

High Precision Instrumentation Package for Monitoring the Tractor Performance

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Abstract:

A high precision computerized instrumentation package was developed and mounted on a Fiat DT980 tractor to monitor the field performance parameters. The parameters included forward speed, slip, fuel consumption and drawbar pull. The data acquisition unit was based on a high speed multi processors Campbell Scientific CR9000 data logger linked to a Toshiba Tecra 8200 microcomputer. A tractor testing laboratory was established at the Agricultural and Veterinary Training and Research Station of King Faisal University for the development and calibration of the transducers. Also the laboratory included an instrumentation teaching unit.

The paper described the development and the setup of the instrumentation package and the calibration of individual transducers of the measured parameters. The results reflected a high precision for the transducers and the data acquisition system. The average calibration constants for the rear wheel speed, fifth wheel, fuel consumption and drawbar dynamometer transducers were 0.0011769 m/pulse, 0.002053133 m/pulse, 0.000142857 L/pulse and 19.8296 N/mV, respectively. The data acquisition system was capable of a scanning rate up to 100K sample/sec.

Introduction:

Proper tractor and implements field management depends on accurate precise performance data that were of concern since the early 1900's by the agricultural engineering researchers, educators, machinery companies and farmers. Hence, transducers and data acquisition development for the measuring parameters of the field performance of agricultural tractors and machinery is of increasing attention by the researchers. These performance parameters includes speed, slip, fuel consumption, drawbar pull and power, wheel torque, three point linkage power, implement position, implement depth, fuel temperature, engine temperature, engine speed, transmission selection, ...etc.

The traditional method such as the measuring tape and the stop watch for the measurement of forward speed and axle speed is still used for calibration of the newly developed dynamic transducers by researchers (Bedri *et al.*, 1981, and Al-Suhaibani *et al.*, 1994). A ferrous gear with magnetic pickup were used on fifth wheel, rear wheel and front wheel to measure the axle speed by Grevis-James *et al.* (1983), Green *et al.* (1985) and Graham *et al.* (1990). Some researchers used shaft encoders to measure axle speed (Al-Suhaibani *et al.*, 1994, and Al-Hashem, 1996).

Recently, special attention is directed by the researchers towards the controls for better management. This is accomplished by first analyzing the collected performance data and then making the proper decision towards a better field performance by selecting shifting, throttle position or implement depth. A high concern is also directed towards tractor and machinery safety during the field operations (Wang and Zoerb, 1990). This led to a progressive enhancements of transducer design for better resolutions, accuracy and faster scanning rate. Here are some of the researchers who contributed in the transducers development: (Bedri *et al.*, 1981; Smith and Baker, 1982; Grevis-James *et al.*, 1983; Green *et al.*, 1985; Owen *et al.*, 1987; Tompkins *et al.*, 1988; Freeland *et al.*, 1989; Thomson and Shinnors, 1989; Graham *et al.*, 1990; Al-Hashem, 1996; and Sumali and Brown, 2001).

The ever developing digital world led to a progressive advancement of data acquisition systems. This was of high concern by the researchers as it enhances the scanning rate for more frequent data. Some of the researchers developed data acquisition units from digital logics and a single chip microcomputer (Bedri *et al.*, 1981, and Tompkins and Wilhem, 1982). Single board microcomputers, mainly KIM-1 and AIM-65, were used for data acquisition and data storage on magnetic tapes by Bedri *et al.* (1982) and Grevis-James *et al.* (1983). Data loggers were under progressive development. Green *et al.* (1985) used CR-5 digital recorder manufactured by Campbell Scientific, Inc. Later, Al-Suhaibani *et al.* (1994) and Al-Janobi *et al.* (1997) used the CR-7, a multiple card microprocessor based data logger. Of the shelf data acquisition boards were used on conjunction with a portable microcomputer on an effort for higher scanning rates (Al-Janobi *et al.*, 1997; Al-Beleiki, 1998; Reinaldo *et al.*, 2001; Sumali and Brown, 2001; Hansson *et al.*, 2003; and Grisso *et al.*, 2003).

At the Agricultural and Veterinary Training and Research Station of King Faisal University, a 3-phase project was initiated to document and improve

tractor performance in the farming production of the eastern province of the Kingdom of Saudi Arabia. Phase I of the project deals with the development of a data acquisition system for monitoring tractor forward speed, rear wheel speed, fuel consumption and drawbar pull. In phases II and III, more tractor performance parameters would be considered that would include wheel torque, PTO dynamometer and three point linkage.

The objective of this study was to develop and install an instrumentation package to monitor and record tractor forward speed, rear wheel speed, fuel consumption and drawbar pull for an average tractor size in Al-Hassa farms.

Materials and Methods

An instrumentation package for monitoring the tractor performance was developed. The package included the data acquisition system and the transducers for monitoring forward speed, rear wheel speed, fuel consumption and drawbar pull. The developed instrumentation package was mounted on a Fiat DT980 tractor (Fig. 1). A tractor testing laboratory was established at the Agricultural and Veterinary Training and Research Station of King Faisal University for the development and calibration of the transducers. The laboratory consisted of an electronic transducer development unit, calibration unit for the individual transducers and the tractor installed measurement units. Also the laboratory included an equipped unit for teaching instrumentation development.



Fig. (1). The instrumented Fiat DT 980 tractor

The specifications of the different transducers used in the instrumentation package is listed in Table (1). The general arrangement of the data acquisition system and the transducers is shown in Fig. (2).

Table (1)
Transducers and specifications

Unit	Item	Supplier	Model No.	Specification (Max)
Data Acquisition	Data Logger	Campbell Scientific Inc.	CR9000	100k sample/second
Data Acquisition	Portable Computer	Toshiba	Tecra 8200	Pentium III 1.0 GHz
Fuel Consumption	Fuel flow sensor	RS	256-225	7000 pulse/L
Forward Speed	Shaft encoder	RS	256-461	1000 pulse/rev.
Rear wheel speed	Shaft encoder	RS	256-499	2500 pulse/rev.
Drawbar Dynamometer	Load Cell	Novatech	50-2-6	10 Tone Bidirectional

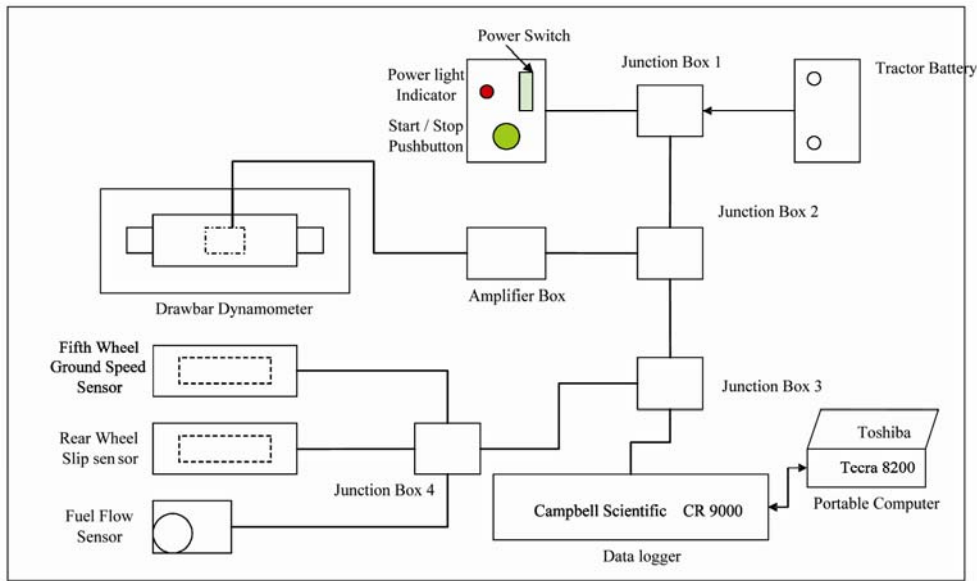


Fig. (2) Line diagram of the instrumentation system

Computerized Data Acquisition system

The data acquisition system for the tractor instrumentation package is composed of a data logger and a portable computer linked together via a TL925-TLINK interface (Fig. 3). A PC9000, a WindowsTM application software that supports CR9000 program generation, real time display of data logger measurements, graphing, and retrieval of data files, was used.

The developed data acquisition system was based on a Campbell Scientific CR 9000 data logger unit driven by a high speed multi-processor base system intended for applications requiring rapid scan rates with system throughput of 100K sample/second and 16-bit resolution. An additional memory card (CS M2M) was used along with the general memory module (CR 9080) that supports 2M flash EPROM and 2M Static RAM. The additional memory card supports two PCMCIA memory cards to assist the data storing capabilities to keep up with the base of the high speed data acquisition system. The data logger was also equipped with the following add on modules:

1. 5 volt analog input module (CR 9050) has 14 differential or 28 single-ended inputs for measuring voltage up to $\pm 5V$. Resolution on the most sensitive range is $1.6 \mu V$.
2. The Excitation Module (CR 9060) has six continuous analog outputs with individual digital-to-analog converters for PID Algorithm, waveform generation, and excitation for bridge measurements. Each analog output will provide up to 50 mA between $\pm 5V$. The module also includes eight digital control outputs (0V low, 5 V high).
3. Counter-Timer / Digital I/O Module (CR 9070). This module features 12 channels that counts pulses or frequency (pulse count) at frequencies up to 5 MHz. In addition, there are 16 independent digital I/O channels for digital control, communication, and triggering.

A Toshiba Tecra 8200 with Pentium III 1.0 GHz portable microcomputer was used to generate the different data logger field testing programs and to access the data, analyze and store it. The portable computer was also important for field monitoring of the data and for transducer calibration.



Fig. (3). Data Acquisition System

Transducers

A fifth wheel was developed to measure the tractor forward speed. It was centered between the rear wheels of the tractor (Fig. 1). This position was found to eliminate any dragging of the wheel that could result in negative slip. A tire with lugs wide enough was selected for the fifth wheel to eliminate any positive slip. The weight of the wheel was also selected to keep the tire in contact with the different types of surfaces and roughness. The main shaft was carried by a pair of roller bearings to assure the free rolling of the fifth wheel. The shaft encoder selected for the fifth wheel was an RS with 1000 pulses per revolution.

The slip of the rear powered wheel was recorded by monitoring the rear wheel rotational speed and the fifth wheel actual forward speed. The rear wheel speed was measured with an RS shaft encoder with 2500 pulse per revolution. A flexible drive was used to transfer the rear wheel rotation to the shaft encoder located behind the driver seat.

The fuel flow rate was measured with an RS 256-225 turbine flow transducer of a range of 3-90 L/Hr. The transducer has a neutrally buoyant rotor that spins with the fuel at rotational velocity proportional to the fuel flow. The rotor movement is sensed when a Hall Effect Switch inside the housing is activated by three small magnets in the turbine. The transducer was connected between the main fuel tank and the injector pump for measuring the fuel flowing from the tank. The return fuel from the injector pump and the injectors was cooled via a heat exchanger placed in front of the tractor radiator and then returned to an intermediate vented fuel tank down stream from the fuel transducer as shown in Fig. (4).

Draft measurement was achieved with a 10 tone Novatech 50-204 bidirectional load cell (Fig. 1). The link points between the drawbar and load were modified to assure that the load cell is maintained horizontally. A special steel cage was designed to save the load cell from dropping down and damage. A Novatech amplifier 58-307 was connected between the load cell and the data logger.

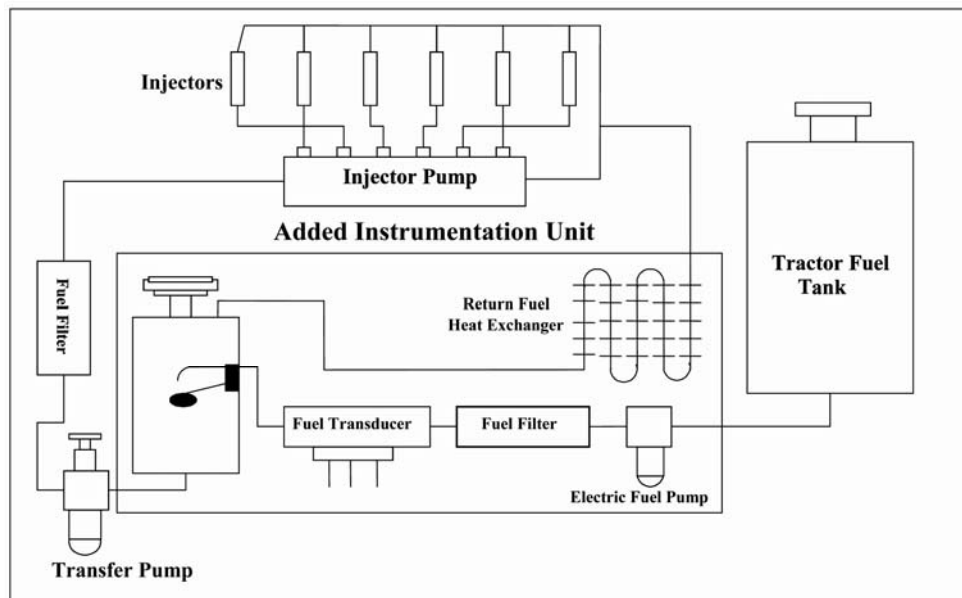


Fig. (4). Design of the fuel measurement system

Calibration and Testing the Instrumentation Package

The drawbar dynamometer calibration constant for tension was concluded from the certificate of system calibration conducted and certified by Novatech, the manufacturer of the load cell. Future calibrations of the load cell will be conducted against known loads on a hydraulic loading rig.

The fuel flow transducer was calibrated by collecting the output pulses for a known volume (100 ml) of No. 2 diesel fuel.

A quick tests were carried to check the number of pulses per revolution for each of the two shaft encoders used on the wheels. The circumferences of fifth wheel (size 145/70-6 @ 24 psi) and the rear wheel of the tractor (size 18.4/15-34 @ 35 psi) were measured under recommended inflation pressure on a straight asphalt course with no load at a speed of 0.5 km/h to assure the absence of slip. The calibration constants in cm/pulse were found. Similar runs have to be conducted on test courses other than asphalt or at different inflation pressures.

Results and Discussion

A high precision computerized instrumentation package was developed and mounted on a Fiat DT980 tractor to monitor the field performance parameters. The parameters included forward speed, slip, fuel consumption, and drawbar pull. The paper described the development and the setup of the instrumentation package.

The instrumentation package was calibrated for each measured parameter. On asphalt surface the fifth wheel circumference measured an average of 1.1767 meter with a standard deviation of 0.003 and the minimum resolution was 0.0011769 meter per pulse. The rear wheel circumference measured an average of 5.13283 meter with a standard deviation of 0.00168325 and the minimum resolution of the rear wheel transducer was 0.002053133 meter per pulse. The wheels calibration curves are shown in Fig. (5). The fuel transducer gave 7000 pulses/L at full scale frequency of 175 Hz and linearity of $\pm 1.0\%$ which counts to a calibration constant of 0.000142857 L/pulse.

The drawbar dynamometer calibration resolution for tension was concluded from the certificate of system calibration conducted and certified by Novatech the manufacturer of the load cell. The average calibration constant was 19.8296 N/mV. The load cell calibration curve is shown in Fig (6).

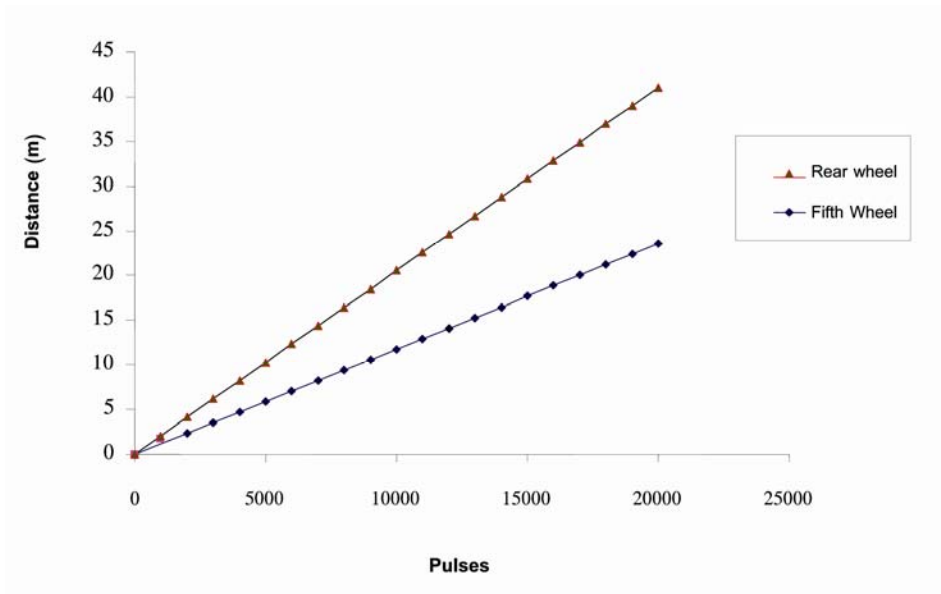


Fig. (5) Rear and fifth wheels calibration curves

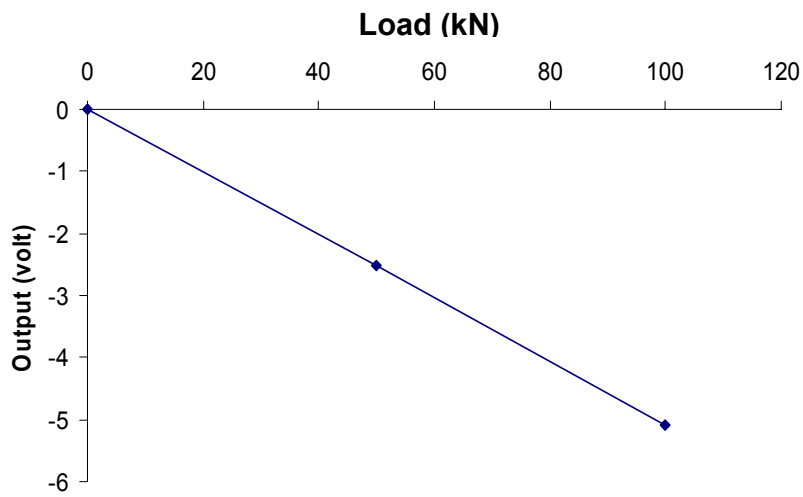


Fig. (6) Load cell calibration curve

Summary and conclusion

A high precision computerized instrumentation package was developed to monitor and record tractor performance parameters such as forward speed, rear wheel slip, fuel consumption and drawbar pull. A special attention was given to the resolution of the transducers, accuracy and the scanning rate. The package was mounted on a Fiat DT980 tractor to monitor the field performance parameters.

The paper described the setup of the package and the calibration of individual transducers of the measured parameters. The results reflected a high precision for the transducers and the data acquisition system. The average resolutions for the rear wheel speed, fifth wheel, fuel consumption and drawbar dynamometer transducers were 0.0011769 m/pulse, 0.002053133 m/pulse, 0.000142857 L/pulse and 19.8296 N/mV respectively. The data acquisition system was capable of a scanning rate up to 100K sample/sec.

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حزمة أجهزة قياس عالية الدقة لمراقبة الأداء الوظيفي للجرار الزراعي

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الملخص :

تم تطوير وتركيب حزمة أجهزة قياس عالية الدقة باستخدام الحاسب الآلي على جرار زراعي Fiat DT980 لمراقبة الأداء الحقل للجرارات الزراعية. تضمنت هذه الحزمة على مجسات لقياس كل من السرعة الأمامية وسرعة العجل الخلفي ومعدل استهلاك الوقود والقوة على قضيب الشد.

توضح هذه الورقة العلمية تصميم ومعايرة كل وحدات القياس لمتغيرات أداء الجرار الزراعي. وأظهرت النتائج دقة متناهية لمجسات القياس ولوحدة جمع البيانات، فقد بلغت معاملات المعايرة لوحدات القياس للعجل الخلفي والعجل الخامس ومعدل استهلاك الوقود والقوة على قضيب الشد ٠,٠٠١١٧٦٩ م/نبضة و ٠,٠٠٢٥٣١٣٣ م/نبضة و ٠,٠٠٠١٤٢٨٥٧ لتر/نبضة و ١٩,٨٢٩٦ نيوتن/ملي فولت، على التوالي.