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Research Article

STUDY ON SENSITIVITY OF LOWER LINK AND TOP LINK DRAFT SENSING IN ELECTROHYDRAULIC HITCH CONTROL SYSTEM

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Abstract: Major impacts on tractor performance during tillage is variation in soil draft. Hence draft control is a vital aspect for farmer in tillage operation. Draft control can be electronic based or mechanical based. Electronic draft control with EHH system is more sensitive than mechanical draft control. Draft control can be done by both top link and lower link sensing but the one with high sensitivity will result in better response time. This paper presents comparative study between lower and top link sensing sensitivity via recreation of field condition in lab known as soil simulator test rig and analyse the performance of the same in the field with help of data logging and instrumentation technique. Results depicts better sensitivity of the lower links (1.048) compared to top link (0.406) which enhances the system response time by 52 to 150 milli seconds depending on soil conditions.

Keywords: *Draft control, EHH¸ Sensitivity, Response time, Draft*

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Introduction

Agricultural tractors are used to tow and move implement. Most implements are mounted type, connected to tractor through three-point hitch linkages. Before the start of farming operation, the farmer sets the draft control at suitable position such that there is minimal slip during tillage. Hence, draft control is a very important function to be taken care of while in tillage operation. These three-point hitch linkages are controlled by Position control lever and draft control lever for mechanical based hydraulics tractors. EHH systems are also now a days available which are better than their mechanical hydraulics counterparts. EHH system has ECU to regulate the amount of lifting and lowering based on the input by set by user and the soil forces experienced by the implement in tillage. ECU sends the current to solenoid operated lifting and lowering control valves which regulates the flow based on current. Hence the draft control can be achieved either by mechanical hydraulics system or by electrohydraulic system. For draft control sensing of the draft force or proportional draft force is essential, in current scenario proportional draft force is only sensed in tractors. In mechanical hydraulic system it is sensed by helical springs and in EHH systems it is sensed by sensors which may be load cell based on magneto resistive principle or in build strain gauges. The proportional draft force can be sensed either through top link or through lower links [1]. Generally lower link sensing methods are used for higher horsepower tractors [2]. Sensitivity here was defined as the change in output or the change in sensed force either in top or lower link to the change in input force or the input draft force. The sensing method in which the sensitivity will be higher will have an advantage over the other type of sensing since, Sensitivity directly affects the response time of the system. Hence significance of sensitivity is very much in draft control because it truly decides which sensing method will be superior. This paper presents a methodology to identify the sensitivity of top link sensing and lower link sensing at the link points of the tractor of the EHH since generally link points of the tractors are used for draft sensing which resembles the mechanical sensing position of the spring.

EHH system description

Implement are attached to the three-point linkage consisting of top and lower links on the tractor. These top link and lower links of the tractor are available at different sizes depending on the category of the tractor. The below [Fig-1] shows Diagram of an EHH system which helps in lowering and lifting of the implement. The hydraulic drive is taken from the pump available as tandem pump in the tractor which operates all the steering and hydraulic systems of the tractor. Then the hydraulic fluid passes through the control valve which is solenoid operated and takes the signal from ECU of the EHH system. The ECU provides current to the valve which regulates the opening and closing of the port and regulates the amount of flow going through the hydraulic system.

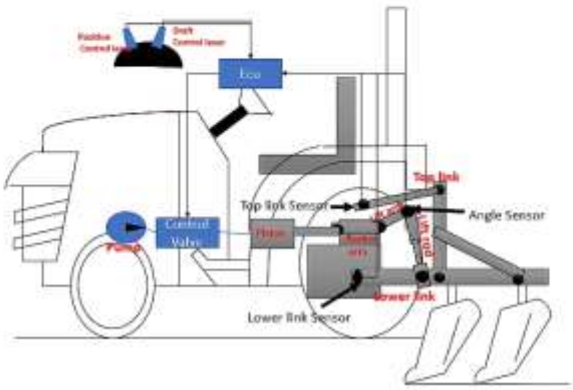

Fig-1 EHH system Layout

This flow extends or retracts the piston of single acting cylinder of the tractor which is mechanically connected to rocker arm, lift rod and lift arm mechanically. This extend and retract movement of the piston makes the lowering and lifting of the cylinder. It is now important to know that how ECU decides upon the current.

The current value is decided upon the Position control and draft control input from farmer, and the feedback signals namely Lower link sensor, top link sensor and the position or angle sensor. Upon processing in the ECU by application software the ECU send the current signal to the solenoid control valve [3-5].

[Fig-1] shows the placement of all the three sensors on the three-point linkage. The top link point, and two lower link points have load sensors which are magneto resistive in nature and have the capacity of measuring up to 20.5 kN both on negative and positive directions. The angle sensor is Hall effect sensor and is calibrated with the system for measuring up to 0° to 90° of angle measurement.

Theoretical considerations

Few assumptions were made for deriving sensed force acting on the lower and top hitch point.

1. The center of gravity and center of resistance of the implement are acting on the same point.
2. Center of resistance is located at a distance of two-third of depth of operation from ground surface.
3. The two lower links are of equal length and coincide together when viewed from side.

[Fig-2] given below shows the free body diagram of an implement while in operation.

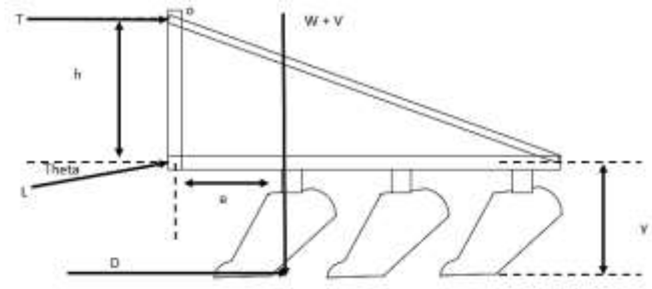

Fig-2 FBD of implement

Taking moment about point X in [Fig-2]

We have,

$$L = \frac{D \times (y+h)}{h \times cos\,(\varphi)} - \frac{(w+Sv) \times e}{h \times cos(\varphi)} \qquad (1)$$

Where

L = Lower link force (N),

T = Top link force (N), D = Draft (N),

e = Distance between Lower link hitch point (m) and Centre of resistance (m)

W = Weight of implement (N)

SV = Vertical soil reaction force (N)

h = Mast Height (m) (for II category hitch system)

φ = Angle made by lower link with horizontal (°)

y = Distance between lower link hitch point and center of resistance (m).

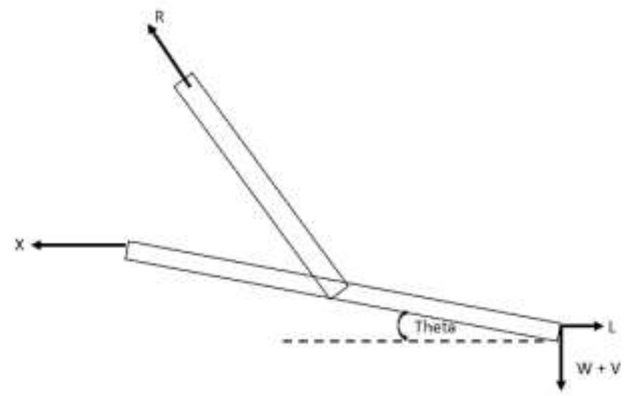

Fig-3 FBD of lower link

[Fig-3] shows the free body diagram of a lower link. The draft load sensor was attached on the lower link point. To know the amount of maximum force acting at the lower link point, the sensed force expression had to be derived. Following assumptions are made for this calculation,

1. The two lower links are of equal length and coincide together when viewed from side.
2. Considering angle between lift rod and horizontal as constant.
3. Considering angle between lower link with horizontal as small.

From [Fig-5] the sensed force can be calculated as,

$$X = L - \frac{(w+Sv) \times j}{f \times tan\,\theta} \qquad (2)$$

Where,

X = Sensed Force on the Link Point (N) R = Lift force (N)

θ = Lift rod to horizontal angle (°)

f = Distance between lower link point and lower hitch

φ = Angle of lower link to horizontal (°).

j = Distance between lower link point and point of connection of lift link (m).

Vertical soil reaction force (SV) depends on the soil condition as well as on the geometry of the implement. Vertical soil reaction force is the product of draft and a constant. The value of this constant was taken from the Kepner, *et al*., (2017) [5] and the draft force was calculated from ASAE draft equation. Other details are taken tractor test report.

Materials and Methods

Selection of Sensor

Selection of load sensors and angle sensor was critical to measure the sensitivity because load cell would provide the output for the input draft force on both top and lower links. The angle sensor would give input about which position the data are captured. A 57 hp tractor with drawbar pulls capacity of 45 hp was selected for this research. From the above equations sensed force was calculate for the selected tractor and the draft force was calculated from ASAE equation [6]. A moldboard plough was selected for calculation because it is a high draft implement and for three-bottom plough the maximum drawbar was matching with the tractor drawbar power. The draft parameters of moldboard plough were considered. The sensed load on lower link was calculated as ± 19 kN with consideration of 1.5 factor of safety because ASAE equation gives a variation of 50% draft value [6]. The nearest range load sensor with magneto resistive characteristic was selected with capacity of measuring ± 20.5 kN. Similarly, for top link also calculations were done and the sensed value was ± 12 kN. The angle sensor was selected based on total transport height that the implement can be lifted and correspondingly rocker arm angle was calculated. The selected angle sensor could measure up to 90°

Soil Simulator Test Rig Development

Soil simulator testing was done to study the characteristic behavior of the lower link sensors and top link sensor upon application of draft load in a simulated environment and to study the relationship between top and lower link load pin sensors. For soil simulation draft force was applied through a hydraulic cylinder to a frame which was connected to the three-point hitch system of the tractor. Hydraulic cylinder had integrated load cell for measuring the input load applied. As shown in [Fig-4] and [Fig-5] dues to application of draft force there was change in sensed force on the lower link and top link load pin sensors. The change in sensor readings upon application of load were captured in NI_DAQ data acquisition system and the data were logged in the computer.

Fig-4 Soil simulator test set up

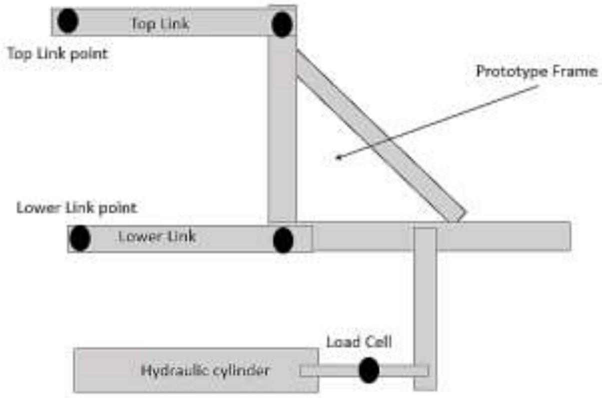

Fig-5 Soil simulator architecture

For capturing data as shown in [Fig-6], all the load pin sensors, Load cell attached to hydraulic cylinder and angle sensor data were connected to DAQ and then data was captured in data logging system.

Fig-6 Soil simulator test rig data capture layout

Field Testing

For field testing a five-tine duck foot cultivator was chosen because it could generate large draft for a 57 hp tractor and the weight of the implement was high. Different soil profile was created in the field by plowing a stretch as shown in [Fig-7]. This testing was conducted on a hard soil condition. The field was ploughed perpendicular to the stretch to observe the change in gain value. For analysis output parameters like lower link sensed forces, top link sensed force and angle sensor reading. All the data were logged in the software and computer.

Fig-7 Preparation of soil

Results

Soil simulator test rig results

The results obtained from the soil simulator experiment is shown in this [Fig-8]. In [Fig-8] it was observed that applied draft force was proportional to top and lower link sensed forces. The angle sensor was kept constant so that the lower link was at horizontal. Upon application of draft the angle fluctuation was less. As the input draft force increases the lower link sensor experiences more tension force and top link sensor experiences compressive force as clearly visible for figure. Though top and lower link experiences negative forces but one is compression and other is tension because both the points experience different forces.

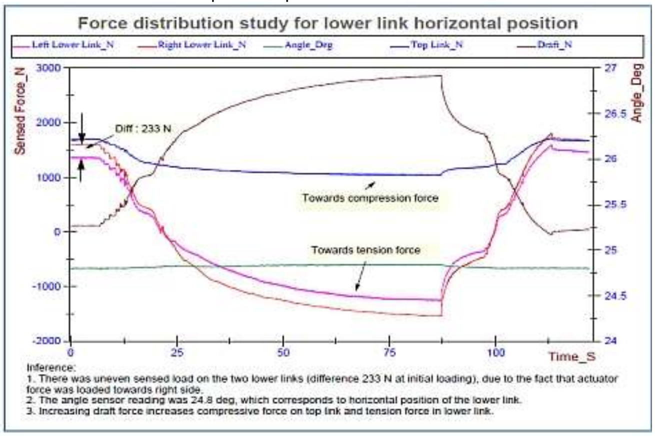

Fig-8 Simulated draft force on link points

It can be seen in [Fig-9] that the relation is not exactly linear between input draft force and the sensed forces on both top and lower links, which may be due to of the angle deviation upon application of higher input draft. It can be seen that the sensitivity of lower link sensing (1.048) is better than top link sensing (0.406). Hence the response for lower link sensor would be better than top link sensor for same input draft force.

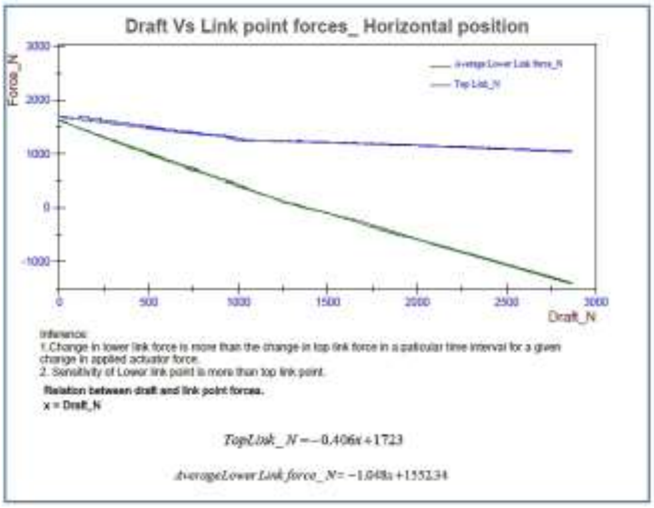

Fig-9 Sensitivity plot for lower and top link

Field Testing for Response time identification in link points

[Fig-10] shows that there is a time lag between average lower link force and top link sensed force for same input draft force. Basically, average lower link force reacts faster than top link sensed force for same input draft. Therefore, sensitivity of the average lower link sensed force is greater than top link sensed force. Time lag varied from 52 ms to 150 ms for hard and soft soil respectively.

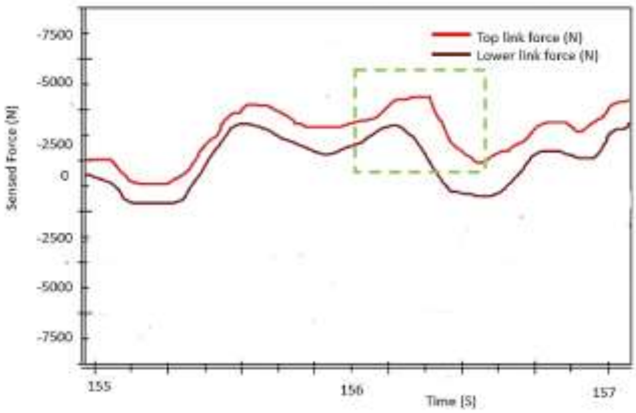

Fig-10 Response time result

Conclusion

Following conclusions were made after the conduction of study:

1. Upon application of draft, the lower link sensor experienced tension force and top link sensor experienced increasing compressive.
2. Better sensitivity of the lower links (1.048) compared to top link (0.406) enhances the system response time.
3. The top link draft sensing was lagging by 52 ms to 150 ms compared to lower link sensing.

Application of research: Study will help farmers and manufacturers in understanding the significance of lower link draft sensing

Research Category: Farm machinery and power

Abbreviations: EHH: Electro-hydraulic hitch
kW: Kilowatt, hp: Horsepower, ms: Milliseconds
ECU: Electronic Control Unit

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Study area / Sample Collection: Chennai

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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