DLG Test Report 6163 F

Maschinenfabrik Bernard Krone GmbH

Trimble Autopilot

Automatic Steering Systems

FOKUS TEST

10/13 Automatic Steering Systems

Test Center
Technology and Farm Inputs

www.DLG-Test.de

Overview

The Focus Test is a DLG usability test intended to allow product differentiation and special highlighting of innovations in machinery and technical products used primarily in agriculture, forestry, horticulture, fruit cultivation and viticulture, as well as in landscape and municipal management.

This test focuses on testing a product's individual qualitative criteria, e.g. fatigue strength, performance, or quality of work.

The scope of testing can include criteria from the testing framework of a SignumTest, the DLG's extensive usability test for technical products, and concludes with the publishing of a test report and the awarding of a test mark.

The DLG Focus Test "Automatic Steering Systems" includes testing the accuracy and operation of automatic steering systems in agricultural vehicles. In addition to measuring the steering accuracy under various operating conditions, examinations are also made of the behaviour during GNSS signal shading and loss of the correction signal, as well as of the operation, the system's display and control elements, the operating instructions and help functions, and the safety devices.

Other criteria were not investigated.

Assessment – Brief Summary

The Trimble steering system, which was connected via the internal ISOBUS on a Krone Big X 700 and tested in this combination, provides a system accuracy in the range of 5-7 cm in conjunction with a local RTK station.

The system exhibited high GNSS signal availability, since the GLONASS satellites are used in addition to the GPS system.

In conjunction with the correction signal transmitted via satellite, the "xFill" function delivers high correction-signal availability. The system's long-term accuracy is excellent when a stationary RTK station is used.

Table 1:
Overview of results

Steering accuracy	**95 % class***
Level 8 km/h	5 cm
Level 15 km/h	6 cm
Beam track 5 km/h	6 cm
Contour 5 km/h	6 cm
Level 8 km/h, long-term test	5 cm
Signal behaviour	**Assessment**
Behaviour on partial shading	[++]
Behaviour on correction-signal loss	[++]
Operation/ergonomics	**Assessment**
Operating instructions/help system	[o]
Operation	[o]
Terminal and control elements	[+]
Safety	**Assessment**
Safety devices acc. to ISO 10975	[+]

* Definition: 95 % of all deviations from the reference line are <= the stated error class

Evaluation range: + + / + / ○ / – / – – (○ = Standard, N/A = Not Assessed)

The Product

Manufacturer and Applicant

Manufacturer: Trimble

Product: Autopilot

Applicant:
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Description and Technical Data

In the test of the Trimble Autopilot steering system, the system was connected to a Krone Big X 700 forage harvester via an internal ISOBUS connection. Here, the steering system accesses e.g. the harvester's factory-fitted steering hydraulics.

The forage harvester has an output power of 570 kW according to the ECE R120 standard; Table 2 summarises the further technical data, the measured vehicle geometry, the tyres used, and the settings parameters used for the steering system. The steering system's settings were configured according to the manufacturer's specifications.

Table 2:
Technical data, vehicle geometry, tyres and settings parameters of the steering system

Technical data of the steering system		
Steering-system type	Trimble Autopilot	
GNSS receiver (incl. antenna)	Display: CFX 750, antenna: AG-25	
GNSS satellite reception	GPS, GLONASS (free of charge)	
Correction-signal system	Local RTK station, xFill technology (backup system following RTK failure)	
Correction-signal transmission route	Radio (local) or satellite (xFill)	
Correction-signal type	Trimble AG GPS 542 RTK station	
Signal accuracy	± 2.5 cm (RTK local)	
Technical data of the forage harvester		
Manufacturer	Maschinenfabrik Bernard Krone GmbH	
Type	Big X 700	
Power (ECE-R120)	570 kW MAX	
Max. speed	40 km/h	
Tare weight	15835 kg	
Total permitted weight	22000 kg	
Measured vehicle geometry		
Axle height, front axle – measuring point	190 cm	
Height of measuring point above ground	44 cm	
Tyres		
	Front axle	**Rear axle**
Type	Continental Contract AC70	Continental Contract AC65
Size	650/75 R32	540/65 R30
Air pressure (manufacturer's specification)	1.3 bar	1.6 bar
Steering-system settings		
Steering aggression	75	
Steering-angle sensor	Not applicable	
P-factor	Not applicable	
Steering behaviour	Not applicable	

The Method

The accuracy of the automatic steering system was determined by measurement with an optical reference system. Here, a tacheometer automatically follows a prism attached to the harvester's cutting-bar mount and records the measured values. The test setup is shown in Figure 2.

The measurements were taken on the testing ground of the DLG Test Center Technology and Farm Inputs in Groß-Umstadt (see Figure 3) and were accompanied by one of the manufacturer's staff.

All settings were configured according to the manufacturer's specifications. The following measurements were taken:

A-B run on an even track at 8 km/h or 15 km/h

The accuracy for a straight-line run was determined at various practice-relevant speeds from starting point A to end point B on the level track. To determine the long-term behaviour with respect to the stored A-B reference line, the test was repeated at 8 km/h after more than 24 hours. The size of the deviation from the reference value obtained in the reference run was determined from the root mean square of three measurement runs in each case. The results were presented in error classes of 1 cm each and the resulting 95 % sum of the error classes; i.e. 95 % of all measurements lie within this range.

A-B run on a beam track at 5 km/h

The steering system's dynamic behaviour on an uneven track was simulated reproducibly on a beam track according to the 78/764/EWG standard in order to measure the cabin and seat comfort (see Figure 4). The industry-standard practice of mounting the GNSS antenna on the cabin's roof leads to varying lateral deviations as a result of the uneven track and the cabin's suspension; these deviations must be corrected by the steering system.

A-B run on an inclined track at 5 km/h

To check the dynamic behaviour while entering and exiting an inclined track with a height of 25 cm (Figure 5), this test also shows the effectiveness of the integrated tilt compensation.

A-B run with partial GNSS shading

In practice, (partial) shading of the GNSS signal primarily occurs as a result of trees or buildings. In the test, this situation is simulated by covering the GNSS receiver with a test hood shielded to a level of 50 % with copper foil. The system's behaviour, such as a visual and acoustic response, can therefore be documented. It is also noted whether it was possible to activate the automatic steering and to drive e.g. with reduced accuracy (fall-back option) under these conditions.

A-B run with total loss of the correction signal

To simulate a total loss of the correction signal, the radio antenna

Figure 2: Measurement setup of the optical reference system

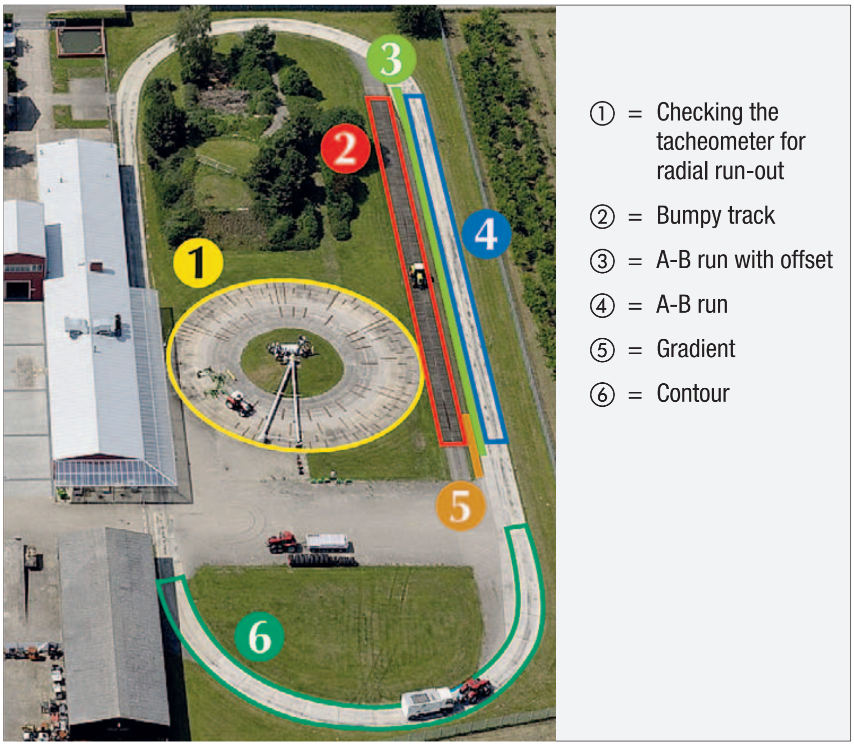

Figure 3: Measurement tracks on the testing ground

Figure 4:
Driving on the beam track at the DLG Test Center Technology and Farm Inputs

of the locally stationed RTK station was removed; to simulate the signal's return, it was reattached. In the meantime, the RTK station remained switched on. For connections via mobile communications, the receiver antenna was removed.

Contour run at 5 km/h

For the contour run (along the semicircle of the test track), a reference line was driven manually and recorded by the steering system. The deviation of the error classes is expressed in relation to the reference run.

Operation and ergonomics

In the field of operation and ergonomics, the operating instructions and/or the help system accessible in the terminal were firstly checked for completeness, clarity and comprehensibility. Further operational aids such as a quick-start guide or a help system accessible via the internet are also included in this assessment. Furthermore, the operation of the help features is tested by way of two specific questions. One was the definition of an A-B path and the other was the help offered for "Troubleshooting signal faults". The operation of the system itself was characterised by the number of operating steps needed to teach in an A-B path and the subsequent activation of the automatic steering function.

The legibility and operation of the terminal during the day and at night are particularly important for practical use. Sunlight from behind during the day is especially problematic for the users because they cannot see the display due to reflections and, where applicable, cannot operate elements on a touchscreen. At night, the terminal must not cause glare or fatigue for the driver.

The safety devices for an automatic steering system are essentially predefined in the ISO 10975 standard. For example, the presence of a driver must be verified using a seat contact, and the automatic steering must automatically deactivate itself in the event of manual intervention or signal faults. The driver should be informed of the deactivation visually or acoustically.

Figure 5:
Driving on the inclined track, 25 cm high

As shown by the example of the A-B runs at 8 or 15 km/h on a level track in Figure 7, the 95 % class of deviations is determined using the frequency distribution and the deviation class. At a driving speed of 8 km/h, the system achieved accuracy in the 5 cm class in 95 % of cases; the same applies to the long-term test after more than 24 hours. The other results are summarised in Table 3 and Figures 7 and 8.

The representation of the A-B run on the inclined track at 5 km/h (Figure 9) shows how the system responds during gradient compensation. The offset on the plateau of the ramp was approx. 10-14 cm. On entering the ramp, there was a brief overshoot in the region of approx. 17 cm; on exiting, this was in the range of approx. 20 cm. After exiting the ramp, for a short time a larger deviation of 10-20 cm from the A-B reference was observed in the level track.

To determine the accuracy in a contour run, a reference line was manually driven along the semicircular section of the test track and recorded by the steering system. The deviation in the error class (Figure 8) is expressed in relation to the reference run.

The shading and signal-loss tests yielded the results shown in Table 4.

The suggested solutions to two predefined problems were determined in order to assess the operating instructions and the help system. Firstly, an A-B path was to be defined. A good description of this can be found in the additional quick-start guide. This functional description is hard to find in the main operating instructions, as all of the device variants are summarised in one set of operating instructions. The assessment is therefore [o] = "Standard".

Table 3:
Accuracy classes achieved under various test conditions

Test condition	95 % class
A-B run on an even track at 8 km/h	5 cm
Long-term accuracy: repetition after >24h	5 cm
A-B run on an even track at 15 km/h	6 cm
A-B run on the beam track at 5 km/h	6 cm
Contour run at 5 km/h	6 cm

Secondly, an assessment was made of the troubleshooting information for signal faults occurring with the GNSS or correction signal. The main operating instructions do not provide an overview, leading to an assessment of [–] = "Worse than standard".

The additional provision of a quick-start guide and a quick-start wizard for saving recurring operating steps is considered positive, such that the operating instructions and help system were ultimately assessed as [o] = "Standard".

With regard to the system's operation, it took seven to eight operating steps to teach in an A-B path, leading to an assessment of [–] = "Worse than standard". The subsequent simple activation of the automatic steering function is achieved very easily via a release switch in the armrest and by pushing a button on the device's joystick; this was assessed as [+] = "Better than standard". The overall assessment of the operation is therefore [o] = "Standard".

Figure 6:
Control and display elements

In the specimen device, the 8"-terminal is attached to the right front bar in a low-vibration manner, and the display is adjustable in all directions (both criteria [+] = "Better than

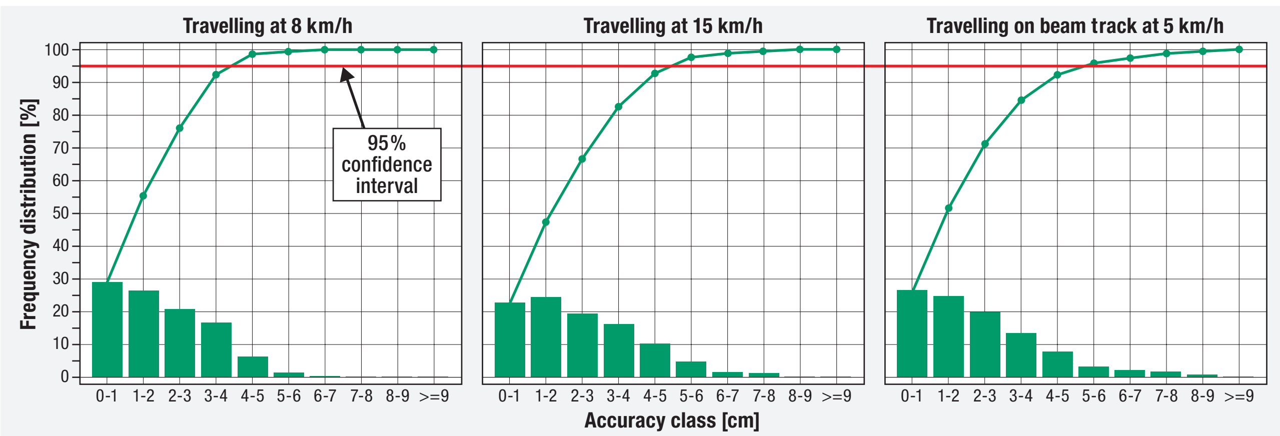

Figure 7:
Deviation rates (A-B run on a level track at 8 or 15 km/h and on a beam track at 5 km/h)

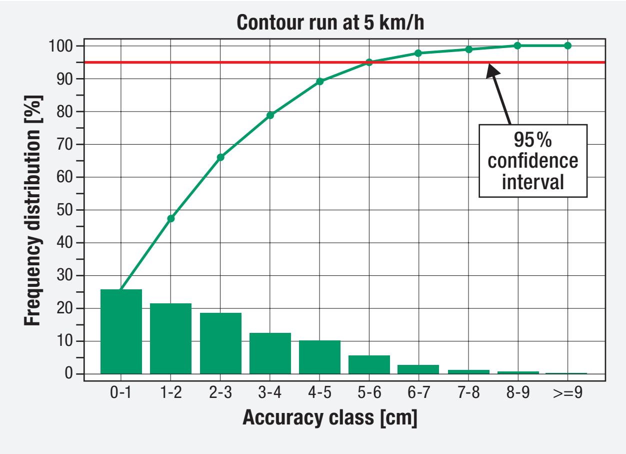

Figure 8:
Deviation rates (contour run at 5 km/h)

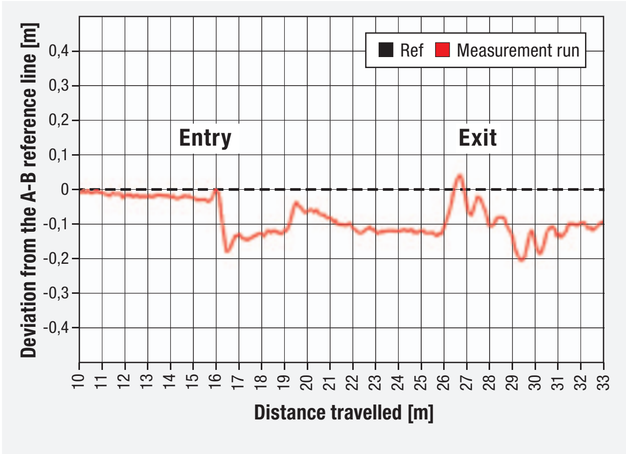

Figure 9:
Comparison of reference/measurement run on the inclined track

standard"). The brightness can be adjusted manually, giving good legibility both during the day and at night ([o] = Standard); this, however, leads to an overall assessment of [+] = "Better than standard" for the control elements and terminal.

With regard to the safety devices according to ISO 10975 (Safety requirements in tractors and machinery for agriculture – Auto-guidance systems for operator-controlled tractors and self-propelled machines), the Trimble Autopilot achieved an overall assessment of [+] = "Better than standard". The presence of a driver is checked continuously, and the automatic steering system deactivates itself immediately if the driver manually intervenes in steering. The same applies should an incorrect direction be possible as a result of signal faults in the GNSS or correction signal; there are even simultaneous warnings for this on the Krone and Trimble display, along with a signal tone.

Table 4:
Results and assessment of the shading and signal-loss tests

Partial GNSS shading		**Assessment**
Time until reaction	5 sec, signal return after total shading	Behaviour on GNSS signal shading: [++]
Visual response	On-screen error message	
Acoustic response	Signal tone	
Comments	Continuous activation in case of partial shading	
Total loss of correction signal		**Assessment**
Time until reaction on signal loss	Switches from RTK to xFill after 5 sec; switches to EGNOS after 20 min (and then switches off the steering function without modifying the basic configuration)	Correction signal loss: [++]
Time until reaction on signal return	5 sec, signal return after total shading	
Visual response	Loss: on-screen error message Return: on-screen icon Additional warning message after 15 min with xFill	
Acoustic response	Signal tone	
Comments	6 cm accuracy at 8 km/h (error class 95 % total) after 5 minutes of xFill operation	

Summary

The test criteria of the DLG Focus Test "Automatic Steering Systems" assess the basic function of a system, as well as the deviations from the ideal line as described in detail above. On a Krone Big X 700, the Trimble Autopilot represents a state-of-the-art automatic steering system and can be recommended for use in agricultural machines and tractors.

Further Information

Further tests on automatic steering systems are available to download at **www.dlg-test.de/lenksysteme**. The DLG Labour Management and Process Technology Committee has published two instruction leaflets on the topic of "automatic steering systems" with the titles "GPS in Agriculture" (Instruction Leaflet 316) and "Satellite Positioning Systems" (Instruction Leaflet 388). These are available free of charge in PDF format at **www.dlg.org/merkblaetter.html**.

Test Execution

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DLG Testing Framework

Focus Test
"Automatic Steering Systems"
(Revised 03/2013)

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The DLG

In addition to conducting its well-known tests of agricultural technology, farm inputs and foodstuffs, the DLG acts as a neutral, open forum for knowledge exchange and opinion-forming in the agricultural and food industry.

Around 180 head-office staff and more than 3,000 expert volunteers develop solutions to current problems. More than 80 committees, working groups and commissions form the basis for expertise and continuity in technical work. Work at the DLG includes the preparation of technical information for the agricultural sector in the form of instruction leaflets and working documents, as well as contributions to specialist magazines and books.

The DLG organises the world's leading trade exhibitions for the agriculture and food industry. In doing so, it helps to discover modern products, processes and services and to make these transparent to the public.

The DLG Test Center Technology and Farm Inputs

The DLG Test Center Technology and Farm Inputs in Groß-Umstadt sets the benchmark for tested agricultural technology and farm inputs and is the leading provider of testing and certification services for independent technology tests. With the latest measurement technology and practical testing methods, the DLG's test engineers carry out testing of product developments and innovations.

As an EU-notified test laboratory with multiple accreditations, the DLG Test Center Technology and Farm Inputs provides farmers and practitioners with important information and decision-making aids, in the form of its recognised technology tests and DLG tests, to assist in the planning of investments in agricultural technologies and farm inputs.

ENTAM

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