed independently. The medium travel speed is recommended for combines and fast travels speed for self-propelled sprayers.

— Relative RVP position measurements shall be performed by tracking sensor at a sampling rate at least 10 Hz. All valid data records (e.g., excluding erroneous tracking sensor measurements) inside a designated test course segment shall be used to calculate the corresponding relative XTE estimates (pass-to-pass and long-term guidance errors). At least 10 s shall be allowed for AGVS to be in steady-state operation before entering each designated test course segment.

4 Test report and calculations

4.1 Test report generation

A test report based on the data collected shall be generated for every AGVS tested. Separate test reports are needed for each vehicle, positioning device, differential correction service, travel speed and/or other options that may affect AGVS performance.

Every test report shall list primary information on the tested product as well as the time and location of the test. At a minimum, the following information shall be included:

— reference to the testing facility and authorities, including: name(s), description of the test course (location and geometry) and tracking sensor;

— information about AGS tested, including: make and brand of the AGS, list of major components installed as a part of the AGS (including an as-tested photograph), firmware version number and the date of its release to customers, brand of the positioning device and description of the differential correction service, and any positioning device and/or control unit settings that might affect the system's performance;

— information about the vehicle tested, including: make, model and configuration of the vehicle used during the test, type of tires, cab suspension and other vehicle specifications that might affect automated guidance performance (e.g., key vehicle dimensions and location of the designated RVP, engine RPM);

— information about conditions of the test, including: date and time for each test run sequence, number of used satellites in view with the corresponding horizontal position dilution of precision (PDOP) values, as shown by the positioning device used for tractor guidance during each test run sequence, number of potential satellites in view with the corresponding horizontal PDOP values, as shown by a stationary receiver installed in the area (with indication of any phenomena that may reduce quality of GNSS performance), weather conditions during the test (temperature, humidity, surface conditions), solar activity quantified by the average sunspot number, distribution of the actual travel speed for valid data points (within marked test course segments);

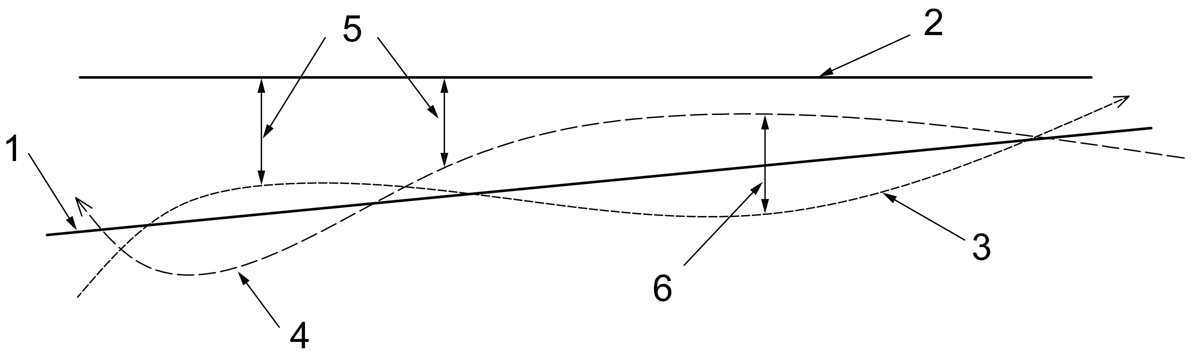
— notes on any malfunctioning, false test run sequences and other abnormal situations occurring during the test.

4.2 AGS performance and error report

AGS performance shall be quantified through the signed and unsigned distributions of pass-to-pass and the long-term guidance errors found using the tracking sensor. A signed error estimate shall be calculated as the shortest horizontal distance between any given position of the RVP and the corresponding RVP position recorded during a previous test run in the opposite direction (Figure 1). Positive error shall mean the RVP of the later pass was to the right of the track from a previous pass (based on the heading of the later pass).

Both pass-to-pass and long-term guidance errors shall be reported as signed distributions with both directional bias (average) and variability (standard-deviation) reported. In addition, cumulative distributions of the absolute (unsigned) pass-to-pass and long-term guidance errors shall be reported along with the indicated 50 %, 95 %, and maximum values of these distributions. The 95 % value of the unsigned error cumulative distribution shall be emphasized as the key quality indicator.

Distributions of revisit time for corresponding RVP position records used to calculate valid pass-to-pass error estimates shall be reported.



Key

1 A–B line
2 permanent surface marker
3 prior RVP travel path
4 later RVP travel path
5 relative position measurements by the tracking sensor
6 relative XTE

Figure 1 — Definition of relative XTE during a steady-state operation

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