Design and Development of Automatic Weighing System for Wheel Loader

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***Abstract*—A loader is a type of tractor used to scoop up loose material from the ground. The relationship between height of bucket and pressure in lift cylinder developed with the help of electronic data acquisition (EDAC) system for study and used in development of automatic on-board weighing system device. A hydro tech data logger is an electronic device that records data over time. On Board Weighing System for wheel loaders consists of a very high capacity pressure sensor fixed to the inlet port of the vehicle's lifting cylinder. The hydraulic pressure in the lifting cylinder is proportional to the load carried in the bucket. Static performance trials on the pressure sensor showed accuracy of linearity between dead load and output pressure. Trials conducted on new developed weighing system and pressure readings collected. Based on the obtained results, it is recommended that the developed weighing system should be incorporated on the wheel loader. The dissertation work is limited to develop automatic weighing system for wheel loader machines.**

***Keywords*— Pressure sensor, electronic data acquisition system, data logger, wheel loader &weighing system**

I. INTRODUCTION

Automation of construction machines is strongly desired for various fields such as mining or disaster-relief works in addition to construction tasks. A wheel loader is one of the most popular construction machines used in such sites. Weighing scales is a measuring instrument for determining the weight or mass of an object. These scales are used in many industrial and commercial applications.

There are different kinds of weighing scales available in the market. On-board weighing scales are used in a wide variety of material handling applications

Fig. 1 Automatic weighing system

wherematerial is loaded into trucks, bays or processing lines. By measuring hydraulic pressure in the lift cylinder, the on-board weighing scales give a display in the cab of each bucket load and the total material loaded. The main motive of this thesis is to developed relation between pressure and weight in bucket.There is lot of research work done on design and development of on-board weighing system. Different pressure sensors are used while making this weighing device. Various complex data and graphs are taken into consideration. Figure 1 shows the automatic weighing system. Primary motivation behind this work is to develop a low cost analog sensor based automatic on-board weighing system that will help the operator for loading material in bucket and avoid overloading. The microcontroller with inbuilt DSP core is heart of a system and gems pressure sensors were used give accurate results while working.

Main Components of system

1. Mechanical Assembly
2. Pressure Transducer
3. Sensors
4. Microcontrollers
5. Keypad

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There are many sensors that do not require signal conditioner circuitry for interfacing with microcontrollers. There are many sensors available in the market with inbuilt signal conditioning and amplification. The conventional selection criteria for hydraulic actuator and their drives are based on load capacity, speed of operation, machine inertia and life expectancy in million of operation cycles.

The automatic weighing system is dependent on various sensors and these sensors shall be scanned at appropriate intervals. The sensor feedback is then interpreted by the control algorithm. The automatic weighing system algorithm continuously communicates with the main controller While pressure sensors detect the pressure at rod end and bore end. The sensors inputs are then analyzed to calculate further course of action. This cycle is repeated various load condition.

II. AUTOMATIC WEIGHING SYSTEM DESIGN REVIEW

This literature review focuses on work done for development of on-board weighing system using different feedbacks like dynamic forces, bucket forces study and all mechatronic system development. The report concludes with the summary of the findings on the literature review with some light on the future scope.

The device study is the excavation arm of a large hydraulic mining shovel having a multi-loop kinematic form.A. S. Hall et al [1] describes excavation of loader arm while digging operation.

Samuel Frimpong et al [2] describes the cable shovel excavator is used for primary production in many surface mining operations. A major problem in excavation is the variability of material dig ability, resulting in varying mechanical energy input an stress loading of shovel dipper and tooth assembly across the working bench.

Young Bum Kim et al [3] attempted to determine excavator operation, based on dynamic models of the excavator as well as soil tool interaction models, excavator motions that are fast, power-efficient, and smooth.

Rolf Isermann et al [4] describes that the design of mechatronic systems requires a systematic development and use of modern software design tools. As with any design, mechatronic design is also an iterative procedure. However, it is much more involved than for pure mechanical or electrical systems.

A wheel loader is a heavy equipment machine used in construction and sidewalk maintenance to move aside or load materials. Following figure 2 shows industrial wheel loader machine.

Fig.2 Wheel Loader

A wheel loader is a type of tractor, usually wheeled, sometimes on tracks, that has a front mounted square wide bucket connected to the end of two booms (arms) to scoop up loose material from the ground.

III. OBJECTIVES

Objective of the present study are:

i. Development of basic instrument weight scale for a hydraulic loader in which load is lifted by bucket or shovel and measure the hydraulic pressure in lift cycle.
ii. To perform static calibration results for general purpose data logger, hydro tech data logger and comparing with actual weighing scale.
iii. To develop relation between pressure and load in bucket.
iv. To find out suitable loader arm position to set up the measurement point.
v. To achieve maximum measurements accuracy thru comparable measured system pressure.

IV. DATA LOGGER TRIALS

In this there were two trials conducted which are as follow:
A.General purpose data logger & test trials
B. Hydrotech data logger

For performance trial mainly three importantposition of loader arm consider which described as below.

1. Loader arm Ground Position:
   In this bucket is rested on ground
2. Loader arm carry position:
   In this position loader arm bucket is at mid level from ground
3. Loader arm full height position:
   This is condition of a loader arm where it reaches maximum lift height from ground.

A. GENERAL PURPOSE DATA LOGGER AND TEST TRIALS

The relationship between height of bucket and pressure in lift cylinder developed with the help of Electronic data acquisition (EDAC) system (HBM) for study and used in development of automatic on-board weighing system device. Following figure 3 shows EDAC System.

Fig 3. EDAC System

The measurement product gives guarantees maximum accuracy of measurement results.Each data acquisition system has unique functionality to serve application-specific requirements, all systems share common components. Following figure 4.EDAC system working. Data Acquisition is the sampling of real world data. It is the national instrument which measure the physical data and convert that data in digital form. That digital form is calculated by transducers/other sensors. It process, analyse, store, and display the acquired data with the help of software. First in 1963 it invented it's call by IBM 7700 Data Acquisition System working shown in figure 3. In 1981 IBM Personal Computer and Scientific Solutions it was the first pc data acquisition system. Each data acquisition system has unique functionality to serve application-specific requirements, all systems share common components that include

- Signals & sensors
- Signal conditioning
- DAQ hardware
- Computer with software.

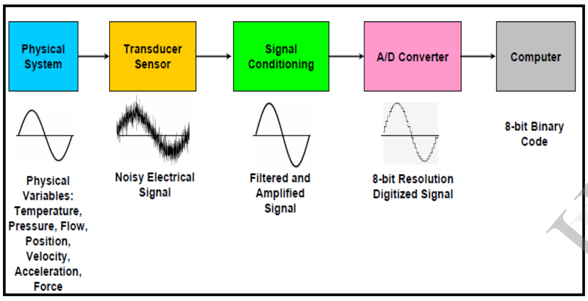

Fig 4. EDAC System working

The EDAC system is used for data acquisition in laboratory research, test and measurement, and industrial automation. In this static test, loader is at stationary condition only there is loader arm movement. Various dead load loaded in bucket and test carried out for fixed throttle and full throttle condition. In stable state one more test carried out for static carry position state and readings note down.Various test conducted by taking different load in bucket and lift raise step response curve plotted. In these graphs X-axis shows bore side pressure of lift cylinder and Y-axis shows loader arm height Figure 5 shows lift raise step response graphs.

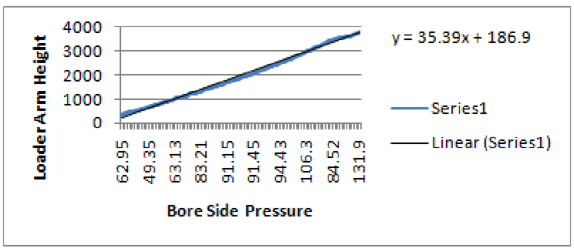

Fig 5 Experimental result for modulation Curve

In this test load in bucket was 1000Kg and as per test condition pressure reading taken, data is collected from EDAC data logger and graphs plotted. The X-axis shows pressure and Y-axis shows loader arm height.Same graph obtained for other weight. The nature of graph achieved linear.

B. HYDROTECH DATA LOGGER

A data logger (also data logger or data recorder) is an electronic device that records data over time or in relation to location either with a builtin instrument or sensor or via external instruments and sensors. Following figure 6 shows hydro tech data logger

Fig 6. Hydro tech Data logger

Tests trials were carried out to determine the measurement linearity between loader arm height and bore end pressure in lift cylinder.The test was conducted under the loading range from 0 to 4000kg. In this chapter we concluded pressure Vs load relationship. Here we plotted various graphs which shows relation between pressure andload.For simple reading, general purpose data logger and for minute accurate reading we have used hydro tech data logger. These readings will helps to us to final weighing device development work.

This test is carried at unladden state of loader. In this test load in bucket is zero i.e. empty bucket. Figure 7 shows pressure and time readings.

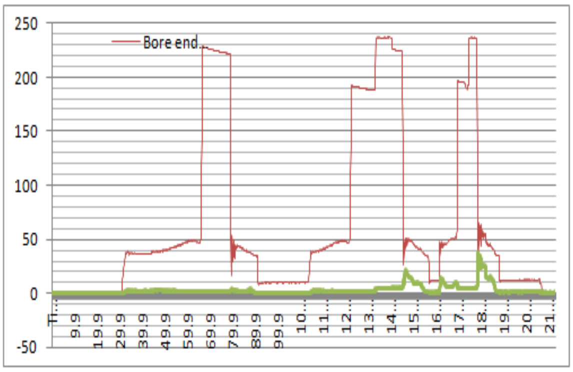

Fig. 7 Experimental result for modulation

The red color line shows pressure at bore end and green color line shows pressure at rod end. In this test trials only pressure at maximum end side means i.e. bore end side considered.

This test is carried at 1000Kg state of loader. Figure 7 shows pressure and time readings. Figure 3.26 shows linear relationship of differential pressure between bore end and rod end entire during lifting range.Tests trials were carried out to determine the measurement linearity between loader arm height and bore end pressure in lift cylinder. These readings will helps to us to final weighing device development work

V. DEVELOPMENT OF ACTUAL WEIGHING SYSTEM

Many technical processes and products in the area of mechanical and electrical engineering are showing an increasing integration of mechanics with digital electronics and information processing. This integration is between the components (hardware) and the information-driven functions (software), resulting in integrated systems called mechatronic systems.A weight calculating unit for calculating the weight of a load carried by the loading section based on the values obtained at least by the first and second displacement detector and pressing force sensor, and a weight indicating unit for indicating a value associated with the load weight obtained by the weight calculating unit.The explorer 16 board used as a main controller board provides a flexible hardware environment for the development of embedded solutions using AT89S8253 series 8 bit microcontrollers.

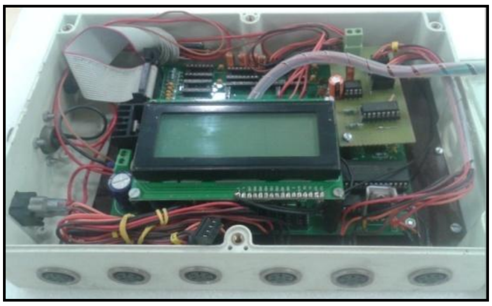

Fig. 8 Main controller using Microchip development board

An analog sensor is wired into a circuit in a way that it will have an output with a specific voltage range, usually between 0 volts to 5 volts

Fig .9 Gems pressure sensor

Since they convert pressure into an electrical signal, they are also termed as pressure transducers.The LM324 series are low−cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. Following figure 10 shows operational amplifier

Fig. 10 Operational amplifier

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate. The matrices are actually an interface technique. It can be used to interface inputs like the PC keyboard keys, but also to control multiple outputs like LEDs.

Fig. 11 A layout of keypad

According to this technique, the I/O are divided into two sections: the columns and the rows. Figure 11 shows a layout ofPCB keypad.

VI. EXPERIMENTAL VERIFICATION

In this section, pressure readings taken from new developed weighing system and compared with hydro tech data logger and EDAC data logger..

A. Experimental Set-up

The final test trials were carried out on wheel loader. The set up consist of battery supply, weighing device , wheel loader, scale, multi meter etc.Figure 12 shows weighing device with battery supply.

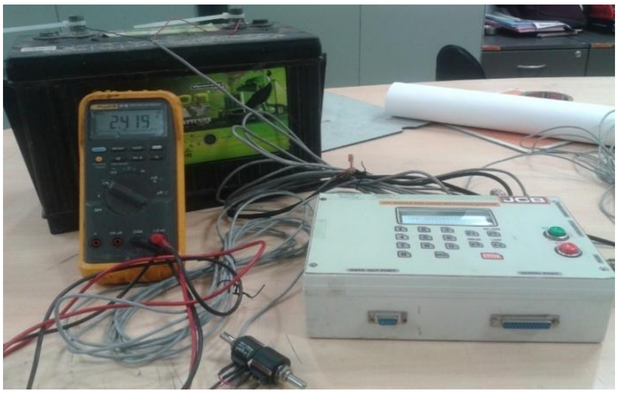

Fig.12 On-board weighing system device with battery supply.

B. Result and Discussion

The plotted measurement calibration in EDAC data logger and hydro tech data logger shows applied load and measured output pressure were highly correlated with new developed on-board weighing system for laden and unladden condition. The linearity was satisfactory .

Load (Kg)	Loader arm angle	New sys pressure	General data logger	Hydrotech	% accuracy w.r.t. General data logger	% accuracy w.r.t.Hydro tech
	17	52.475	47.3	56	-11	6
Laden(1000Kg)	22	67.175	55.23	74.13	-22	9
	70	194.25	204	237	5	18
	70	217.75	222.1	239	2	9
	17	20.75	39	39	44	47
Unladen	22	39.675	45	45	16	12
	70	204	227	227	0	10
	70	210	235	235	-3	8

Table 1 test readings

The X-axis shows bore side pressure in bar of lift cylinder and Y-axis shows Loader Arm height in mm. The plotted measurement calibration shows when height of loader arm increases then the pressure also increases simultaneously and highly correlated for laden and unladen state of loader. Rom result table following graph plotted for laden shown in figure 13 and for unladden condition of loader shown in figure 14 as below

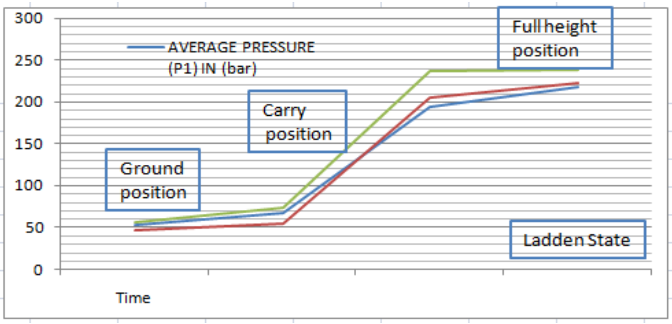

Fig.13 Experimental result for modulation Curve for change in pressure for ladden state

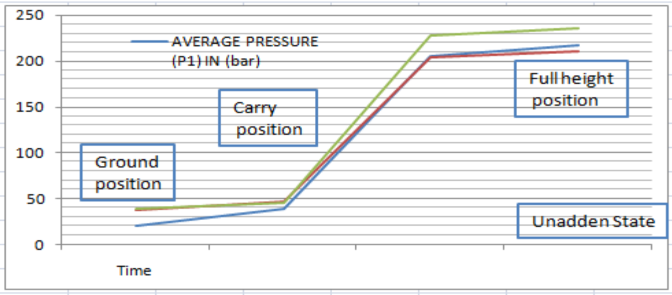

Fig.14 Experimental result for modulation Curve for change in pressure for un ladden state

The multiple trials on the loader concluded, following concluding remarks.

Achievements

The instrument has been successfully developed with basic logic considering the steps of operation of machine in actual work conditions

A relation tried to be established between the actual load handled and the pressure responses of the lift system.

Initial data gathered in different working conditions from different resources to demonstrate the relativity of the lift system parameter which are directly measurable and the load lifted by the machine.

The static calibration method developed to compare the results of the developed apparatus with the other data logger and comparison is made to determine the accuracy of the initial logic set up.

VI.CONCLUSION AND FUTURE SCOPE

With a basic intention to develop a loader weigh instrument development with minimal cost, the important conclusion is drawn from the present study is that basic level of hardware has been developed with preliminary logic to ascertain the relationship of lifted load and cylinder pressures at different lift heights and at different load conditions

A prior calibration method is achieved with available sensors with functional keys of instrument. The developed equipment system was successfully able to scan and record the measured signals by the pressure sensor as programmed and the results were accurate to 6% to 9% in the proposed range of load heights with feasibility of measurements.

FUTURE SCOPE

The following are the future scope for this thesis.

- Currently the system is developed for wheel loader, now in future scope for this system is to develop unique universal load weighing system for all kind of earthmoving and handling machines like Backhoe, Excavator and Loaders.
- To improve precise accuracy of current device.

- To provide initial input data about the machine and the site parameters like site name, Dumper ID, Driver ID, etc to support to the logged data
- To log the data by the trip form and to summarize the results of specified time durations as required
- To develop printer and wireless operating facility.

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