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Improvement in Secondary Suspension of "IRY-IR20" Coach using ADAMS/Rail

By:

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Abstract

Rail Coach Factory, Kapurthala, an Indian Railway Coach Manufacturing unit, have developed and manufactured "IRY-IR20" Light Weight High Speed broad gauge (1676 mm) coaches fit for 160 KMPH operation. IR20 bogies based on Eurofima design were developed and used for these coaches. Indian Railways now intend to standardise FIAT type bogies for its next generation of coaches being developed under Transfer of Technology (TOT) contract with M/s LHB-FIAT. It was considered prudent to attempt adoption of springs common between FIAT's and Indian Railway's IR20 bogies. To assess feasibility of using FIAT springs in IR20 bogies, vehicle dynamics analysis has been carried out.

Two vehicle models have been prepared, one with existing IR20 secondary suspension springs and another with FIAT bogie secondary suspension springs keeping all other parameters same for the vehicle dynamic analysis. An evaluation copy of ***ADAMS/Rail*** *software version 9.1 has been used to find out a suitable arrangement, which could be used to get similar or better ride indices.*

1. INTRODUCTION

Rail Coach Factory, Kapurthala is a leading Railway Coach manufacturing company in India. RCF have developed and manufactured "IRY-IR20" Light Weight High Speed broad gauge (1676 mm) coaches fit for 160 KMPH operation. IR20 bogies were developed and used for these coaches. The prototype rake of "IRY-IR20" is in service since 1998 after clearing extensive field trial. A second IRY-IR20 rake has also been produced. In 1998, Indian Railways entered into a supply & TOT contract with M/s LHB-FIAT for light weight high speed coach and decided to standardise FIAT bogies for next generation of coaches. It was considered fruitful to attempt adoption of springs common between FIAT and IR20 bogies. Adoption of standardised suspension shall lead to indigenous availability of helical flexi-coil spring for the two IRY-IR20 rakes which otherwise would have required uncommon springs throughout the life of coaches.

Figure - 1   Indian Railway IRY-IR20 Coach

Two vehicle models have been prepared, one with existing secondary suspension springs and another with FIAT bogie secondary suspension springs keeping all other parameters same for the vehicle dynamic analysis. After several attempts a suitable arrangement could be developed so as to get similar or better ride indices.

As a result of encouraging simulation studies, it has been decided to pursue the proposal and conduct oscillation trial with the new suspension. An evaluation copy of ***ADAMS/Rail*** software version 9.1 has been used for the purpose. ***ADAMS/Rail*** has been helpful to RCF in deciding on a suitable secondary suspension for its "IRY-IR20" coaches.

Following steps have been carried out during the Vehicle Dynamic Simulation Study:

1. Preparation of vehicle model.
2. Calculation of pre-loads on springs
3. Eigen value analysis
4. Preparation of linear contact model level II a
5. Creating a measured track model
6. Assembling the system model
7. Stability analysis
8. Comfort analysis

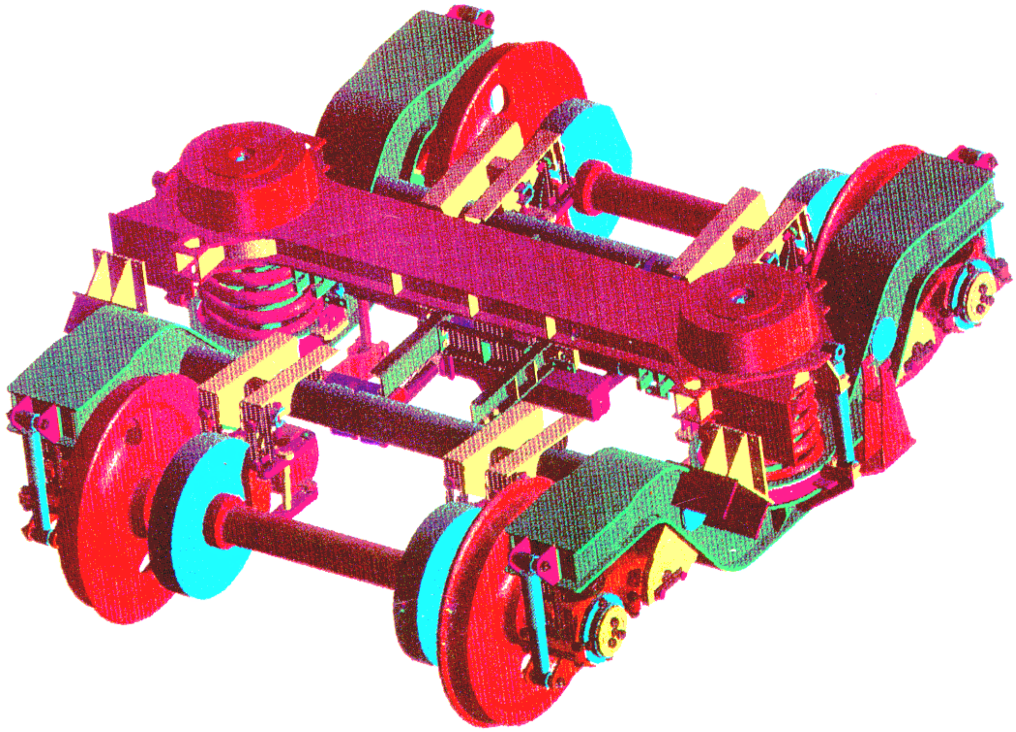

Figure - 2 Indian Railway IR-20 Bogie

2. VEHICLE MODEL

Rendered CAD models of IRY-IR20 coach and IR20 Bogie have been shown in Figure-1 & Figure-2 respectively. Vehicle model has been prepared with the help of modeling facility available in the software. Two wheelset and axle parts have been created from the library of ***ADAMS/Rail*** specifying the location of centre of mass, mass & mass inertia as per the IR20 bogie wheel base and wheel diameter and mass properties. The two side frame of the bogie frame have been created with the E***xtrusion Tool*** and rigidly connected by two cross tubes, which have also been created from E***xtrusion Tool (Cylinder option)***. The mass properties of bogie frame are modified using the ***Modified Object (User Input facility)*** of the ***ADAMS/Rail*** and the part has renamed as Bogie1. The axle control arms used in a bogie have been modeled as a separate rigid body from ***Rigid body Link Tool***. All four axle control arms have been used to connect the two wheelset parts to the Bogie1 part at four symmetric locations as per geometric location in IR-20 Bogie. The wheelset has been connected to one end of axle control arm with ***Revolute Joint*** in order to allow the rotation of the wheelsets around the global y-axis (spin rotation). The second end of control arm has been connected to the Bogie1 with a ***Bushing Element from Rail Tool Box*** having the stiffness as per the characteristic of axle control arm rubber bush. The primary suspension spring is modeled as a ***Bushing Element*** having stiffness same as IR20 primary spring stiffness characteristic. The primary vertical damper has been modeled from the ***Main Toolbox Spring Element***. All these ***Connecting Elements*** have been connected between two rigid bodies after creating ***Markers*** on the respective bodies at required locations. The rendered ***ADAMS/Rail*** model of IR-20 Bogie has been shown in Figure-3.

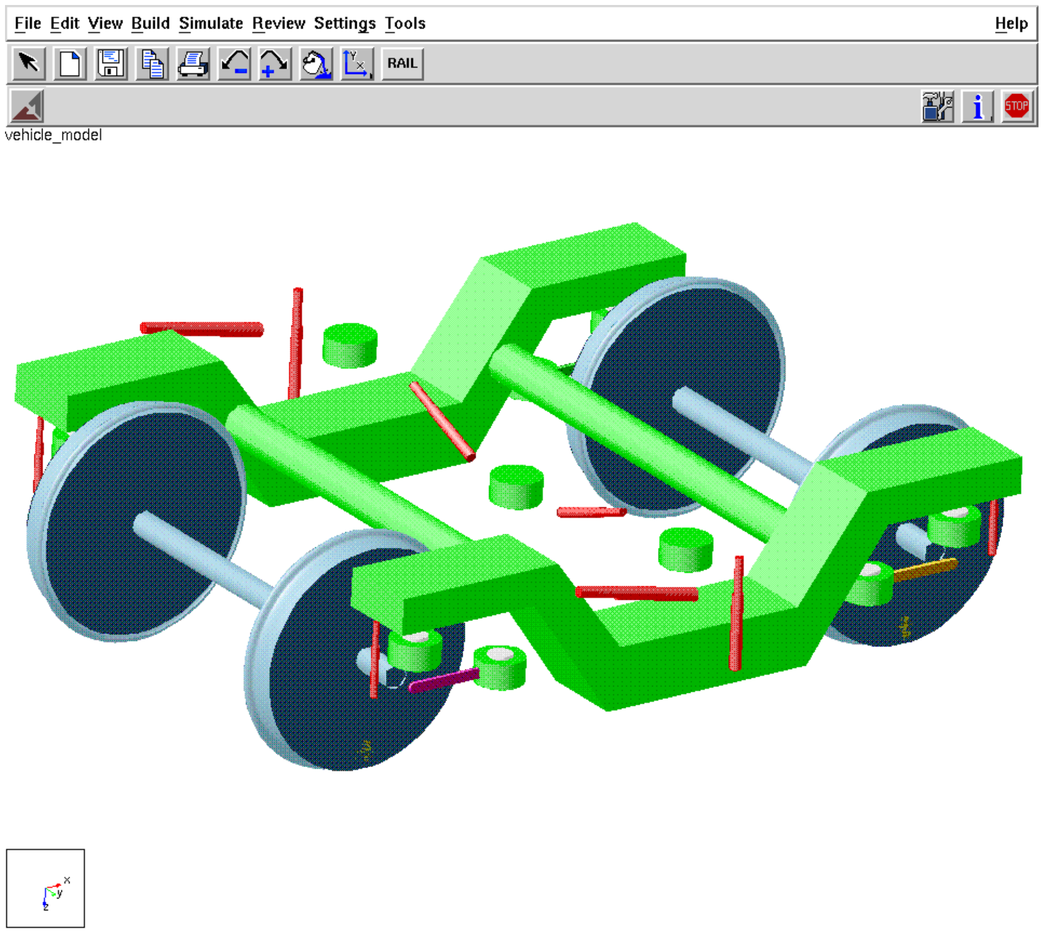

Figure - 3 ADAMS/Rail rendered model of IR-20 Bogie

Bogie1 part is then copied as a new rigid part named as Bogie2. The Bogie2 part is transformed according to the centre pivot distance of the IRY-IR20 Coach. A carbody part has been created by ***Extrusion Facility*** of ***Main Tool Box***. The locations of center of mass and mass properties are modified according to the existing coach properties. The carbody is connected with both the bogies with secondary suspension. Secondary Suspension includes secondary spring, secondary vertical damper, secondary lateral damper, yaw damper and anti-rotation stop connections. The shaded model of IRY-IR20 coach has been shown in Figure-4 and sketchmetic model has been shown in Figure-5.

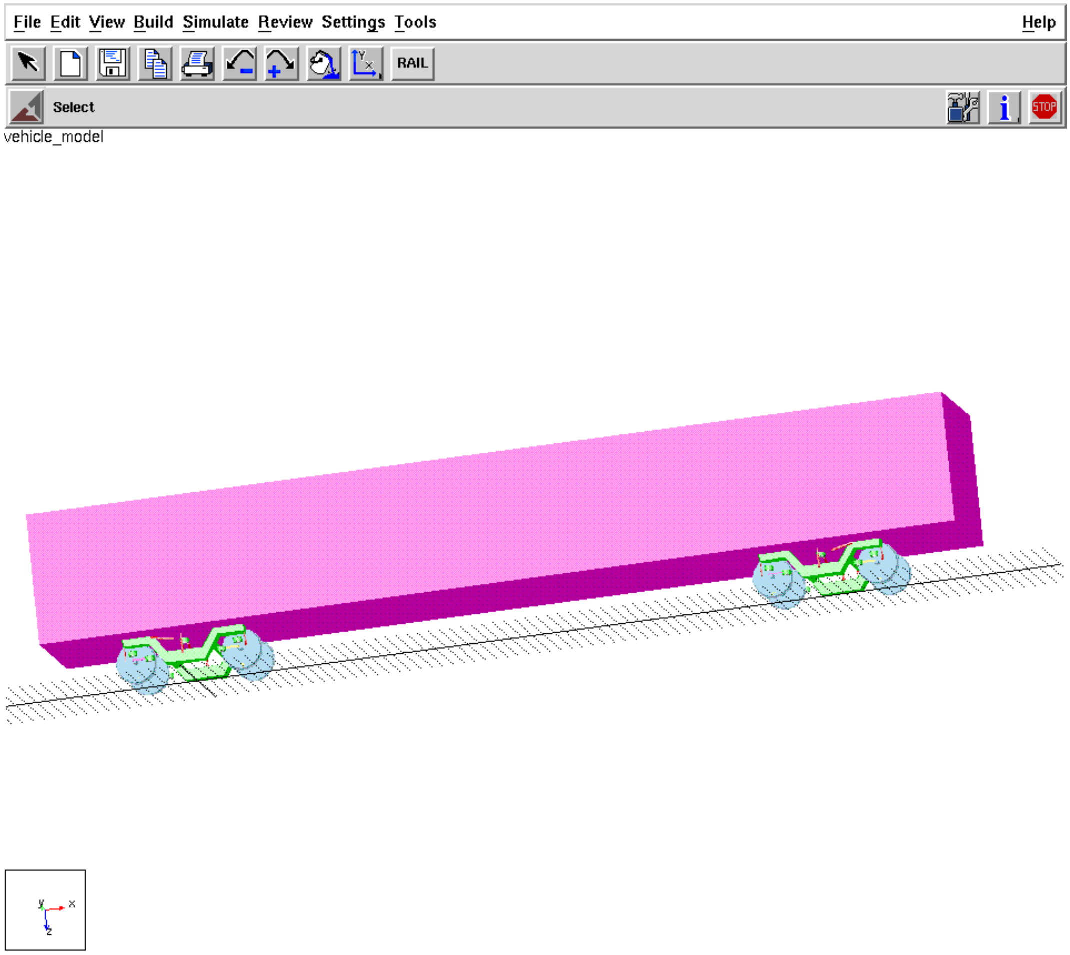

Figure - 4 ADAMS/Rail rendered model of IRY-IR20 Coach

3. CALCULATION OF PRE-LOADS

Pre-loads on the suspension elements, secondary springs and primary springs have been calculated with the help of ***Rail Tool Box - Bushing*** facility before the eigen and stability analysis. The output listing of vertical pre-load thus calculated for both the vehicle models by the system are listed in Table-1 and Table-2. The suspension characteristic of IR20 secondary suspension and FIAT secondary suspension are not very much different hence the preloads shown in Table-1 and Table-2 are nearly same.

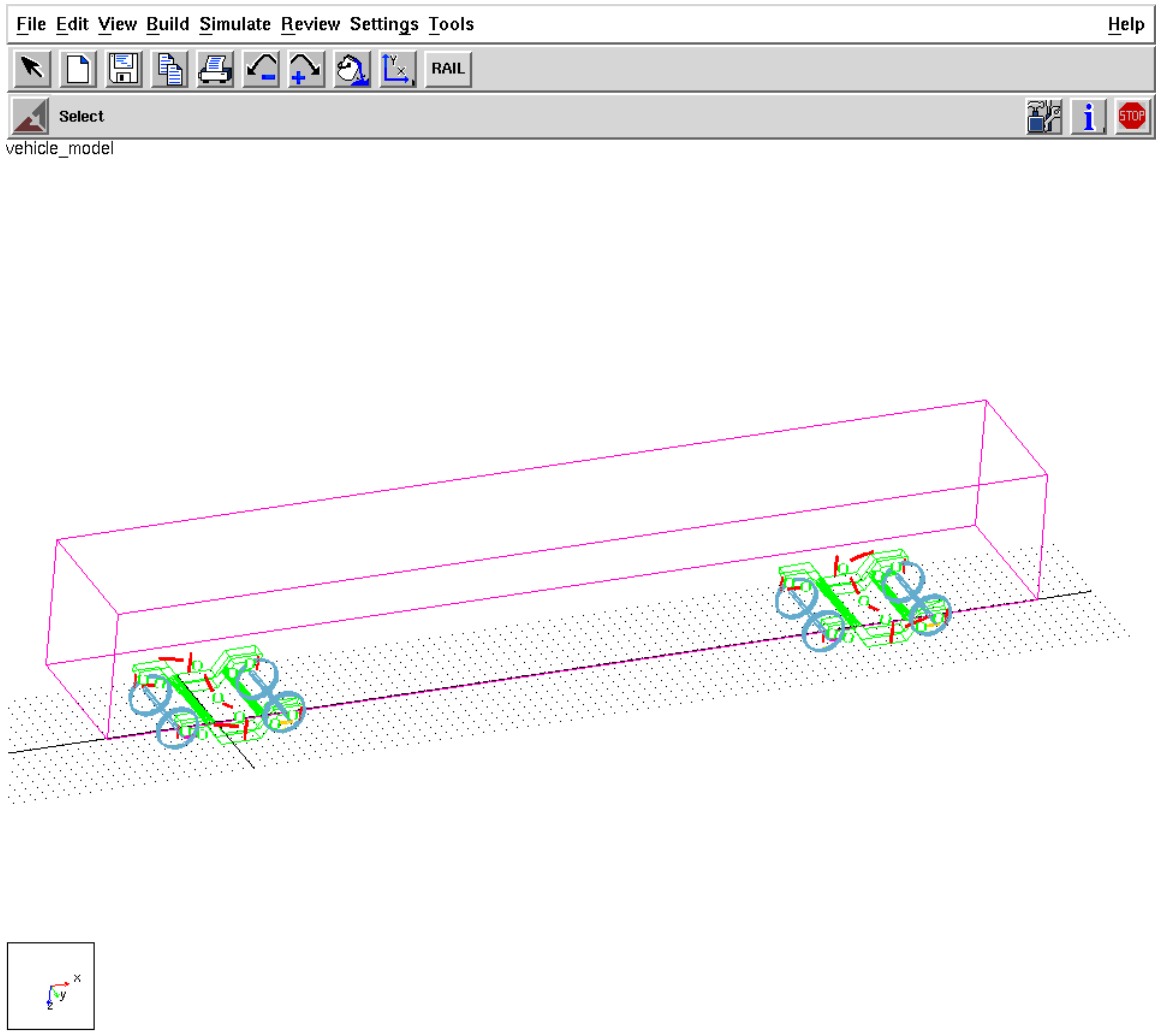

Figure - 5   ADAMS/Rail model of IRY-IR20 Coach

Table-1 : Preloads of vehicle model with existing IR20 secondary suspension

```
C A L C U L A T E D    P R E L O A D S

Model: .vehicle_model
Date  : 21 Aug 1999  10:37

.vehicle_model.PVS_1     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_2     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_3     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_4     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_1_2     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_2_2     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_3_2     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_4_2     0.000e+00    0.000e+00    3.771e+04
.vehicle_model.SVS_1     0.000e+00    0.000e+00   -6.857e+04
.vehicle_model.SVS_2     0.000e+00    0.000e+00   -6.857e+04
.vehicle_model.SVS_1_2     0.000e+00    0.000e+00   -6.857e+04
```

```
.vehicle_model.SVS_2_2    0.000e+00    0.000e+00   -6.857e+04
```

Table-2 :Preloads of vehicle model with modified FIAT secondary suspension

```
C A L C U L A T E D    P R E L O A D S

Model: .vehicle_model
Date  : 21 Aug 1999  12:42

.vehicle_model.PVS_1    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_2    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_3    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_4    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_1_2    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_2_2    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_3_2    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.PVS_4_2    0.000e+00    0.000e+00    3.771e+04
.vehicle_model.SVS_1    0.000e+00    0.000e+00   -6.854e+04
.vehicle_model.SVS_2    0.000e+00    0.000e+00   -6.854e+04
.vehicle_model.SVS_1_2    0.000e+00    0.000e+00   -6.854e+04
.vehicle_model.SVS_2_2    0.000e+00    0.000e+00   -6.854e+04
```

4. EIGEN VALUE ANALYSIS

The Eigen value analysis has been done to find out the system's natural frequency and different mode shapes. After performing the linear simulation, mode shapes were studied with the help of animation facility available in main tool box. This helped in better understanding of the behavior of the system. The eigen values obtained from the analysis of two vehicle models have been listed in Table-3 and Table-4. Frequency separation between bogie frame pitching & carbody bending expected 9 Hz was satisfactory. Lower Center Roll & Upper Center Roll frequencies were found in the acceptable range of 0.7 Hz to 1 Hz.

Table-3 : Eigen values of vehicle model with existing IR20 secondary suspension

EIGEN VALUES (Time = 0.0)

MODE NUMBER	UNDAMPED NATURAL FREQUENCY	DAMPING RATIO	REAL		IMAGINARY
1	7.313903E-01	1.471149E-01	-1.075984E-01	+/-	7.234324E-01
2	7.743236E-01	2.198320E-01	-1.702211E-01	+/-	7.553819E-01
3	1.116669E+00	4.212944E-01	-4.704462E-01	+/-	1.012733E+00
4	1.137997E+00	4.455224E-01	-5.070031E-01	+/-	1.018815E+00
5	4.979409E+00	7.418363E-02	-3.693907E-01	+/-	4.965689E+00
6	6.756577E+00	1.288465E-01	-8.705611E-01	+/-	6.700258E+00
7	1.747741E+01	4.510715E-01	-7.883561E+00	+/-	1.559838E+01
8	1.747764E+01	4.498134E-01	-7.861679E+00	+/-	1.560968E+01
9	1.879525E+01	4.349938E-02	-8.175818E-01	+/-	1.877746E+01
10	1.879484E+01	4.268441E-02	-8.022468E-01	+/-	1.877771E+01
11	2.678560E+01	5.073536E-01	-1.358977E+01	+/-	2.308217E+01
12	2.689135E+01	4.998518E-01	-1.344169E+01	+/-	2.329090E+01
13	3.489866E+01	4.010738E-01	-1.399694E+01	+/-	3.196877E+01

14	3.538176E+01	4.051970E-01	-1.433659E+01	+/-	3.234705E+01
15	4.134471E+01	2.591352E-01	-1.071387E+01	+/-	3.993242E+01
16	4.137899E+01	2.612129E-01	-1.080873E+01	+/-	3.994236E+01
17	4.593894E+01	1.687390E-01	-7.751689E+00	+/-	4.528022E+01
18	4.606430E+01	1.613511E-01	-7.432526E+00	+/-	4.546072E+01
19	2.057960E+02	1.120665E-01	-2.306284E+01	+/-	2.044996E+02
20	2.057960E+02	1.120665E-01	-2.306284E+01	+/-	2.044996E+02
21	2.081500E+02	9.528913E-02	-1.983443E+01	+/-	2.072028E+02
22	2.081528E+02	9.530104E-02	-1.983718E+01	+/-	2.072054E+02
23	2.088239E+02	1.021555E-01	-2.133251E+01	+/-	2.077314E+02
24	2.088242E+02	1.021583E-01	-2.133312E+01	+/-	2.077317E+02
25	2.102723E+02	9.914710E-02	-2.084789E+01	+/-	2.092363E+02
26	2.102722E+02	9.913599E-02	-2.084554E+01	+/-	2.092363E+02

Table-4 : Eigen values of vehicle model with modified FIAT secondary suspension

EIGEN VALUES (Time = 0.0)

MODE NUMBER	UNDAMPED NATURAL FREQUENCY	DAMPING RATIO	REAL		IMAGINARY
1	8.526967E-01	1.087925E-01	-9.276700E-02	+/-	8.476355E-01
2	9.080932E-01	1.700727E-01	-1.544418E-01	+/-	8.948637E-01
3	1.178485E+00	4.383014E-01	-5.165318E-01	+/-	1.059256E+00
4	1.202446E+00	4.355542E-01	-5.237303E-01	+/-	1.082397E+00
5	5.004161E+00	8.086900E-02	-4.046815E-01	+/-	4.987771E+00
6	6.710569E+00	1.427029E-01	-9.576177E-01	+/-	6.641891E+00
7	1.738993E+01	4.724666E-01	-8.216162E+00	+/-	1.532659E+01
8	1.746332E+01	4.681074E-01	-8.174708E+00	+/-	1.543184E+01
9	1.882627E+01	3.829499E-02	-7.209518E-01	+/-	1.881246E+01
10	1.882761E+01	3.916794E-02	-7.374388E-01	+/-	1.881316E+01
11	2.734412E+01	4.734142E-01	-1.294509E+01	+/-	2.408579E+01
12	2.737397E+01	4.655178E-01	-1.274307E+01	+/-	2.422702E+01
13	3.521263E+01	4.261888E-01	-1.500723E+01	+/-	3.185455E+01
14	3.567486E+01	4.330767E-01	-1.544995E+01	+/-	3.215579E+01
15	4.104161E+01	2.434353E-01	-9.990976E+00	+/-	3.980696E+01
16	4.100375E+01	2.390952E-01	-9.803801E+00	+/-	3.981448E+01
17	4.522210E+01	1.749079E-01	-7.909700E+00	+/-	4.452499E+01
18	4.543220E+01	1.670572E-01	-7.589774E+00	+/-	4.479375E+01
19	2.057109E+02	1.121208E-01	-2.306448E+01	+/-	2.044138E+02
20	2.057109E+02	1.121208E-01	-2.306448E+01	+/-	2.044138E+02
21	2.080759E+02	9.524780E-02	-1.981877E+01	+/-	2.071299E+02
22	2.080777E+02	9.525506E-02	-1.982045E+01	+/-	2.071315E+02
23	2.087478E+02	1.022333E-01	-2.134096E+01	+/-	2.076540E+02
24	2.087485E+02	1.022392E-01	-2.134227E+01	+/-	2.076546E+02
25	2.102023E+02	9.927654E-02	-2.086815E+01	+/-	2.091638E+02
26	2.102037E+02	9.929862E-02	-2.087294E+01	+/-	2.091648E+02

5. PREPARATION OF LINEAR CONTACT MODEL LEVEL II A

The linear contact model level IIa has been used in the stability analysis and ride comfort analysis. The contact table parameters have been used according to the IRY-IR20 coach design and IR requirements. ADAMS/Rail automatically calculates the wheelset loads and Kalker coefficient for the pre-defined contact model. The same contact model has been used for both the vehicle models with existing IR20 secondary suspension and FIAT secondary suspension to assemble into two separate system models.

6. STABILITY ANALYSIS

The stability of IRY-IR20 passenger coach has been investigated by evaluating the hunting critical speed. The critical speed of the vehicle at frequency range 0.1

to 10 Hz, have been find out from stability analysis. The stability analysis have been performed in seven step of linear analysis for different values of velocity for both the system models. The minimum velocity has been taken as 40 m/s and maximum as 90 m/s for the final results. The plots of stability analysis have been enclosed in Figure-5 and Figure-6, which are nearly same for both the system models. The graph between Damping ratio [%] & Velocity has been shown in Figure-5 and between Undamped natural frequency [Hz] & Damping ratio [%] has been shown in Figure-6. The plot shows that the critical speed for the IRY-IR20 coach is more than 52.5 m/s hence the passenger coach is fit for running upto 180 KMPH.

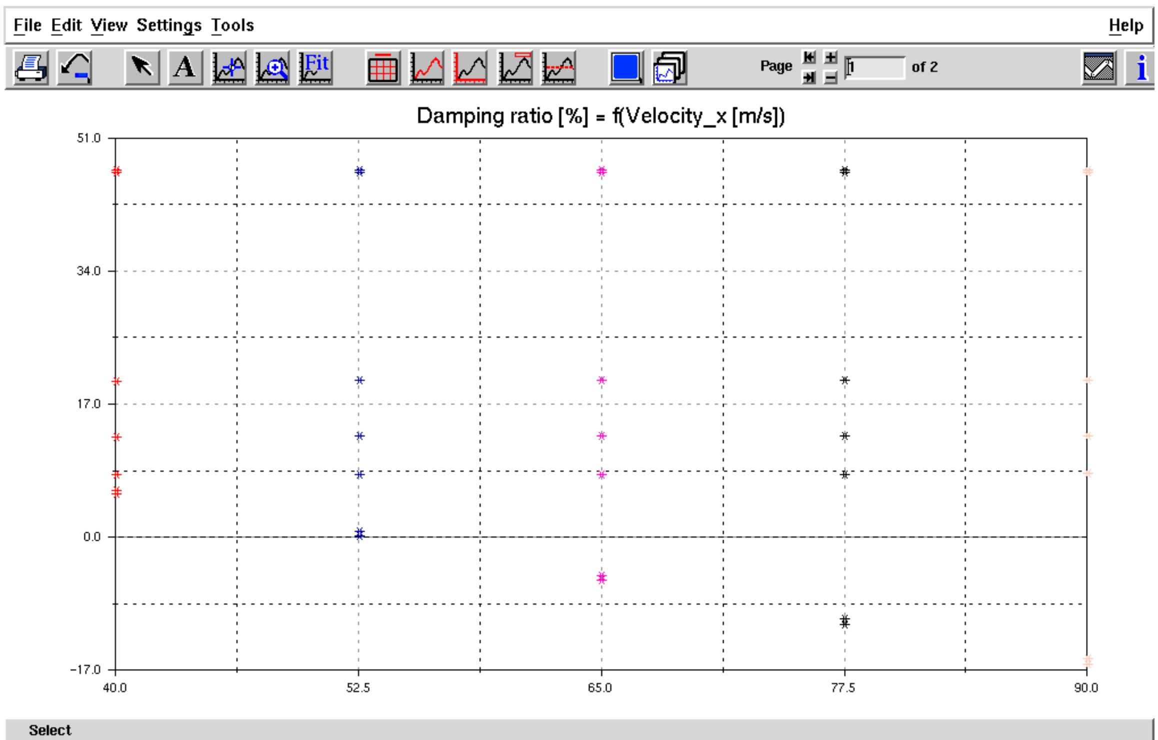

Figure - 5 ADAMS/Rail stability results.

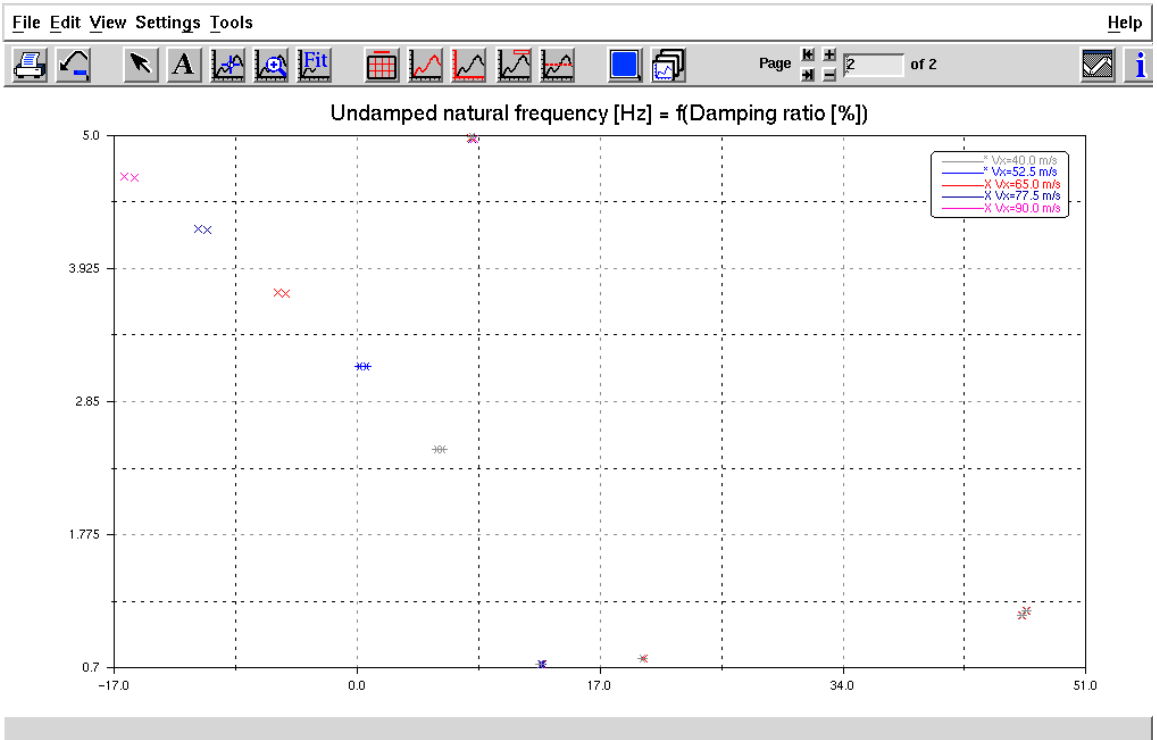

Figure - 6 ADAMS/Rail of stability results.

7. COMFORT ANALYSIS

Comfort analysis has been done on a standard measured track of length 250 m. For the purpose of analysis, ***UIC60 track*** and ***S1002 wheel*** profile available in the ***ADAMS/Rail system library*** have been used. The analysis has been performed on system model to calculate the lateral and vertical acceleration of the system. The comfort analysis has been done for IRY-IR20 coach with existing secondary springs and with FIAT type secondary spring keeping all other parameters same. For the purpose of comfort analysis, speeds of 60 KMPH, 120 KMPH and 180 KMPH have been considered.

ADAMS/Rail provides ride comfort values in terms of ***ISO 2631*** and ***ORE C116***. The acceptance criteria adopted on Indian Railway is a maximum Sperling Ride Index of 3.5 at 180 KMPH vehicle speed. The ride index values have been calculated with the help of a conversion graph using the ISO 2631 values obtained as software outputs. The Sperling Ride Index values have been calculated using the Sperling formula and lateral & vertical acceleration values obtained from the acceleration output graphs. The calculated Sperling Ride Index values have been found within permissible limits. The Sperling Ride Index obtained has been shown in Table-5.

Table-5 : Sperling Ride Index of both the system models

S. No.	Vehicle Model	Speed 60 KMPH		Speed 120 KMPH		Speed 180 KMPH	
		Vertical	Lateral	Vertical	Lateral	Vertical	Lateral
1	With IR20 secondary suspension	2.509	2.657	2.512	2.668	2.531	2.671
2	With FIAT secondary suspension	2.528	2.638	2.532	2.647	2.557	2.667

8. CONCLUSION

The vehicle dynamic analysis comparison of IRY-IR20 coach on a UIC60 standard track with the use of FIAT springs in lieu of existing IR2O springs, keeping all other parameters same, indicates that the lateral ride values improve whereas vertical ride values tend to deteriorate marginally. ADAMS/Rail has been helpful to RCF in deciding on a suitable secondary suspension for its "IRY-IR20" coaches. The visual interface & animation tool of ADAMS/Rail enabled easy identification of modes and obtaining a physical feel of the model. It is also felt that in stability analysis, eigen vector listing should be made available to users for enhancing the appreciation of the simulation.

9. ACKNOWLEDGEMENT

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