EFFECT OF THE SATELLITE GUIDANCE SYSTEM ON THE MACHINE WORKING WIDTH

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ABSTRACT

Insufficient use of machine working width has the effect on decreasing of machine work efficiency. Overlaps and skips cause negative after-effects on individual machine operations. Negative after-effects could be as follows: soil compaction, over or under application of fertilizers and chemicals, increased fuel consumption, increase in working time, etc. Control of implement working width with support of satellite guidance system could correct these problems. Availability of satellite guidance systems, which allow greater accuracy and controlled movement of machines, gives a possibility to reduce the economic costs of production and increase the environmental sustainability. The objective of this article was to evaluate keeping working width for manually and automatically guided tractor and tillage implements. Automatic guidance is provided by a satellite navigation system. In experiments a dual frequency RTK GNSS receiver and field controller Topcon GRS-1 was used for measuring working width. In manually guided experiment the sum of the absolute values of off-track errors was 8.66m. It represents an error from the ideal passes with the value of 6.88%. In automatically guided experiment the sum of the absolute values of off-track errors was 4.45m, which represents technological deficiencies with the value of 3.71%. Effective use of a satellite guidance system helps reduce overlaps and skips.

Key words: working width, guidance system, overlaps, skips, off-track error

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INTRODUCTION

Insufficient use of machine working width has the effect on decreasing of machine work efficiency and increasing input costs of production. Skips (unprocessed area) and overlaps (repeatedly processed area) caused by passes of machines have negative effect on soil compaction, over application of fertilizers and chemicals, increased fuel consumption, increase in working time, etc. in a number of field operations (e.g. soil cultivation, seeding, application of fertilizers and chemicals and harvesting). Use of machinery guidance on satellite navigation principle can correct these deficiencies. The criteria of work quality when using the satellite guidance systems are the accuracy of the received signal and its transmission to movement control (ASABE Standards, 2007; Gavric et al., 2011).

During soil cultivation when an implement makes a pass in the field it is favourable for the operator to overlap slightly into the previous pass, for instance where the soil has already been cultivated, as opposed to under cultivating and leaving a strip area. Due to this overlap, the working (operating) width of the implement is not defined by the physical dimension of the implement, but rather it is constrained by the amount of overlap loss (ASABE Standards, 2005). The same implement can have a different working width depending on how much overlap the operator allows. In order to have an economically efficient operation, however, the overlap loss on each pass should be as small as possible. Unnecessary overlap in a system will result in extra passes in the field and therefore money and resources being lost (Shinners et al., 2012).

The primary advantage of using a GNSS-based guidance system is a reduction in application errors (overlaps and skips). One other benefit often overlooked is the potential energy savings (Shannon – Ellis, 2012).

Evaluating the need and efficiency of using the satellite guidance, which eliminates unproductive passes, requires knowledge of the actual condition of the machine in operation. Experimentally comes to accurate identification and evaluation of the real working width during tractor and implement passes. One of the methods of accuracy measurements of guidance systems using tractor and implement is by GNSS navigation device (Vašek – Rataj, 2011).

Kroulík (2013) studied in his work linking of working widths. He compared manual guidance, automatic guidance and different accuracy levels of these systems.

The objective of this paper was to evaluate keeping working width for manually and automatically guided tractor and tillage implements.

MATERIAL AND METHODS

Experimental measurements were carried out on fields which belong to the SUA University Farm, Ltd., Kolíňany. Soil cultivations were carried out on the fields. Machine working width was observed by passes of tractor and implement guided manually and automatically. Experiments were conducted during normal machinery field work.

In experiment without satellite guidance system (manually guided – MG) were assessed: tractor New Holland T6070 and disc harrow Agrometal PB 4-083.4 with 3.7m effective working width.

In experiment with satellite guidance system (automatically guided – AG) were assessed: tractor John Deere 8230 cultivator Lemken Thorit 9/500 KUA with 5m working width. Tractor was equipped with autopilot JD AutoTrac Integrated with display Greenstar 2. This system is using correction signal SF2 (accuracy ± 0.1m). Operator set in navigation device guidance pattern A-B. Working width of individual parallel passes was set to 4.8m which means that overlap was set to 0.2m.

In both experiments was used dual frequency RTK GNSS receiver and field controller Topcon GRS-1 for measuring working width. Receiver worked with the correction signal 'SKPOS-cm' with RTK accuracy (± 0.02m).

Scheme of experiments is shown in Fig. 1. Value Bk represents implement width. Value Bp represents operating (effective working) width. Value PN represents a set distance of parallel passes (set overlap) and value ΔB is off-track error (overlap or skip). Evaluation distinguishes between: overlapping parallel passes (obtained value < 0) and unprocessed areas - skips (obtained value > 0). Obtained values were recorded and processed by tools of mathematical statistics (Vašek et al., 2012).

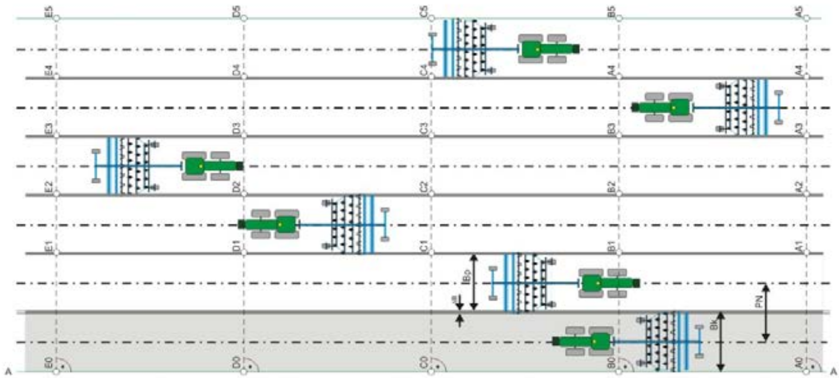

Fig. 1 Scheme of the experiments (Bk – implement width, Bp – operating (effective working) width, PN – set overlap, ΔB – off-track error)

First tractor and implement pass outlined the base line for measured set. Along the edge of A-A were outlined measurement points A0-E0. Points A0 and E0 were targeted by device Topcon GRS-1 and on the basis of these points was determined the reference line. With each tractor and implement pass, in measurement points were detected perpendicular distances A0-A1, A0-A2, A0-A3, A0-A4, A0-A5, etc.

RESULTS AND DISCUSSION

In MG experiment operator guided tractor manually according to his abilities. Following the methodology (Fig. 1) were evaluated 3 sets of passes (total number of 37 passes). In each pass were outlined 9 measuring points at 5m distance. During operation were on measured area carried out 333 measurements. Guidance pattern consisted of cluster which contained several passes. Every time it was measured the same side of implement. The results are given in Tab. 1.

Tab. 1 Descriptive statistics of ΔB off-track error from MG experiment

Mean value, m	-0.156
Standard deviation, m	0.273
Minimum value, m	-0.920
Maximum value, m	0.634
Range, m	1.554
Number of values	333

The results show there are considerable extremes during passes. Shorter working width due to overlapping was detected in 79% of observations. Unprocessed areas (skipping) were detected in 21% of observations (Fig. 2). Trend of effective working width in 1st set of MG experiment is shown in Fig. 3. Predominant value of off-track error (< 0) causes a gradual reduction of the total effective working width. The linear dependence (Fig. 3) shows that implement width (3.7m) is eliminated after 29 passes, respectively each 29th pass is redundant and causes extra costs.

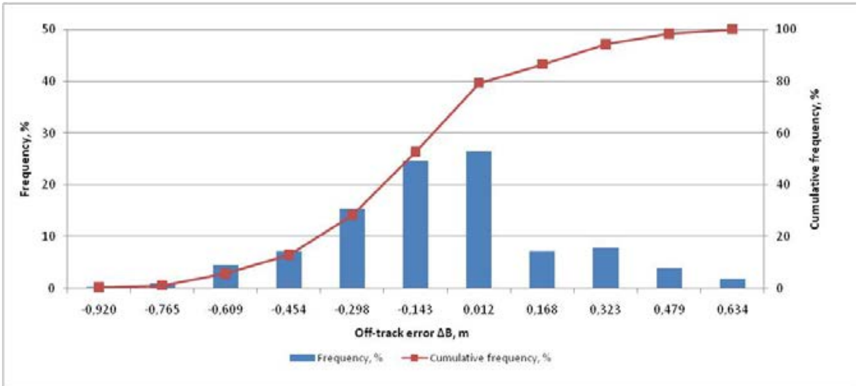

Fig. 2 Distribution of ΔB off-track error values in MG experiment

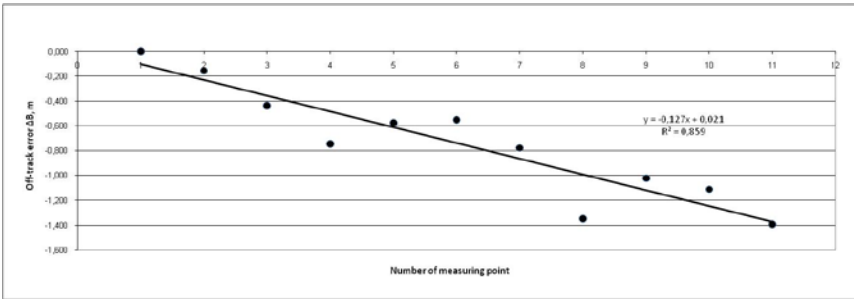

Fig.3 Trend of ΔB off-track error values in 1st set of MG experiment

In MG experiment were created 34 contact passes on which off-track errors were measured. In the ideal condition a distance from the first to the last pass is 128m. The sum of the absolute values of off-track errors (which means technological deficiencies) is 8.66m. It represents an error from the ideal passes (for 3.7m width) with the value 6.88%.

In AG experiment operator guided tractor by guidance system JD AutoTrac Integrated with display Greenstar 2 with correction signal SF2.

According to the methodology (Fig. 1) were evaluated 5 sets of passes. In each set were evaluated 5 passes, where in each pass were outlined 5 measurement points at a distance of 10m. During operation 125 measurements were carried out on measured area. Guidance pattern was A-B. In each set alternately right and left side of the implement was measured. The results are given in Tab. 2.

Tab. 2 Descriptive statistics of ΔB off-track error from AG experiment

Mean value, m	-0.007
Standard deviation, m	0.200
Minimum value, m	-0.356
Maximum value, m	0.363
Range, m	0.719
Number of values	125

Also in AG experiments off-track errors were evaluated. Distribution of values seems symmetrical. Shorter working width caused by overlapping was detected in 47% of observations. Unprocessed areas were found in 53% of observations (Fig. 4).

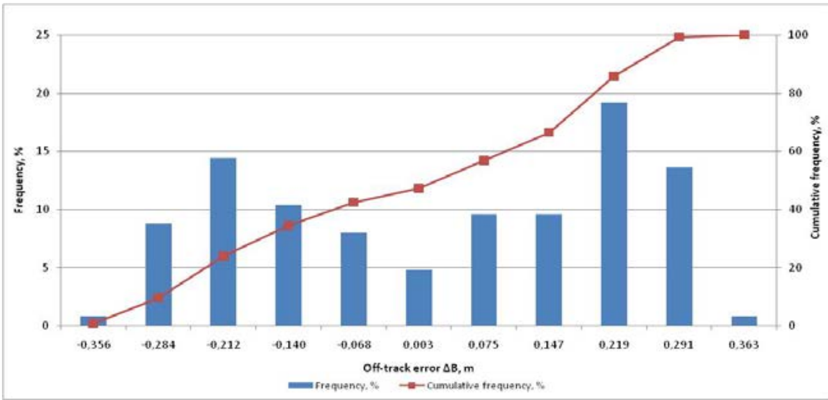

Fig. 4 Distribution of ΔB off-track error values in AG experiment

In AG experiment were evaluated 34 contact passes on which there were measured off-track errors. By guidance system setting parameter, in ideal conditions it represents a distance of 120m from the first to the last pass. The sum of the absolute values of off-track errors is 4.45m, which represents technological deficiencies with the value of 3.71%.

Issue of machine working width for different guidance patterns directly affects the performance and efficiency of the machinery deployment. However, a relatively small number of authors scientifically deal with this issue. Presented results extend the published findings. By manually guided machine deficiencies of working width arise in the range 17-25%. The average loss of area is 6.88%. Achieved deficiencies in automatically guided machine are at the level of 7.5%, which represents a loss of area 3.71%. Similar results was presented by Shinners et al. (2012), which states for mowers the deficiencies to value 16.13% and using GNSS-based guidance system reduce these values by 50%. Comparable data are also mentioned by machinery manufacturers, which state the values of overlaps ranging from 5% to 10% (John Deere, 2013). Shannon and Ellis (2012) studied and analysed potential energy savings in fuel using GNSS technology to apply fertilizer to a corn/soybean rotation. Comparisons were made looking at overlap reductions from 5% and 2.5% to 0% for nitrogen application and 10% and 5% to 0% for phosphorus and potassium applications. Comparison of 5% and 0% overlap on example of distance calculations showed that it made 2 passes difference between 5% and 0% overlap scenario.

CONCLUSIONS

The results showed that evaluate and analyse effective working width is important and significant. In this paper, off-track errors of machine working width for manually and automatically guided tractor and implement were evaluated. Work efficiency of tractor and implement depends on the sufficient use of machine working width. In this experiment according presented methodology it was founded that technological deficiencies at automatically guided machine are 6.88% and at manually guided machine they are 3.71%. Effective use of a GNSS-based guidance system helps to reduce overlaps and skips. The current findings showed the necessity for further research.

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