Evaluation of Wheel Load & Lateral Forces, using Lateral & Vertical Force Measurement Wheel in Dynamic Condition at Rail Wheel Contact Point

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***Abstract* —Vertical and lateral forces of the railway vehicle are frequently produced by shortwave length track irregularity, track geometry and stiffness irregularities, discontinuities like rail joints and crossings. These large forces are undesirable; they have a significant effect the stability of the railway vehicle. In order to assess the stability of a rolling stock, it is important to measure the forces acting at the rail–wheel contact point. Correct assessment of these forces becomes a must for locomotives, coaches and wagons, where the magnitude of these forces is high, and they play an important role in determining the safe speed potential of the rolling stock. These forces are measured by lateral & vertical force measurement device. This study is the technological development for the measurement forces at the rail wheel contact point during dynamic condition.**

Keywords — Lateral forces, vertical & lateral bridges, wheel sets, Plausibility Check

I. INTRODUCTION

This Testing is conducted on a new or modified design of rolling stock, which is proposed to be cleared for running on the track. The purpose of these tests is, thus, an acceptance of a railway vehicle by conducting dynamic behavior tests in connection with safety, track fatigue and quality of ride.

Vertical and lateral forces are developed between the rail and the wheel as a result of dynamic interplay of track and vehicle characteristics. It is important to understand these forces because of their role in vehicle stability and track stresses. Generally these forces can be classified into three categories, namely, static forces, quasi-static forces and dynamic forces.

Static forces arise due to static wheel load applied on the rail. Quasi-static forces are developed due to one or several factors, which are independent of the parasitic oscillations of the vehicle and do not vary in a periodical manner. Centrifugal forces caused by cant excess or deficiency, curving action on points and crossings and forces due to cross winds fall in this category.

Dynamic forces are caused by track geometry and stiffness irregularities, discontinuities like rail joints and crossings, wheel set hunting and vehicle defects like wheel flats. Dynamic forces are the most significant ones in the study of vehicle stability and rail stresses and are also the most difficult to mathematically determine or to experimentally measure.

II. BRIEF DESCRIPTION OF DYNAMIC FORCES & EXISTING METHOD USING CALCULATION OF STABILITY [4].

According to KTH, the frequency ranges for the vertical dynamic forces are 0-20 Hz for sprung mass, 20-125 Hz for un-sprung mass and 0-2000 Hz for corrugations, welds and wheel flats. The vertical forces in the lower frequency range are produced due to vehicle response to changes in the vertical track geometry like unevenness and twist whereas forces in the higher frequency range are caused by discontinuities like rail joints, crossings, rail and wheel surface irregularities. A wheel flat produces high frequency peaks at regular intervals, which is easily distinguishable from other surface irregularities.

The net lateral forces acting on the track by the wheel set can lead to the distortion of track laterally, causing derailment. In other words, this force is a measure of lateral strength of the track. This force is equal to the lateral force at axle box level as a result of reaction of the wheel set with the vehicle body/bogie. This force, usually denoted by the symbol Hy, can be measured with the help of a load-cell placed between the journal face and the axle box cover or the bogie frame and the axle box.

Generally, $m\ddot{y} = FLY + FRY + NLY + NRY + FSY$. Where, FLY and FRY are the lateral creep and frictional forces acting on the left and right rail-wheel contact points, NLY and NRY are the lateral components of the normal forces on the left and right rail wheel contact points, m is the mass of the wheel set and $\ddot{y}$ is lateral acceleration of the wheel set. The quantities FLY + NLY and FRY + NRY are the lateral forces recorded by a measuring wheel at the left and the right rail wheel contact point and are conventionally denoted as YL and YR respectively. The quantity FSY is conventionally denoted as HY.

III. LATERAL FORCES [2] :-

On Indian Railways,[4] the criterion for lateral force at axle box level, Hy, lasting for more than 2 meters should not exceed 0.85*[1+P/3] tonss, where P is the axle load in tonss.

As per UIC-518, lateral force ∑Y over 2m track is ∑Ylim = α (10 +P/3), where, P is static axle load and ∑Y are expressed in kN, α =1 for traction units, passenger stock (tractive and trailer stock) and α =0.85 for wagon. Instability has been defined as sliding rms of ∑Ylim = ∑Ylim/2. However, for lateral forces at axle box level, HY, the safety limit is defined as Hlim = β (10+P/3) where β = 0.9 for tractive stock & passenger stock (tractive and trailer stock) and β =0.75 for empty wagon and β = 0.8 for loaded wagon. Instability has been defined as sliding rms of ∑Hlim = ∑Hlim/2. Thus, it is seen that limiting Y values are 10% higher than limiting H values. Even with a measuring wheel, forces with frequency up to 25-30 Hz only can be measured, whereas for contact stresses, On IR [3] & [4], no limit has been fixed for maximum or minimum permissible vertical forces though wheel 'on-loading' or 'off-loading' of more than 50% are viewed with concern from design point of view. For calculation of rail stresses a dynamic augment of 50% is assumed.

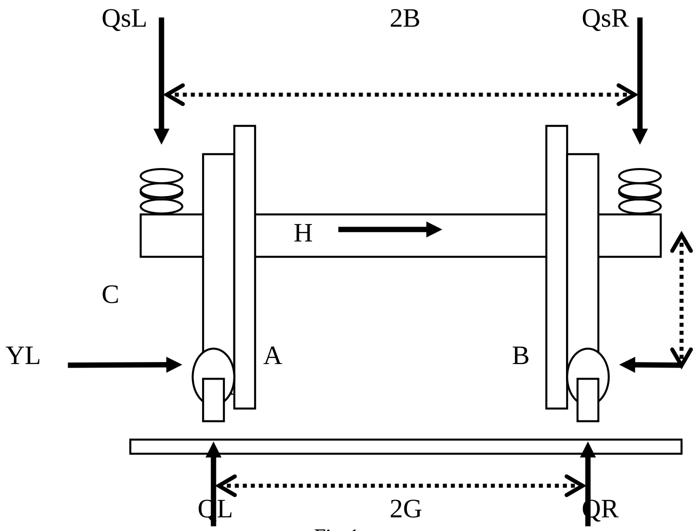

Fig-1

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The digital evaluation method, the number of samples contained in a 2m slide is determined from the sampling rate and the vehicle speed. The slide can be shifted either by one sample or by 0.5 meters at a time. For a large number of samples, the former method increases the analysis time considerably. In measuring wheel method, since Hy cannot be measured, the value of ΣY is taken as a substitute. The remaining analysis is similar to the digital method at axle box level.

IV. DERAILMENT COEFFICIENT [8]:-

Derailment can happen when the values of lateral and vertical forces acting at the rail-wheel contact point assume a critical combination leading to mounting of the flange on the rail. This phenomenon is known as derailment by flange mounting. Vehicle does not overturn and that the outer rail is capable of sustaining the lateral load, the limiting lateral force, which may be applied to a wheel, is determined by the possibility of the flange climbing the rail, thus producing derailment. As the vertical load carried by the wheel opposes this action, it is necessary to determine the relationship between the limiting horizontal force and the vertical load coming on the wheel.
Then, resolving the forces, it is seen that if the wheel is not to derail,

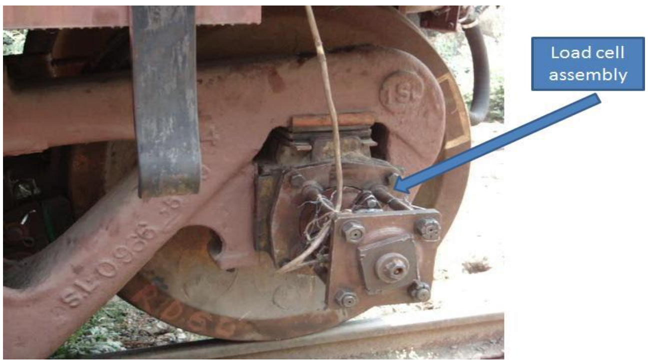
$$Q \sin\theta - Y \cos\theta - \mu QR > 0 \quad \text{---------- (1)}$$
$$QR = Y \sin\theta + Q \cos\theta \quad \text{---------- (2)}$$

Substituting QR in equation (1),

$$Q \sin\theta - Y \cos\theta - \mu [Y \sin\theta + Q \cos\theta] > 0$$
$$\text{Or, } Q[\sin\theta - \mu \cos\theta] - Y[\cos\theta + \mu \sin\theta] > 0$$
$$\text{Or, } Q[\sin\theta - \mu \cos\theta] > Y[\cos\theta + \mu \sin\theta]$$
$$\text{Or, } Y/Q < [\sin\theta - \mu \cos\theta] / [\cos\theta + \mu \sin\theta]$$
$$\text{Or, } Y/Q < [\tan\theta - \mu] / [1 + \mu \tan\theta]$$

Where, Y and Q are the instantaneous values of the lateral and vertical forces at the rail-wheel contact point, θ˚ is the angle of flange with horizontal plane and μ is the coefficient of static friction between wheel tread and rail.
It can be seen from Nadal's formula that for μ =0.27 and θ˚ =60˚, Y/Q =0.997 or 1. This is the limiting value beyond which the wheel flange will tend to mount on the rail table. The other question is that of the duration for which this ratio can exceed the value of 1.

V. DEVICE USED BY INDIAN RAILWAY FOR MEASUREMENT OF FORCES [4]:-



(Measurement of lateral forces)
Fig-2

(Measurement of Vertical forces)
Fig-3

Existing method of the vertical forces measurement, only the dynamic augment due to sprung masses is taken into consideration, and the vertical forces due to the unsprings masses are assumed to be same as the static value. With the measuring wheel, the instantaneous values of YL/QL and YR/QR are calculated and the higher of (YL/QL)1/20th second and (YR/QR)1/20th second is determined for comparing with the limit value.

2. *METHODOLOGY USED FOR LATERAL & VERTICAL FORCE MEASUREMENT AT RAIL WHEEL CONTACT POINT [4]:-*

The measuring wheel Technique for measurement of lateral and vertical forces at rail wheel Contact point. The wheel itself is instrumented and acts likes a transducer, which converts the physical forces experienced on the wheel because of rail wheel interaction into electrical signal.

2.1. HOW THE INSTRUMENTED WHEEL WORKS[8]:-

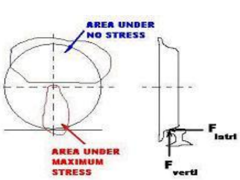


Fig 4

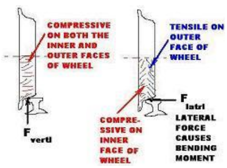


Fig 5

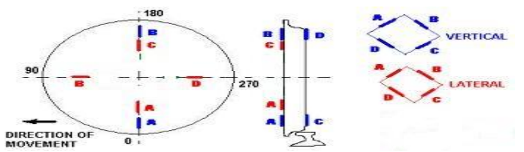


Fig 6

- It can be seen from the above figure 4 that at a particular instance, the vertical and lateral forces exert stress/strain between the axle and the point of rail-wheel contact. The effect is maximum along the line joining the center of axle and rail-wheel contact point. So, strain gauges for measuring these forces have been fixed in the radial direction.

- From the above figure 5 we can see that for measuring vertical force, if we keep one active arm of the Wheatstone bridge on the inner face and another active arm on the outer face, then strain due to lateral force will be compressive on one active arm and tensile on the other active arm. Therefore, assuming the magnitude of these compressive/tensile strains to be equal, they will cancel out. So, the bridge will measure pure vertical force.
- For measuring lateral force we have fixed only one arm of the bridge active. This arm will also get affected due to the vertical force acting. So, to find the lateral force we will have to deduct the effect of vertical force. we have tried to find out a point where there is maximum effect of lateral force and minimum effect of vertical force.
- The wheel is constantly rotating, so a number of bridges has formed on the faces of the disks for continuous recording of vertical and lateral forces acting on the wheel. The number of bridges required can be reduced by judiciously fixing the strain gauges of bridges on the wheel face. e.g. if we fix the 'B' and 'D' gauges of the vertical bridge directly opposite on the inner and outer faces of the disk, then when the wheel has turned 180˚, 'B' and 'D' become the active gauges and 'A' and 'C' dummy gauges for the vertical bridge. So, one vertical bridge covers two positions of the wheel. fig 6 given below:-

2.2. *THE INSTRUMENTED MEASURING WHEEL MEASURE THE INSTANTANEOUS VALUES OF THE FOLLOWING PARAMETERS AT THE RAIL-WHEEL CONTACT POINT [4] –*

- Vertical Force (V in tons)
- Lateral Force (L in tons)

Besides the above two primary parameters, the measuring wheel will also be able to determine the following instantaneous values for the left and right wheel discs:

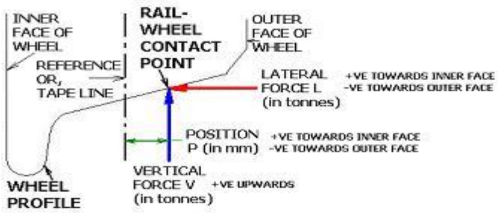


Fig-7

- Derailment coefficient (L/V ratio)
- Minimum L/V ratio acting for 1/20 seconds (L/V1/20 sec)
- Minimum Lateral Force acting over 2 meters (L2m tons)
- Resultant Lateral Force acting on the wheel set (in tons)
- Speed of the rail vehicle (in km/h)

2.3. DESCRIPTION OF INSTRUMENTED WHEEL SET [4]:-

- The instrumented wheel set system utilizes Strain Gauge Bridge applied to the disc of the wheel for sensing vertical and lateral load. All the surfaces of the disc should be machined to ensure their symmetry and the wheel does not have holes. The position of the strain gages are based on an analytic and experimental study of strains on the surface of wheel which result from vertical and lateral forces at the wheel/rail interface. Five strain gauges bridges are used on each wheel disc. Three as vertical bridges, two as a lateral bridge, the vertical bridges are responded when the vertical force act rig on the wheel. The lateral prides are responded when the lateral load acting on the wheel.

Fig-8

2.4. VERTICAL BRIDGE:-

Each of three vertical bridges consists of twelve strain genes with three gauges in each arm of the bridge of the bridge as illustrated in the fig (1). Six of the gages are applied to each side of the disc. Three centered about one and of a diametric line and the other three centered about the opposite end of the line. All the gauges are oriented in the radial direction.

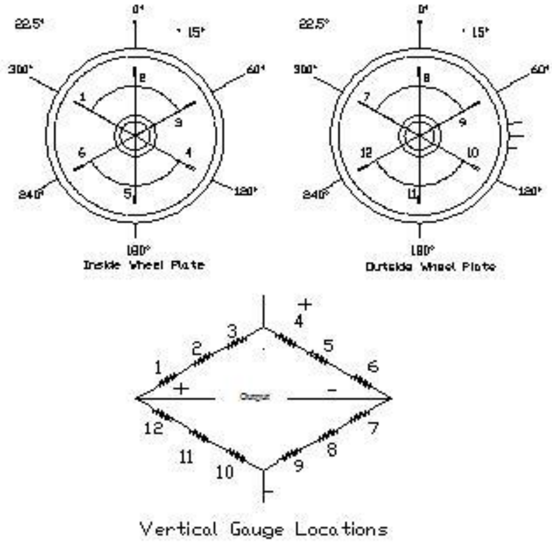


Fig-9

2.5. LATERAL BRIDGE:-

Each of the lateral bridges consists of eight strain gauges arranged with two gages in each arm of the bridge. The bridge configuration and ganged placemat are illustrated in fig (2). All the gauges are applied to the inside plate surface. Four gauges are centered about one end of a diametric line and the other four are centered about the opposite end of the line. All gauges are oriented in the radial direction. Each bridge is used to sense the lateral load in two 90 sectors which is centered 180 apart. The gauges are mounted at a diameter where there is a minimum interaction with the vertical load.

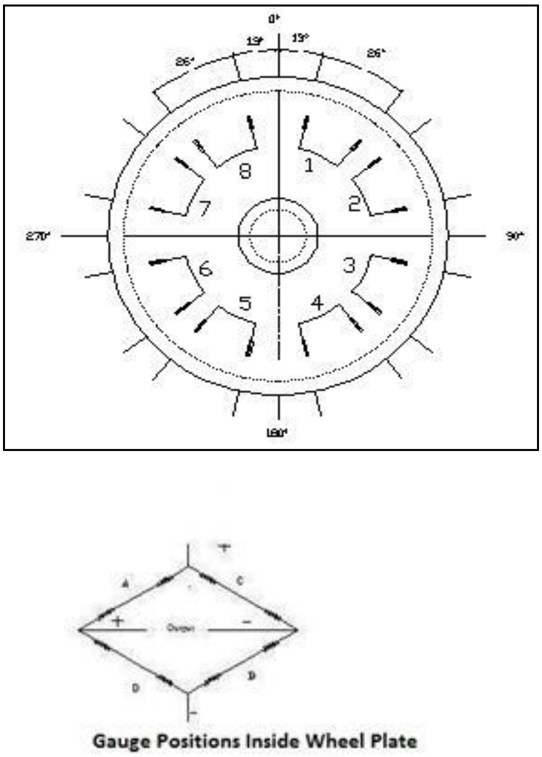


Fig-10

The output of each type of bridge is oscillatory once wheel revolution with the absolute value of the signals being equal for a constant load. Axis symmetric surfer stains such as those due to centrifugal force and rim temperature effects are cancelled out by this bridge arrangement.

2.6. ANALYSIS OF GAGE LOCATION:-

FEM Results on the Calibration rig, using strain gauges radially on the wheel faces on both sides and taking strain values. It was found there was minor variation in the location decided by the FEM and the actual strain values obtained.

2.7. LOAD CALIBRATION DATA

The above Instrumented wheel disc axle arrangement placed on the measuring Wheel test Rig in the test rig. The application of vertical & lateral load shall be calculated as per wheel load (max axle load/2) & proud homes limit i.e. 0.85(1+P/3) tones respectively, where P is the axle load in tones. The vertical application load should be more than 50% higher from the static wheel load & the lateral application load should be higher than the proud homes limit. The load calibration data are obtained by subjecting the wheel sets to a series of loads in a calibration test rig. At each loading position a series of loads are applied up to maximum calibration loads. The bridge output data summarized for loads applied to the axes of bridges 0, 60, 120, 180, 240, and 300 degree for vertical bridges, and 0, 90, 180 and 270 degree for lateral and position bridges.

The vertical calibration consists of recording bridge output signals for the load sequence 0, 3, 6, 9, 12, up to 1.5 times of axle load. The lateral calibration consists of recording bridge output signals for the loading sequence 0, 2, 4, 6, up to proud homes limit.

2.8. UNCERTAINTY IN MEASUREMENTS [11]

The vertical track force uncertainty budget is presented. The estimated final result – uncertainty in this system is -3.5 - +3.0 kN for each wheel. If a symmetric normal distributed uncertainty E_k ±3 kN where the individual vertical forces are independent is assumed the total uncertainty for measured bogie load ΣΣQ is

$$E_{bogie} = \sqrt{\sum_{k=1}^{4} E(k)_x^2}$$

3. BRIDGE SUMMATION AND ESTIMATED RESULT OF WHEEL LOAD & LATERAL FORCES

The output signals from the vertical bridge and lateral bridges are summed to give continuous output signal as the wheel set rotates. And these summed values are used as input data for the equations that are used to correct the cross talk effects.

The summed equations of the signals are as given below:

a. For the three Vertical bridges
VA = ABS (V1) + ABS (V2) + ABS (V3)

b. For the two Lateral Bridges
LA =Sqrt ((L1)^2+(L2)^2)

3.1. BRIDGES OUTPUT IN RESPONSE TO 12T VERTICAL LOAD APPLIED WITH 7T LATERAL LOAD.

Wheel Angular Position (deg)	V1 Bridge output	V2 Bridge output	V3 Bridge output	L1 Bridge output	L2 Bridge output	VB	LB
0	-10.07	-2.49	2.03	6.15	0.24	14.59	6.15
30	-7.03	-7.32	-0.54	5.52	3.27	14.89	6.42
60	-2.29	-10.5	-3.03	3.56	4.3	15.82	5.58
90	0.25	-7.32	-7.71	0.59	4.64	15.28	4.68
120	2.93	-2.69	-10.06	-2.44	4.05	15.68	4.73
150	7.52	-0.35	-6.77	-4.88	3.27	14.64	5.87
180	10.06	2.2	-2.2	-6.96	-0.15	14.46	6.96
210	6.19	7.74	0.83	-5.13	-2.98	14.76	5.93
240	1.81	10.16	3.03	-3.56	-4.54	15	5.77
270	-0.78	7.13	8.19	-0.49	-5.54	16.1	5.56
300	-3.12	2.64	10.15	2.49	-4.49	15.91	5.13
330	-7.54	-0.38	6.83	2.05	-3.08	14.75	3.7
360	-10.07	-2.49	2.03	6.15	0.24	14.59	6.15

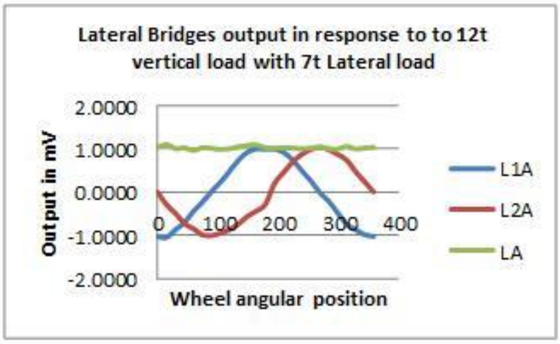


Fig-11 (a)

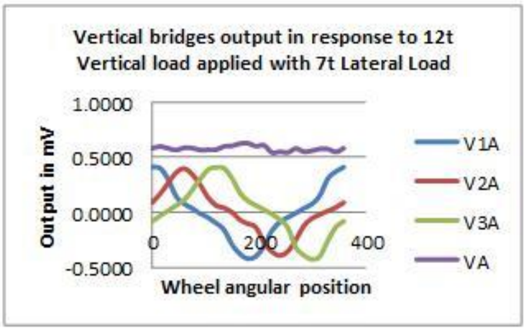


Fig-11 (b)

Graphical representation of vertical & Lateral Bridges output in response to 12t Vertical load with 7t Lateral Load

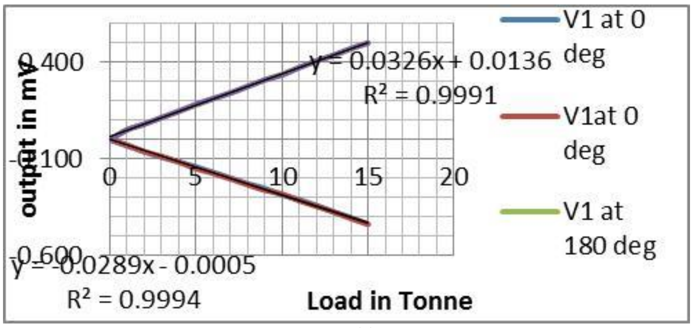


Fig-11 (c)

GRAPHICAL REPRESENTATION OF VERTICAL BRIDGE OUTPUT IN RESPONSE TO VERTICAL LOAD

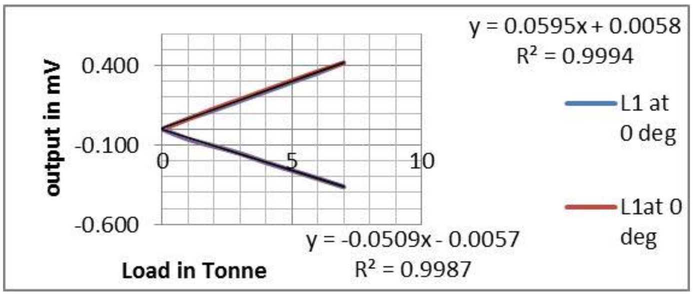


Fig-11(d)

GRAPHICAL REPRESENTATION OF LATERAL BRIDGE OUTPUT IN RESPONSE TO LATERAL LOAD

3.2. *AUTHENTICATION OF MEASURING WHEEL SET [8]:-*

- Plausibility Check: methods to check that certain known mechanical laws are fulfilled when applied to the calculated forces
- Sum of Vertical Track forces:
  - ➢ Quick Check:
    - i. Run the train on a good quality track without any rail corrugations.
    - ii. Run the train at a speed within the speed range for which the measurement wheel is approved for at least five minutes.
    - iii. The average sum of Q forces for each axle shall coincide with the weight obtained by measuring the vehicle using weighbridge.
  - ➢ Extensive Check:
    - i. The quasi static sum of Q forces on several straight track sections for each axle shall coincide with the weight obtained by the scale.
- Sum of Lateral Track forces:-

This check can be done if track forces are measured on all wheel sets in a bogie. The uncompensated lateral acceleration in the track plane is used as a reference. Any offset has to be accounted for. The offset values are computed as the mean values for the nearest available straight level track.

Principle: Newton's force equation says F=ma

If $\sum Ytot$, sum of Y forces on the wheel sets in a bogie, m is either the vehicle mass related to the bogie and a_γ is the measured lateral acceleration. This gives the relation:- $\sum Ytot = ma_\gamma$

Quick Check:

- Low pass filter the Y-forces and a_γ with a low cut-off frequency 0.3Hz
- Plot the $\sum Ytot$ 0.3Hz versus a_γ 0.3Hz
- The regression in this graph should make a straight line with the inclination m.

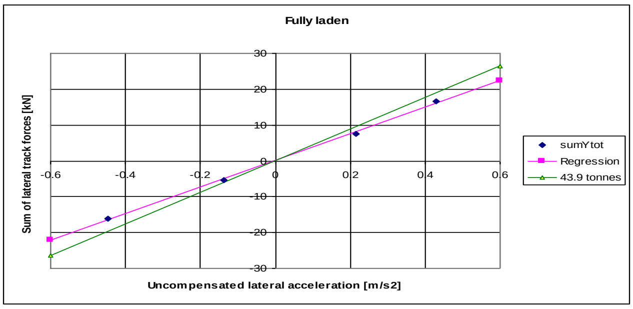
➢ Extensive Check:

- Plot the quasi static $\sum Ytot$ versus a_γ.

❖ The regression in this graph should in the ideal case make a straight line with the inclination m.

❖ The results considered are averages over track sections were the assumption of static equilibrium if fulfilled i.e. in the circular parts of curves and on straight track.

❖ After verification of measuring wheel set through plausibility check, further test are required to be conducted on same and different speeds on the same section of track to check the repeatability of data.



Sum of lateral track forces versus lateral acceleration fully loaded

Fig-12 (a)

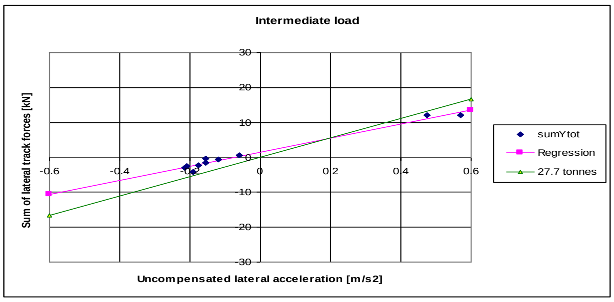


Fig-12 (b)

Sum of lateral track forces versus lateral acceleration – intermediate load

4. VALIDATION BY FIELD TRIAL

Confirming the dynamic force measurement capability for an instrumented wheel set by measurements is not directly possible. The reason for this is that the forces in the contact point between the wheel and the rail only can be measured by the wheel itself. Any other means of measuring these forces would be by an indirect method measuring somewhere else in the mechanical system i.e. measurements at the axle box level where it is possible to mount load cells that can be calibrated thus giving a proper reference for the force. Taking great care not to short circuit the path of forces from the contact point to the load cells usable measurements up to at least 10 Hz would be feasible. At higher frequencies there are limitations in the validity of the method. The reason for this is the mechanical filtering caused by the stiffness's and weights in wheels, axle box fasteners and other mechanical parts involved. The uncertainty in this validation method is seems to be large to acceptable. Measuring wheel for Railway vehicle was put under Railway stock for validation of its performance in the field. The field trial was conducted on the railway track at the up to speed up to 100 Kmph and the raw data have been analyzed.

4.1. DISCUSSION AND RESULTS

- GRAPHICAL REPRESENTATION OF RAW SIGNALS OF VERTICAL BRIDGES

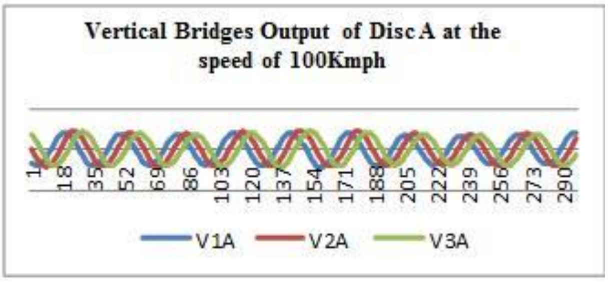


Fig-13 (a)

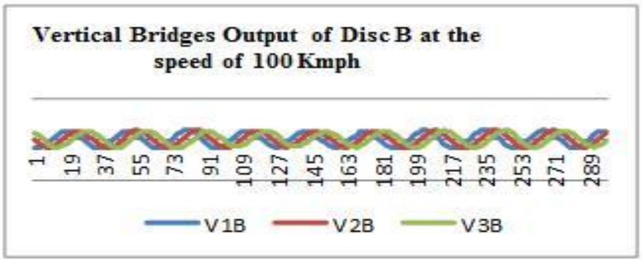


Fig-13 (b)

- ❖ The sampling rate of acquired data is 300 samples per sec. and the above sample data is shown at the speed of 100kmph for 1 sec.
- ❖ As per theoretical calculation the frequency of vertical Bridges signals at 100 kmph comes to 10 Hz, by considering the diameter of Instrumented wheel set is 1000 mm.
- ❖ The three vertical Bridges are fixed on wheel disc at 60 degree apart, so the theoretically phase difference should also be 60 degree of three vertical bridges.
- ❖ As per the data shown above, one cycle of all three vertical bridges of disc A i.e. V1A, V2A and V3A takes 0.10443 seconds and by further calculation frequency becomes 9.89 Hz, which is 1.1% on lower side from theoretical values for all the three vertical bridges of disc A.
- ❖ As per the data shown above, one cycle of all three vertical bridges V1B, V2B and V3B takes 0.1033 seconds and by further calculation frequency becomes 9.89 Hz, which is matching with theoretical values for all the three vertical bridges of disc B.
- ❖ As per the data shown above, time difference in phase of V1A to V2A and V2A to V3A is for 0.0167 seconds and by calculation the phase differences in the wave shapes comes to 58.07 degrees which is 3.05% on lower side from theoretical values.
- ❖ As per the data shown above, time difference in phase of V1B to V2B and V2B to V3B is for 0.0167 seconds and by calculation the phase differences in the wave shapes comes to 57.08 degrees which is 4.2% on lower side from theoretical values.

- GRAPHICAL REPRESENTATION OF RAW SIGNALS OF LATERAL BRIDGES

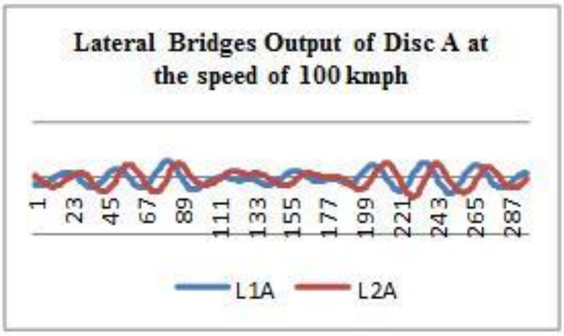


Fig-14 (a)

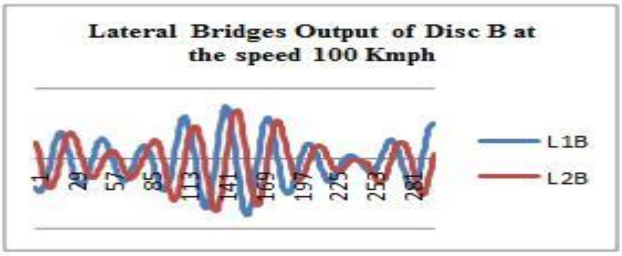


Fig-14 (b)

- The sampling rate of acquired data is 300 samples per sec. and the above sample data is shown at the speed of 100kmph for 1 sec.
- As per theoretical calculation the frequency of Lateral Bridges signals at 100 kmph comes to 10 Hz, by considering the diameter of Instrumented wheel set is 1000 mm.
- The two lateral Bridges are fixed on wheel disc at 90 degree apart, so the theoretically phase difference should also be 90 degree of two lateral bridges.
- As per the data shown above, one cycle of both the lateral bridges L1A and L2A takes 0.1033 seconds and by further calculation frequency becomes 9.89 Hz, which is matching with theoretical values for both the two lateral bridges of disc A.
- As per the data shown above, one cycle of both the lateral bridges L1B and L2B takes 0.1033 seconds

and by further calculation frequency becomes 9.91Hz, which is matching with theoretical values for both the two lateral bridges of disc B.

- As per the data shown above, time difference in phase of L1A to L2A is 0.0267 seconds and by calculation the phase differences in the wave shapes comes to 88.93 degrees which is 3.2% on lower side from theoretical values.
- As per the data shown above, time difference in phase of L1B to L2B is 0.0267 seconds and by calculation the phase differences in the wave shapes comes to 88.93 degrees which is 3.2% on lower side from theoretical values

4.2. DATA ANALYZED THROUGH SOFTWARE FOR ANALYSIS.

4.3.

i. GRAPHICAL REPRESENTATION OF VERTICAL LOAD

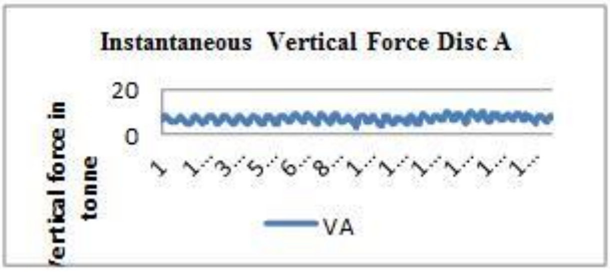


Fig-15 (a)

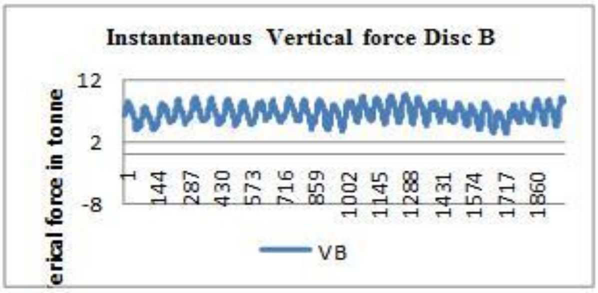


Fig-15 (b)

- The gross weight of the coach is 52.05 tons, and axle load comes to 6.281t.
- The average vertical load of above graphical data is 6.47t for disc A and 6.32t for disc B, which is processed through Analysis software for measuring wheel.
- As per Track fatigue of UIC 518 [2] Qlim = 90+ Q0; Qlim and Q0 expressed in kN, Q0 is being the static load on each wheel, in this case which is equal to 63.46kN, hence Qlim = 153.36kN, all Values in the processed data for vertical load for both the discs are well within this limit.

ii. GRAPHICAL REPRESENTATION OF LATERAL LOAD

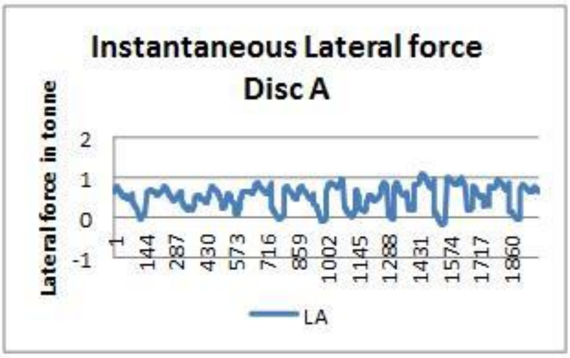


Fig-15 (c)

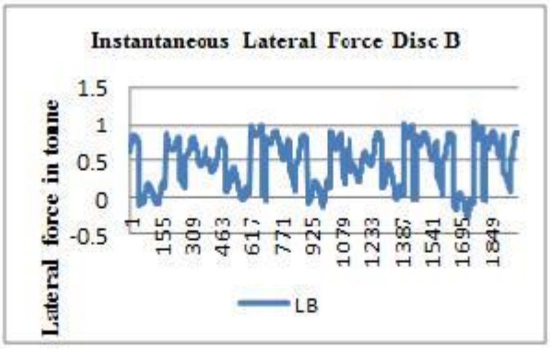


Fig-15 (d)

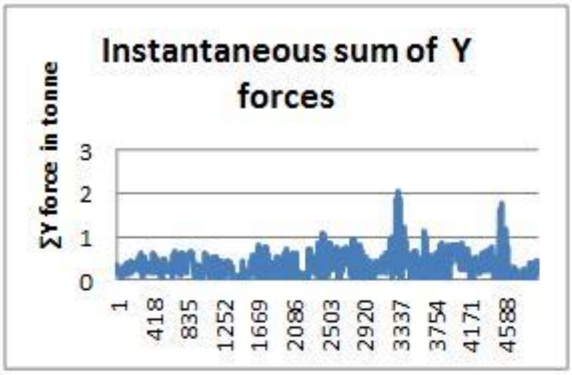


Fig-15 (e)

- As per UIC 518 [2] Safety, the sum of guiding forces ∑Y2m comes to 5.42t for Railway vehicle on which the measuring wheel is fitted.
- All the values are well within this limit 5.42t

iii. GRAPHICAL REPRESENTATION OF INSTANTANEOUS Y/Q RATIO PER WHEEL (DERAILMENT COEFFICIENT)

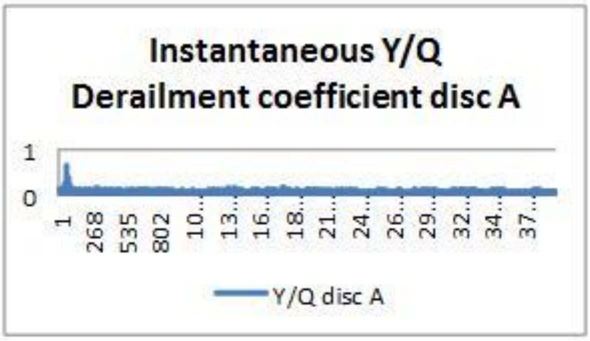


Fig-16 (a)

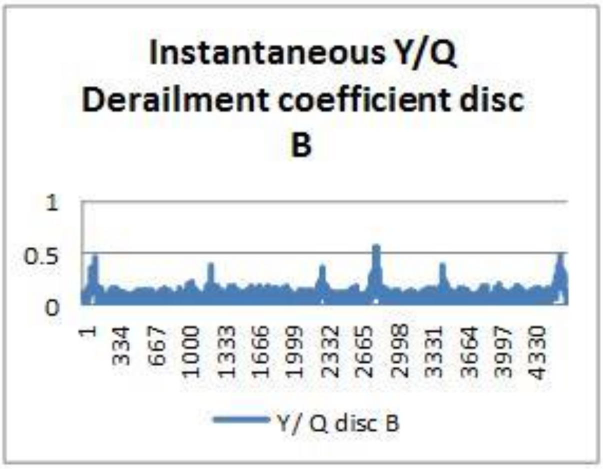


Fig-16 (b)

4.3 CHECK FOR VERTICAL FORCES

The Values for vertical forces were used for checking the Vertical forces obtained during the field validation trials.The Sum of Vertical forces are shown in below table:

Section	avg QA(0.3Hz)	avg QB(0.3Hz)	ΣQ
KM1	6.86	6.501	13.361
Km2	6.81	6.549	13.359
KM3	6.542	6.357	12.899
KM4	6.328	6.238	12.566
KM5	6.529	6.352	12.881
KM6	6.234	6.134	12.368
KM7	6.345	6.005	12.35
KM8	6.239	5.998	12.237
KM9	6.453	6.213	12.666
		average	**12.743**

ΣQ average values for the analyzed sections are 12.743 tones. The weight according to stamping in Railway vehicle is 52.20t, from which the weight over one axle comes to 13.055t i.e. a variation of 2.44%, which is reasonable

4.4. *Check for Lateral forces*

This check can be done if track forces are measured on all wheel sets in a bogie. The uncompensated lateral acceleration in the track plane is used as a reference based on the Newton's force equation of F=ma.

If ∑Ytot, sum of Y forces on the wheel sets in a bogie, m is the vehicle mass related to the bogie and a_γ is the measured lateral acceleration. This gives the relation:

$\sum Ytot = ma_\gamma$

The observation of Raw signals indicate that the results obtained for the Lateral forces are satisfactory.

5. CONCLUSION

Field measurements of high-frequency wheel-rail contact forces have been performed using an instrumented wheelset. Measuring wheel validation method is used as per international standards [1] & [7]. Four different classes of rail irregularities are identified which all require consideration of high-frequency dynamics when evaluating wheel-rail contact forces. Nine stretches of track were selected for inspection and measurement of irregularities. The expected correlation between measured corrugations and dynamic forces is confirmed. It is found that high-frequency dynamics significantly contributes to contact forces important in the development of rolling contact fatigue. The above observation of the raw and analysed data obtained through Instrumented Measuring Wheel set during the field validation trial, the performance of the Instrumented Measuring Wheel and result obtained through the Analysys software Appears to be satisfactory.

6. REFERENCES

[1] INTERNATIONAL STANDARDS EN 14363.
[2] UIC- 518 (Testing and approval of railway Vehicle from the point of view of their dynamic behavior Safety- Track fatigue & Riding Quality)
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