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Using Comfort Related Data of Indian Railways for Fault Finding On Track: A Case Study with Multiple Profile

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Abstract*— Derailment has always been one of the major concerns for railway. It is a unique challenge for railways to ensure that wheels stay on the rail. Railway technologies have advanced significantly in recent years and safety levels are high compared with the early days and also compared with other transport modes. Derailments however, unfortunately, still frequently occur. The issue of comfort in respect to vibration has become a common question to the railways since vibration plays a major role for ride comfort and ability to perform desk activities. Several factors influence vibration discomfort in relation to passenger activities, e.g. seat design, seated posture, use of backrest, etc. To avoid derailments, railway collect comfort related data from multiple profile trains (i.e. Express, Superfast, passenger's trains etc) for finding the damage among thousands of tracks when trains travel from one station to another station. In this study we analyzed the received data on the basis of ENV12299 standard and using Visual Studio 6.0. MS Access database is used to store the report data. The frequency variations observed during the experiment relate only to the cause of losing lateral control at wheel and rail interface.

***Keywords*— Railway, Derailment mechanisms, Vibrations, Lateral control**

I. INTRODUCTION

Railway vehicles provide a range of more comfortable facilities compared to the other means of passenger transportation in respect to the ability of performing sedentary [1] activities like reading, writing, etc. Facilities that are commonly seen in railway passenger cabins are tables, spacious seats, pantry cars, toilets, etc. As a consequence, many passengers particularly in suburban area choose the railway to be able to work while travelling but the issue of comfort in respect to vibration has become a common question to the railways since vibration plays a major role for ride comfort [10] and ability to perform sedentary activities. Several factors influence vibration discomfort in relation to passenger activities, e.g. seat design, seated posture, use of backrest, etc, Passengers usually adopt their posture to attenuate the intensity of vibrations and jerks in order to perform their activities satisfactorily. There are, however, limitations in the seating place since the transmission of vibrations to the human body is higher if a passenger uses armrest, backrest or places both feet on the floor [1].

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Attenuation vibration exposure is the primary requirement to improve both ride quality and activity performance. There are various means by which the vibration can be expressed, such as displacement, velocity and acceleration of these physical quantities acceleration is generally adopted as preferred measure of quantifying the severity of human vibration exposure.

The objectives of this study are (i) to determine to what extent vibrations affect sedentary activities (ii) to observe the level of vibration discomfort on same track while travelling through different trains according to the ENV -12299:1999 [1] standard.

The leading train accident causes are:
Rail, joint bar, and anchoring
Track geometry defect
General switching rules
Wheels
Axles and journal bearings
Switches
Frogs, switches and track appliances
Bogie components
Train handling/train makeup
Highway rail grading
Page Layout

II. RAILWAY VEHICLE DERAILMENT MECHANISMS

Railway derailments [9] due to loss of the lateral guidance at the wheel and rail interface may be classified into four major causes: wheel flange climb, gauge widening, rail rollover, and track panel shift, based on the ways that wheel - rail lateral constraints are lost.

A. Flange Climb Derailment

Wheel flange climb derailments [5] are caused by wheels climbing onto the top of the railhead then further running over the rail. Wheel climb derailments generally occur in situations where the wheel experiences a high lateral force combined with circumstances where the vertical force is reduced on the flanging wheel. The high lateral force [5] is usually induced by a large wheel set [7] angle-of-attack. The vertical force on the flanging wheel can be reduced significantly on bogies having poor vertical wheel load equalization, such as when negotiating rough track, large track twist, or when the car is experiencing roll resonances. Flange climb derailments generally occur on curves. The wheels on the outer rail usually experience a base level of lateral force to vertical force ratio (L/V) [5] that is mainly related to:

Curve radius
Wheel – rail profiles

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Bogie suspension characteristics
Vehicle speed

These factors combine to generate a base wheel set angle of attack, which in turn generates the base level of lateral curving force.

B. ENV-12999:1999

The effect of magnitude of vibration on human comfort can be evaluated according to ENV- 12999: 1999 [4]. Two methods are available for the assessment of the passenger perception of mean comfort under ENV-12999: 1999:

1. A simplified method based on measurement of acceleration on the floor (NMV).
2. A complete method based on measurement of acceleration at the interface between passengers and the vehicle (NVA, NVD).

This study was conducted with restriction to apply simplified method only. Hence the vibration was measured on the car body floor at the positions defined in ENV-12999: 1999 [4]. Necessary frequency weighting and averaging procedures that can be applied to the measured accelerations are provided in the standard.

The evaluation method according to ENV-12999: 1999 consists of the following:

- Measuring the vibration signals
- Signal processing
- Frequency weighting,
- Calculation of r.m.s value [1]-[3] for time intervals of 5 s,
- Calculation of the cumulative distribution for a total time interval of 5 minutes,
- Calculation of the 95% probability sample,
- Calculation of Mean Comfort Index NMV [2] at each measuring point.

The duration of the measurements shall be a multiple of five minutes. The minimum required is four zones of five minutes, each zone travelled at constant speed, which allows this method to be applied.

C. Methodology

As per ENV-12999: 1999 Mean comfort index (NMV) is calculated using the formula

$$N_{MV} = 6\sqrt{(a_{XP95}^{Wad})^2 + (a_{YP95}^{Wad})^2 + (a_{ZP95}^{Wad})^2}$$

Where

a_{XP95}^{Wad} Weighted r.m.s acceleration corresponds to 95 quantile in X(Lateral) direction.

a_{YP95}^{Wad} Weighted r.m.s acceleration corresponds t 95 quantile in Y(Lateral) direction.

a_{ZP95}^{Wad} Weighted r.m.s acceleration corresponds t 95 quantile in Z(Vertical) direction.

Algorithm:

Step 1: Obtain reading for weighted r.m.s acceleration in X (Lateral) direction

Step 2: Obtain reading for weighted r.m.s acceleration in Y (Lateral) direction

Step 3: Obtain reading for weighted r.m.s acceleration in Z (Lateral) direction

Step 4: Squaring individual values

Step 5: Addition of Squared values

Step 6: Get the root value of the addition

Step 7: Multiply the result by Constant to get value of NMV

D. Comfort scale

In order to interpret the evaluated values in terms of mean comfort, ENV-12999: 1999 proposes a comfort scale as shown in the Table I1.

Table. I. Scale in comfort units for N_{MV}

Mean Comfort	Index Scale
N <1	Very comfortable
1≤ N < 2	Comfortable
2≤N<4	Medium
4≤N<5	Uncomfortable
N ≥ 5	Very Uncomfortable

E. Vibration measurements and Results

All the vibration measurements were made on the compartments of Goods train, Local train, Express and Super Fast express. Vibration readings were taken during both up and journey of each type of train in the route from various destinations during normal running.

A tri-axial accelerometer was used to measure the vibrations for all the directions on the floor. The duration of the measurement was about 40 – 50 minutes for each journey; records are taken at a sampling rate of 1 sample per 5 seconds. These readings were analysed according to ENV-12999: 1999.

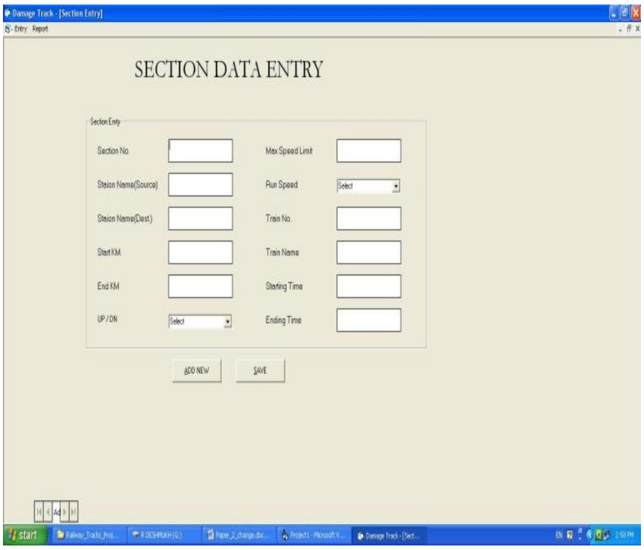

Fig: 1 Frequency Reading Entry Screen

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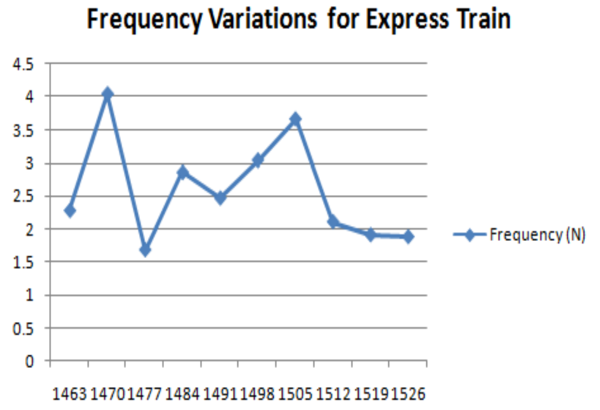

Fig: 2 Frequency Reading variations of Express Train at average speed limit 60 kmph.

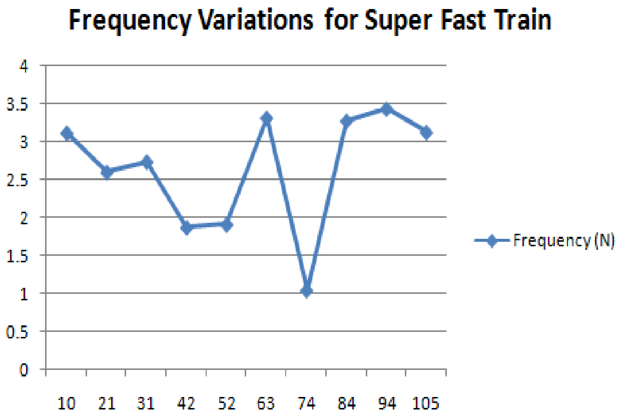

Fig: 3 Frequency Reading variations of Superfast Train at average speed limit 90 kmph

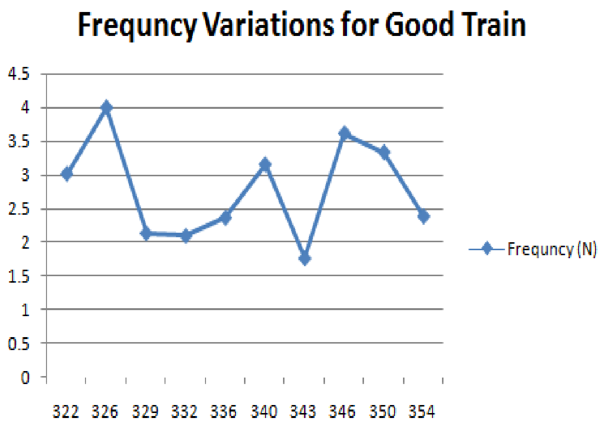

Fig: 4 Frequency Reading variations of Goods Train at average speed limit 30 kmph

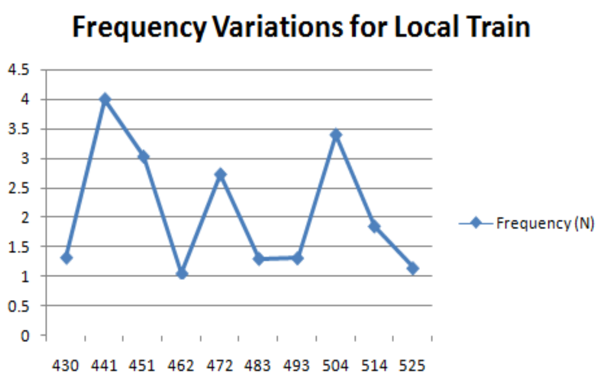

Fig: 5 Frequency Reading variations of Local Train at average speed limit 40 kmph.

F. Results & Discussion

The floor vibration was determined in span of 5 second. These mean values were predicted for each different train. Similarly the mean comfort index was calculated for each train as per the ENV-12999:1999 using Visual Studio 6. It was observed that for Express train, comfort level was worst between track number 1463 and 1470. For Super Fast train comfort level was found worst between track number 84 and 94. For Goods train vibrations exceeded frequency of 4 between track number 322 and 326. Finally, for Local train comfort level degrades around track number 441.

In general Mean Comfort (NMV) was higher in the Super Fast Express than that obtained in the Express, Goods or Local train. It indicates that the speed directly makes an impact on the generation of vibrations in the tracks. However it depends on the conditions of compartment body as well. The predicted results were cross checked and were in line with the records of Indian Railways.

G. Conclusion

Our results are used as a tool to predict the activity comfort of onboard train passengers which was supported by the readings taken from the instrument and our simulations.

ENV 12999:1999 was used to evaluate the ride comfort levels. Different types of trains such as super fast, express, local and goods train were considered for the study.

Comfort level values are categorized from Very uncomfortable to Very Comfortable levels. The above results are the outcome of vibration measurements directly taken from the track.

This study shows that low levels of vibrations may affect the deskbound activities like paper work or so. Further research on this issue is required to achieve more conclusive outcomes. They can be helpful to predict and determine the comfort level on various rail tracks with different types of trains.

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