Study of the relation between the modes of contour anti-erosion tillage of slope agricultural landscapes and the spatial location of the machine-tractor aggregate

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Abstract. The article deals with the study of the relation between the modes of contour anti-erosion tillage of slope agricultural landscapes and the spatial location of the machine-tractor aggregate. Within anti-erosion technologies for the cultivation of agricultural crops on limited areas of slope lands cut by ravines we propose an original approach to contour tillage with the use of active working parts. The main conditions determining the angles set when tilling the underlying surface by a tractor that are necessary to control active working parts of agricultural machines are considered. It is noted that contour tillage with a zero deviation of technological furrows does not require additional agro-technical and hydro-technical anti-erosion melioration measures.

1. Introduction

The need to differentiate anti-erosion measures within a single agricultural landscape is determined by the variety of natural conditions and slope parameters: steepness, exposure, shape and length \cite{1, 2}. Applying energy approach to describe soil erosion properties makes it possible to assess erosion resistance of the slope adequately \cite{3, 4} and plan land melioration measures for land protection. The specific power of the water flow can be used as a quantitative measure that determines soil destruction and removal \cite{4}. Contour tillage is one of the most effective ways to reduce the power of melting or rainwater running. The efficiency of contour tillage of a slope is evident and proven in a number of works \cite{5, 6}. When using contour tillage, the water flow is highly efficiently damped by furrows due to the fact that the tillage goes along the level lines. Since soil properties determining erosion resistance vary greatly on a slope, we suggest using data on spatial location and acceleration of tillage machinery to improve contour tillage. Anti-erosion technology of differential soil tillage should be developed for every specific agricultural landscape taking into account the reliable information about the slope obtained from the sensors installed on the tillage machinery. It is possible to get information about the landform in different ways and at different periods of time.

Modern portable devices allow you to get data on slope properties both before and during tillage with machine-tractor aggregate. Application and wide introduction of contour tillage is somewhat
restricted by the existing range of traditional anti-erosion machines for this type of work and operations on steep slopes. However, in case, when tilling regular areas with these machines on a steep slope, it is necessary to know and take into account the deviation angles of tillage direction relative to the slope.

Poor implementation of the above anti-erosion agricultural measures may cause intensive soil erosion. Such cases are observed when technological furrows are located at an angle to the horizontal of the slope [4, 7]. It is obvious that in any soil cultivation, technological furrows are formed when the aggregate moves and they can accumulate and keep precipitation water moving from the watershed.

2. Materials and methods

To implement contour tillage on steep slopes effectively it is not enough to use the existing range of traditional anti-erosion machines for this type of work and operations [4, 8]. When tilling a slope, we used data on spatial location of tillage equipment obtained from the gyroscope and accelerometer. They are used to calculate the deviation angle of tillage direction relative to the slope when tilling regular areas on steep slopes [9-12].

Data obtained from the gyroscope allow you to determine the (actual) position of normal vector \( n \). The Gyroscope gives the projection values of the gravity vector on axis \( X, Y, Z \). Angles \( \alpha \) and \( \beta \) of spatial location of the tillage machinery are calculated on the basis of these data (see figure 1).

Angle \( \theta \) – the angle between the direction of the tractor movement and the horizontal which is determined by \( \alpha \) and \( \beta \).

\[
\begin{align*}
\sin \beta &= b, \quad (1) \\
\frac{b}{c} &= \frac{\sin \beta}{\sin \alpha}, \quad (2)
\end{align*}
\]

(1) and (2) result in

\[
\tan \theta = \frac{d}{c} = \frac{b/\sin \beta}{\sin \beta/\sin \alpha} = \frac{\tan \alpha}{\sin \beta}. \quad (3)
\]

Then, based on the design parameters and the features of tillage machinery, we select the rotation rate of the driving shafts of the mechatronic unit (figure 2), which transmits the main rotational movement to the working parts:
where:  
- \( n \) – the number of screw revolutions per second, \( \text{c}^{-1} \);
- \( h \) – pitch of the helical "spiral", \( \text{m} \);
- \( t \) – time, \( \text{s} \);
- \( V_T \) - tractor speed, \( \text{m} / \text{s} \);
- \( n \) - normal to the surface.

The interval between the data received from the gyroscope and the smartphone accelerometer varies from 0.1 to 5 seconds. The lowest value is due to the fact that the frequency of vibrations of the tractor frame usually does not exceed 5 Hz. In case of cab vibration insulation it reaches only 2...4 Hz, depending on the machinery mode (figure 3).

**Figure 2.** Calculation diagram to determine the dependence between the tractor speed and the revolutions of the working part.

**Figure 3.** Android application Interface for receiving, processing and transmitting data to a mechatronic unit via Bluetooth.

The tractor body vibrates because of the working engine and the roughness of the soil surface. These vibrations result in invalid data received from the gyroscope. To eliminate and reduce their influence on sensor readings, we use accelerometer data which change greatly with vibration. These data allow you to determine the current vibration frequency and, if possible, eliminate its impact. Then the received data are processed by the sliding average method and the rotation rate value of the driving shaft of the mechatronic unit calculated according to the formula (4) is transmitted via Bluetooth to the controller.

### 3. Results and discussion

The main problem in data processing is "outliers" or "misses" - incompatible with the rest of the data because of errors caused by machine-tractor aggregate vibrations. Statistical methods are used to correct these data or not taken into consideration at all. In addition, the accelerometer data are used, which simplifies determining the moments corresponding to the maximum acceleration values caused by the tractor cab vibration and exclude them from the general data set. These data allow you to determine the current vibrations frequency and, if possible, eliminate their impact. This approach is
due to the extremely short period of time for receiving and processing data and for sending a signal to Bluetooth, as well as for adjusting the speed of rotation of the mechatronic unit driving shaft. Figure 4 shows the data received from the sensors, and figure 6 shows the formula that have been processed and received at the input (4).

![Figure 4. Time scan of the data received from the sensors (x, y, z are projections of the g vector to the coordinate axes, respectively).](image1)

![Figure 5. The data received from the sensors after processing (x, y, z are projections of the g vector to the coordinate axes, respectively).](image2)

Thus, we get data from the sensors after processing, using modern telematics systems. You can transmit information on the deviation angle of the direction of machine-tractor aggregate movement from the horizontal. Then we can compensate this deviation by making technological furrows horizontal with active working parts of agricultural machines when tilling.
4. Conclusions
Within anti-erosion technologies for the cultivation of agricultural crops on limited areas of slope lands cut by ravines we propose an original approach to contour tillage with the use of active working parts. The main conditions determining the angles set when tilling the underlying surface by a tractor that are necessary to control active working parts of agricultural machines are considered. It is noted that contour tillage with a zero deviation of technological furrows does not require additional agro-technical and hydro-technical anti-erosion melioration measures.

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