

# STATIC TESTING OF DRAFT SENSOR FOR THREE POINT HITCH DYNAMOMETER UTILIZATION

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## Abstract

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This paper investigates the possibilities in design of universal three point hitch dynamometer. Approaches in different hitch dynamometers are explained and pros and cons are mentioned. Also main parts and functional principle of draft sensor are clarified. The main goal of this research is clarification and examination of draft sensor output signal on angular draft force dependences. Utilization of draft sensor as a source for draft force sensing in lower arms is intended and examined. Research was focused on loading of draft sensor in different directions for proper screening of voltage output. Special loading device was designed and used with respect of real mounting conditions and force loading identically to bearing pins of tractor hitch lower arms. With usage of calibrated load cell and National instrument sensing control unit stage loading diagram of draft sensor was obtained. Results show basic feedback of voltage output on force load angle variation. In non-load condition, voltage output fluctuates around 5 V. In the main direction of draft force application voltage drop occurs from 5 V up to 3.16 V. Reverse direction of loading brings the voltage output increment from 5 V up to 7.06 V. When the load is applied with angular inclination voltage output changes are diminished up to 90° and draft sensor shows voltage output symmetry against the main axis. Based on stage loading diagram the appropriateness of draft sensor usage in design of universal three point hitch dynamometer is discussed in paper summary. Also further research opportunities and results application are suggested.

Keywords: tractor hitch, draft sensor, three-point hitch dynamometer, directional loading device, stage loading diagram, force transfer

## INTRODUCTION

Ordinary ploughing is a one of the most energy-intensive operations in crop production. Based on tractor engine nominal power and torque, equivalent plough is mounted. Rig utilization is based on this well-known fact and this approach affect field performance and fuel consumption. Another variable that affects the rig performance is an adjustment of three point hitch. Inappropriate coupling often causes increase in wheel slip and undesirable load transfer which estuary unsuitable weight distribution. This adjustment affects not only the field performance, but also soil compaction due to load transfer from tractor tilt and force resultant from ploughing directly on wheel load (Portes *et al.*, 2013). Wheel slippage increase leads to

loss in traction power causing hectare performance loss. Finding of the optimal setting of tractor hitch requires load cell measurement for analysis of the force effects. Several methods for force obtaining are suitable. For example technical design of three point hitch dynamometer was designed by (Palmer *et al.*, 1992) and (Godwin *et al.*, 1993). Implement with commercial load cells was developed and used for several measurements. Solution disadvantage was implementation of device between tractor and plough. Geometry and trajectory of original coupling between tractor and plough were changed. Another solution is usage of three point hitch dynamometer. Simply it's an ordinary tractor hitch fitted by strain gauges on each link. From this kind of hitch forces output could be achieved for an

analysis. Fitting of load cells directly on the arms of three point hitch will preserve original geometry and its trajectory. Draft sensors located in lower arms pins brings an option for draft force monitoring. It is important to obtain the response of draft sensors for this purpose. This paper devotes to the description of draft sensor stage testing. Methodology of the measurement is mentioned at first then conclusion and discussion follows. All results will be used in design of three point hitch dynamometer for adjustment and calibration of draft sensor outputs and for better clarification of draft sensor behavior and function.

## MATERIALS AND METHODS

### Three Point Hitch Dynamometer

There are several designs of tractor hitch dynamometers. One of them is equipment which uses ordinary linkage mechanism known as tractor hitch. Each link is fitted by calibrated load cells for a proper measurement of force during the field operations. There are at least five load cells on that kind of hitch. One is located on upper link, others are placed on lower arms and rest of them on lift arms. This composition allows monitoring of draught forces and momentums generated from implement. Disadvantage of this approach is utilization only on one testing specimen of a tractor. There is a possibility of device reinstallation but only on tractors of the same brand and hitch category.

Another option is to develop central T-shaped box which can be telescopically adjusted and installed between tractor and implement. This approach brings the opportunity for universal solution. Still there is one major disadvantage. Geometric configuration of the rig is amended due to diameters of T-shaped box. Original connection is not respected (Al-Jalil *et al.*, 2012).

Then there is an idea of usage of draft sensors as strain gauges for monitoring of draft force in lower arms. With a combination of upper link fitted by strain gauge and this kind of solution idea of

universal tractor hitch dynamometer arises. There is necessity of draft sensors suitability investigation.

### Draft Sensor Definition

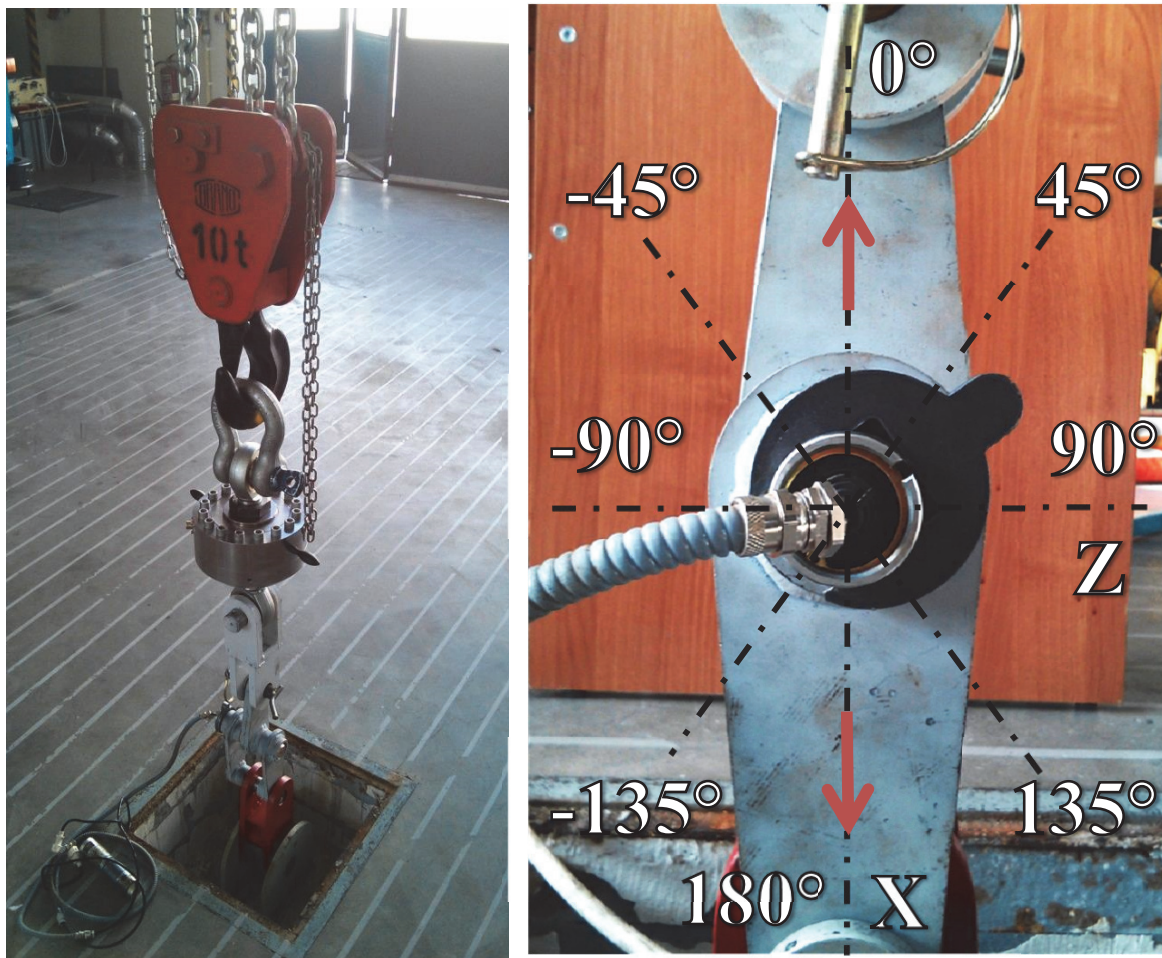
Draft sensors takes the form of bearing pins located between tractor body and lower arms. Magneto elastic effect is used when the shear stresses occur at the bearings. Draft sensor operating principle consists of primary and secondary coil, primary and secondary pole face and steel sleeve. In case of non-load condition, a symmetrical magnetic field is formed between the poles by means of the primary coil. When the draft forces are introduced, there is a change in the originally isotropic magnetic properties. Subsequently, the magnetic field becomes asymmetrical. Magnetic potential difference occurs between the secondary poles. This causes a magnetic flux through the secondary circuit. Voltage is induced in the secondary coils. This voltage is proportional to the influencing force. Signal is amplified and rectified in an integrated evaluation circuit. Subsequently amplified signal serves as a input for electrohydraulic hitch control of the tractor. This is essential signal for Draft control. In draft control, the controlled variable is the force at the trailing linkage. If the force in trailing linkage can be kept constant, tractor power can be used optimally especially during the ploughing of undulating land and inhomogeneous soil (BOSH EHR).

### Loading Device

Design of loading device was based on technical documentation from draft sensor manufacturer. Diameters and dimensions of magneto elastic pin were taken into account. Also connection and mounting position of pin was reflected in loading device design. Draft sensor is mounted into the loading device into pin chamber and it is clamped by clamping segment. Clamping segment serves as angular set up. For connection of strain gauge pin bed is located on one side of loading device. Towing gap serves to loading device anchoring. Designed and manufactured loading device is plotted in Fig. 1.



1: Loading device with draft sensor



2: Measuring system (on the left), loading diagram (on the right)

### Measuring System

For draft sensor loading, portal crane was used. This solution brought simple and easy control of draft sensor preloading. Between the crane hook and anchored anchor loading device with draft sensor and strain gauge were fitted. Total carrying capacity of portal crane and strain gauge with range of 0 to 10 kN were taking account during the draft sensor loading. Strain gauge HT 250 was installed between loading device clamping and cranes hook and it was calibrated according to ČSN EN ISO 17025. For draft sensor voltage and load cell force output reading National Instrument modular sensing control unit was used. Connection between draft sensor and modular sensing control unit was realized according to circuit scheme from manufactures user guide. For power supply MPS 3003L-3 power supply module was used and pre-set on output of 10 V. Voltage supply was maintained on constant level during whole measurement states. For recording of voltage output from draft sensor and force level LabView software with proper program was applied. Measuring system is plotted on Fig. 2 (on the left).

### Loading Cycle

Draft sensor mounted into loading device was tested in several geometric configurations. Default position was selected on the basis of main draft force direction during the field operations. In this case lower arms of three point hitch are parallel to the field surface. This position was marked as 0. Angle increments of 45° were realized. Applied force was in range 0 N up to 70 kN with increment of 10 kN. Loading diagram is plotted on Fig. 2 (on right). Force was always applied in longitudinal axis of loading device. Loading in different angles was realized by draft sensor rotating in appropriate direction according to loading diagram.

### RESULTS

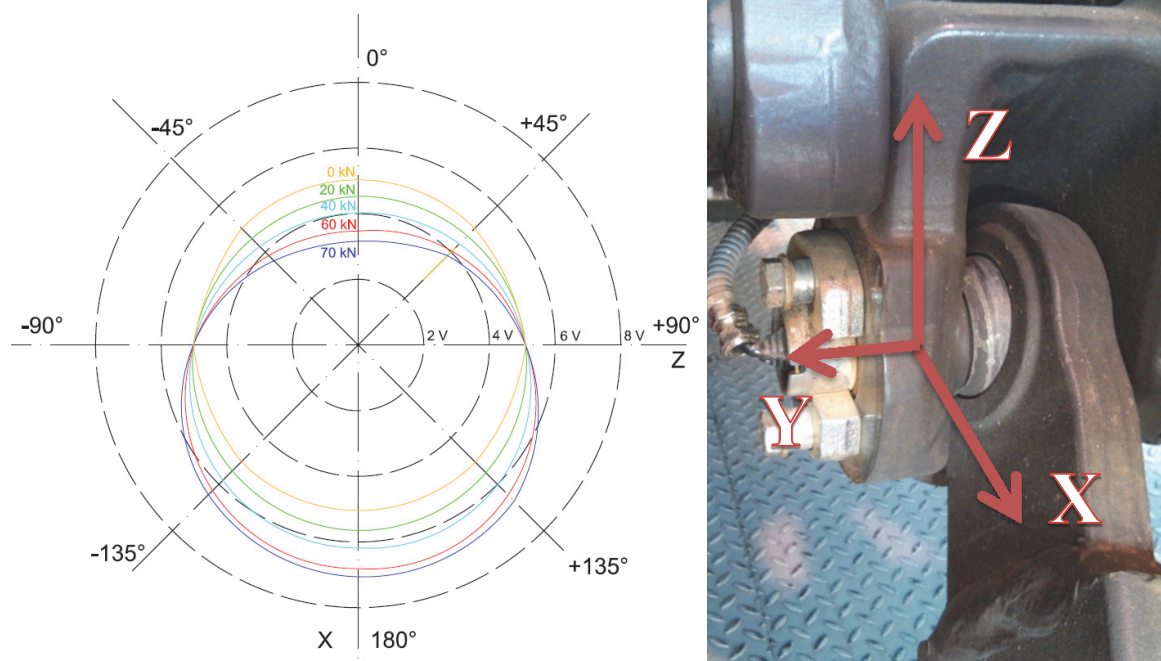
Voltage output from draft sensor and force load from strain gauge were obtained. Obtained values were formed into the Tab. I.

Stage loading diagram was constructed in 360° spectrum for clear presentation of results. Stage loading diagram is plotted in Fig. 3 (on the left). Coordinate system location of draft sensor is plotted in Fig. 3 (on the right). Definition of the x-axis which corresponds with longitudinal axis of tractor and



I: Obtained values of voltage output and force load

Voltage output [V]		Angular position [°]						
Force Load [kN]	0	45	90	135	180	-45	-90	-135
0	5.06	5.06	5.06	5.05	5.04	5.03	5.03	5.03
10	4.79	4.86	5.08	5.29	5.36	4.80	5.01	5.25
20	4.53	4.71	5.11	5.51	5.65	4.58	5.01	5.42
30	4.26	4.54	5.14	5.76	5.92	4.44	5.00	5.64
40	4.03	4.36	5.17	6.01	6.18	4.24	4.99	5.83
50	3.76	4.19	5.19	6.26	6.47	4.04	4.99	6.07
60	3.47	4.04	5.22	6.46	6.81	3.85	4.99	6.27
70	3.16	3.85	5.25	6.72	7.06	3.63	4.99	6.45



3: Stage loading diagram (on the left) and coordinate system location (on the right)

original mounting position of draft sensor with cabling is also plotted in Fig. 3 (on the right).

When the shear stress is occurred at the draft sensor, magnetoelastic effect is performed. In non-load condition, symmetrical magnetic field is formed. Voltage output in this case fluctuates around 5 V in all angular orientations. During the loading in zero position, significant voltage change is recorded. Voltage drop from 5 V to 3.16 V persists and at maximum load voltage difference of 1.9 V is reached. With angle increase, voltage output sensitivity declines up to minimum in case of 90° angular position. This phenomenon was observed also in angular range from 0° to -90°. There is evident voltage output symmetry along X axis which corresponds with longitudinal axis of tractor. Similar behavior of the draft sensor was expected because the resultant and tractor pull power force are located in longitudinal direction. During the loading in 180° position significant voltage change appears. Voltage upsurge from 5 V to 7.06 V occurs

and at maximum load voltage difference of 2.02 V is reached. This phenomenon refers to several conclusions. When the shear stress from tension occurs, voltage output declines with force load increase. Subsequently when the shear stress from strain occurs, voltage growth arises with force load increase. These findings must be taken into account in voltage output scanning of draft sensor in terms of force monitoring in tractor hitch lower arms.

## DISCUSSION

Soil stress and soil compaction are familiar problems of ordinary ploughing. Tractor tilt, load transfer and inappropriate connection between tractor and implement are the main factors affecting increase in soil bulk density near the soil surface and potential growth of subsoil compaction (Keller *et al.*, 2002). One of the possibilities for reduction of these effects is correct tractor hitch geometry presetting for tillage power optimization (Bentaher *et al.*, 2008).

Three point hitch dynamometer is required for searching of optimum adjustment. One of the most advantageous alternatives in design of universal three point hitch dynamometer with economical aspect consideration is usage of draft sensors as a source for monitoring of draft forces generated in lower arms due to draft sensors application in serial production of nowadays tractors. In this case observation of draft sensor signal output in dependence on applied force is very important.

Final design of universal hitch dynamometer should use force monitoring of upper link fitted by strain gauge and draft force sensing with usage of draft sensors located in lower arms as bearing pins. Replacement of lift arms with linkage equipped by strain gauge arises. There is an option of strain gauge connecting link usage. Future research opportunity is design and manufacturing of three point hitch dynamometer prototype.

## CONCLUSION

This work is aimed on static testing of draft sensor for three-point hitch dynamometer utilization. During the laboratory measurements of draft sensor in different loading conditions brought essential conclusions for future design of universal three point hitch dynamometer. Loading device design and manufacturing enabled the testing of draft sensor in 360° range. This measurement provided full-screen voltage output depending on force magnitude and direction of force operation. Voltage output and draft force magnitude were monitored by National Instruments sensing control unit and LabView software usage. Draft sensor showed voltage output symmetry along X axis. Dissimilar voltage output occurred when tension or strain was applied. When the shear stress from tension was applied, voltage output declined with force load increase. Subsequently when the shear stress from strain occurred, voltage growth raised with force load hike. In case of force direction change, voltage sensitivity varied with respect to the loading direction. The sensor is insensitive on loading in perpendicular directions to longitudinal axis of tractor both in 90° and -90° point of action of the force. This attribute is advantageous for monitoring of draft force due to horizontal forces elimination. During the laboratory measurement calibrated strain gauge sensor was used which allows the results utilization for static calibration of measuring system. Suitability of draft sensors in design of three-point hitch dynamometer is evident from obtained results. This fact is also confirmed by sensors voltage output exploitation in electro-hydraulic hitch control at draft or mixed control operating modes.

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