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DRAFT SENSOR LOADING ANALYSIS

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Abstract

SLIMAŘÍK DUŠAN, SEDLÁK PAVEL, DOSTÁL PETR. 2014. Draft Sensor Loading Analysis. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 62(5): 1103–1108.

This article deals with loading analysis of draft sensor which is used in nowadays tractor as standard. Directional sensitivity and response to the loading force of draft sensor behavior are the main goal of this work. For this purpose special measuring chain was developed. Experiment was realized with ZETOR 130 HSX which uses BOSCH draft sensors as a source for force sensing. Applied loading was measured with calibrated load cell located in measuring chain between draft sensor and ratchet mechanism. In total, three positions of lower arms were examined. Maximum loading force reached value of 30 kN. This was limited by ratchet mechanism regulations. Each configuration represents different loading conditions on draft sensor. The measured load curves were compared to each other for clarifying of draft sensor directional dependency. The obtained information's about draft sensor are summarized in the end of the text. The results achieved from realized measurement shows force dependence on the output voltage of draft sensor.

Keywords: draft sensor, tractor, three-point-hitch, draft sensing

INTRODUCTION

Draft sensing used in plowing operations was invented in 1925 by Harry Ferguson. Three-point-linkage was used for connecting the plough with the tractor. Also Ferguson found connection between wed field conditions and the power of the tractor which can be transferred to the soil. Reduction of the wheel-slip could be realized by increasing vertical forces. Ballast-weight can be used or weight-transfer procedure from carried implement can increase the amount of vertical force. In this operation, tractor partly carries the plough during ploughing. Fixed position of plough could not provide weight-transfer due to large variations of working depth dependent on soil structure. Control system which can hold plough in differential positions was invented and survived and is still used nowadays. First system worked with upper link force sensing. This was used on small ploughs. Correlation between working depth and link-force must be clear and without changes in the direction of the force (H. Hesse, 2001). Multi-furrow ploughs required draft-control system working on the sum of the lower-link-forces. This idea is widely used in BOSCH EHR system hitch control. First generation of electro-hydraulic regulation system of tractor hitch was developed in 1979 (BOSH EHR, 2012).

Draft sensor is one of the main parts of electronic device of modern tractor hitch which is placed in lover arms joints (F. Bauer, 2013). This application of draft sensor is used for measurement of draught force. The draught force is generated for example from plowing operations. This force is used for electro-hydraulic hitch control (H. Hesse, 2001). Mechanical tension is transferred to electrical voltage output. This output is used for control unit of EHR system. Another input for EHR control unit is settings from tractor operator. All these factors interfere to regulation of tractor three-point-hitch. Determination of response to directional loading of draft sensor is the main goal of this work. Another goal is to define if draft sensor brings information about spatial strain or if it determines the spatial component of the resultant.

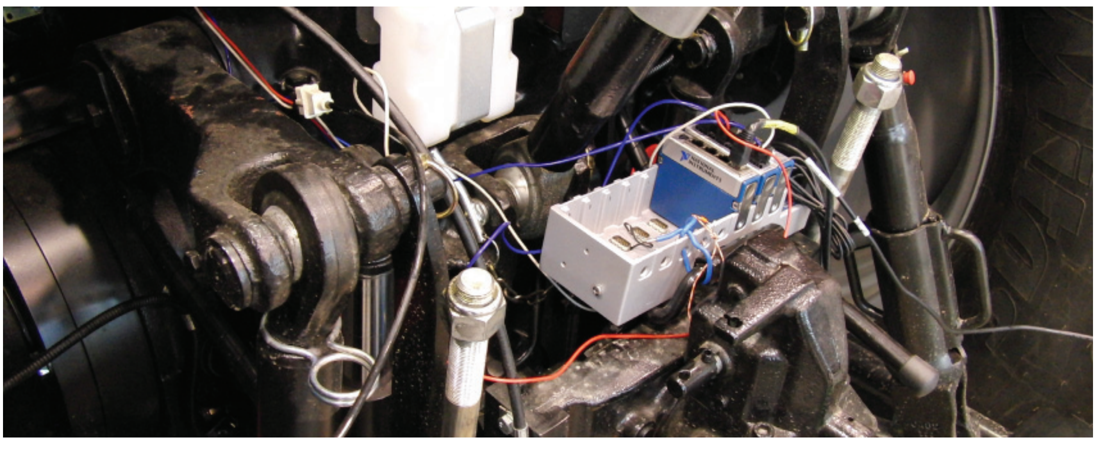
MATERIAL AND METHODS

Experiment was realized on ZETOR 140 HSX, plotted on Fig. 1, equipped with BOSCH KMB RE 95 170 draft sensors placed in lower arms joints of tractor hitch. Draft sensors are fitted in predefined position based on manufacturer's technical drawings as can be seen on Fig. 2.

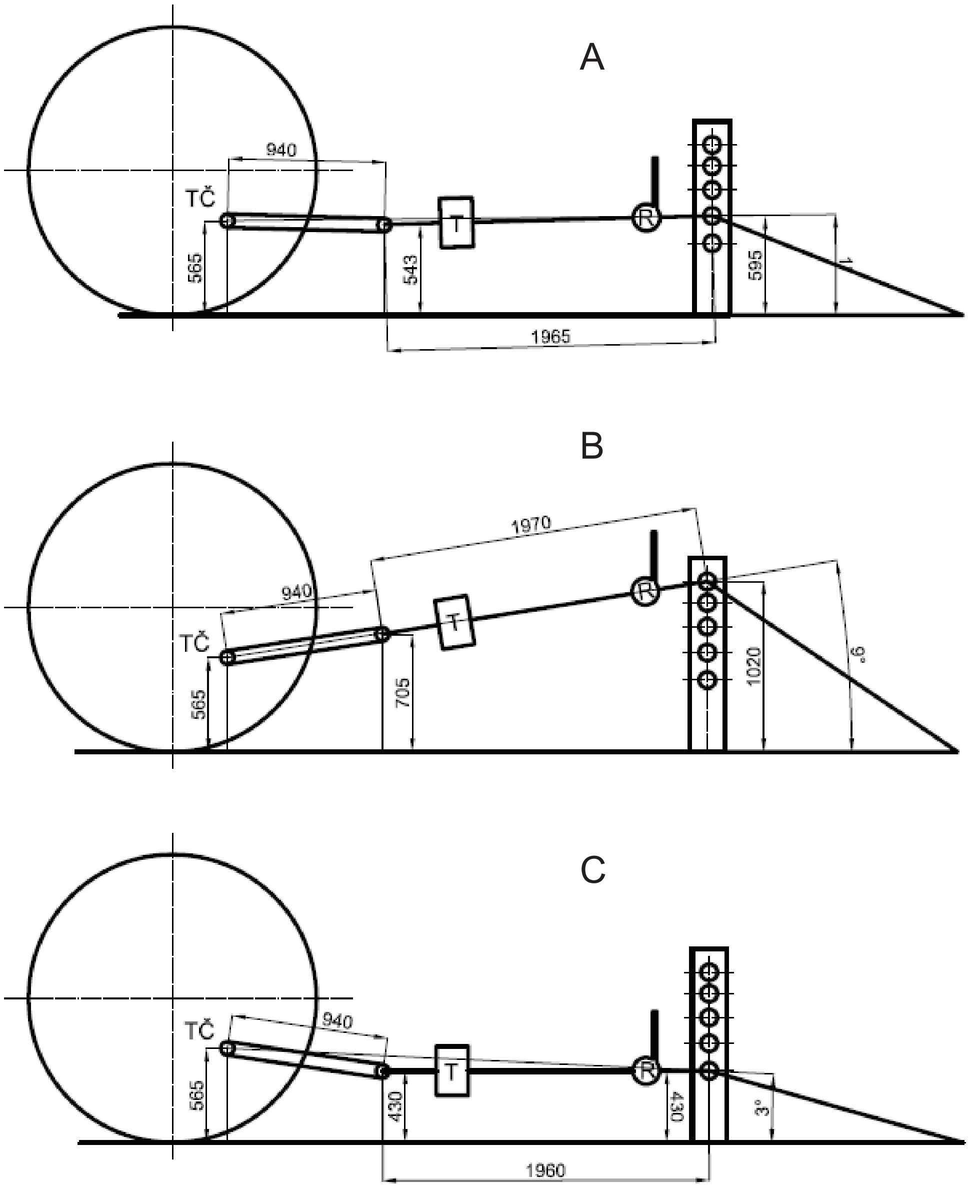
From drawings, specific mounting placement and connection of cabling is defined. National Instruments modular sensing control unit was used for monitoring of draft sensor signal output.

Subsequently three point hitch was fitted with adjustable spacer and strain gauge load cell connected to each other by chain. Also output from the load cell was monitored by modular sensing control unit. LabView evaluation program processed all measured outputs. Specific script was used. Draught force, draft sensor signal and power supply of sensor was displayed on users interface. Measured values were saved into text document by macros. Ratchet mechanism used for generation of draught force was integrated between anchored

1: *Zetor HSX 140 and measurement chain*



2: *National Instruments modular sensing unit*



3: *Types of geometrical configurations*

beam and adjustable spacer. Tractor restriction displacement was realized by spacer beam fitted between tractor and anchored beam. This application allowed extrapolation of draught force. There was possibility of lateral forces generation from connected lift arms. Due to, they were removed. On draft sensors gradual load with delay was applied. When maximum load was reached, loading starts to decrease for measurement of draft sensor hysteresis (3).

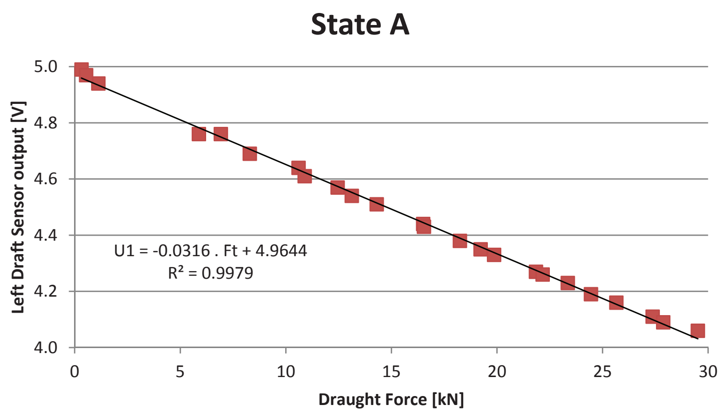
Three geometrical configurations were measured. Schematics of geometrical configurations are shown on Fig. 3 with dimensions. Objectives of this measurement, was to encumbered draft sensor in outer locations which are used in agricultural deployments.

First case represents three-point hitch in its middle position. This position shows work with mounted implements as a solid fertilizer spreader. Second case shows geometrical configuration in highest position of the three-point hitch. Most important case is the last one. This represents three-point hitch in plowing operation. Last one is the most essential for further experiments.

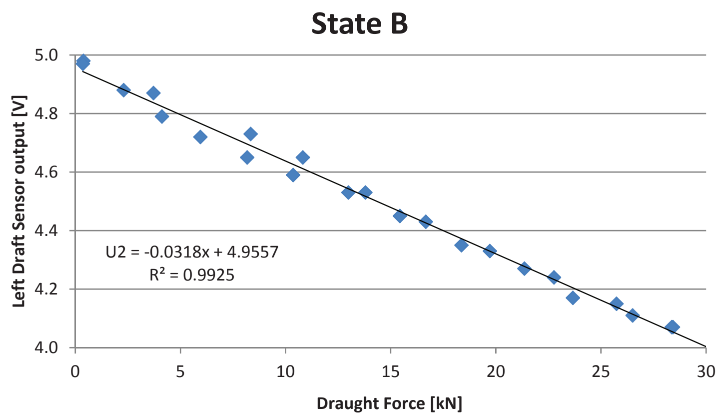
MEASURED AND COMPUTED VALUES

Measured values were evaluated. Graphs were plotted for each type of geometrical configurations. Dependence between draught force and left draft sensor output was examined. Results were printed into graphs and they are sequentially showed on Figs. 4, 5 and 6. Displayed draught force was inferred on adjustable spacer placed in lower arms joints. Distributed force was transferred to draft sensors over three point hitch links. Symmetry of loading was maintained. Due to boundary conditions draft sensors were loaded by half of drought force. In the following graphs total draught force in dependence on left draught sensor voltage output is plotted. Signal from right draft sensor was not evaluated, because it wasn't possible to take out output signal of this sensor. Voltage on the left draft sensor was measured in a range from 5 to 4 V with draught force going from 0 to 30 kN.

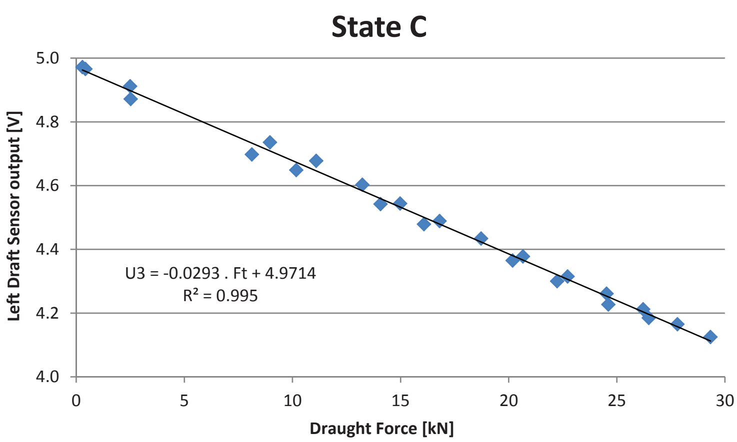
For comparison from all states, if draft sensor is loaded by specific constant force in different directions, diverse output is generated. The proof of this assertion was cleared by substituting specific force to equation of regression. After that appropriate voltage was determined. It was possible to determine behavior of the draft sensor in dependence on the directional loading by comparing output voltages. Calculated values are shown in Tab. I. For state A equation number 1 was



4: *Draught force and left draft sensor voltage output dependence – state A*



5: *Draught force and left draft sensor voltage output dependence – state B*



6: *Draught force and left draft sensor voltage output dependence – state C* determined. Also equations of state B and C were determined and they are printed below:

Equation U1: $U1 = -0.0316.Ft + 4.9644$ [V], (1)

Equation U2: $U2 = -0.0318.Ft + 4.9557$ [V], (2)

Equation U3: $U3 = -0.0293.Ft + 4.9714$ [V]. (3)

I: *Calculated voltage from regression equations*

Voltage	Draft force Ft [kN]				
	20	22	24	26	28
U1 [V]	4.33	4.27	4.21	4.14	4.08
U2 [V]	4.32	4.26	4.19	4.13	4.07
U3 [V]	4.39	4.33	4.27	4.21	4.15

Calculated values of voltage output shows the fact, that different voltage is generated in the draft sensor during directional loading caused by constant pulling force in different directions.

CONCLUSION

From loading of draft sensor is evident, that the output voltage depends on direction of loading and overall loading force. During the loading, linear voltage output is generated. With loading force increase, output signal degrease. Difference between unloaded and fully loaded sensor output is 1 V. This conclusion brings general behavior of draft sensors. Before using these sensors as a source of monitoring of draught forces, would be appropriate to determine the calibration range in total angular directions.

Nowadays produced tractors are equipped by draft sensors, installed in both lower arms pins. These elements are used for correct function of EHR systems. Connecting to the cabling is easiest way for obtaining a source signal. For monitoring of all forces in three-point hitch, load cells in upper link and both lift arms are necessary. Lower arms forces would be measured just by using the tested draft sensors. As a result, it would be possible to measure all forces with small financial budget.

SUMMARY

When draft sensor, used in modern concept of three point hitch, is loaded, mechanical tension is transformed to the electrical signal. Due to realized measurements function and behavior of draft sensor while loading by draught force was cleared. Result of this measurement is that the draft sensor measures spatial tension and transmits it to the electrohydraulic system control unit in a form of voltage signal.

The whole experiment was separated into three basic geometrical configurations. First configuration shows three-point hitch in middle position. This position represents work with mounted implements. In second case, upper position is represented. Third configuration simulated three-point-hitch in lowest position, such as is used for example during plowing.

It would be appropriate to measure the draft sensor in a wilder angular range for confirmation of this thesis. It is realizable for example by using appropriately constructed preparation, which would be able to press the draft sensor in random angular directions. Obtained information's could be used, for designing of tensometrical three point hitch. This equipment serves for measuring of forces generated from attached implements (H. F. Al-Jalil *et al.*, 2001). Based on this, forces acting on driving wheels may be evaluated (P. Portes, 2013). For draft and speed measuring, portable instrumentation systems could be also used (N. P. Thompson and K. J. Shimmers, 1989). But for this method, special device must be designed which is disadvantageous. Usage of draft sensors placed on lower arms as a cell for force measuring eases access to the issue. Another opportunity is using obtained information's in diagnosis of non-destructive methods, when analogical principle could be used for draft sensor functionality testing. Future experiments leads to usage of draft sensors for measuring forces in both lower arms of tractor hitch. In general, voltage output will be transformed by voltage converter to force value.

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