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Development and Implementation of Remote Duty Cycle Data Acquisition and Analysis

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ABSTRACT

In the competitive automotive industry, launch of a new vehicle has become a norm to stay ahead, also the vehicle manufacturers are competing in terms of increased warranty on the new launch. Hence it is imperative for rigorous validation of new vehicle in very short period and requires to map customer usage pattern in least possible time.

This work is based on an extension of internet of things (IOT), which provides a tool of capturing vehicle duty cycle by using combination of analog and digital sensors with appropriate ADC. The system is enabled with algorithm/ coded to log result, whenever measured physical parameter goes above/below predetermined level. The work involves implementation of an auto start and auto shutdown of the system based on vehicle ignition. Thus, this paper presents a system that is capable of continuous, real time recording and edge computing (auto post processing) physical quantity and ensures complete elimination of human interface, thereby enabling Remote Data Acquisition, Analysis and Reporting system (Proposed system). The proposed system is fit and forget and cost-effective solution, it can be fitted in any number of vehicles to acquire data for large number of kilometers to map system level usage pattern. Against the conventional method with limited kilometers of data to map customer pattern. The present work is an implementation of Remote Data Acquisition, Analysis and Reporting system in measurement of required vehicle parameters of temperature and humidity in field working conditions.

KEYWORDS: Drag force; Vortex generator (VG); Aerodynamics forces; Flow separation; Velocity distribution; Pressure distribution; CFD.

Introduction

The global method for vehicle validation in automobile industry includes collection of road load data acquisition at different customer site and extrapolation of the collected data to predict the life of a vehicle component. But the quantum of the data used to predict the life is limited to only certain distance in certain geographical location while vehicle is used at all locations. There is a need for extensive data acquisition which maps the vehicle usability in maximum possible geographical condition for high level of confidence. But the current methodology of data acquisition is manual, laborious, costly, with this it is difficult to acquire data for all the geographical locations. Also, data acquisition and data post processing activity are carried out in series; which leads to prolonged product validation cycle.

The accomplishment of the vehicle durability assessment starts with understanding precisely about the load that the vehicle will undergo during their anticipated lifetime. RLDA/Duty Cycle is an excellent method to measure vehicle response for different working condition. The RLDA/Duty Cycle includes acceleration, deceleration, displacement, force and any other physical parameter or the combination of the parameters of the vehicle system. Depending on the vehicle system physical parameter is selected.

The proposed work presents an Internet of things (IOT) based system which includes raspberry pi coupled with a signal converter, GSM connectivity, power control circuit and processing algorithm. This system has wide accessibility as the user with internet connection can download/view the data/result from anywhere across the globe. Another important feature of this design is the reprogrammable and open source nature of the product; the program/application can be flashed remotely to incorporate the improvements in the underlying algorithm to suit the requirement.

The proposed system can be installed in many vehicle parallelly, as shown in Fig.1. with that it has an upper hand over the current method in terms of extent of data used to predict life/validate the system and the extrapolated results will be close to the real-life application. Vehicle validation depends on its subsystem validation, temperature and humidity are selected for the presented work.

ABBREVIATIONS: IOT - Internet of Things; RLDA - Road Load Data Acquisition; ADC - Analog to Digital Converter; GSM - Global System for Mobile; GPS - Positioning System

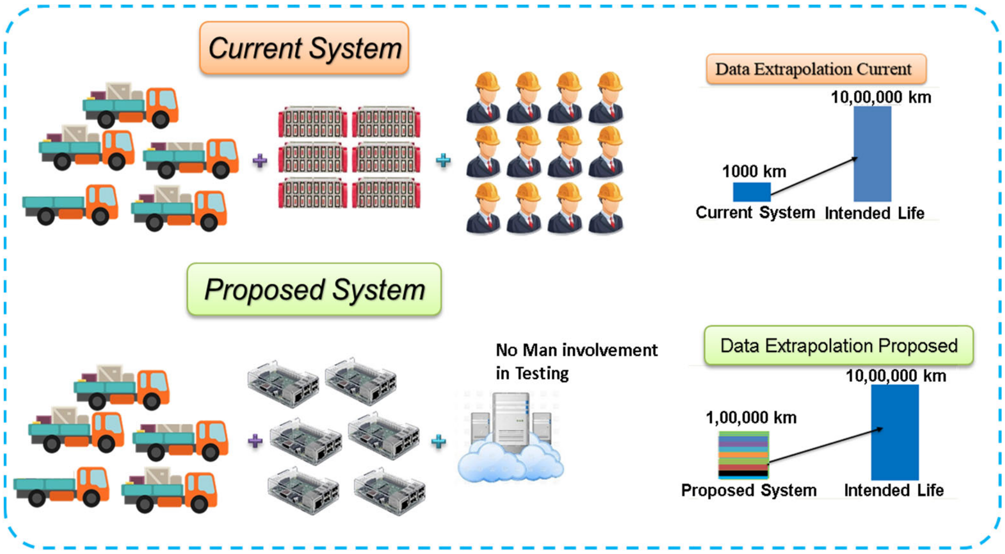


Fig. 1. Extent of data collection in current and proposed method.

Current Method of Data Acquisition for Duty Cycle Measurement

The important parameters for any duty cycle are required related measurement parameters which is useful to get insights for the particular duty cycle. Example parameters are temperature, pressure, speed, strain, force, displacement and humidity etc. Each duty cycle requires different set of parameters to perform the exercise. Fig.2 shows the current method for measurement data for duty cycle. The sensors for different measurement parameters are connected to the data logger.

Working of the system

The input sensors connected to the data loggers are handled by the test engineer and data is acquired during the vehicle movement. Acquired signals are checked for signal anomalies (if any) and are corrected. Then measured signal is calculated using pre-determined algorithms and software's and result is published in presentable format. Since data loggers available in the market are very costly, it needs a human interface to ensure safe operation of the system.

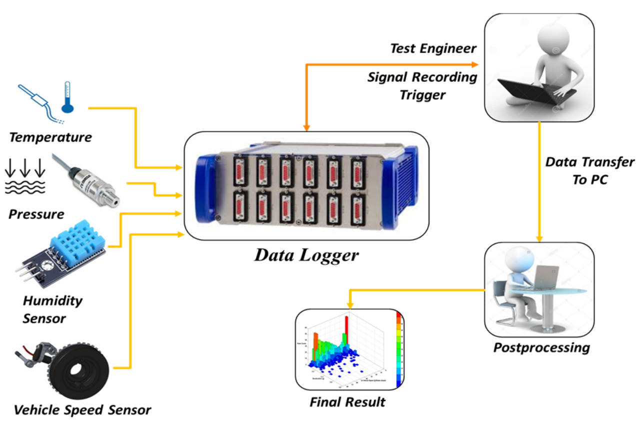


Fig. 2. Process flow for current method of duty cycle measurement.

The current method of data acquisition is laborious, costly and time-consuming and it is very difficult to use such a system to map customer usage pattern from all the geographical condition. Also, human interface is required for raw data handling and post processing of the data.

Proposed In-House Developed System Design and Architecture for Duty Cycle

The system is developed in-house with a concept of modularity. Major components of the system are made up of modules with integrated circuits. Each of these modules has a special function to perform in the system. There are various readily available, and few specifically developed modules used to actualize the project. Various components and modules are listed below in hardware subsystem design. The c and python programming languages are used to log the data, analyze, post process and upload the result to server.

Hardware Subsystem Design

1. **Raspberry pi:** It is used as the base system.
2. **Power Trigger Circuit:** Ignition is connected to raspberry pi and auto start stop module, auto start stop module includes a microcontroller which ensures power supply to the raspberry pi based on the ignition status.
3. **ADC or Signal Converters:** It is coupled to the raspberry pi to log different signal. Such as temperature board or ADC board
4. **Temperature, Humidity and Displacement sensor** are connected to the system for duty cycle inputs
5. **GPS module** is used to obtain geographical details of the vehicle movement
6. **GSM module** along with serial communication module used to upload the data to the cloud or server.

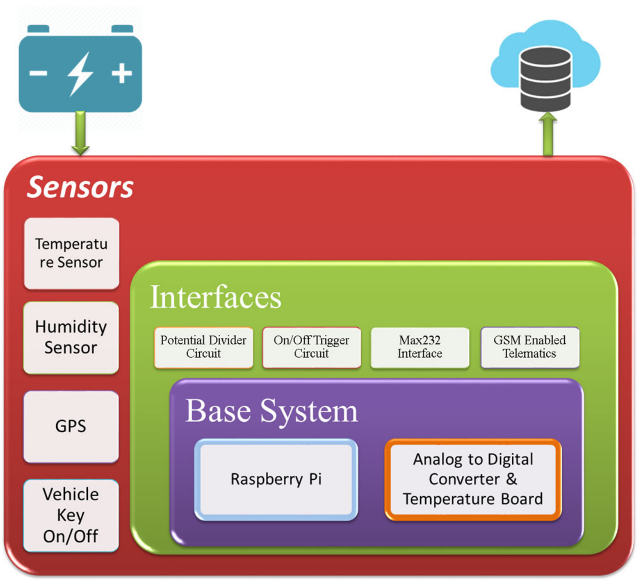


Fig. 3. Hardware details.

Software Subsystem Design

The software can be broadly divided into two parts data logging and data analyzing.

1. **Data logging:** - An application is developed in C or python language which records data from sensors through ADC at 1000 Hz sampling rate.
2. **Data analyzing:** - An application is developed using python which checks for the abnormality in the recorded data and calculates predetermined parameters as per the algorithm.
3. Both the applications are compiled and made auto executable during the boot-up of raspberry pi.

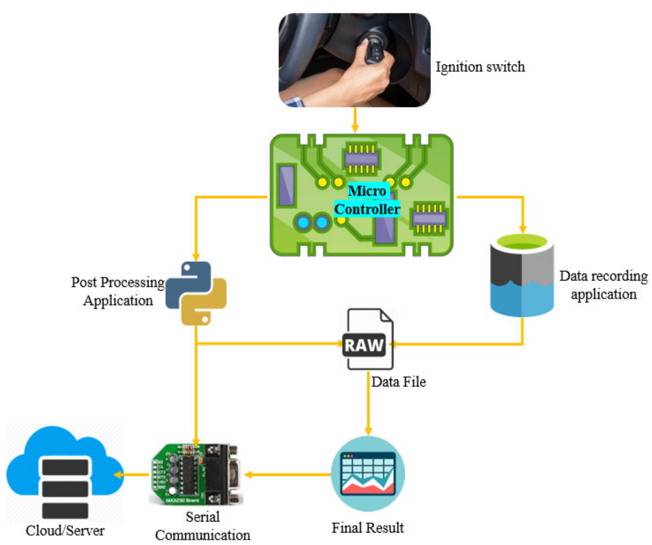


Fig. 4. Software flow for data recording and post-processing.

Working of the System

The raspberry pi is powered by the power trigger circuit, when the ignition is switched on and raspberry pi boots data logging and post processing application is activated. Concept of parallel computing is used to log sensor (connected to ADC) input by data logging application and parallelly post processing application computes the desired output results to the server based on the measured parameter. The raspberry pi (base system) which has been programmed, sends the temperature and humidity output to the GSM telematics, through serial communication and then the result gets uploaded to server. Once the vehicle is switched off, the system stops logging the data, it ensures that the last logged data is post processed and required results are sent to the server, and then switches off itself. Hence the system is fool proof and works without any human interface. Fig.5 shows the proposed process for duty cycle measurement.

System Validation

Dedicated calibration system used in the industry is used to validate the system. Calibration master and proposed systems are connected in the temperature calibration system for capturing temperature values. Simultaneous data acquisition was carried in both the systems during temperature increments. Data acquired from calibration master is compared with proposed system. Whereas in the proposed system, data is acquired and uploaded to the server.

Temperature values on both the system are then compared with temperature increment values (Refer Figure 6). Based on comparison, it is evident that the proposed system is in line with the existing proven system available in the industry.

Humidity sensor is checked by single point verification with calibrated humidity meter in ambient and dry air condition and found in line with the humidity meter. Displacement sensor is calibrated using the proposed system with respect to known displacement. After internal validation, the product is installed in field vehicle for real time.

Results and Discussion

After internal validation, the product is installed in field vehicle for real time measurements. Test data were acquired in on-road test vehicle. Measurement captured in proposed remote data acquisition system is processed internally and analyzed output is uploaded in cloud. Temperature data is measured in engine mount of vehicles mentioned in Figure 7 to study temperature distribution of engine mount in different category of vehicles

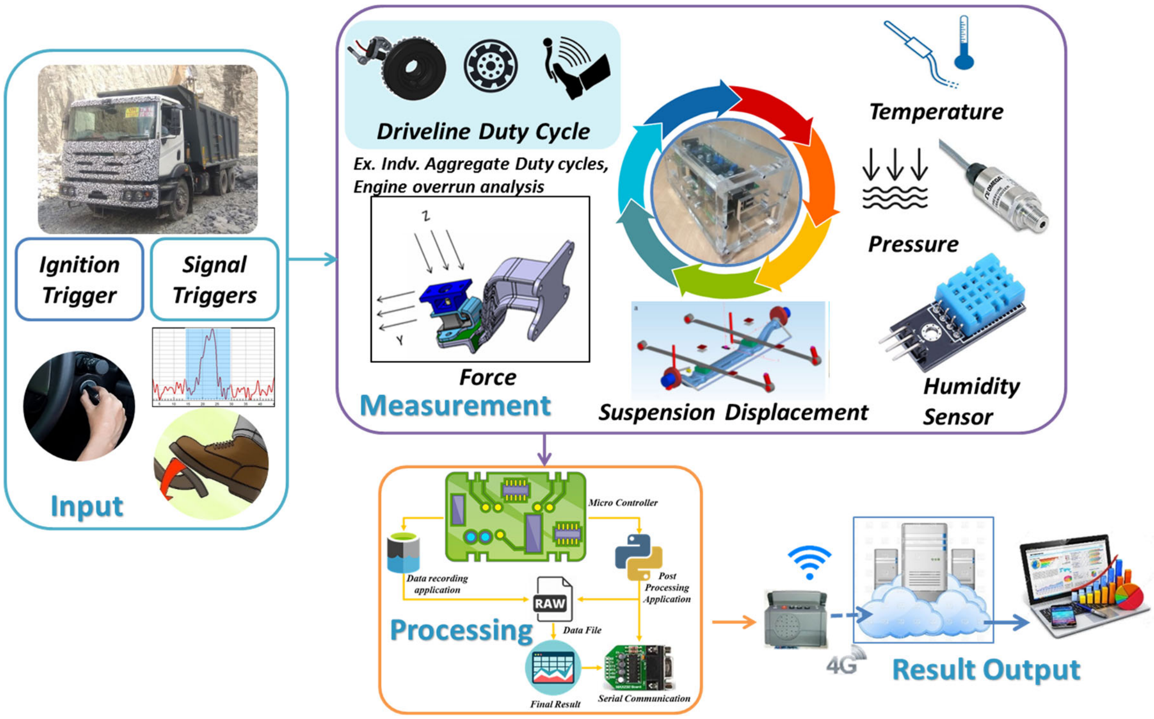


Fig. 5. Process flow for proposed method of duty cycle measurement.

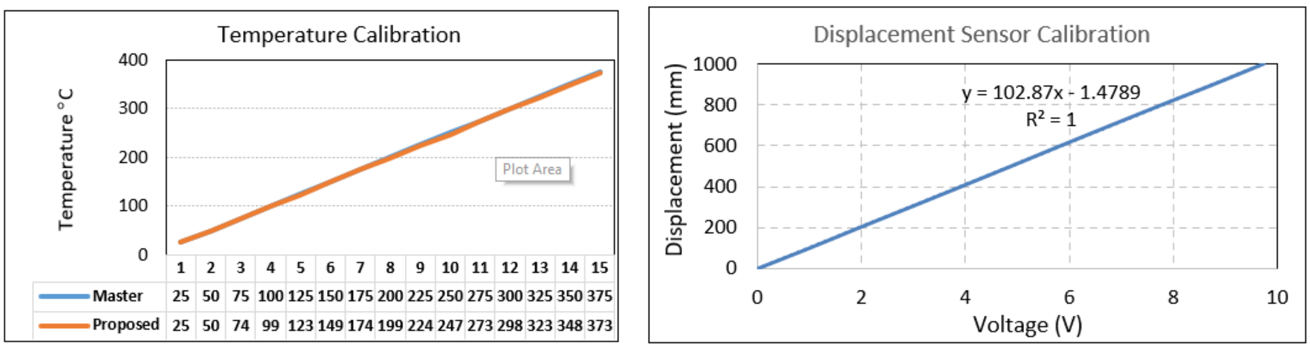


Fig. 6. Calibration and comparison of temperature and displacement value system.

Vehicle Model	Field Trial Details	Covered (Km)	Time (Hrs)
Vehicle A - MHCV	Route A	2000	30
Vehicle B - MHCV	Route B	3000	54
Vehicle C - MHCV	Route C	1400	21
Vehicle D - ICV	Route D	9000	180
Vehicle E - Passenger	Route E	2000	100

Fig. 7. Representative vehicle images and details of proposed system validation.

Processed output is then converted to graphical representation for ease of viewing, as shown in Fig 8. This provides information on temperature distribution throughout vehicle running condition in different weather and road events.

Humidity is measured inside the air tank of vehicle to study the humidity of air in different vehicle operating conditions. Humidity sensor and mounting image is shown in Fig 9.

Humidity measurement of vehicle air tank in vehicle running condition in continuous road operation shown in Fig 10.

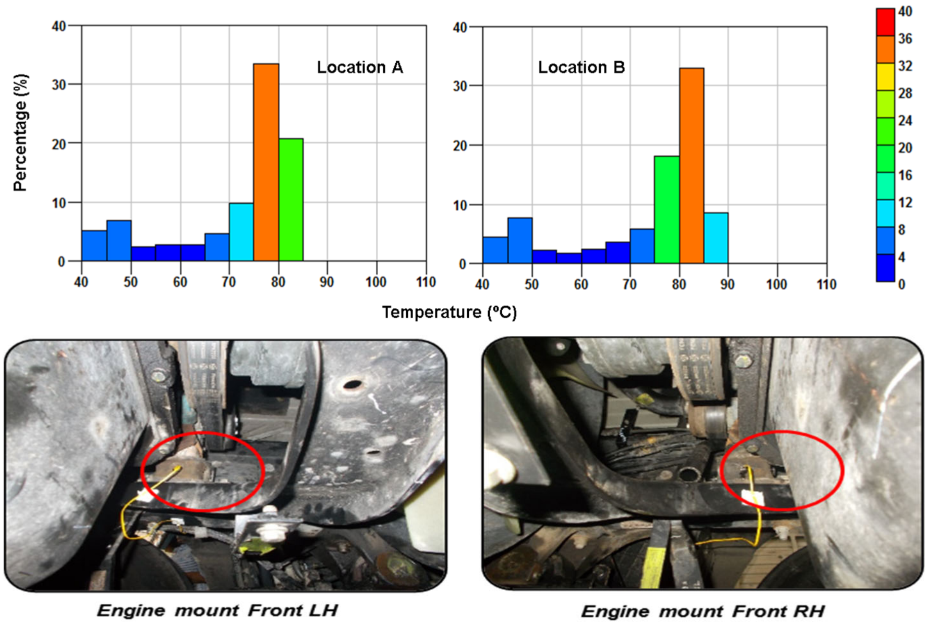


Fig. 8. Temperature measurement location and processed output results.

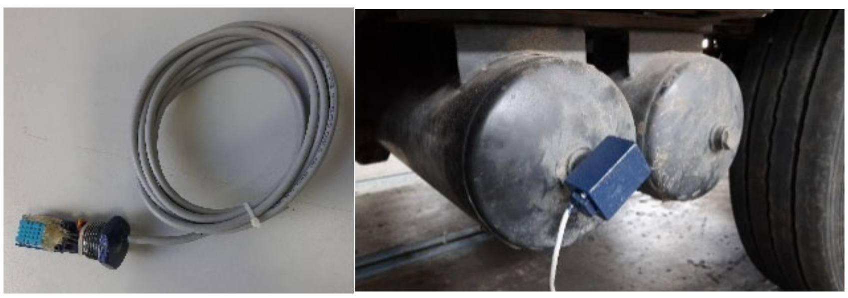


Fig. 9. Humidity sensor and mounting image.

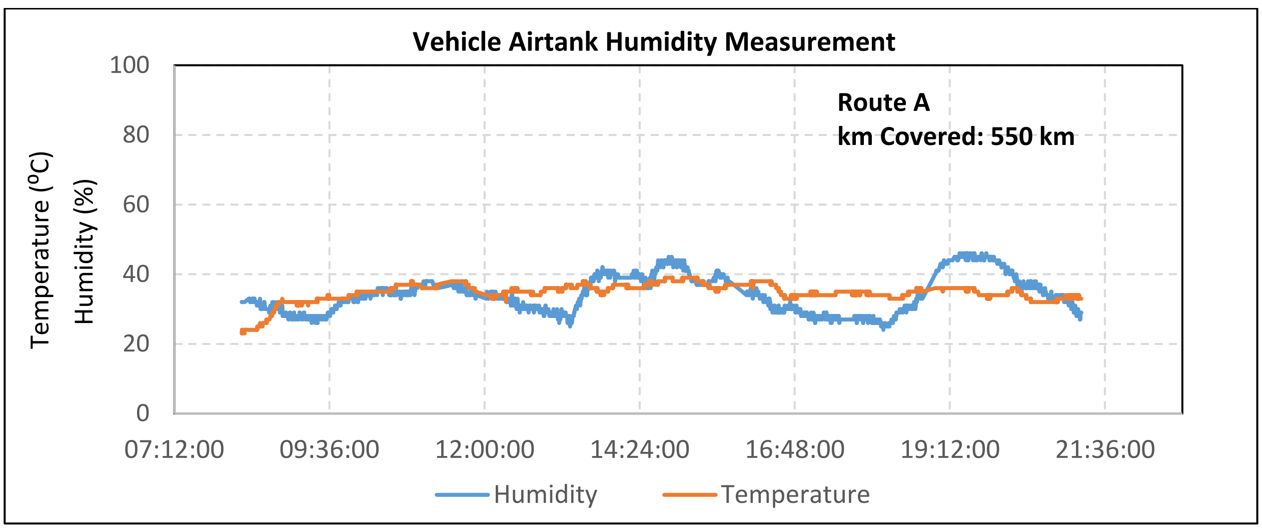


Fig. 10. Humidity measurement results vehicle operating condition.

Similar to temperature and humidity, displacement or any other analog voltage signals can be measured using the proposed remote data acquisition system. In figure 11 displacement sensor mounting and output distribution plot is shown. Raw measured displacement data is converted automatically in post processing and distribution output is stored.

The proposed system is cost effective, it can be installed in many vehicles in different operating conditions and data collated from all the regions can be used as a duty cycle input to validate the system.

Automated Post Processing of Signals

Measured signals using proposed system output data are analysed automatically and only processed output data are shared in the cloud. The measured data are usually larger in size due to higher measurement samplings and longer time recording. So handling of large amount of raw data outputs in remote and cloud is extremely difficult. Based on individual parameters measured, different analysis techniques are written in python code. Raw data recordings are captured in 1 Hrs of segment intervals and saved temporarily. Python code written in such a way that after every intervals of signals saved, post processing analysis code will be triggered and analysed.

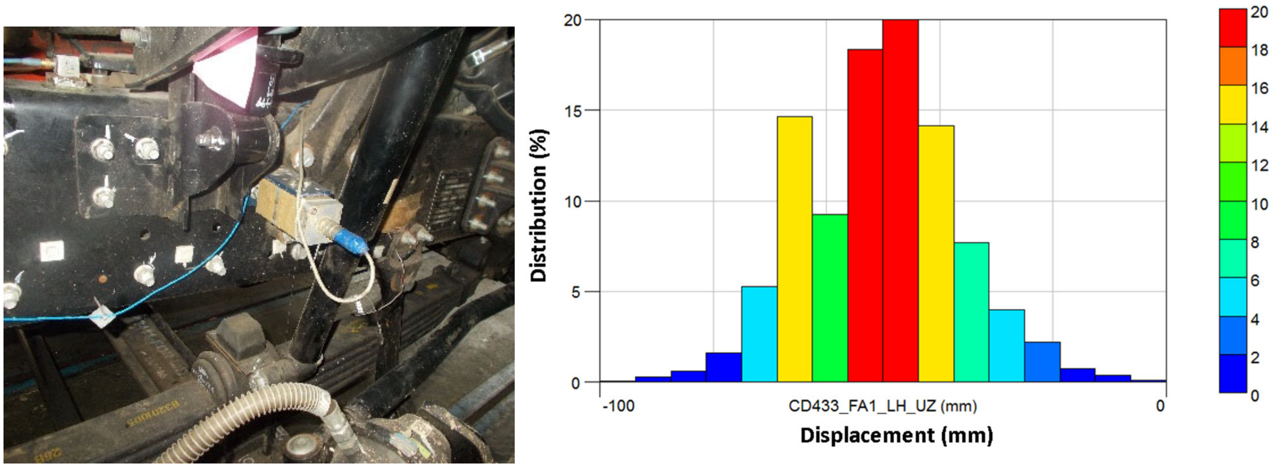
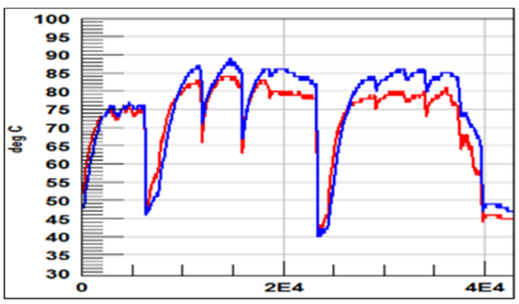
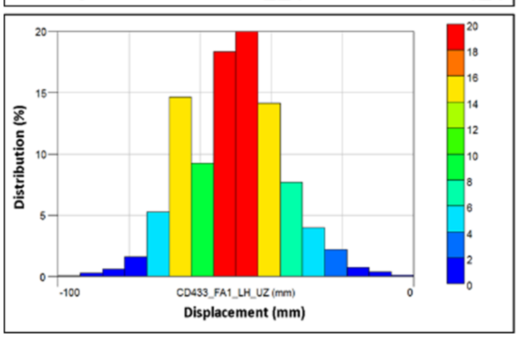


Fig. 11. Displacement measurement results in field vehicle running condition



Cycle List									
Range	Mean	Count	i_start	i_end	maxcycle	mincycle	direction	fromcycle	tocycle
0.065	0.337	1	88	114	0.370	0.305	-1	0.370	0.305
4.064	17.857	1	512	680	19.889	15.825	-1	19.889	15.825
0.021	20.156	1	1036	1052	20.166	20.146	1	20.146	20.166
9.463	13.548	1	1434	1684	18.280	8.816	1	8.816	18.280
1.061	9.261	1	2054	2144	9.792	8.731	1	8.731	9.792
0.339	8.414	1	2286	2320	8.583	8.245	1	8.245	8.583
22.210	11.198	0.5	0	894	22.303	0.092	1	0.092	22.303
27.565	8.520	0.5	894	2594	22.303	-5.262	-1	22.303	-5.262
10.840	8.796	1	3288	3466	14.216	3.376	1	3.376	14.216
30.191	9.833	0.5	2594	3074	24.929	-5.262	1	-5.262	24.929



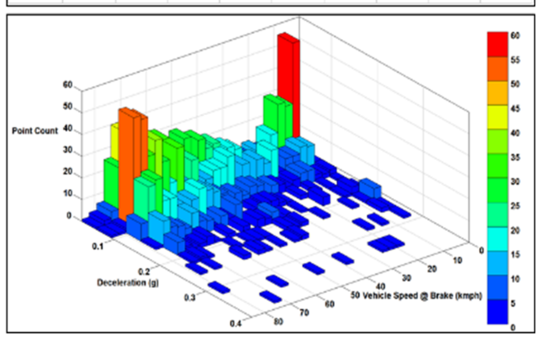


Fig. 12. Representative plots for automated processing results.

Automated post processing analysis takes care of converting raw data into required output results. Example, displacement signals are measured in 100 Hz (samplings per second) and recorded throughout vehicle running condition. This provide in GB size of raw data for a day. Handling this would be difficult in cloud, hence in post processing raw data is analysed and converted to peak and valley with index. Also rainflow distribution cycles are calculated for individual patches and temporary data is deleted. This post processed output data reduces data size drastically. Analysed output data are continuously collated and generates a rich data bank for product validation. All required results are provided directly without any additional requirement of manual post processing.

Advantages and Challenges

The system replaces the conventional data logger which requires human interface for data recording, data handling and post processing. Whereas the proposed system eliminates human interface for the above said activities. Unlike conventional IoT system which is limited to low frequency data acquisition, the proposed system is capable of handling high sampling (1000 Hz), real time post processing and Internet of thing-based data sharing to cloud opens many opportunities for the system in the field of RLDA.

1. The advantages of the proposed system are,
   a. Disruptive technology to replace high cost data acquisition system
   b. More amount of data collected from different terrain
   c. Post processing and data handling time is eliminated
   d. The system can be used for the measurement of different parameters and the capability of the system shown below
      i. Temperature study
      ii. Displacement study in suspension and other aggregates
      iii. Torque duty cycle
      iv. Critical strain location
      v. Force measurement on different aggregates
      vi. Road profile measurement
   e. Cost effective solution, the price of the system is Rs. 20,000 while data loggers available in the market costs minimum Rs. 5 lakhs.
   f. No human interface required in data logging
   g. Extended warranty based on customer usage pattern
2. The challenges with the system are,
   a. Not suitable for severe environmental conditions
   b. Ability to withstand for only lesser shock loads
   c. Lesser robust compared to existing dedicated systems

Fig. 13. Collated data from different terrain.

Future Scope

1. Bringing automation of handling the output and use of big data analytics to map terrain wise vehicle utilization
2. Increased channels for recording different parameter duty cycle together

Increasing system reliability for tough terrains Ability to withstand high shock loads.

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