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Smart Sensor for Analyzing Train Vibration in WCR Zone

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Abstract: In the present paper a smart vibration sensor is developed for railway electric engine WAP-7. Which is a self-sensation device equipped with recording and wireless communication interface. One programmed microcontroller 89C52 is used, which record vibration of trains with real time into memory. There is certain limit of vibrations, which is acceptable by track. Beyond this limit track can be damaged and may result major casualty. Smart sensor indicate the level of current vibration with its ideal value for prevention of excessive vibration it starts buzz ring. The work is highly applicable to the high speed trains. The high level vibration cause serious accidents due to the vibration. *Copyright © 2009 IFSA.*

Keywords: Microcontroller, Wireless communication, Vibration, Train, Real-time

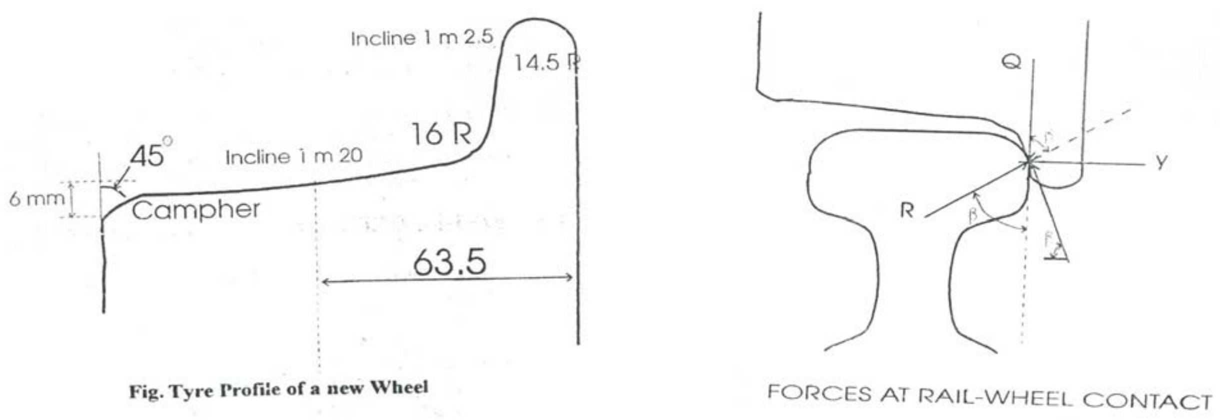
1. Introduction

High-speed trains are one of the most impressive developments of the recent years having brought a new degree of comfort for travelers. These train posed serious accidents because of the high level of vibration, which they can generate.

There is certain limit of vibrations, which is acceptable by track. Beyond this limit track can be damaged and may result major casualty. Vibration induced by train is an important data for accident investigation team. There are certain limits of vibration from 0 to 100 Hz, which is acceptable to proper train movement beyond this limit accident, may be occurred.

Railway is an enormous medium of communication in India. Rate of accidents of rails are increasing swiftly, to decrease the rate of accident it is important to give attention but more important to know about the appropriate reason of accident. Vibration induced by train is an important data for accident investigation team. There are certain limits of vibration, which is acceptable to proper train movement beyond this limit accident, may be occurred [1-6].

There are drastic changes in vibration parameter of train due to sudden braking, collision of train with another object, uncertain increment in train speed and many other improper operations. The explanation of vibration with speed and wheel conditions is given by Nadal's formula and Tyre wheel profile as shown in Fig. 1 [7].



(a) (b)

Fig. 1. Nadal's formula and Tyre wheel profile.

The Nadal's formula gives mechanism of wheel flange climbing. The ration of lateral forces to vertical wheel load Y/Q has a major contribution in determining derailment tendency of the rolling stock. When this ration, exceeds for a sufficiently long period of time, a critical state occurs when climbs and mounts on the rail table and causes derailment.

Equation (1) denotes the condition for excessive vibration and its factors.

$$Y/Q < (\tan\beta - \mu)/(1 + \mu\tan\beta) \quad (1)$$

Where μ is coefficient of friction, B is Flange angle, Y is Lateral flange force, Q is Wheel load, R is Normal reaction from rail, and μR is frictional force acting upward

The present paper discusses effect of train speed on train vibration in theoretical and practical ways. A microcontroller based circuitry is designed, which can record vibration parameter of train using real time programming. The recorded data of train vibration give immense support to accident investigation team to generate a report. With the help of this data, investigation team get support and provide attention to save trains from such type of causality. This data can be stored into memory as well as can be downloaded into laptop or computer using wireless communication.

In present study WAP – 7 engine is selects for taking observation .WAP-7 is an electric engine has Co-Co types bogies, weight 123 ton, three phase induction motor, generate 6000 hp and having 182 Kn braking efforts [8].

2. Analysis of Train Vibration

The speed of train in India has increased dramatically. To avoid serious impact on trackside environment, it is important to quantitatively estimate the increase in ground vibration that will result from higher train speeds.

The relationship between train speed and ground vibration is expressed by the power of velocity law [2].

When train speed changes from Vo to V the increase in ground vibration level, ΔVL (dB), can be expressed as

$$\Delta VL = 10\ \alpha\ \log10\ (V/Vo) \tag{2}$$

The nature of vibration induced by train depends on the train speed as well as the nature of soil shown in Fig. 2 and Fig. 3. Table 1 shows the nature of soil with its attenuation factor α. In recent study the west central railway zone was selected and vibrations were recorded from Bina – Katni junction. Between these junctions the nature of soil changes rapidly due to variation in geo-technical structure inside the earth as shown in Table 2.

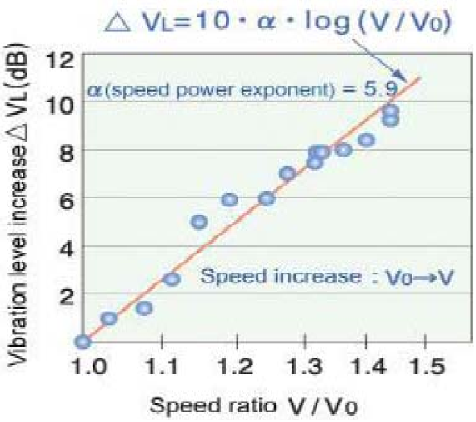


Fig. 2. Increased vibration level with increasing speed (Courtesy- Hidefumi YOKAYAMA).

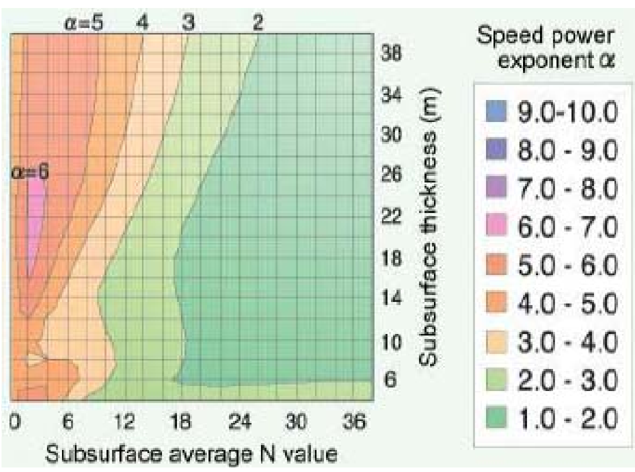


Fig. 3. Calculation of the speed power exponent using the subsurface average N value and thickness as parameters (Courtesy- Hidefumi YOKAYAMA).

Table 1. Soil nature.

Soil Type	Soil Attenuation, α [m^{-1}]
Viscous soil Bad soil Sand and silt	0.04-0.12 0.10 0.04

Table 2. Nature of soil in WCR zone.

S. No.	Station Distance	Soil Type
1.	978 Km (Bina) to 1074 Km (Girwar)	Viscous soil (good for track)
2.	1100 Km (Patharia) to 1125 Km (Damoh)	Bad soil
3.	1125 Km (Damoh) to 1142 Km (Bandakpur)	Viscous soil
4.	1214 Km (Reethi) to 1235 Km (Katni)	Viscous and bad soil

At low frequencies (around 20 Hz) the maximum level of train induced ground vibration highly depends on train weight, its speed as well as the nature of soil. This limits the axle loads and speed allowable for train traffic. Stabilization of the soft soils under the track is done by embankment process. Apart from this 1540-1660 sleepers in each kilometer of railway track having weight 52-60 Kg, are used. Frequency of sleepers is also supportable to absorb the train-induced vibration. Relation between vibration and train speed is given by equation (2).

3. Smart Vibration Sensor

Smart Sensors provide features required in order to further expand applications of sensing technologies in a cost effective manner

- Electronic “Data Sheets”
- Self Identification
- Smart Calibration & Compensation
- Digital Sensor Data
- Sensor Communications for Remote Monitoring and Remote Configuration Smart vibration sensor. Fig. 4 shows the basic block diagram of smart sensor.

Basically the smart sensor partitioned into two parts. One part is network independent and other is network dependent as shown in Fig. 5.

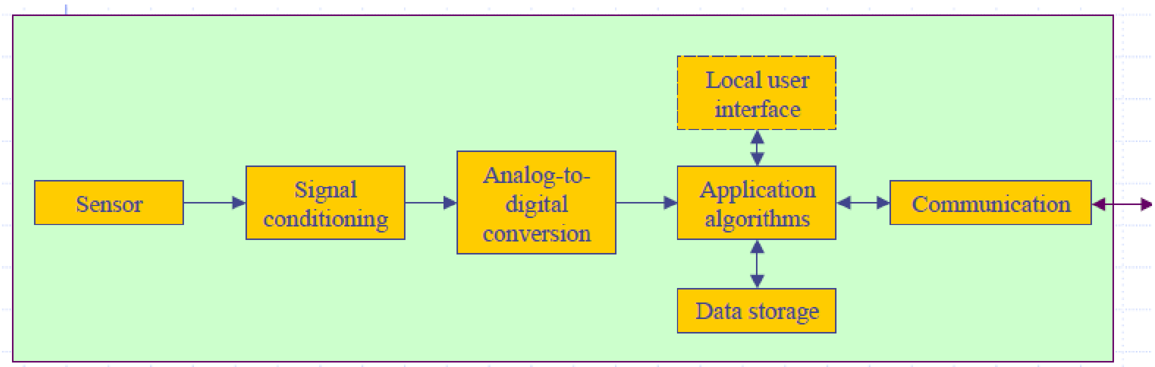


Fig. 4. Block diagram of smart sensor.

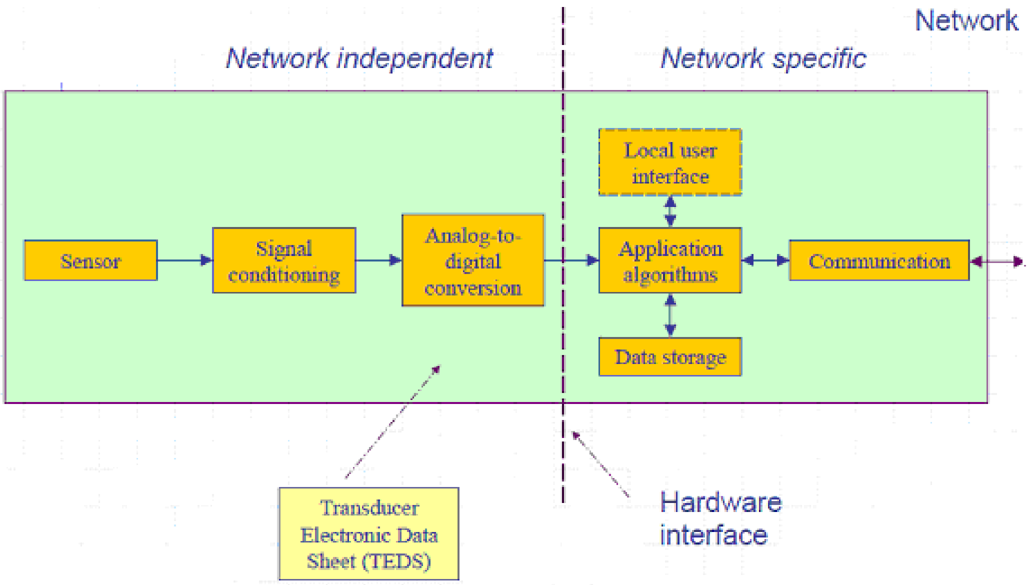


Fig. 5. Partition in smart sensor.

3.1. Vibration Sensor Interface with Microcontroller

The basic hardware of the Smart vibration sensor is shown in Fig. 6. The system configuration with a 89C52 microcontroller consist of, parallel to serial converter (74ls164), RS232 interface (MAX 232), switch panel, real time clock (RTC 1307), EEPROM 24C1024 and 16x2 LCD. The microcontroller 89C52 is the CPU for the system. Smart vibration sensor is implemented in this system. The interface of the sensor with microcontroller is done by monostable multivibrator. The microcontroller is programmed to store the data coming from vibration sensor. It is capable of addressing 1024 K program and Data memory and also has 256 byte of on-chip data memory, 8K-program memory. It is also configured with three timers, a serial port for establishing a serial communication; four general purpose parallel I/O ports with interrupt control logic. This system uses MAX 232 to establish a wireless communication taking IR/RF wave as data carrier between the smart sensor and the PC. The system is configured with EEPROM 24C1024 for data storage of vibration with real time using RTC 1307. The total system runs at the speed of the system clock of 11.9 MHz. Smart sensors also has battery backup in power cut conditions.

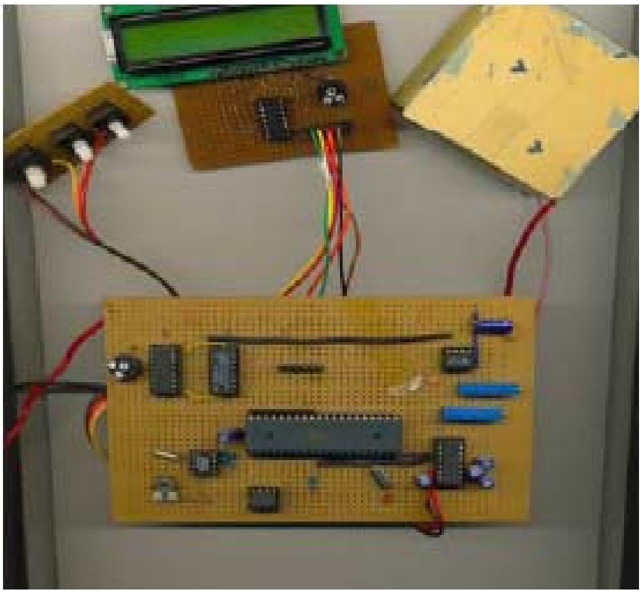


Fig. 6. Smart vibration sensor with interfacing card.

3.2. Software Implementation

A, C - language program is developed with the help of Keil compiler. This program is transferred to microcontroller using device programmer lab tool – 48UXP. The program works in following steps
a) System initialization: Display initialization.
b) The default value display.
c) The controller goes to interrupt mode whenever a toggle switch is pressed.
d) Software implementation for external PC interfaces at hyper terminal using RS232 communication.

3.3. Smart Vibration Sensor Wireless Interface with PC/Laptop

For wireless interfacing of smart vibration sensor, MAX 232 is used for transmission of data with IR carrier waves. MAX 232 interface with port 3 of microcontroller 89C52. Transferring of data via wireless communication is done by interrupting of switches shown in switch panel. With MAX 232 one IR source is used for generating carriers. One receiver circuit is used with PC/ Laptop, in which IR detector is used for detection of signals. Receiver is connected with PC/ Laptop using serial interface. The received data is shown in PC / Laptop's hyper terminal. Fig. 7 shows the smart sensor.

Fig. 7. Smart Sensor.

4. Testing

After the physical acceptance test for the PCB, functional testing was also carried for various subunits; the test carried out has shown correct result as observed by the required waveform on the storage CRO.

5. Conclusions

The sensor with microcontroller interface has been designed, developed and tested for reliability of electronics. The sensor can be accessed wirelessly from PCs/Laptop's. This sensor is useful for recording the vibrations of trains with respect to date and time by which investigation team can get the appropriate reason of accident due to vibration. Smart vibration sensor doesn't require wired communication. It can be communicated with PC/ Laptop's using wireless communication.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
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- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
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