SHORT COMMUNICATION

PROGRESS ON THE IN-FIELD MEASUREMENT OF CANE MASS USING A BELL LOADER

HOLMES M[1], STRANG G C[1], VAN ZYL R[1], SMITHERS J C[1], BEZUIDENHOUT C N[1], and LYNE P W L[2]

[1]*School of Bioresources Engineering & Environmental Hydrology, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3209, South Africa. beeh@ukzn.ac.za, Strang@mweb.co.za, VanZylRO@ukzn.ac.za, smithers@ukzn.ac.za, bezuidenhoutc@ukzn.ac.za*

[2]*South African Sugarcane Research Institute, P/Bag X02, Mount Edgecombe, 4300, South Africa. Peter.Lyne@sugar.org.za*

Abstract

In-field measurement of sugarcane is required for several reasons. These include optimising vehicle payloads, determining cane cutter wages and bonuses, and potential applications of site-specific agriculture. This short communication reports on the results obtained in a final year Bioresources Engineering design project at the University of KwaZulu-Natal (UKZN), South Africa, where instrumentation was installed onto a Bell loader to enable real-time cane mass measurements. Sensors were strategically positioned on the loader and integrated through digital processing, to measure the forces experienced by the loader resulting from any load within the grab. These include the placement of strain gauges onto the Bell loader grab support arm, connecting pressure transducers to the vehicle's hydraulic system, measuring the loader arm position using a potentiometer and installing a clinometer. Two sets of measurements were used to calibrate and verify a grab load model, respectively. The inaccuracies obtained from the system indicate that the relationships developed are not adequate for field operation. Accuracies are, however, significantly improved when the vehicle does not operate on slopes. Further development into the optimum sensor and model configurations and calibration are required.

Keywords: in-field loading, precision agriculture, bell loader, engineering

Introduction

There are several reasons why it may be beneficial to have in-field measurements of cane mass. First, cane bundle weights can be recorded to allow for equitable cane cutter bonuses. Secondly, cane mass recovered from a certain area could be captured for precision agriculture and site-specific management purposes, and thirdly, cane loaded onto long-distance vehicles can be weighed in order to maximise vehicle payloads.

This short communication reports on a Bioresources Engineering final year engineering design project undertaken at UKZN where significant progress was made towards installing and calibrating measuring equipment onto a Bell loader (Holmes and Strang, 2004).

Materials and Methods

Foil type strain gauges (Chalmers, 1982) were strategically attached to the Bell loader grab support arm (Figure 1). These devices change electrical resistance when strained and can hence detect bending within the support arm's elastic range. Bending within the grab support arm, however, is not only determined by the grab load, but also by the angle of the loader's boom to the vertical gravitational force. The boom's angle relative to the vehicle's vertical plane was measured electronically by installing a potentiometer near the point of the boom's rotation (Figure 1). Potentiometers generate an electrical output proportional to position, which was calibrated against the angle of the boom.

In-field loading often occurs on slopes and, for calibration purposes, it was necessary to record the vehicle's orientation with respect to the vertical gravitational force. This was done by mounting an AccuStar II/DAS 20® clinometer onto a surface close to the operator control. The AccuStar clinometer contains a cavity filled with dielectric fluid and inert gas. Capacitance changes generated by the fluid are converted into angles.

In addition to the above mentioned instrumentation, a pressure transducer was installed in the main boom hydraulic line. This instrument relays different electrical signals under different pressures, and is therefore capable of measuring the combined mass of the boom, grab and its load.

All electrical signals generated by the above-mentioned instruments were conveyed to a Campbell Scientific CR10X data logger, which was mounted in a safe location at the back of the vehicle (Figure 1). Data were captured in-field and analysed later. It could, however, be expected that an onboard processor may be able to analyse and display results during vehicle operation.

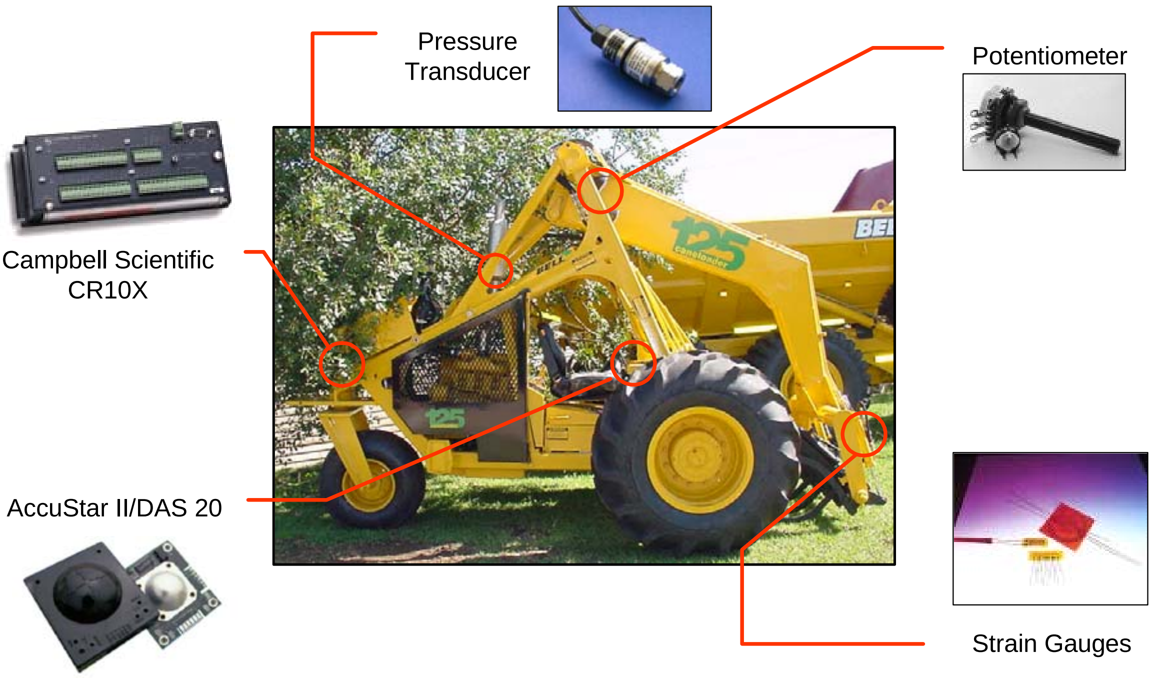


Figure 1. The placement of instrumentation on a Bell loader to enable real-time mass recordings.

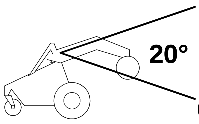
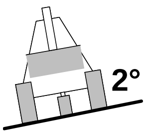
Model Calibration and Verification

Two independent data sets, each containing more than 13 000 data points, were collected for calibration and verification purposes. In both cases, known weights, ranging from 40 kg to 260 kg, were inserted in the loader grab and instrument measurements were logged at different boom angles and on different slopes. An empirical model containing a linear response to strain gauge readings and parabolic responses to boom angle and gravitational angles was calibrated on the data. A similar model was also calibrated replacing strain gauge readings with pressure transducer readings. During calibration these models yielded R^2 values of 0.92 and 0.91 for the strain gauge and transducer based systems, respectively.

Results and Discussion

Table 1 reflects the Root Mean Square Errors and Mean Errors obtained during the independent model verification exercise. It is believed that these errors are still too large for operational use and that further research is needed to improve the system. The strain gauge based system, however, performed significantly better than the pressure transducer system (RMSE=18.03 kg versus RMSE=74.17 kg). This is mainly because several other factors, such as the direction in which the loader arm is moving, may impact on the hydraulic pressure. It is also noted that the system performed better when operated on level ground and when the grab support arm was close to perpendicular to the gravitational horizon. This is because of additional structural strength provided by the vehicle and not measured by the instrumentation, when the system performs at an angle. It is postulated that additional strain gauges placed at strategic structural points may significantly improve the system's accuracy.

Table 1. Root Mean Square Error (RMSE) and Mean Error (ME) in Bell loader mass measurements performed by an on-board automatic weighing system. Separate results are reported for measurements taken when the grab arm was within 20° perpendicular to the horizon and for when the axle plane inclination was below 2°.

	Strain gauge		Pressure transducer	
	RMSE	ME	RMSE	ME
All data	18.03 kg	0.00 kg	74.17 kg	14.73 kg
 Grab arm angle	12.47 kg	0.12 kg	61.49 kg	10.85 kg
 Axle plain inclination	12.75 kg	0.61 kg	69.68 kg	15.51 kg

The system described in this paper has made favourable progress towards in-field cane mass measurements. The design is simple, relatively inexpensive and user-friendly. More research, however, is needed to:

- determine optimal strain gauge placements,
- enable an on-board real-time mass display unit,
- improve measurement accuracies on slopes, and
- investigate the impacts of non-uniform load distributions within the grab.

REFERENCES

Chalmers GF (1982). Materials, Construction, Performance and Characteristics. Chapter 1, pp 1-7 In: AL Window and GS Holister (Eds), *Strain Gauge Technology*. Applied Sciences Publishers, Essex, England.

Holmes M and Strang GC (2004). Automatic Sugarcane Weighing System. Final year design report, School of Bioresources Engineering & Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg.