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SMOOTHING OF DRAFT FORCE SIGNAL DURING PLOWING BY SAVITZKY - GOLAV FILTER

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Abstract: The measurement of draft force and soil resistance during plowing can be performed using a strain transducer. They are placed on the lower tractor links, two sensors on each side. After calibrating the sensors, acquiring and processing the data, the draft force Fout and Fin are obtained, which correspond to the measurements on the two sensors on the outside of the arms and the measurements on the sensors on the inside of the lower links. Extreme values of the force signal as a function of time are extremely pronounced due to changing conditions during the measurement. This paper investigates the influence of one of the possible Savitzky-Golav smoothing signal filters. First, the appearance of the force maps is shown in the experimental field of dimensions 120x60 on which the force effect is most uniform. The corresponding diagram is also given with a display of the signal based on the sensor measurements. Then, the data is filtered and the appearance of the new signal diagram is given. Descriptive statistics finally provides a measure of the influence of the applied filter. Statistical parameters have shown that the influence of the investigated filter is minimal.

Key words: draft force, strain transducer, filter, mapping, Savitzky-Golav smoothing

1. INTRODUCTION

There are several methods for defining the Rx horizontal draft of the tractor attach ment. Horizontal draft varies depending on the method of soil tillage, size of attachment and implement, speed of motion and soil type. A number of methods have been developed for analytical evaluation of the attachment draft. Based on theoretical considerations and experiments, Goryachkin [1] developed an equation for the plough horizontal draft evaluation:

$$R_x = Gf + kabn + \varepsilon abnv^2 \tag{1}$$

The first term of this equation is frictional resistance, where, G [N] represents plough weight and f (-) is coefficient of friction. Average value of the coefficient of friction is in the range of 0,3–0,5 [2], however it can have higher value for compact soils. The second term is the force required for cutting and deforming of a clod. Coefficient k [N/m^2] is soil specific resistance that depends on the soil type [3] parameter a [m] is plowing depth, third term of the equation denotes the force required to bring clod into motion and turn it over. Coefficient ε [Ns^2/m^4] depends on the plough body shape, soil properties and tractor speed v [m/s]. This term increases as speed is increased. For speeds up to 5 km/h the value of the third term does not exceed 5% of the overall plowing resistance. Recommended plowing speeds are in the range of 5–10 km/h to achieve satisfactory plowing quality. Value of the coefficient ε ranges from 3000 to 10 000 Ns^2/m^4 [4]. The impact of plough geometry on horizontal draft is given via the plough body width b. To precisely define the impact of geometry, an experiment has to be conducted [3].

Based on data presented in considering the assumptions and adopted parameters' values as follows: $f = 0,5$; k = 5000 N/m^2 (medium heavy soil – sandy clay); $\varepsilon = 5000$ Ns^2/m^4, approximate value is obtained for the plough draft and tractor pulling force, respectively, which is used in the mapping procedure 9515 kN for the tillage depth of 20 cm.

2. MATERIAL AND METHODS

Key elements of the system used for indirect measuring the values of the plough draft force in this research were strain transducers. Theses sensors are installed on the lower links of the tractor lift mechanism. Sensors were placed on both sides of the two lower links facing each other longitudinally. Strain transducers of the HBM manufacturer model SLB700A/06 are designed purely to measure static and dynamic strains within the load limits. The measurement signal from the sensor is received and processed by means of the amplifier, manufacturer HBM, model Quantum MX840A.

Location positioning equipment of the manufacturer AG Leader Technology included the antenna model GPS1600 for Egnos signal reception and tractor monitor model Integra for monitoring the motion of the tractor-machine unit. The antenna signal was simultaneously introduced directly into the computer via a specially designed adapter. Data was stored, visualized and afterwards analyzed using software CatmanEasy 4.2.2.14, manufacturer HBM. Additional data processing was done with software SPSS Statistics 21 from IBM, for statistical data analysis and SMS Advance from AG Leader Technology for mapping.

Raw results for lower links strain measurements represent strain signals on the strain transducers. Prior to measurement, zero balance of all sensors was done while tractor was in an idle state with a plough lowered to the ground. Data was collected during plowing with the measurement resolution 50 Hz. This way, 195 040 strain values were collected for each individual sensor.

3. RESULTS AND DISCUSSION

The results of draft force measurements can be presented in several forms. In practice, the most common way is through force maps, which show the site-specific force distribution (Figure 1) and are used to determine input application maps based on the princi-

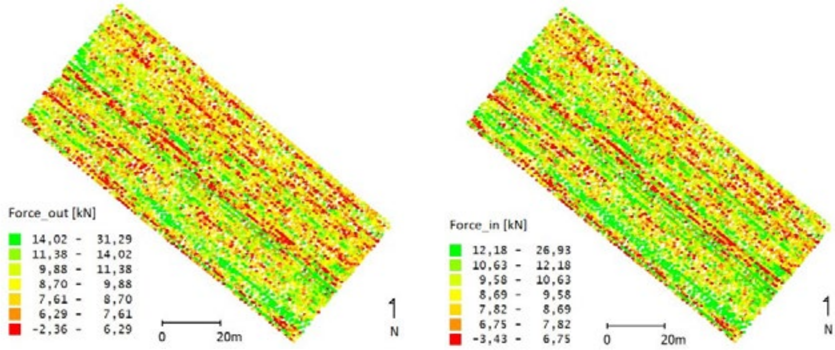

Fig. 1 Representation of site-specific draft force, kN, software SMS Advance by AG Leader Technology

The maps shown are obtained based on the numerical values of the measured force, the values of which are obtained by calculation in accordance with the calibration of the strain transducers. The measured forces using pairs of sensors from the outer and inner sides of the levers can be displayed in the time domain (Figure 2). The diagrams, as well as the numerical values of the forces, show their correlation for both measurement methods, so it can be concluded that the sensors can be placed either on the outer or inner side of the levers. Significant oscillations and frequent changes in amplitude can be observed on the representative real-time graphs of pulling force, so the use of filters is quite useful from this aspect.

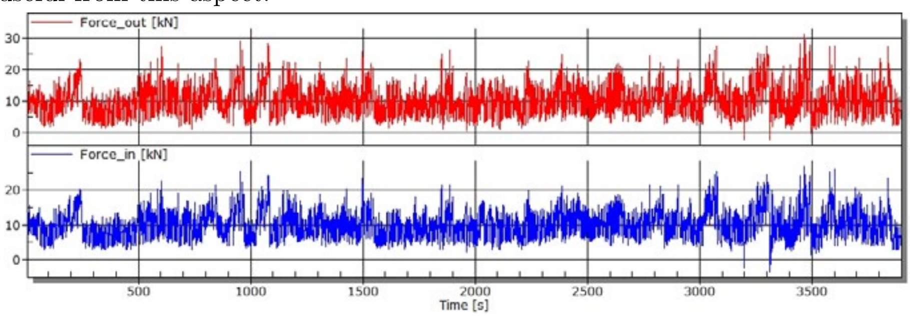

Fig. 3 Representative real-time graphs of draft force by Savitzky-Golay filtering

	N	Minimum	Maximum	Mean	Std. Deviation
Force_out	195040	-2,356	31,290	9,863	3,795622
Force_in	195040	-3,430	26,930	9,868	3,175271
Force_out_filter	195040	-2,343	30,765	9,863698	3,767148
Force_in_filter	195040	-3,422	26,659	9,868082	3,147096
Valid N	195040				

Statistical indicators do not show a significant difference between the original and filtered relevant force values.

4. CONCLUSIONS

For mapping of draft force and soil resistance and consequently soil compaction by applying the described method, two sensors are sufficient. Average value of forces Fout and Fin is approximately very equal for given conditions and in given measured range, therefore either only outside or only inside sensors can be employe [14, 15]. Output voltage signals on sensors installed on the same links are of similar absolute values but different sign. Signal diagrams and statistical analysis have shown a significant need for data filtering. This way, too large amplitudes of output voltage and draft force can be avoided and thus more reliable maps obtained. The Savitzky-Golay filter is not a necessary tool and does not change the picture of the location specificity of the draft force.

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