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Research Article

DESIGN AND DEVELOPMENT OF THREE-POINT HITCH DYNAMOMETER-INSTRUMENTATION AND CALIBRATION

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Abstract: Three-point hitch dynamometer for the tractor was designed, developed, instrumented and calibrated. This three-point hitch dynamometer is suitable for use with tractors having category II or III hitch. The dynamometer has 6 load cells for measuring the soil reactions on the implement. These load cells are mounted between two sub frames and connected with Wireless Sensor Network. The data acquisition system was NI WSN-3214 Strain Nodes, NI 9792 WSN real-time Gateway and computer running NI LAB View 2013 software with developed data logger program. The procedure for calculating the tillage force was developed and the dynamometer was tested in field and verified.

Keywords: *Three points hitch dynamometer, Draft, Calibration, WSN and Data acquisition system*

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Introduction

Energy management in farming system will be of vital importance in future years. This will be brought about by the increased cost of all forms of energy and the need to produce crops with optimized inputs. In order to have better management of energy, an understanding of draft requirements must be developed for tractor mounted implements operating in various soil types and conditions. The newly developed three-point hitch dynamometer, which is intended for measuring draft of tillage machinery, satisfied both structurally all the conditions under which the preliminary tests were carried out, with wide range of possibilities for processing the obtained data. As such, this developed system is adequate for the operation of large number of carried and partially carried agricultural machines of II and III categories [5], machines are easily attached to measuring frame and transport is safe. Smith and Barker (1982) constructed a dynamometer which utilized six commercial load cells mounted in a triangular pattern [9]. Three of the load cells were mounted at the vertices of the triangle to measure draft force. Two cells were mounted in the legs of the triangle to measure vertical and horizontal forces and one cell was mounted in the base of the triangular pattern to measure only horizontal force. Thus, it was possible to identify both the vertical and horizontal components of implement reaction. Another feature of the Smith-Baker dynamometer was the installation of an inclinometer within the dynamometer frame. The inclinometer readings were used to determine the angular position of the tractor bottom links.

Jonathan Chaplin *et al*., (1987) designed, constructed and calibrated three points hitch dynamometer [2]. It was concluded that instrument has an accuracy of 5 %, for the 5 to 45 kN draft forces in all directions. Errors in recovery of the applied load were attributable to the alignment of the load cells and the friction in the ball end connections between the load cells and supporting frame. The dynamometer performed well in the field and satisfied the design requirements. Garner *et al*., (1988) constructed the three points hitch dynamometer and it made possible the measurement of the complete tractor-implement, force moment system in a vertical longitudinal plane [3].

In calibrating the dynamometer, it was found necessary to use a test stand in which horizontal, vertical and moment loads could be applied simultaneously. Palmer, (1992) described the three-points linkage dynamometer for the measurement of loads on agricultural tractors by implements mounted on a standard three-point linkage conforming to categories 1, 2 or 3 [7]. It could also be used with other mounted implement, such as lifting or carrying devices, included PTO driven equipment. The use of six orthogonal load cells allows the applied load to be fully resolved into its components. The computer-based instrumentation system can be programmed to calculate and record any combination of the components of the applied load and speed. Manohar Jesudas, (1994) developed tillage dynamometer for evaluating the performance of deep tillage tool [6]. The working principle of operation of the dynamometer was similar of the tillage meter. The tool was mounted on a subframe and was held in equilibrium by the reactions provided by the system of six dynamometers. The hydraulic pressure recording dynamometers were used to measure and record the pressures. It was observed that the accuracy of the sensing unit compared to most of the state of art dynamometer systems was exceeded 99.9 percent.

Kheriralla *et al*., (2003) developed and calibrated three-point hitch dynamometer which measure horizontal and vertical forces existing at the three points linkage of the Massey Ferguson 3060 tractor for mounted implements having hitch category I and II [4]. Between tractor - three points linkage and implement, it has inverted (U frame) assembly consist three extended octagonal ring transducers. Operating range for horizontal and vertical force of transducer designed as 25 to 10 kN though the three points hitch dynamometer designed for 50 to 20 kN. Alimardani *et al*., (2008) investigated the draft power requirement for pull type implements [1]. The force between tractor and mounted implement is considered by designer which justifies the needs of three points hitch dynamometer. In this study, three points hitch dynamometer having high sensitivity and strength, measuring five force components simultaneously, compensating the temperature changes using the full Wheatstone bridge and adapted to the tractor categories 0 and 1.

Pijuan *et al*., (2012) designed the three points hitch dynamometer to measure the longitudinal, vertical and lateral forces [8]. The data come from six independent links with the corresponding load cells. The developed three points hitch dynamometer can be attached to II and III category agricultural tractors. Based on that, a previous study determined that the maximum allowable load is 80 kN in longitudinal, 80 kN in vertical and 45 kN in lateral direction. Also, this dynamometer has been built with adjustable pin joints that allow attaching it to a wide range of implements.

Materials and methods

Design and development of three points hitch dynamometer

A three-point hitch dynamometer was developed as a universal three-point hitch dynamometer *i.e*. it can be fitted to any tractor–implement combination. These three points hitch dynamometer is a double frame unit. The front side of tractor end frame is attached to the tractor while the rear side implement end frame is attached to the implement shown in [Fig-1].

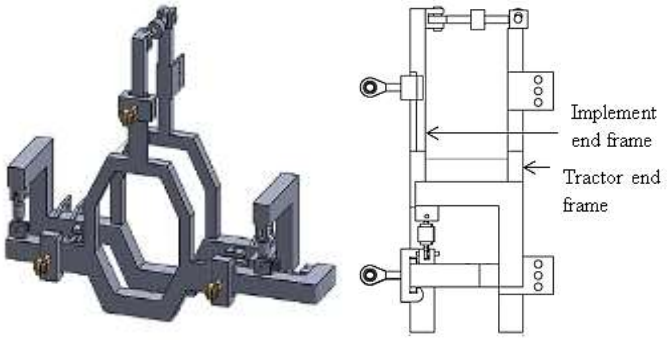

Fig-1 Design and development of Three points hitch dynamometer

The hitch points of the implement end frame are movable for hitching with implement. The three points hitch dynamometer can be easily connected or disconnected with the tractor and implement. It uses six load cells for sensing and measuring the draft forces of the implement. The total weight of the three points hitch dynamometer with all accessories was 130 kg. The developed three points hitch dynamometer can be attached to category II or III tractors. The design of three-point hitch dynamometer hexagonal pattern and also allows mounting of Power Take-Off (PTO) driven implements without torque sensing.

The main components of the three points hitch dynamometer are shown in [Fig-2].

- Tractor end frame
- Implement end frame
- Load cells
- Telemetry data acquisition system

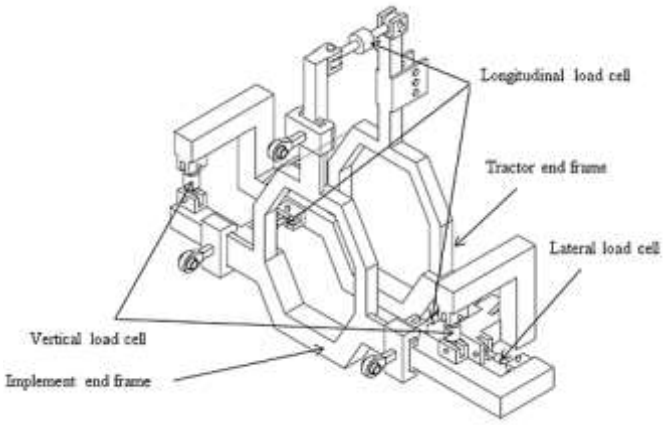

Fig-2 General view of three point hitch dynamometer

Construction

The three points hitch dynamometer is a double frame unit with the front end attached to the tractor while the rear end is attached to the implement. Tractor end frame consists of rectangular and square pipes of 80 × 75 × 6 mm and 50 × 50 × 2.5 mm. The three points hitch assembly is provided in the front portion of the tractor end frame and other side of tractor frame provided with the load cell mounting assembly unit. The weight of the tractor end dynamometer frame was 67 kg. Implement end frame consists of rectangular and square pipes 80 × 75 × 6 mm and 50 × 50 × 2.5 mm. The two lower links and one top link assembly is provided in the rear side of implement end frame and tractor side of the implement frame provided with the load cell mounted unit. The weight of the implement end frame was 60 kg. Implement end frame provided with movable lower links and top link for II or III category implements, similar to tractor hitch link.

Load cell

The design of three points hitch dynamometer required six cylindrical load cells on three orientations. The six load cells are equally arranged in every direction *i.e*., three load cells for longitudinal direction, two load cells for vertical direction and single load cell for lateral direction. The load cells have maximum and minimum capacity of 2000 kg and 500 kg. These load cells are connected between tractor end frame and implement end frame with eye rod end bearing.

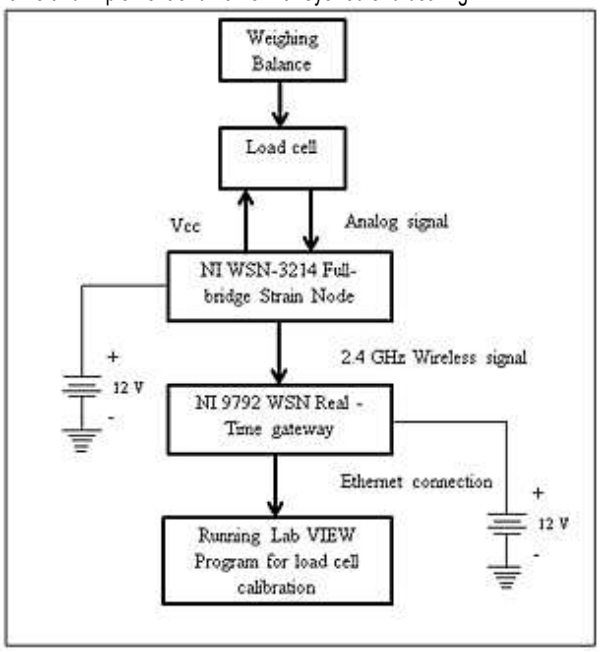

Fig-3 Load cell calibration

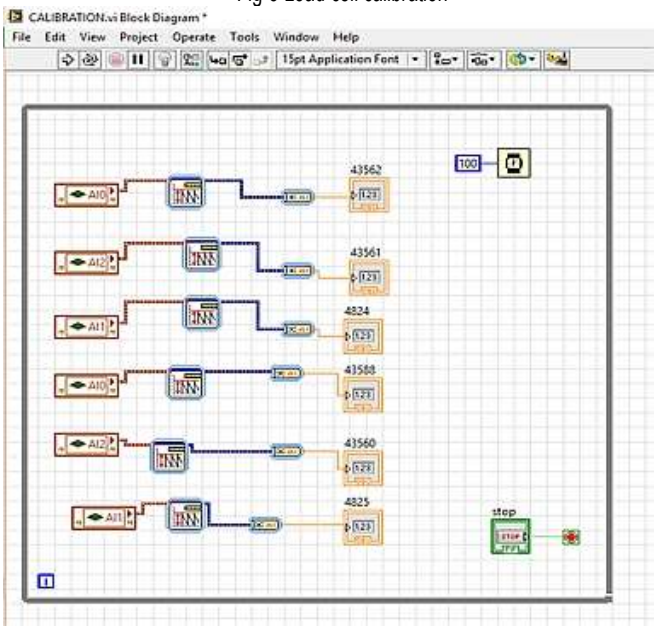

Fig-4 Lab VIEW Block Diagram for Load cell Calibration

Load cell Calibration

Most systems, before the start of the measurement, it is necessary to know its dependence of output quantity on input quantity characteristic.

This characteristic of load cell with strain gauges represents dependence of the output voltage of load cell on the load itself. It is important to perform a calibration in order to determine this characteristic. The calibration procedure is implemented as shown in flow chart [Fig-3] & [Fig-4]. The calibration of load cells is done with developed Lab VIEW program. Load cell is attached with electronic balance and whole unit mounted in chain jack. The known load of load was applied in chain jack, as increasing manner. The mounted unit loads are verified with electronic weighing balance (kg) and readings from Lab VIEW and were noted (mV) down. After the procedure finished the calibration curves are plotted.

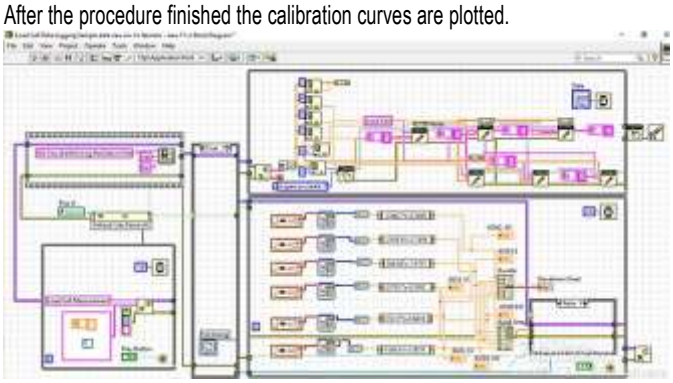

Fig-5 Development of Data logging program for field evaluation

A virtual instrument has been created in Lab VIEW software for measure the output voltage of load cell. After virtual instrument for calibration of load cell was developed, the Lab view data logging program for field trail developed as shown in [Fig-5].

Force and moment components of dynamometer and implement

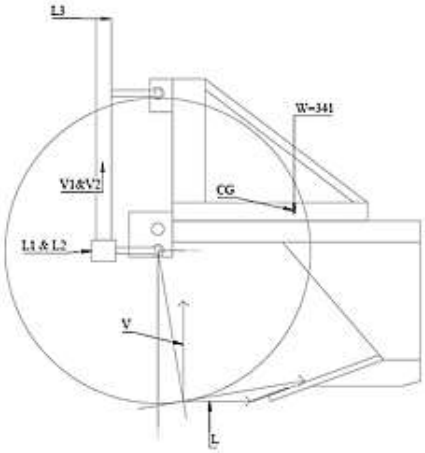

Fig-6 Force and moment components of three points hitch dynamometer

The force and moment components in the Cartesian coordinate system, as shown in [Fig-6] were computed from the following equations

$\Sigma Fx = 0$

$L1 + L2 - L3 - L = 0$ (1)

$\Sigma Fz = 0$

$V1 + V2 - V - W = 0$ (2)

$\Sigma Fy = 0$

$S - S1 = 0$ (3)

Moment @ L1 in x – x

$VxVy + V1 \times (b - a) - V2 (b + a) = 0$

Moment @ L1 in z – z

$L3 \times a - L2 \times 2a - LLy - SxLx = 0$

Moment @ y – y then L1

$L3 \times h + W \times Xw - YI(L) + (V1 + V2)V0 = 0$

ΣFx, ΣFy and ΣFz were force components along the x, y and z axes. L1, L2, L3, V1, V2 and S were forces on load cells. a, b and h were the position parameters of the load cells, and W was the weight of the sub frame and implement.

Data acquisition system

The six load cells were connected to the Wireless Sensor Network 4-Ch Full Bridge Strain Node, each for connected three load cells. The NI WSN-3214 Strain Node mounted on top of the three points hitch dynamometer in implement side frame. The data acquisition system was NI WSN-3214 Strain Nodes, NI 9792 WSN real-time Gateway, computer running NI LAB View 2013 software with developed data logger program as shown in [Fig-7]. This data acquisition system powered with 12V, 7 Ah DC battery in remote side of the field. The computer was utilised for developed data logger LAB View program.

NI 9792 WSN Real-Time Gateway & Recording system

NI WSN 3214 Strain Node

Fig-7 Wireless Sensor Network Data acquisition system

Results and discussion

To measure the draft at tractor and mounted implements with the designed three points hitch dynamometer, the load cells were individually calibrated and then calibration constants were used to obtain the exerted forces directly. As expected, the relationship between the output voltage for the individual load cells and applied load was linear as shown in [Fig-8].

After the calibration done, tillage force system for three points hitch dynamometer was developed. With developed system, the three points hitch dynamometer tested in field condition and verified as shown in [Fig-9].

Fig-9 Dynamometer tested in actual field condition

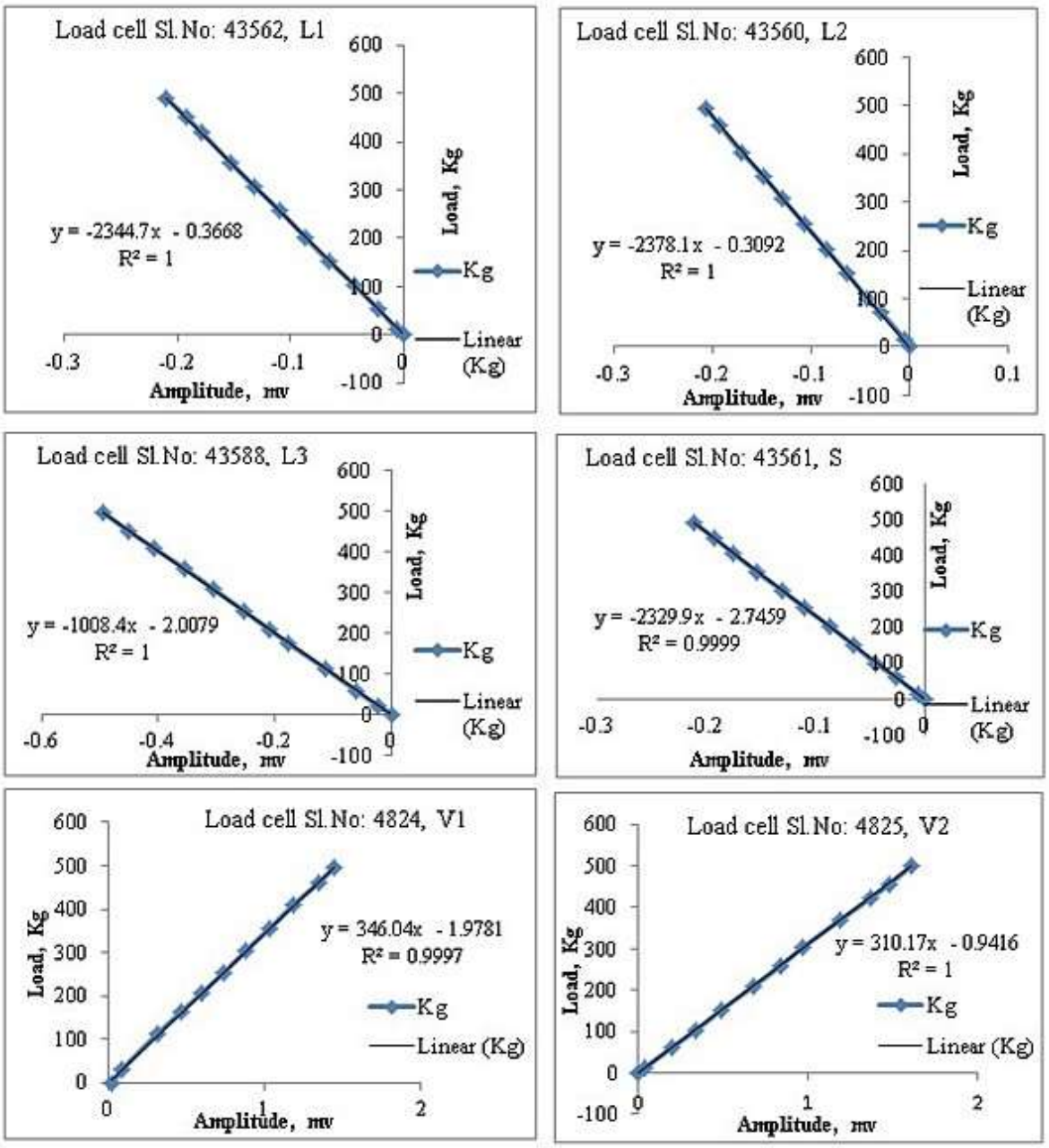

Fig-8 Different load cell calibration curves used for draft measurement

Conclusion

The three points hitch dynamometer was designed, developed, instrumented and calibrated. Instrumentation of the three points hitch dynamometer allowed for evaluating the horizontal, vertical and side forces generated by tractor for mounted tillage implements having hitch category II or III. Also load cell have maximum and minimum capacity of 2000 kg and 500 kg, respectively. The load cells show good linearity between applied load and output strain and good measurement accuracy between applied load and measured load (correlation coefficient nearly to 1). The developed dynamometer was verified in field and it is easy to attach with tractor and implement to transport.

Application of research: To reduce the draft and optimise primary tillage implement, the three points hitch dynamometer was designed, developed, instrumented and calibrated.

Research Category: Farm machinery and Power Engineering

Abbreviations: NI - National instruments
WSN –Wireless Sensor Network
Lab VIEW – Laboratory Virtual Instrument Engineering Workbench

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Study area / Sample Collection: Agricultural Engineering College & Research Institute, Coimbatore, 641003

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

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