In-Motion Weighing with Vehicle Data Collection System

Harish Kumawat
Department of Electronics and communication
Shri Vaishnav Institute of Technology and Science, Indore, India

Preet Jain
Electronics and communication
Shri Vaishnav Institute of Technology and Science, Indore, India

***Abstract* - This paper is based on weighing of a vehicle while it is in motion. The technique used in this, is measuring the axle weights. The simple averaging algorithm can be applied to process the load cell data of an individual axle and calculate the output as gross weight of a vehicle. There is also a provision of speed measurement system along with the WIM scales. The data of vehicle such as, weight, speed, number of axles, overloading, and vehicle count, i.e., number of vehicles passing the system is stored using a data logging software and can be easily viewed at the hyper terminal of the personal computer.**

Keywords: Load Cell, In-motion weighing, Speed, weight, Data logging.

I. INTRODUCTION

The WIM system in India is not as much popular. To make it famous among the weighing industries, various features can be added in the system. The system can be used for screening of vehicles according to their weight, total number of vehicles in a day can be counted, axle load measurement can also be done, can also be used to determine the spacing between the axles.

In-motion weighing system measures the axle weight of a moving vehicle. The main motto of introducing this system is to reduce the damages to roads and bridges due to heavily loaded trucks. Hence it is a matter of great concern to us to safeguard the highways and bridge. So for this, there must be regulations on loaded vehicles. The first step towards this is to implant a Weigh In-Motion (WIM) system at dense traffic areas and on highways.

To measure the axle weights of a vehicle, the load cell is placed beneath the road surface. The strip is placed over the load cell, at the road surface level, such that the weight of axle shares only on the load cell (Fig.1). The data of each axle is recorded and processed in a microprocessor and then the final gross weight is displayed over the screen.

The WIM data are used for a wide variety of applications depending on the requirements of the user or user groups. The WIM stations equipped with a remote system can be used for various practical applications like statistics, interval measuring and online traffic control, pre-selection of overloaded vehicles, estimation of the current loading of road or bridge constructions and so on. The evaluated results can also be used as a basis for determining dimensions in road and bridge construction or for optimizing resurfacing work.

The WIM system in India is not as much popular. To make it famous among the weighing industries, various features can be added in the system. The system can be used for screening of vehicles according to their weight, total number of vehicles in a day can be counted, axle load measurement can also be done, can also be used to determine the spacing between the axles.

The dynamic calibration of a WIM-system can be done in several ways: at a low speed with standard trucks or at a high speed with an instrumented vehicle. In the case of low speed calibration it is assumed that the dynamic part of the axle loads is negligible. Then the WIM-system can be calibrated to the axle loads that are measured when the vehicle is static. However, when the operational range of the WIM-system is tested at considerably higher speeds with such a standard truck, then the systems is in effect not calibrated for this operational range. Since the speeds at the test site vary around 15-40 km/h, high speed calibration is preferred. At low speed weighing, speed is considered below 5km/h for better results, while 5-10 km/h is also considered but at low accuracy for low speed WIMs.

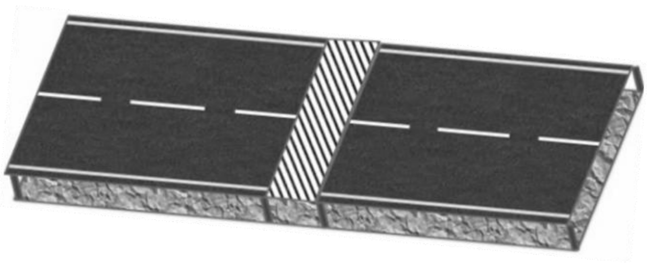

Figure 1: Load cell strip placed at road surface level.

II. NEED OF WIM SYSTEM

The evaluated results can also be used as a basis for determining dimensions in road and bridge construction or for optimizing resurfacing work. Both traffic volume and axle loading are continuously increasing worldwide and with the repetitive pounding of roads, this often produces complex fatigue failure modes. In the interest of minimising the damage inflicted by overloaded vehicles passing over critical road sections, particularly older bridges, various highway authorities are pursuing a policy of spot checks on vehicles suspected of exceeding maximum load regulations. Traffic flow analyses including weight data are useful beyond statistics for traffic planning, maintenance prognostics and for automatically influencing the rolling traffic.

WIM system reports can be implemented to improve knowledge of traffic for economic surveys, statistics and management as well as collection of reliable data as a background which helps in technical designing for pavement and bridge, as well as maintenance.

III. LITERATURE REVIEW

Till now, many inventions have done and lots of people have worked on different weighing methods for in-motion vehicles. The principle of measurement is developed and the estimation is done for measuring uncertainty by Grey Error Theory [1]. Theoretical analysis and experimental research are given by them to show that the method could be used to solve the weighing problem for in-motion vehicles with higher accuracy.

The evaluation is also done by new mass-estimation method for axle weights of In-motion vehicles using vehicle model. The models used for estimation are two-axle model, three axle model and five axle model [3]. The trial is done on three type of vehicles and their result is used to improve the WIM output.

Apart from these weight estimation methods, an advance algorithm for estimating axle weights of in-motion vehicle has also been taken into practice. A signal processing method has been implemented to improve the accuracy of measured axle weights of an in-motion vehicle. There is also some change in the platform, i.e., the length of the platform is increased approximately three times than the regular conventional type [5].

The idea of using a bridge as a scale for the weigh-in-motion (WIM) of trucks has been explored and investigation is done using the least amount of above-deck mounted sensors so as to make system installation and maintenance easier and cost effective [2].

Various techniques are there for increasing the accuracy and performance of the WIM system along with reducing the cost. Different techniques are applied to the WIM weights which are being measured to reduce or minimize the effects of dynamics of vehicle, but it cannot be totally eliminated [4]. The single load cell WIM is determined to be most effective system in all aspects like accuracy and expected life.

IV. PROPOSED WORK

The system can be made more effective and economic than the conventional one. The new implementation in this WIM system is to implement the whole weighing system using single core processor. It will just consist of single embedded micro-processor unit. Most of the conventional systems used DSP processors for removing the noise signals as well as vibrations in weight signal. But in this proposed system, the signal processing unit is excluded and the WIM measurement technique has been altered. Instead of following conventional methods to measure weight, the weight measurement will be done at very low speed to avoid the jerks caused by the vehicle when they were at high speed. Along with that, the dynamic effects of a vehicle are also neglected. The vehicle is detected by the IR sensor. As soon the sensor detects the vehicle, the load cell starts taking the weight. In other words, it can be said that the vehicle detection sensor is used to trigger the controller to start processing the load cell data.

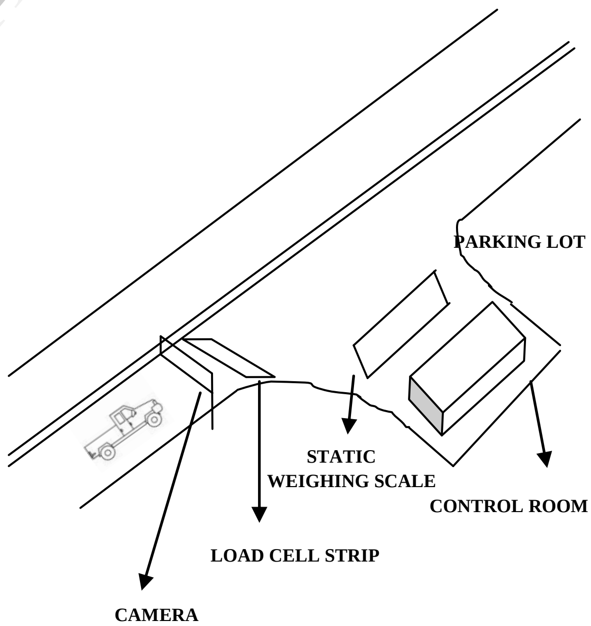

Figure 2: WIM system with Screening of vehicles

The vehicles which are found overloaded and not following the norms of that particular WIM system, can be screened. If required, the victim can be fined or penalized. All the movement of the vehicles in the WIM system is monitored in the control room. The screened vehicle can be kept at the parking space near the control room (Fig.2). There is also a speed measurement system along with the weighing instruments to monitor the vehicles so as to regulate them at certain limits.

V. COMPONENTS OF WIM

Basic components of WIM system are as follows:

A. Mechanical Structure
B. Weight sensor
C. Amplification unit and ADC
D. Processor and data storage unit
E. User communication unit

A. Mechanical Structure

The mechanical structure consists of a stripe of metal plate placed at the ground/ road level. The plate is mounted on the load cell such that the load coming on the plate is shared only on the load cell. The structure is placed by digging the road portion and placing the load cell in the pavement. The load cell wires are taken out from the upper most corner of the pit. Pavement is made such that the rain water can be drained easily so as to protect the load cell and the wiring circuitry.

B. Weight Sensor

The fundamental and important component of a system is weight or mass sensor. Here the sensor used is Load cell. The weight of a vehicle is sensed by the load cell and the signal is sent to the next unit for further processing. The load cell is a transducer which converts physical quantity into electrical quantity. Load cell consist of three parts, namely strain gauge, Wheatstone bridge and spring element.

The spring element is responsible for the maximum capacity, i.e., the maximum load capacity depends on the spring element. Metal plate is fixed to the load cell. When the load is on the metal plate, the spring element bends resulting in the change in length if strain gauge. Hence due to this change in length, the resistance gets changed. This change leads to the electrical signal output.

Wheatstone bridge is an electrical circuit used to measure the unknown resistance. It is a balancing circuit consist of four resistors. When the input voltage is varied, we get a proportional output to the other end. In balance condition, the output is zero.

Strain gauge is mounted on the spring element. It is a resistive element which converts applied force to an electrical form. One resistor in wheat stone bridge is replaced by a strain gauge, which results in the unbalanced condition.

C. Amplification unit and ADC

The signal which comes from the sensor, i.e., load cell is very weak. So this signal needs to be amplified. The unit required for this purpose is known as Signal Conditioning unit. The use of this circuit is to manipulate an analog signal in such a way that it means the requirement of next stage for further processing. The unit has two main functions: to increase the resolution of the input signal, and increases its signal-to-noise ratio (SNR).

The amplified signal is passed to the Analog to Digital Converter (ADC). The function of this convertor is to convert the analog signals coming from the sensor to the digital form. The WIM system operates in large weight values, hence the ADC required in weighing industry needs higher resolution.

D. Processor and data storage unit

The output of the ADC is thus carried to the processing unit, generally a micro-processor. The processor is the heart of the whole system. All the data processing and calculations are done by the micro-processor. Many high speed processors are available in the market which can be used to process the weighing data of the WIM system.

The data of the WIM system can be used to monitor the daily traffic and many other uses. So for this, the data base management system can be applied along with the WIM system. The database can be of Vehicle number, gross and tare weight, axle weight, axle spacing, number of axles etc.

E. User communication unit

The user communication unit consist of display section. The display unit can be LCD, graphical LCD, or even touch screen graphical display can be used for user interface.

VI. WORKING

The detector of the weighing system is a road weighbridge that is installed in the road, such that the surface of the road weighbridge is just at the same level of the road. The road-weighbridge is nearly as long as the diameter of a tire. The axle weighing system measures each axle weight of a vehicle while it passes the weighbridge. The total weight of the vehicle could be estimated by using the whole signals that are obtained while the vehicle passes through the road-weighbridge. The conventional calculating method in the axle weighing systems is called "Mean Value Method". By taking mean value of each segmented part of the signal obtained while the axle is completely on the road weighbridge, each axle weight can thus be determined. The data flow of the WIM system is shown in (Fig.3).

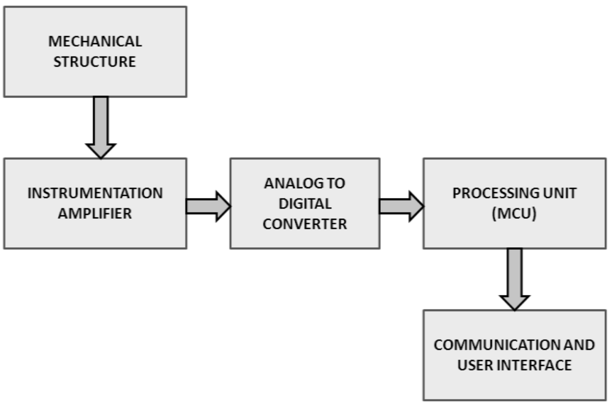

Figure 3: Block Diagram of Weighing System

However this method does not tab the vibration component into account, and thus the accuracy of the determined axle weights is inevitably low. We do not think it would be accepted for more strict regulation of the overloaded vehicles.

The foremost sensor in the system is vehicle detection sensor. This sensor first detects the vehicle heading towards the WIM system. It is placed about 50-100 meters away from the load cell strip. To save the power, the whole system is kept at power down mode. Hence this is used to trigger the WIM system as well as it can be used to count the number of vehicles passed through the system in a single day.

Thus the load cell senses the weight of a vehicle and sends the data to the instrumentation amplifier. The amplified signal is forwarded to the analog to digital converter. The analog signal is hereby converted to the digital form. This digital data is fed to the microcontroller unit which consists of processor. Here the data is calibrated and processed in the user readable format. This value is displayed on the user interface section.

VII. RESULTS

The proposed work has been studied and thereafter implemented. This project has been performed at very small scale and just of a prototype; hence results are not that much accurate, but near to the accuracy. The sensor used is single ended shear beam type load cell. The processing of speed is done by the ARM processor (LPC2129).

The WIM and data collection system prototype is shown in the (Fig. 4) below.

Figure 4 : WIM prototype; IR sensor sensing the vehicle

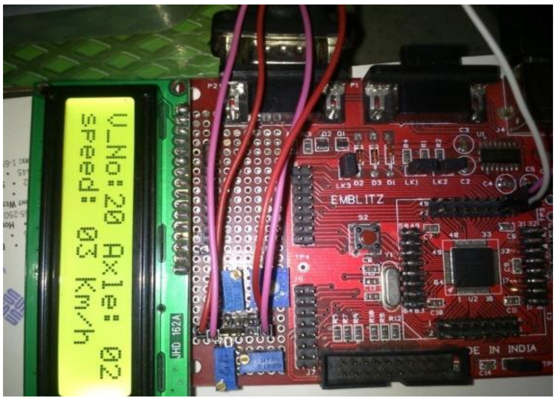

Figure 5 : ARM processor; showing details of vehicle

The details of vehicle like speed, number of axles and vehicle number count has been calculated, processed and shown in (Fig.5).

The testing is done at different weights. There are around 4-5 readings taken by the prototype model for eight different weight. The experiment is done using a two axle vehicle. The readings taken are weight on both the axles, gross axle weight and measured weight. The results are shown below (Table 1).

Table 1 : Experimental readings of WIM

S. No.	**Axle #1 Wt. (in gm.)**	**Axle #2 Wt. (in gm.)**	**Gross Axle Wt. (in gm.)**	**Measured Readings Wt. (in gm.)**
1	157	185	342	322 316 322 310 322
2	160	250	410	412 391 417 401 422
3	178	240	418	427 422 427 407
4	201	265	466	446 460 445 451

5	185	297	482	490 494 482 497
6	224	337	561	552 561 558 569 561
7	290	335	625	633 618 625 615 610
8	305	335	695	671 704 694 707

The reading for axle #1 and axle #2 loads is shown in (Fig. 6) and (Fig. 7) respectively. Along with that, the gross axle weight is also shown. These are the reading for axle weighing of a vehicle.

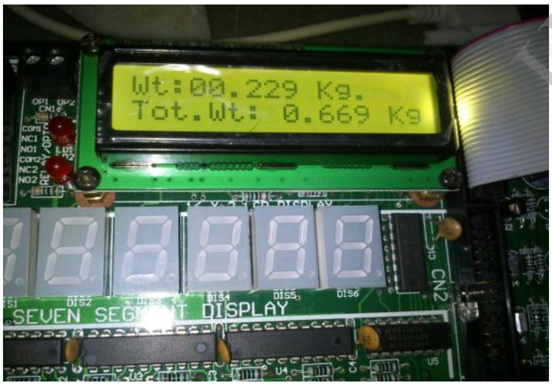

Figure 6 : Axle #1 weight

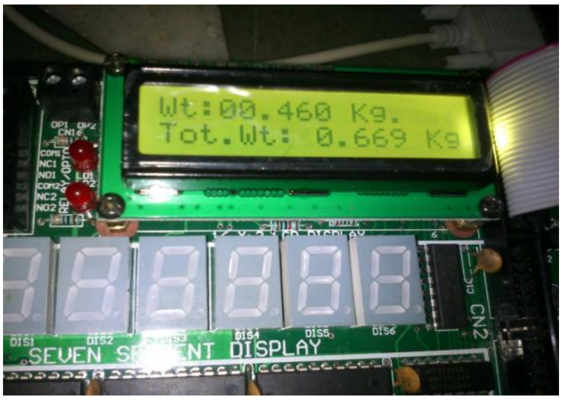

Figure 7 : Axle #2 weight; gross axle weight

VIII. CONCLUSION

This project have been developed using least available resources and at very small scale. Due to this, the higher accuracy is not expected. However the results from this prototype are satisfactory.

Mostly the WIM systems are installed at toll-plazas. So low speed WIMs can be easily implemented where there is a controlled traffic at regulated intervals. The accuracy of low speed WIM is similar to that of static axle weighing system. The proposed model is an economic version of conventional low speed WIM systems.

The system can be used with various advance technologies such as Zigbee, Wi-Fi and RF devices for transmitting the data to the control room. Also the wireless communication can be used for sending the data to the Wi-Fi LED displays. The system can also be integrated with the novel data processing software which can provide a precise measured value.

REFERENCES

[1]. S. Fujimoto, T. Ono, Z. G Wang, K Ohsaka: Evalualion of an In-Motion Vehicle Weighing Method via Grey Estimation Model, Pmc. of SICE Annual Conference 2002, Papa No. SICE02-0500 (2002)

[2]. Sarah K. Leming, Harold L. Stalford, “Bridge Weighin-Motion System Development Using Superposition of Dynamic Truck/ Static Bridge Interaction”, Proceedings of the American Control Conference, Denver, Colorado June 4-6, 2003.

[3]. K. Fukuda, K. Kameoka, T. Ono and K. Yoshida, “Evaluation of a New Mass-estimation Method for Axle Weights of In-motion Vehicles Using Vehicle Models”, Proceedings of the 17th IMEKO TC3 International Conference, Istanbul/Turkey, 2001, pp. 219-229

[4]. Andrew J. Pratt, Rob Bushman, “Weigh In Motion Technology - Economics and Performance”, Presented at NATMEC ’98, Charlotte, North Carolina.

[5]. K. Fukuda, K. Yoshida, T. Ono, K. Kameoka, T.Hirata, “An advanced algorithm for estimating axle weights of in-motion vehicles”.