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Longitudinal stability indication for 2WD tractors working in different field operations

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ABSTRACT

A microcontroller based digital display unit was developed for 2WD (two-wheel drive) agricultural tractors to measure and display the weight transfer from tractor front axle. The device includes a transducer for measuring the tractor front end reaction, an amplifier to amplify the transducer signal and a microcontroller to calculate and display the weight transfer from the front axle. The developed device can be mounted on any make and model of 2WD tractor. The digital display unit was rigorously tested in the laboratory as well as in the field. The weight transfer of the tractor from tractor front axle to rear axle was measured to find the stability of the tractor for different agricultural operations like ploughing, harrowing and tilling operations. It was observed that, the weight transfer during ploughing operation was greater than the harrowing followed by tillering operation.

INTRODUCTION

The agricultural tractor is rather a heavy machine and is used for a variety of operations from tillage to haulage and also, under diverse conditions. For haulage it may work on a farm road or on a concrete road, on leveled surface or on steep slopes. Also for tillage it may work on field that may or may not be leveled. The soil type and conditions may also vary. The nature of operations too will differ. Whatever the case may be, one of the most important considerations is to ensure safety in operation or in other words a hazard free operation. This is possible when a tractor is stable during a static as well as a dynamic situation.

Tractive ability of a tractor is normally affected by soil reactions against the front and rear wheels. Weight transfer or weight shift is, in fact, reaction transfer or change in the reactions of front and rear wheels of the tractor. Weight transfer, because of drawbar loading, decreases soil reaction against the front wheels and increases the reaction against the rear wheels, thus adding maximum drawbar pull which the tractor can produce while all other parameters remain constant. In addition to drawbar pull, the weight transfer to rear axle is also contributed by the implement hitched to the tractor. Weight transfer can cause a significant increase in the dynamic load on the drive tires, especially with mounted implements in high draft operations. This causes a significant increase in the dynamic load on the drive tires. Weight transfer for a tractor operating with mounted implements can be up to 65% of the drawbar pull (Zoz, 1970).

Harbarta (1971) investigated the problems involved in steering ability of a tractor with implements. He analyzed the minimal values of the load on the front axle of a tractor and quoted that regardless of the load of the tractor, the load transferred by the front wheels of the tractor on to the road should not be less than 20% of the weight of the tractor. To achieve longitudinal stability and maneuverability of the tractor, he emphasized that the load of the controlled axis of the tractor in static condition on plane ground should be at least 25% of the instantaneous weight of the tractor. The analytical mechanics of farm tractors have been studied by several researchers in the past (Sack, 1956; Koch et al., 1970; Smith and Liljedahl, 1972; Mitchell et al., 1972) with a

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view to develop mathematical models for predicting their rearward overturning behavior. Rowe et al. (1976), Spencer and Owen (1981) and Spence et al. (1983) developed instrumented tractors to measure the weight transfer by mounting strain gauges on the front and rear axles of the tractor, however, the dimensions of the axle resulted in very small strains induced by wheel loads.

Farm tractor accidents are estimated to claim many lives annually throughout the world. Of these fatalities, approximately 70% are caused by the tractor either overturning sideways or rearward. McClure and Benson (1961) reported that 67% of overturnings were to the side and 33% were to the rear. They also reported that rearward overturnings are more likely to be fatal than the sideways overturnings. Rearward overturning takes place when dynamic front wheel reaction is reduced to zero due to excessive drawbar loading or rear wheel slippage. If this reaction could be measured and displayed near tractor seat the operator can take precautionary measure to avoid overturn. To address this issue a device has been designed and developed to measure and display the dynamic weight retained on the tractor front axle (Kumar and Pandey, 2012), later on by using this developed device a study was conducted to measure the weight tracer and stability of agricultural tractor for different agricultural operations.

MATERIALS AND METHODS

Development of force transducer and digital display unit

Force transducer

A diesel tractor (Ford 3630 rated PTO power 33.8 kW) having 19600 N weight, was used as a test tractor in the present study. The front axle of the test tractor consisted of a hollow centre beam with a telescopic section at each end. Seven holes at 50 mm intervals were provided in the telescopic sections for increasing or decreasing the length of the axle. A ring transducer was developed for measuring the front end reaction of tractor. Linearity of the transducer bridge output voltage with the load on front axle justified the suitability of the transducer for the present work.The static weight coming on the tractor's front axle was 6566 N. Considering a maximum of 30% of front axle weight to be sensed by the transducer, a ring transducer with the maximum loading capacity of 2450 N was designed and fabricated. Analog signal was obtained from ring transducer which is linear with weight transfer. The loading abutments were integrally forged to the ring and were threaded internally on the diametrical opposite loading axis. Four electrical strain gauges, each of 350Ω and 2.6 gage factor were oriented in full bridge pattern which formed a Wheatstone bridge as shown in Figure 1, to determine the tensile and compressive forces coming in the ring transducer due to corresponding tractor weight on the front axle. The design dimensions of this transducer were finalized considering a maximum of 30% of the front axle weight to be sensed by the transducer. The developed transducer was calibrated for both the tensile and compressive forces. A good correlation (R2=0.99) was found between the applied load and transducer bridge output for the whole range of the front axle loading.

Processing and digital display unit

The processing and digital display unit included a signal amplifier and a microcontroller unit.

Development of signal amplifier

During the calibration of ring transducer, it was observed that the maximum signal output from the transducer was 0.1 to 0.7mV, which is too low a signal value to be fed to the analog to digital converter (ADC) of the microcontroller unit. To amplify the signal from transducer output, an amplifier was designed and developed.

Development of microcontroller unit

Microcontroller is a highly integrated chip which consists of a central processing unit (CPU), random access memory (RAM), some form of read only memory (ROM), input/output (I/O) ports, and timers. Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task of controlling a particular system. The output of the amplifier was fed to the Atmel microcontroller unit of ADC to convert the analog values into digital values through a single channel. The microcontroller program was written in C language in code vision AVR software, the flow chart of overall program is shown in Figure 2. The microcontroller processes the weight transfer signal received from the amplifier and displays in terms of percentage weight transfer on the liquid crystallized display (LCD) screen. The percentage weight transfer is defined as follows:

Percentage (%) weight transfer =

$$\frac{\text{Static weight on front axle - Dynamic weight on front axle}}{\text{Static weight of the tractor}} \text{X} 100$$

In addition to this display, an indicator, with light emitting diode (LED) and an alarm system was provided to reduce strain on an operator's eye. For this, three types of LEDs

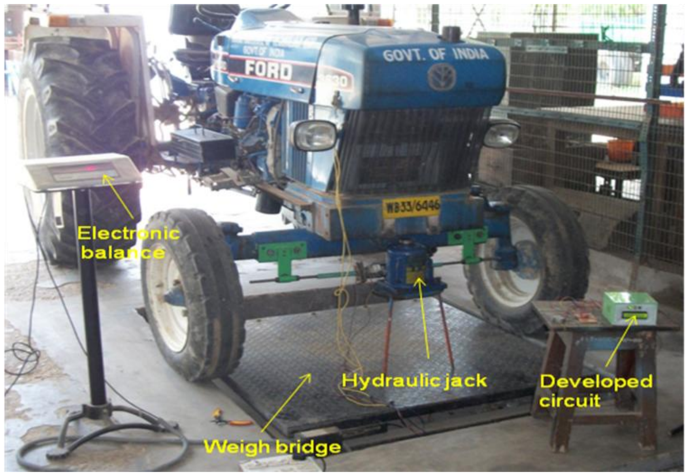

Figure 1. Setup for the evaluation of developed circuit in laboratory condition.

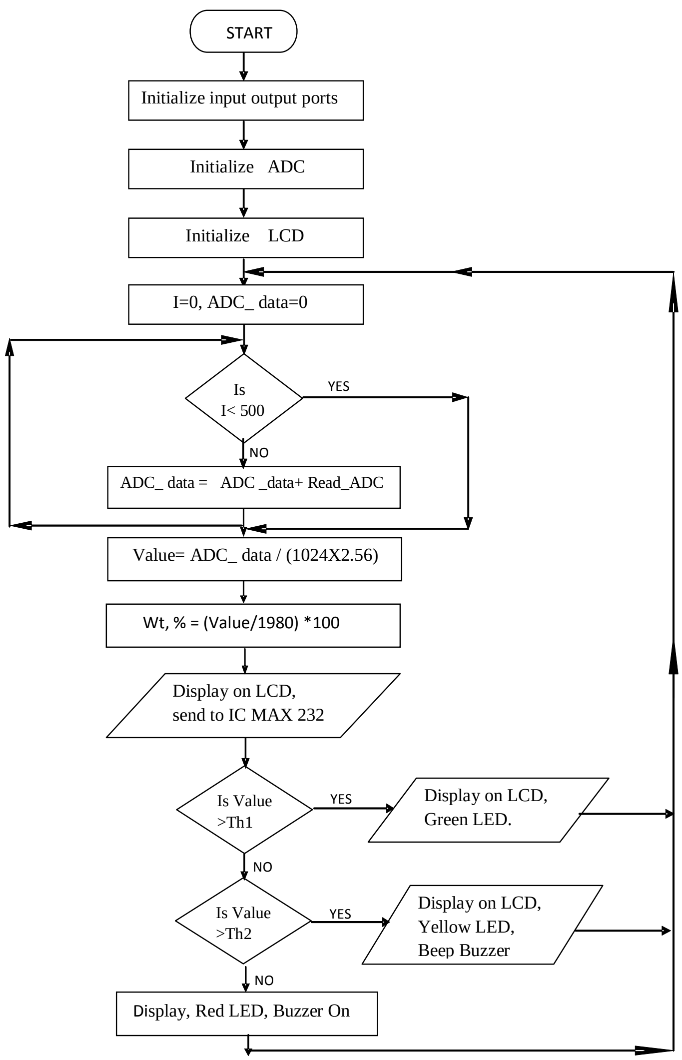

Figure 2. Flow chart for the tractor front end reaction measurement.

Figure 3. Overall view of the developed processing and display unit.

were selected. (i) Green led indicates the safe zone of operation. In this zone the load on the front axle to be considered is more than 25% of the total tractor front axleweight, (ii) Yellow led indicates the warning zone of operation and also beep on. In this zone the load on the front axle to be considered is 25 to 20% of the total tractor front axle weight, (iii) Red led indicates the danger zone of operation and also buzzer on. In this zone the load considered is less than 20% of total tractor front axle weight. The out put voltage in safe, warning and danger zones is taken as thresholdvoltage value 1 (Th1), thresholdvoltage value 2 (Th2) and thresholdvoltage value 3 (Th3), respectively. The developed device completes the entire process in a time of 0.5 milli seconds and for every one second it sends the signal to the computer for storage of values. The front view of the developed device is shown in Figure 3.

Testing of the developed device

Tests were conducted to determine the suitability of the developed device for the purpose of indicating the tractor front end reaction in laboratory conditions, followed by in field condition. Output of the transducer bridge (Wheatstone full bridge) was measured for the complete range of tractor front axle loading. The front end of the tractor was lifted with the help of hydraulic jack for unloading the axle. The output from the transducer was connected to the developed device and the power supply was given from the tractor 12V battery to the developed device. The setup for the evaluation of developed device in the laboratory condition is as shown in Figure 1.

RESULTS AND DISCUSSION

It was observed that with the front axle weight more than 25% of the total tractor weight the Green led was blinked. When the weight was reduced to 25 to 20% of the total tractor weight, the Yellow led was blinked and beep was on. Lastly, when the weight was less than 20% of the total tractor weight, the Red led was blinked and buzzer was on. The maximum percentage difference between observed weight transfer using developed circuit and the actual weight transfer using the electronic balance was 0.85, 0.95 and 0.93% for the safe, warning and the danger zones, respectively.

Weight transfer measurement under field demonstration

Field tests were conducted to measure the weight transfer of the tractor, from tractor front axle to tractor rear axle for different agricultural operations. In this study, weight transfer were measured using a 2-bottom mould board plough, disc harrow and 13 tine cultivator for ploughing, harrowing and tillering operation, respectively as shown in Figure 4. A total area of one hectare was selected and sub-divided in to plots for different agricultural operations. The depth of operation was varied from 10cm to 20cm. The output of the tractor front axle

Figure 4. Test tractor with the mould board plough and developed device during the field operation.

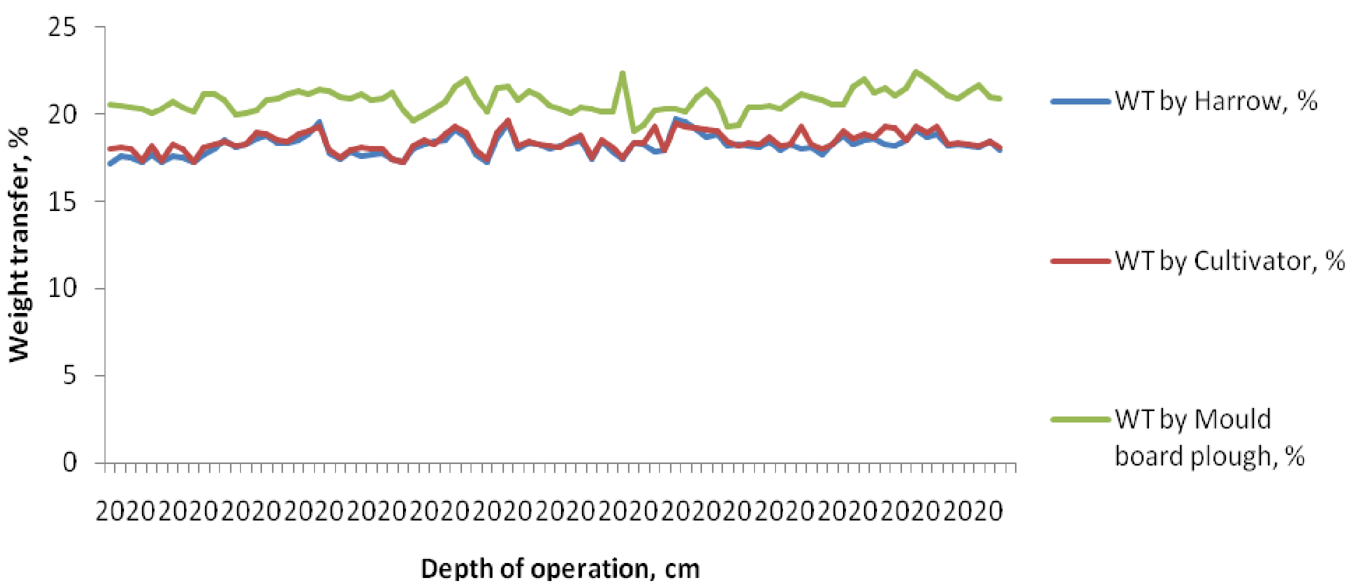

Figure 5. A comparison of weight transfer for different agricultural operation at a depth of 20 cm.

mounted ring transducer was directly connected to the developed processing and weight transfer display unit. The instrumented three-point linkage was connected to the data acquisition system to measure and compare the weight transfer experimentally. The weight transfer data obtained for the different agricultural operation was collected from the developed device using a laptop and the graph between weight transfer and depth of operation was plotted as shown in Figure 5. It was observed that, the weight transfer for ploughing operation was greater than the other operations because of more draft requirement of the mould board plough. It was also observed that the weight transfer for harrowing and tillering operation was approximately closer because of less draft requirement. This results were compared with the DAS and was found to be similar.

Conclusion

A processing and digital weight transfer display unit was developed for 2WD (two-wheel drive) tractors to measure the weight transfer from the front axle to the rear axle. The display unit provides a safe green zone, warning yellow zone and danger red zone to the operator. These zones will help the tractor operator to operate the tractor very reduced hazard. With the help of the developed device, a study was conducted to find the weight transfer of tractor for different agricultural operations and it was found that the weight transfer of the tractor with mould board plough combination is more than the other operations. This was observed to be similar with the results recorded with data acquisition system.

REFERENCES

Harbarta F. (1971). Determination in relation to safety of operation of the minimal load on the front axle of a tractor with implements attached. J. Agric. Eng. Res. 16(2):126-140.

Koch J.A., Buchele W.F. & Marley S.J. (1970). Verification of a mathematical model to predict tractor tipping behavior. Trans. ASAE 13(l):67-72,76.

Kumar A. & Pandey K.P. (2012). A device to measure dynamic front wheel reaction to safeguard rearward overturning of agricultural tractors program in visual basic for predicting haulage and field performance of 2WD tractors. J. Comput. Electron. Agric. 87:152-158.

McClure W.R. & Benson J.L. (1961). An analysis of 212 fatal Ohio farm tractor accidents. ASAE Paper No 61-129, ASAE, St. Joseph, Mich.

Rowe E.P. & Spencer H.B. (1976). An instrumented tractor for use in motion behavior studies on sloping ground. J. Agric. Eng. Res. 21:355-360.

Sack H.W. (1956). Longitudinal stability of tractors. Agric. Eng. 37(5):328-333.

Smith D.W. & Liljedhal J.B. (1972). Simulation of rearward overturning of farm tractors. Trans. ASAE 15(5):818-821.

Spencer H.B. & Owen G.M. (1981). A device for assessing the safe descent slope of agricultural vehicles. J. Agric. Eng. Res. 26:277-286.

Spencer H.B., Owen G.M. & Greenhill A.L. (1983). A microprocessor-based safe descent slope meter. J. Agric. Eng. Res. 28:269-272.

Zoz F.M. (1970). Predicting tractor field performance pp. 70-118, ASAE, St. Joseph, Mich. 49085.