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Changes in the Overdrive Signal of the Electric Motor of Trimble's EZ-Pilot Parallel Driving System

***Abstract**. Tests on changes in the overdrive signal of the electric motor of the parallel driving system were carried out for 3 modes of parallel driving. Measurements were carried out when driving automatically in straight lines, curves and making turns. A set consisting of a Trimble CFX-750 navigation panel together with the EZ-Pilot automatic driving system and a DCM-300 modem for receiving the RTK correction (RTN) transmitted over the GPRS network were used as additional devices mounted on the tractor and performing the function of automatic driving on parallel lines. The tests carried out showed that the smallest operating times of the system's motor on the same measurement sections occurred when driving on straight lines at a speed of 10 km·h^{-1}. In many cases, the terrain and uneven surface on the first drive contributed to an increase in the operating time of the motor, and thus increased the load on the electrical system.*

Streszczenie.** Badanie zmian sygnału przesterowania silnika elektrycznego układu jazdy równoległej przeprowadzono dla 3 trybów jazdy równoległej. Pomiary przeprowadzono podczas jazdy automatycznej po liniach prostych, łukach i wykonywaniu zakrętów. Zestaw składający się z panelu nawigacyjnego Trimble CFX-750 wraz z systemem automatycznej jazdy EZ-Pilot oraz modemu DCM-300 do odbioru poprawki RTK (RTN) transmitowanej siecią GPRS wykorzystano jako dodatkowe urządzenia montowane na ciągniku i realizujące funkcja automatycznej jazdy po liniach równoległych. Przeprowadzone badania wykazały, że najmniejsze czasy pracy silnika układu na tych samych odcinkach pomiarowych wystąpiły podczas jazdy po liniach prostych z prędkością 10 km·h^{-1}. W wielu przypadkach ukształtowanie terenu i nierówna nawierzchnia na pierwszym jeździe przyczyniły się do wydłużenia czasu pracy silnika, a tym samym do zwiększenia obciążenia instalacji elektrycznej **(Zmiany sygnału przesterowania silnika elektrycznego systemu jazdy równoległej EZ-Pilot firmy Trimble).

Keywords: precision agriculture, telematics, mechanical engineering
Słowa kluczowe: rolnictwo precyzyjne, telematyka, inżynieria mechaniczna

Introduction

Driving a tillage unit automatically or assisting the tractor's guidance process is common and is the standard for more expensive machinery units. Today's guidance systems can be divided into three main groups. The first are systems whose override of the driving path of the aggregate is traditionally (manually) done by the operator and the signal and indications of the direction and amount of steering turn come from the GPS system. In the case of the second system, the entire operation is carried out automatically, that is, the machine aggregate drives itself on the field, and the operator plays the role of supervising the entire process. The third system of machine aggregate guidance does not require the use of GPS receivers, but requires the use of sensors, usually optical, which can generate a signal in real time to correct and override the driving path of the aggregate. Global Navigation Satellite System (GNSS) and automatic steering control are now widespread on farms in developed countries [1]. The name Global Navigation Satellite Systems (GNSS) encompasses all available systems, such as the U.S. Global Positioning System (GPS), China's BeiDou Satellite Navigation System (BDS), Russia's GLObal NAvigation (GLONASS) and Europe's Galileo, which are used in current vehicle navigation systems [2, 3]. Many older solutions used by farmers are based on GPS-only navigation. In these devices, unlocking GLONASS, BDS and Galileo requires the purchase of an unlock code and software update, and in some solutions, a replacement GNSS receiver. Therefore, hardware cost is a key factor in the navigation system used [4]. Over the past two decades, much research has been done in developing and analyzing GPS-based guidance systems. Today, the technology is available for full vehicle guidance. The automation of the vehicle is causing the driver's responsibilities to shift from actively controlling the vehicle to monitoring performance [2]. Navigation systems are available with a precision guidance range that fits most mechanical operations and new functional capabilities [1, 4, 5, 6, 7, 8, 9]. The benefits of GNSS-based guidance are reduced skips and overlaps between passes with seeding, spraying, fertilizing, tilling, harvesting, and especially when operating machines with large working widths [1, 6, 7, 8, 10]. The main advantage of using GPS is input savings through more accurate application of seeds, fertilizers, chemicals, fuel and labor, as well as increased benefits to the agricultural production process [6, 7, 8]. This technology reduces the risk of improper agrochemical application and can protect water quality. In addition, GNSS navigation can be used with Controlled Traffic Farming (CTF) technology, which minimizes soil compaction in the cultivation zone by restricting traffic to fixed tracks [9]. In addition to the aforementioned advantages, a great benefit of guidance systems is the reduction of driver fatigue. According to Tamirata et al. [11] automatic steering reduces operator stress. When driving with steering systems, heart rate as a measure of stress was always lower. In conclusion, steering systems increase the comfort and ergonomics of tractor workstations. Modern technology uses machines that operate at high capacities that allow lower unit production costs. The degree of precision in the organization of machine work forces a detailed analysis of each component of working time and then its minimization. Technical capabilities allow tracking the machine in real time and generating information about the estimated economic result of its operation. The degree of computerization makes it possible to control machine settings remotely through a virtual terminal, thus relieving the operator, who has access to interactive assistance from the dispatcher, in addition to being able to use the experience of other operators. Widespread access to the Internet of GSM networks and GPS has allowed virtually automated technologies contributing to the optimization of the work process [12].

Purpose and scope of the study

The purpose of the study was to analyze the change in the overdrive signal of the electric motor of Trimble's EZ-Pilot parallel driving system during 3 parallel driving modes. The scope of the study included taking measurements of the width of wheel tracks left on the soil after making 10 passes. The timing of the system was recorded using a camera that recorded the system's operation during the run.

Material and methods

Tests on changes in the overdrive signal of the electric motor of the parallel driving system (Figure 1) were carried out for 3 modes of parallel driving. Measurements were carried out when driving automatically on straight lines and making turns (Figure 2) and curves (Figure 3). A set consisting of a Trimble CFX-750 navigation panel together with the EZ-Pilot automatic driving system and a DCM-300 modem for receiving the RTK correction (RTN) transmitted via the GPRS network was used as additional devices mounted on the tractor and performing the function of automatic guidance on parallel lines (Fig. 1).

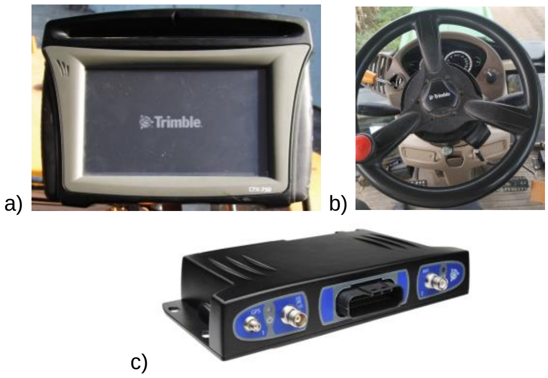

Fig. 1. Trimble navigation suite: a) CFX-750 navigation panel, b) EZ-Pilot system, c) DCM-300 modem

Straight line crossings were carried out on a 50-meter section marked in Figure 2 with a straight line A-B and made in three parallel crossings. Between the lines parallel to the A-B straight, turns were recorded. The passage was repeated 10 times.

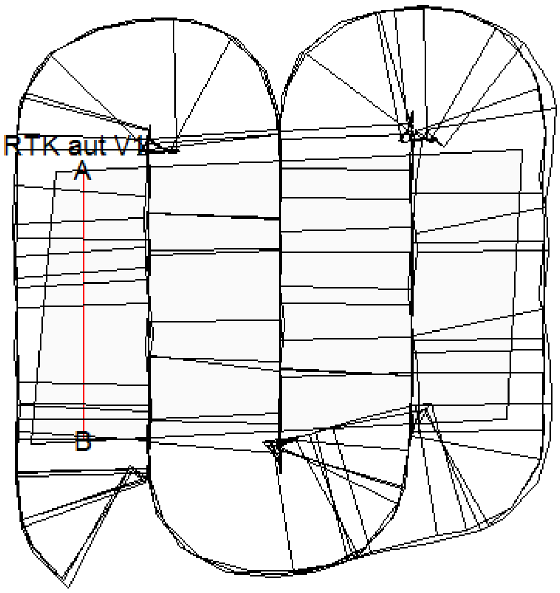

Fig. 2. Driving traces recorded by navigation at three paths and turns

Fig. 3. Traces of travel along the A-B curve line recorded by navigation

During the run, deviations (Figure 4) from the assumed trajectory were recorded by the camera, which caused the system's motor to be overdriven by a rotation angle to correct the course. After conducting 10 runs, the deviations and their smallest and largest values were measured. And the running time of the parallel driving system's motor. Measurements were made for two driving speeds of 7 and 10 km·h^{-1}.

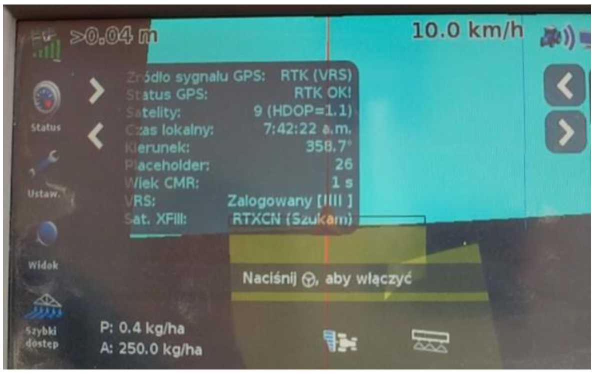

Fig. 4. Trimble CFX-750 navigation panel screen during operation

Measurements were taken at 25 locations along the length of the A-B straight line at 2-meter intervals (Figure 5). Measurements during turnarounds were taken at 5 places along the curve. Measurements on the A-B curve line were taken at 50 places along the length of the line at 2-meter intervals.

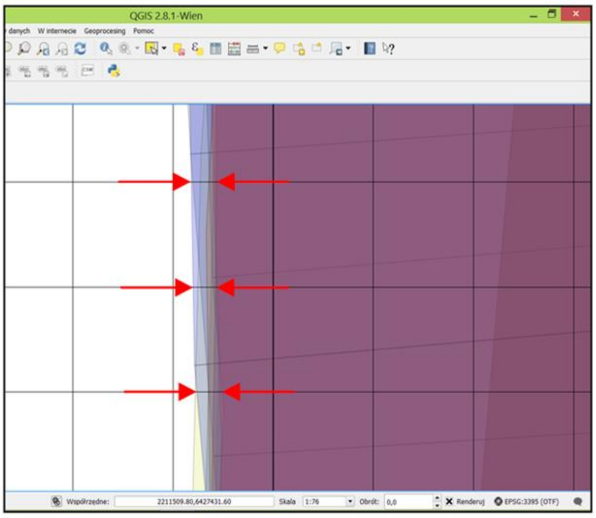

Fig. 5. Measurement of deviations from the determined straight line A-B

Results

An analysis of the video footage from the tests showed that in the case of journeys made along curved lines or making turns regardless of the driving speed, the guidance system worked 100% of the time. Only a change in the intensity of the system's operation was observed in the initial and final stages of guiding, when the tractor changed direction. The material for straight-line travel differed between speeds of 7 km·h^{-1} and 10 km·h-1. At lower speeds, the system was observed to start up and correct the trajectory more frequently, resulting in operation of the system for an average of 80% of straight-line travel time. At a straight-line speed of 10 km·h^{-1}, it was the electric steering motor that started up for an average of 74.8% of straight-line driving time.

Figures 6 and 7 show the width of the tractor's wheel tracks after a ten-turn automatic drive at speeds of 7 km·h^{-1} and 10 km·h^{-1}, respectively.

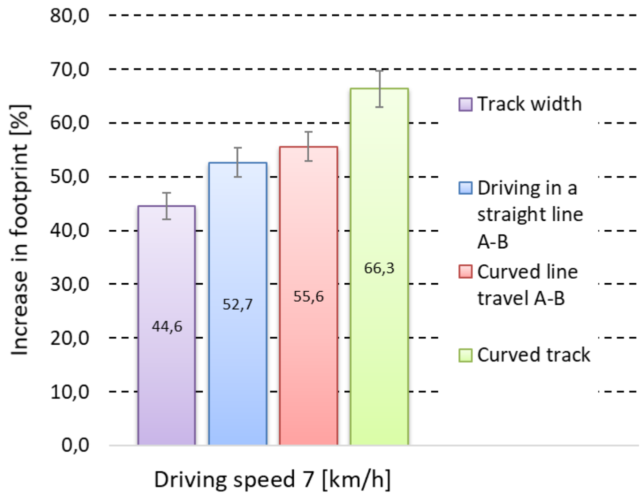

Fig. 6. Width of driving traces in cm after 10 repetitions for a speed of 7 km·h^{-1}

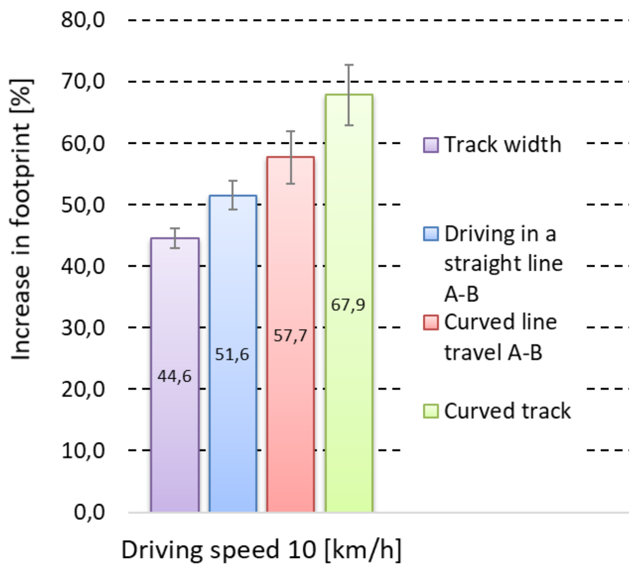

Fig. 7. Width of crossing traces in cm after 10 repetitions for a speed of 10 km·h^{-1}.

The smallest average values of the width of the traces were obtained for driving on straight lines A-B and amounted to 52.7 cm with a coefficient of variation of 4.8% (Fig. 6). Driving the tractor on curved lines A-B was characterized by a greater width of the obtained traces, and here the average width was 55.6 cm with a coefficient of variation of 4.7% (Fig. 6). The highest average value of the width of the traces was obtained in the case of driving at the headlands and was 66.3 cm with a coefficient of variation of 6.1% (Figure 6).

Increasing the driving speed to 10 km·h^{-1} only in the case of driving on straight lines A-B resulted in a decrease in the average width of traces to 51.6 cm with a coefficient of variation of 4.1% (Fig. 7).

The other variants of the crossings showed both greater trace width and variability. The crossings along the A-B curve had an average width of 57.7 cm and a coefficient of variation of 7.3% (Figure 7). The worst performing ride was when making a turnaround, and here the trace width was 67.9 cm with a variability of 8.5% (Figure 7). Figures 8 and 9 show the range of track deviation for the analyzed combinations of experience.

Figure 8 shows the results for deviations from the set track at speeds of 7 km·h^{-1}. The smallest values after ten passes were obtained for the A-B curve line and averaged 10.1 cm with a variability of 28.8%. The runs made on the A-B curve line showed an average deviation of 11.6 cm with a variability of 22.7%. The largest deviations appeared in the case of performing reversals and amounted to 13.8 cm with a variation of 29.7%.

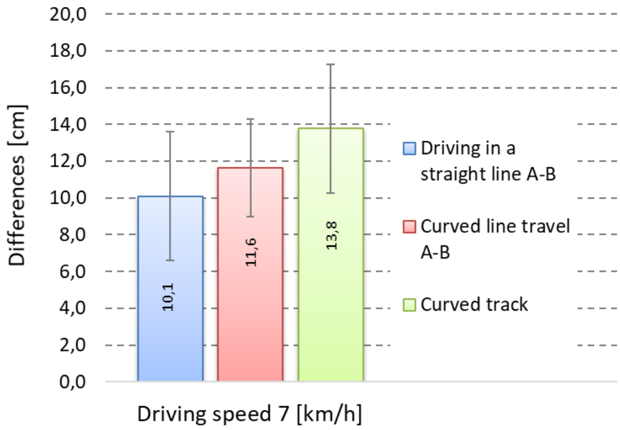

Fig. 8: Deviations in cm after 10 repetitions for a speed of 7 km·h^{-1}

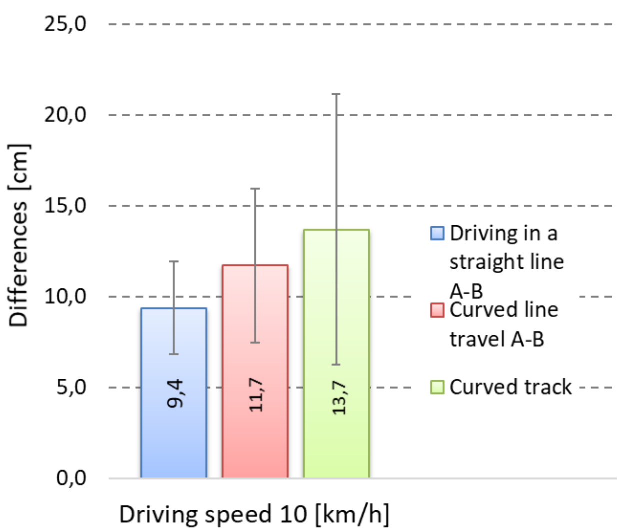

Fig. 9. deviations in cm after 10 repetitions for a speed of 10 km·h^{-1}

Figure 9 shows the results for runs at a speed of 10 km·h^{-1}. The smallest values, even compared to the runs obtained above, appeared for the A-B curve line and averaged 9.4 cm with a variation of 20.7%. The crossings made along curve line A-B showed an average deviation of 11.7 cm with a variation of 30.9%. The largest deviations appeared in the case of making reversals and amounted to 13.7 cm with a variation of 54.5%.

The study showed that an increase in speed only when driving on straight lines A-B improves the quality of the resulting tramlines and contributes to reducing the operating time of the navigation system. The need to make curved line crossings requires a reduction in travel speed, which will also reduce abrupt changes when overdriving the steering system during directional changes.

When making straight-line passes, the system ran the longest during the initial stage of straight-line driving, after about 5 seconds there were interruptions in the operation of the electric motor moving the tractor's steering wheel.

Conclusions

The study showed that the smallest operating times of the system's engine on the same measuring sections occurred when driving on straight lines at a speed of 10 $km \cdot h^{-1}$. In many cases, the terrain and uneven surface at the first run contributed to the increase in the engine operating time, and thus increased the load on the electrical system. In the future research the conditions of the soil [13,14].

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