Dynamic Analysis of Railway tracks with and without disabled fasteners and Ballast

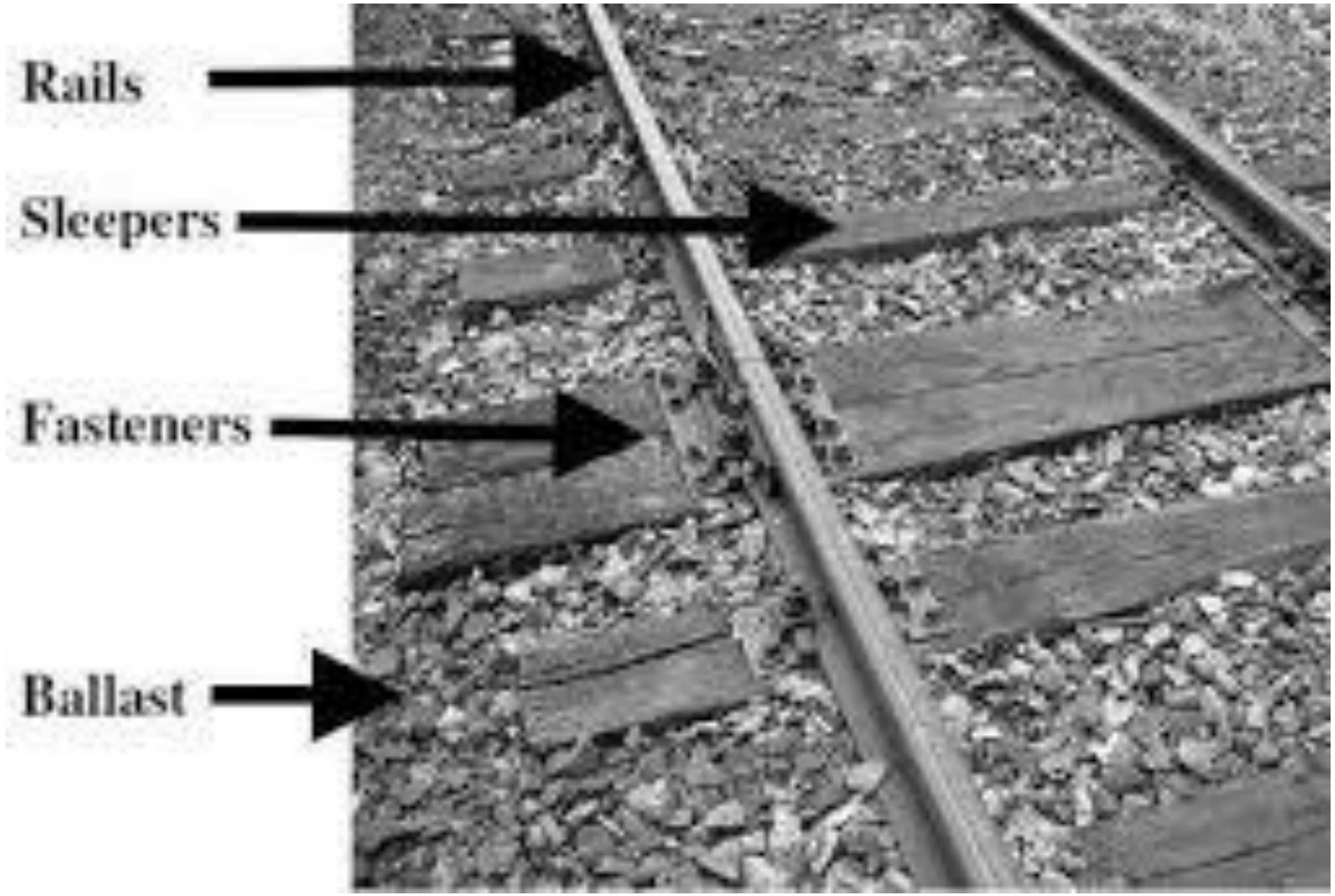
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

M Dheeraj Varma(ME19MTECH11008)
Sachin Garg(ME19MTECH11010)
Tharun Reddi(ME19MTECH11011)
Patil Ajiket J (ME19MTECH11013)
M Anand Kumar(ME19MTECH 11027

Contribution in Project

- M Dheeraj Varma – CAD Model
- Sachin Garg – Research Paper Explanation
- Tharun Reddi – CAD Model and Report
- Ajiket Patil – Simulink Model
- Anand Kumar – Report Writing

Presentation was made by all group members

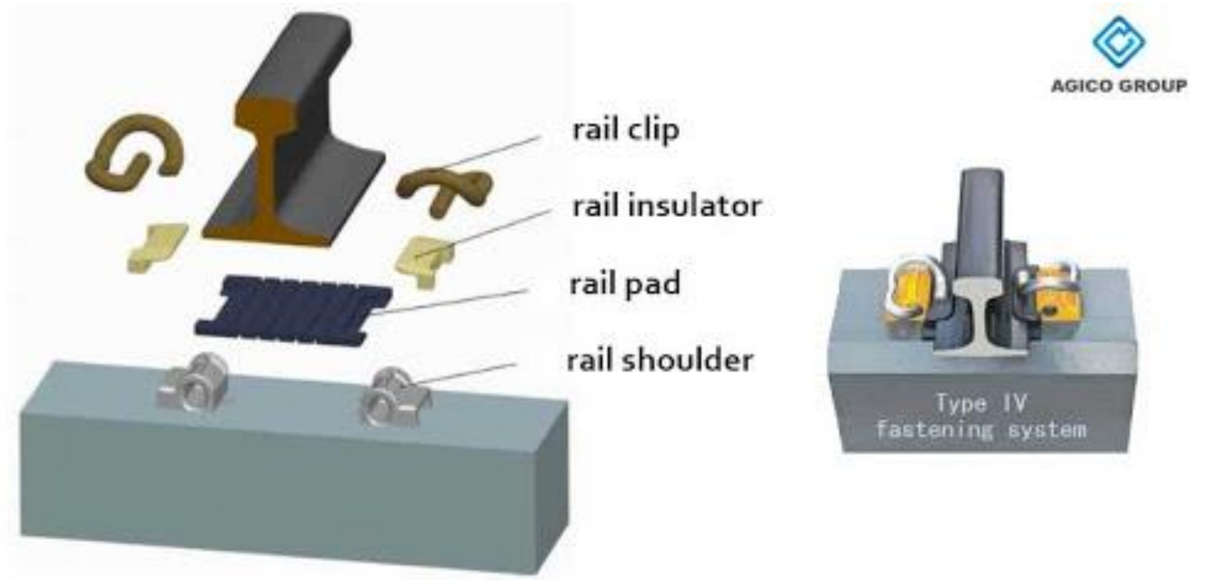


Layout of Railway Track

Introduction to Rail fastening systems

- A Rail fastening system is a means of fixing rails to railroad ties or sleepers
- Rail fastening systems typically include tie plate, rail clips, spike, insulator etc.
- Rail fasteners keeps the rails fastened to the sleepers by transferring the forces
- They provide a proper slope (1:20, 1:40) of the rail foot in the transverse plane and thus prevent the rail from longitudinal movement
- Rail fasteners also damp vibrations and noise from the rails

Rail Track Fastening components



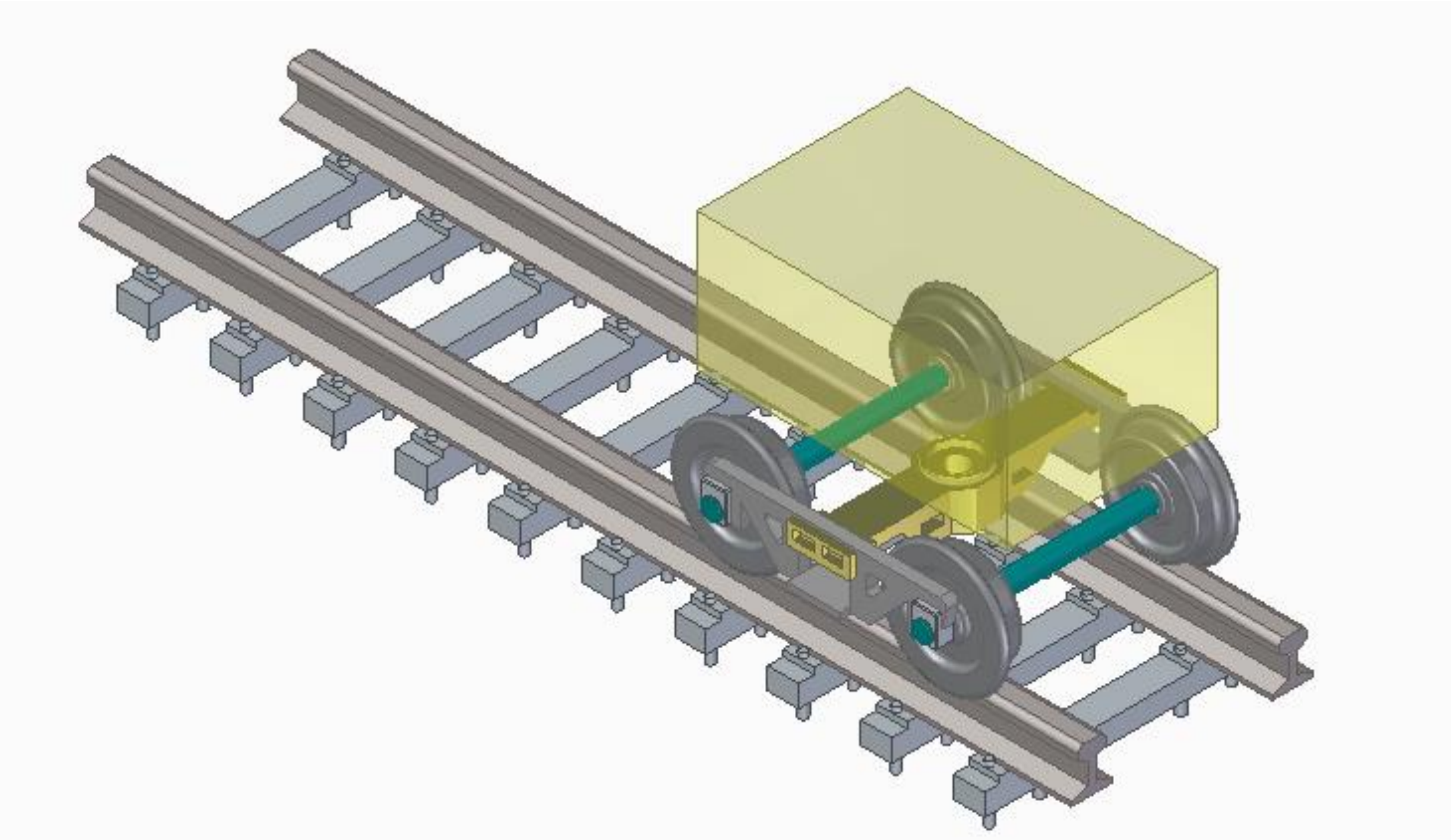
Functions of Rail Fastenings

- Hold rails securely in the rail seat
- Limit the rotation of the rail about the outer edges of the rail foot
- Minimize longitudinal movement of rails through creep and thermal forces
- Assist in retention of track gauge
- Prevent damage to the rail

What is Disabled and without Disabled Structure?

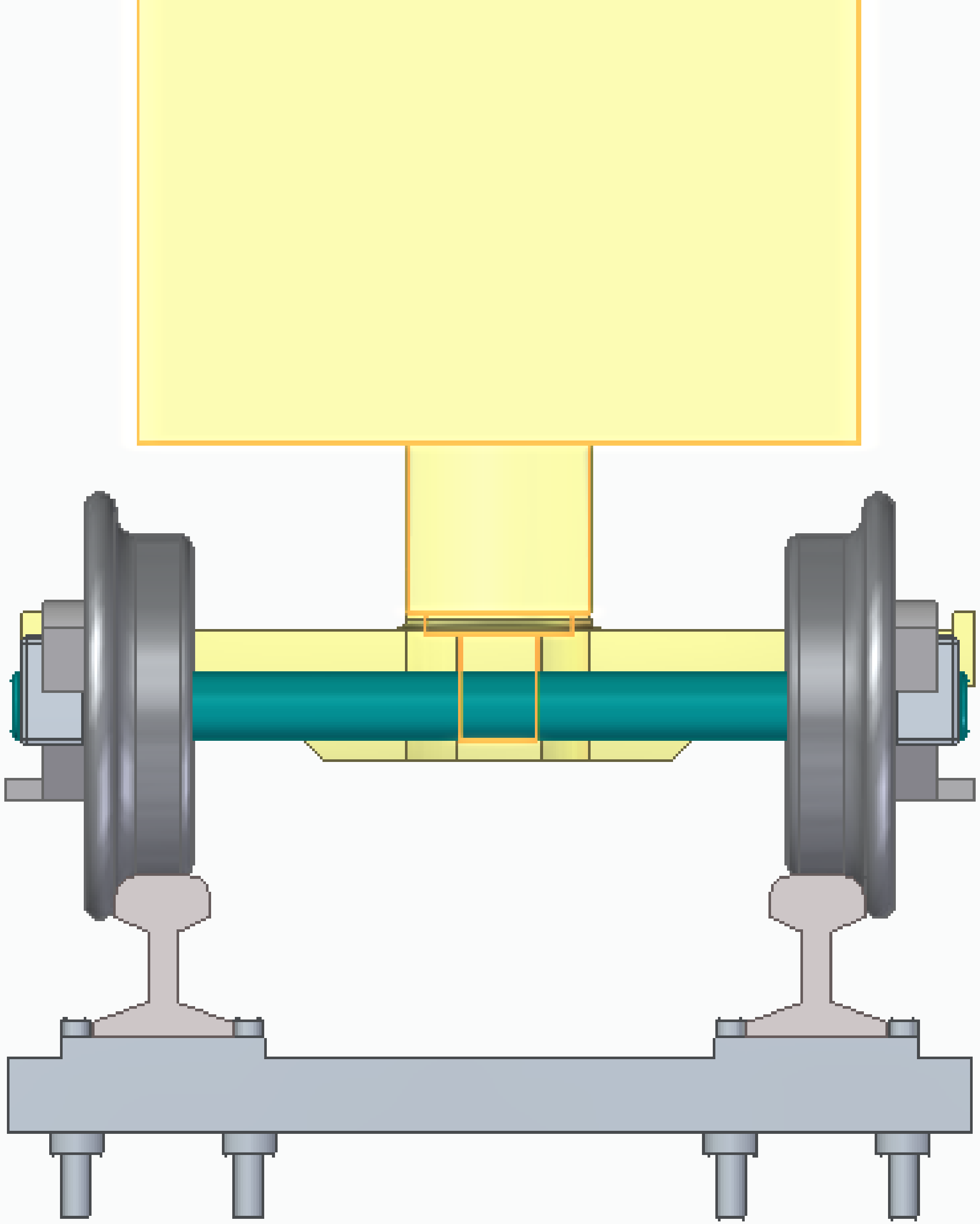
- We know that rails are attached to sleeper with the help of fastening components. Load of the railway comes onto the track, goes to sleeper and ballast and ultimately goes to ground.
- If in case the rail fastening gets loosened or the ballast which is in between the sleepers and below it gets collapsed or subsided, the resistance which they(rail fastening and ballast) offer gets reduced, and thus it increases the chances of derailment.
- In other words if rail fastening and ballast are replaced by spring and damper, loosening of fastening and collapsing of ballast leads to decrease their stiffness and damping value. Hence they will carry less load and more vibrations will be there.
- So disabled structure means loosening of fastening and collapsing of ballast, otherwise the structure is non-disabled.

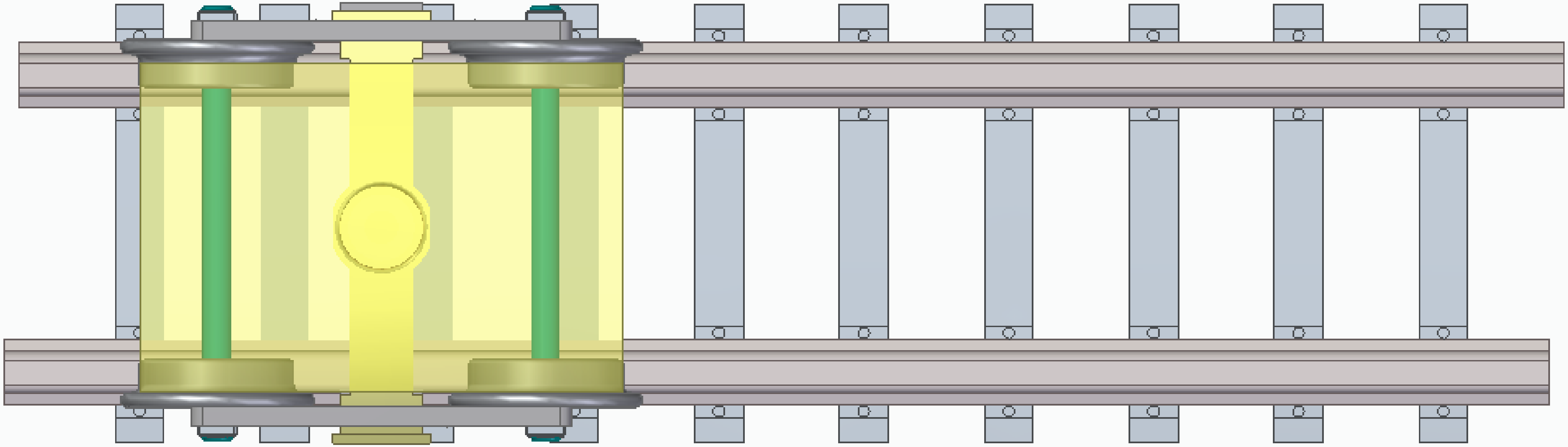
CAD MODELS (Isometric view)



Passenger Car running on track

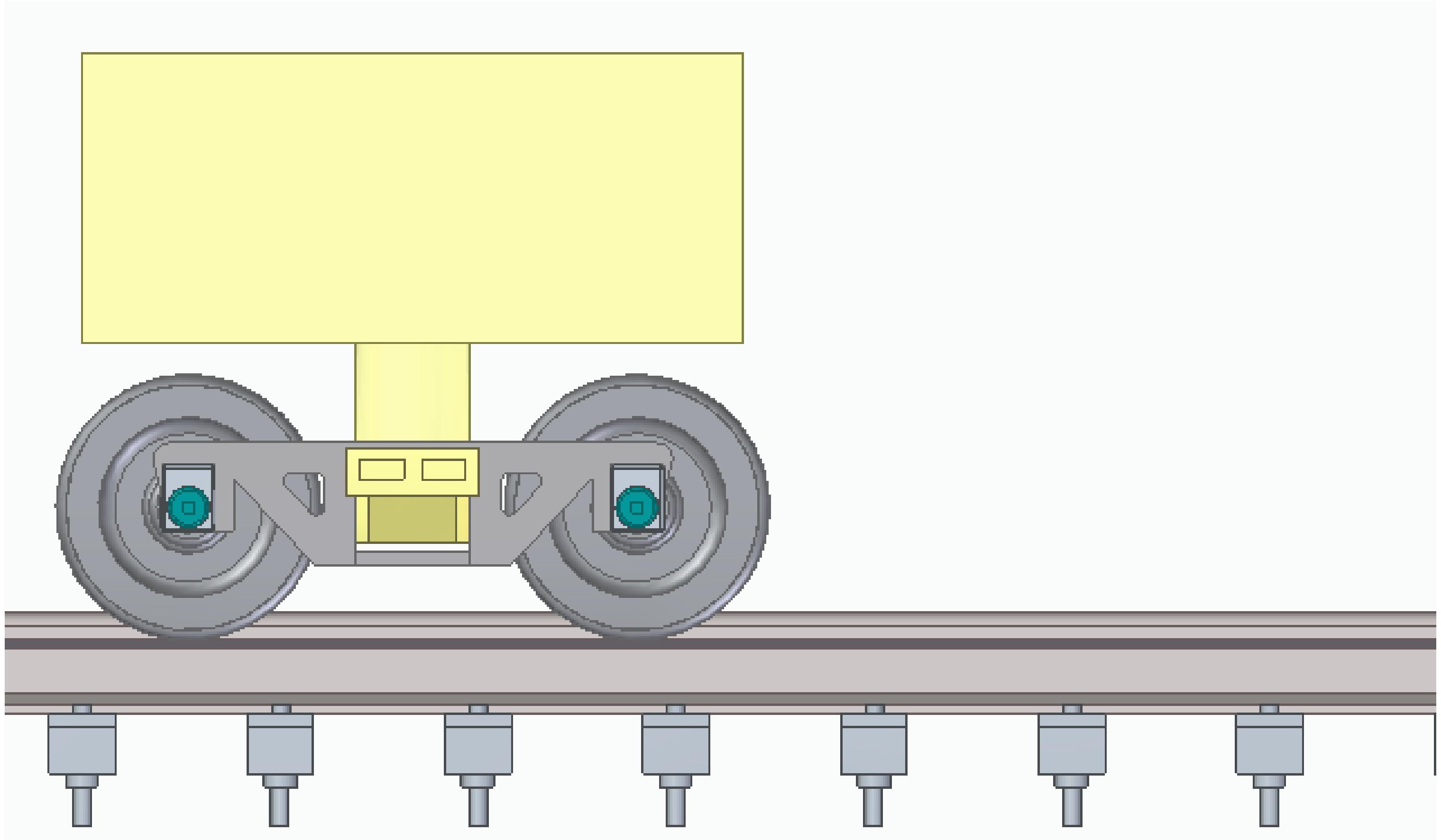
Front View



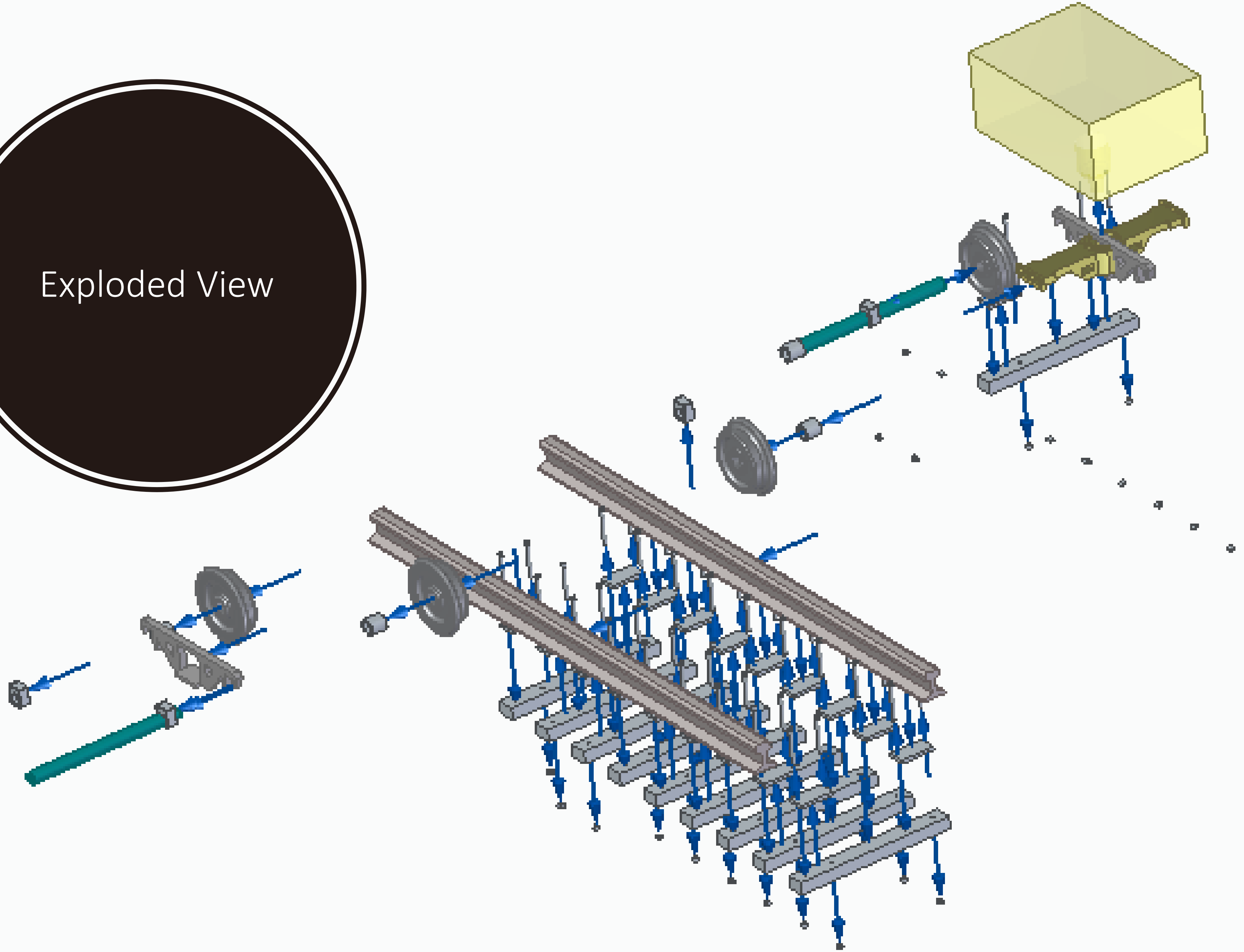


TOP view

Side View



Exploded View



Components of the Railway track system

1) Carriage
2) Suspension II
3) Bogie frame
4) Suspension I
5) Wheelset
6) Rails
7) Sleepers
8) Ballast
9) Roadbed

Mathematical Modelling

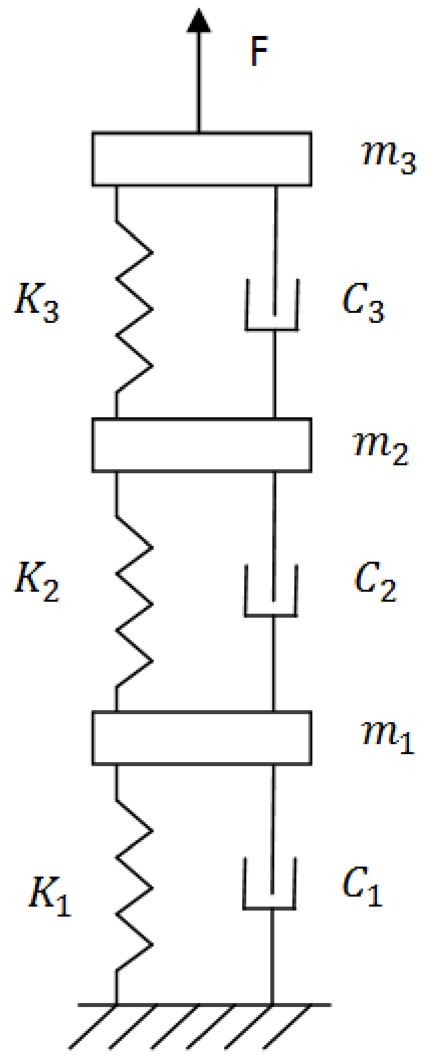
- The model is designed as a multi (3 DOF system)

The equation of motion is

- $M\ddot{X} + C\dot{X} + K\,X = F_0$

- The masses are

m1=Ballast and Roadbed
m2=Sleepers
m3=Rails



Equations of motion

- Applying Generalized Newton's second law of motion

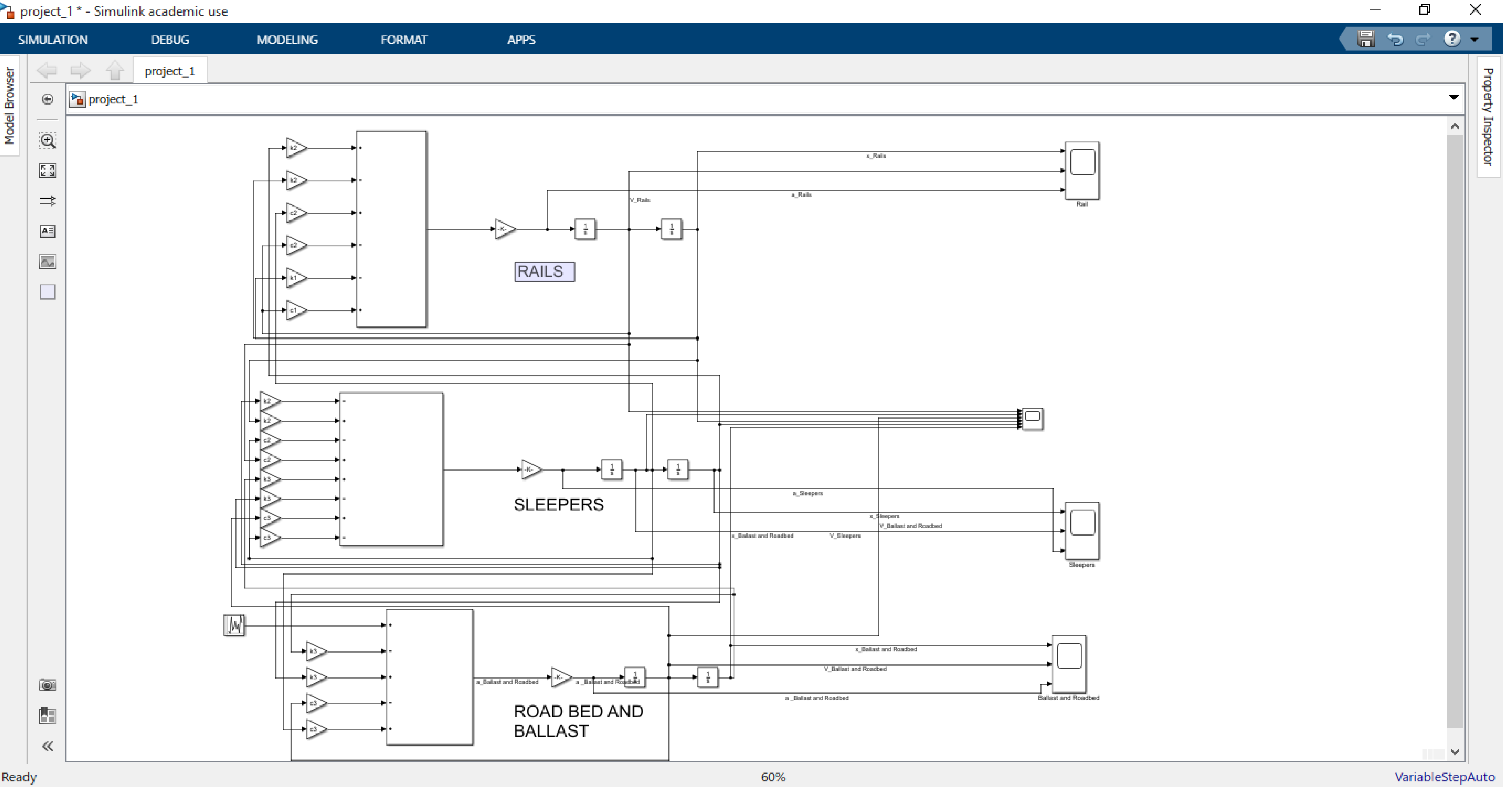
$$m_3\ddot{x}_3 = F_0 - k_3(x_3 - x_2) - C_3(\dot{x_3} - \dot{x_2})$$

$$m_2\ddot{x}_2 = -k_2(x_2 - x_1) - C_2(\dot{x_2} - \dot{x_1}) + k_3(x_3 - x_2) + C_3(\dot{x_3} - \dot{x_2})$$

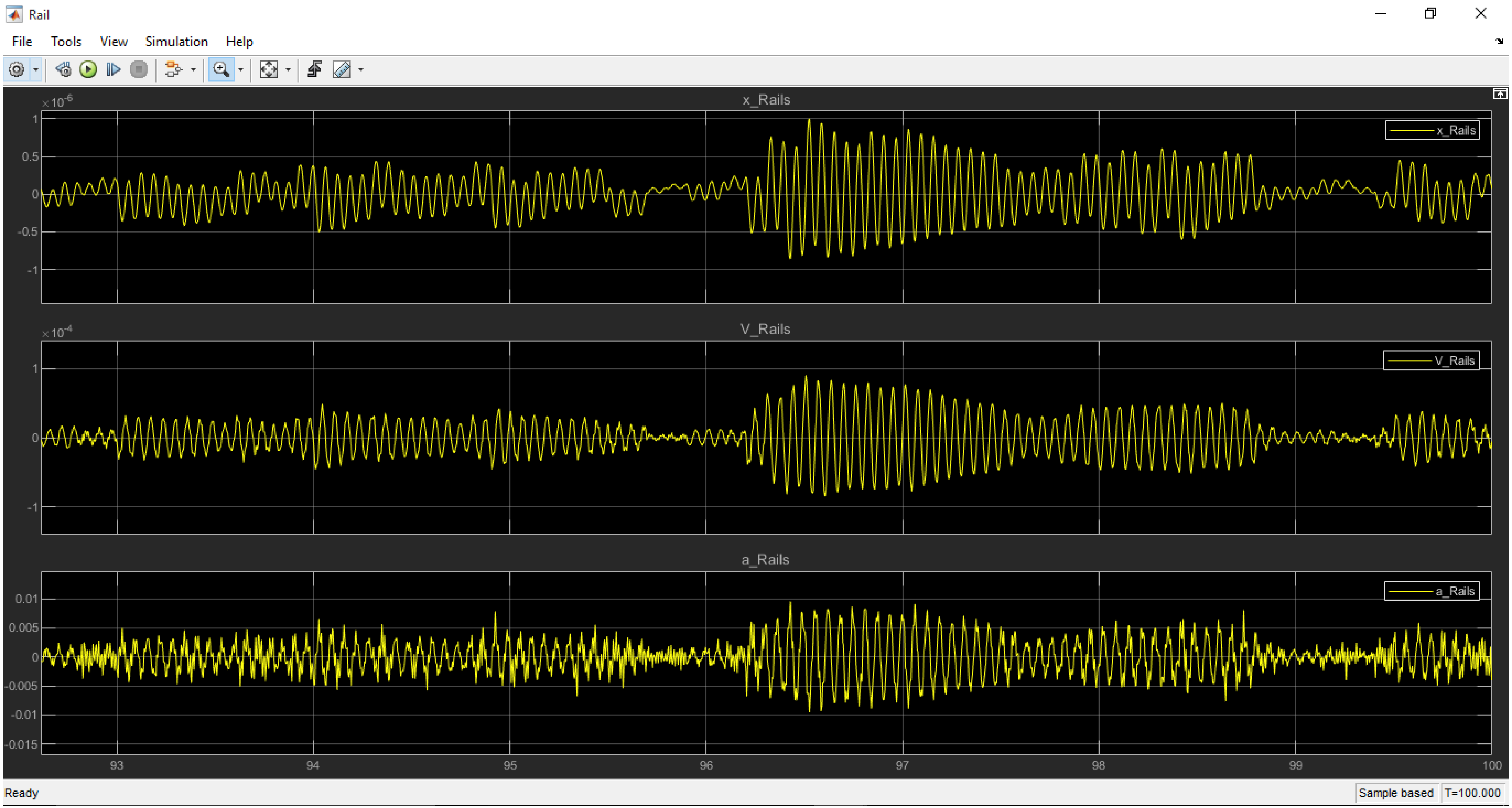
$$m_1\ddot{x}_1 = k_2(x_2 - x_1) + C_2(\dot{x_2} - \dot{x_1}) - k_1 x_1 + C_1\dot{x_1}$$

The irregularities of the track are considered in the forcing term as the wave form of the sample irregularities from zhai et al.

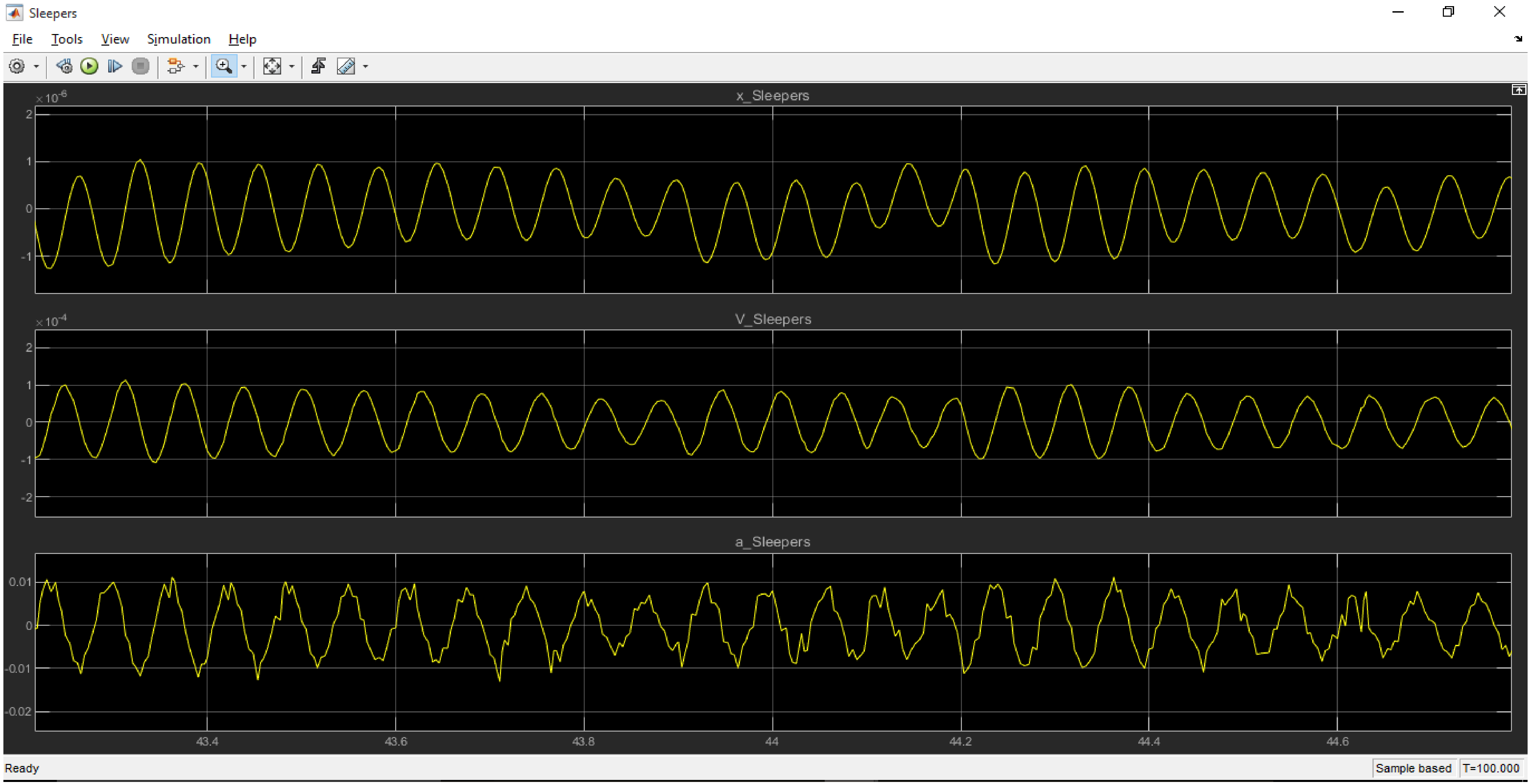
Simulink Model



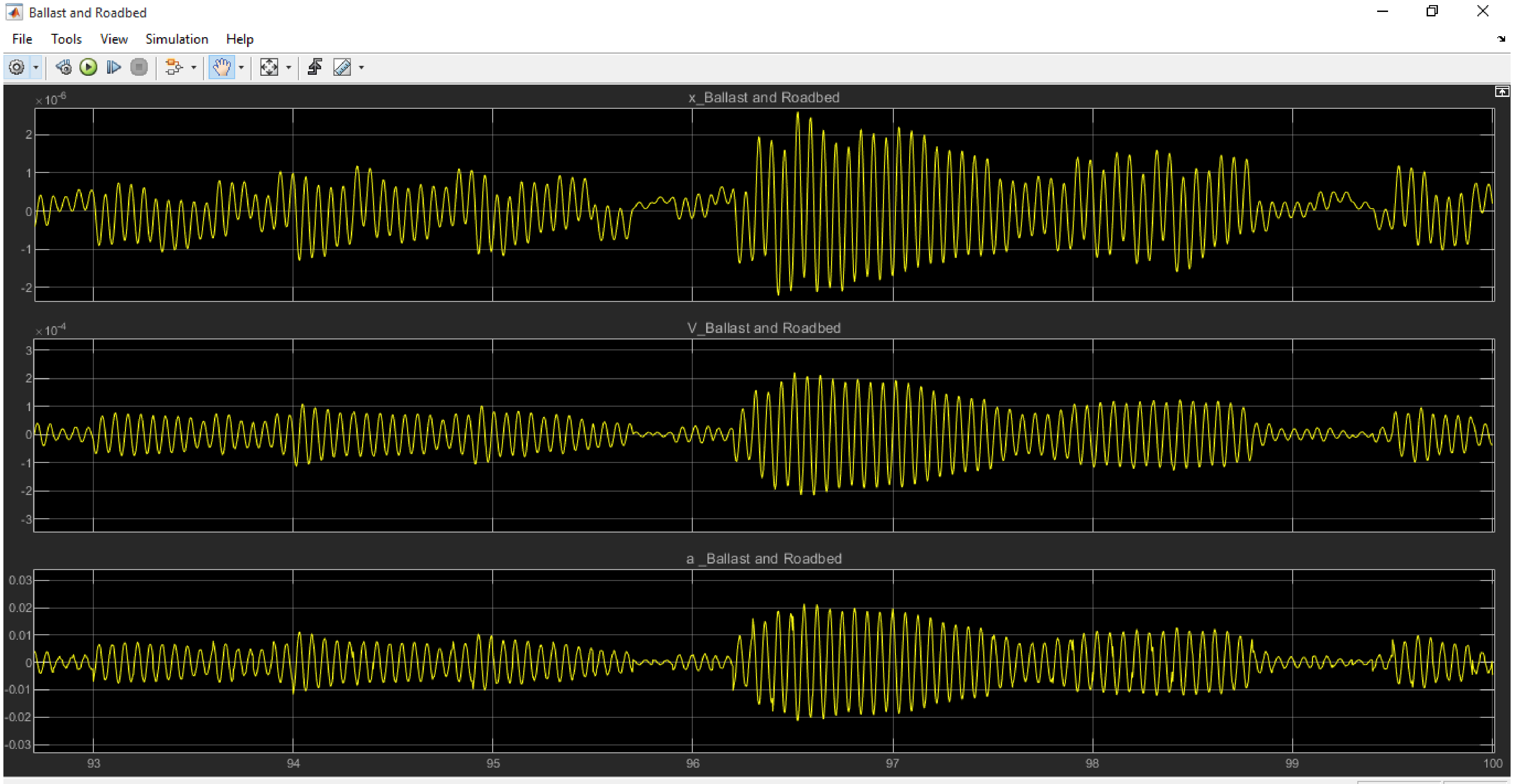
Displacement, Velocity and Acceleration of Rails



Displacement, Velocity and Acceleration of Sleepers



Displacement, Velocity and Acceleration of Ballast and Roadbed

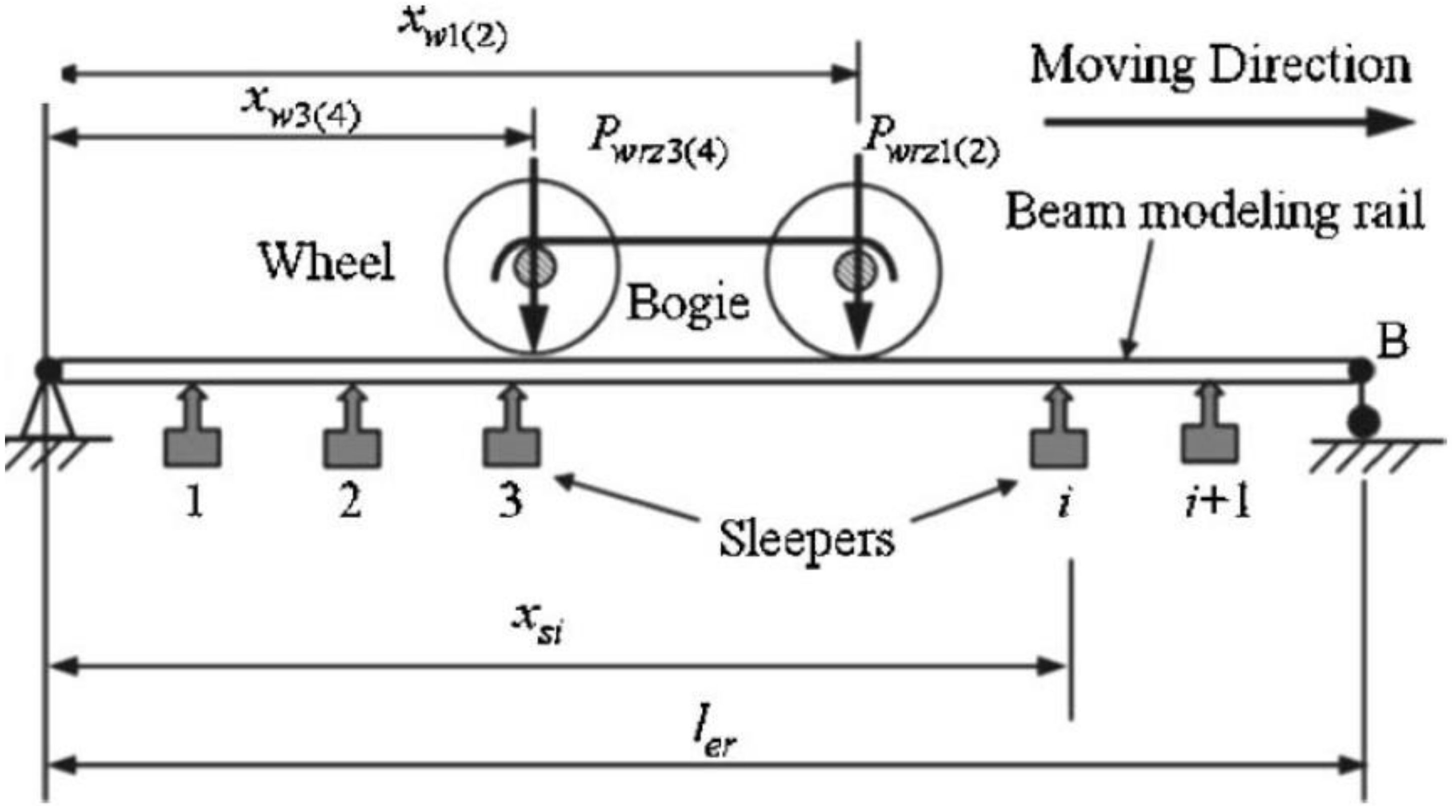


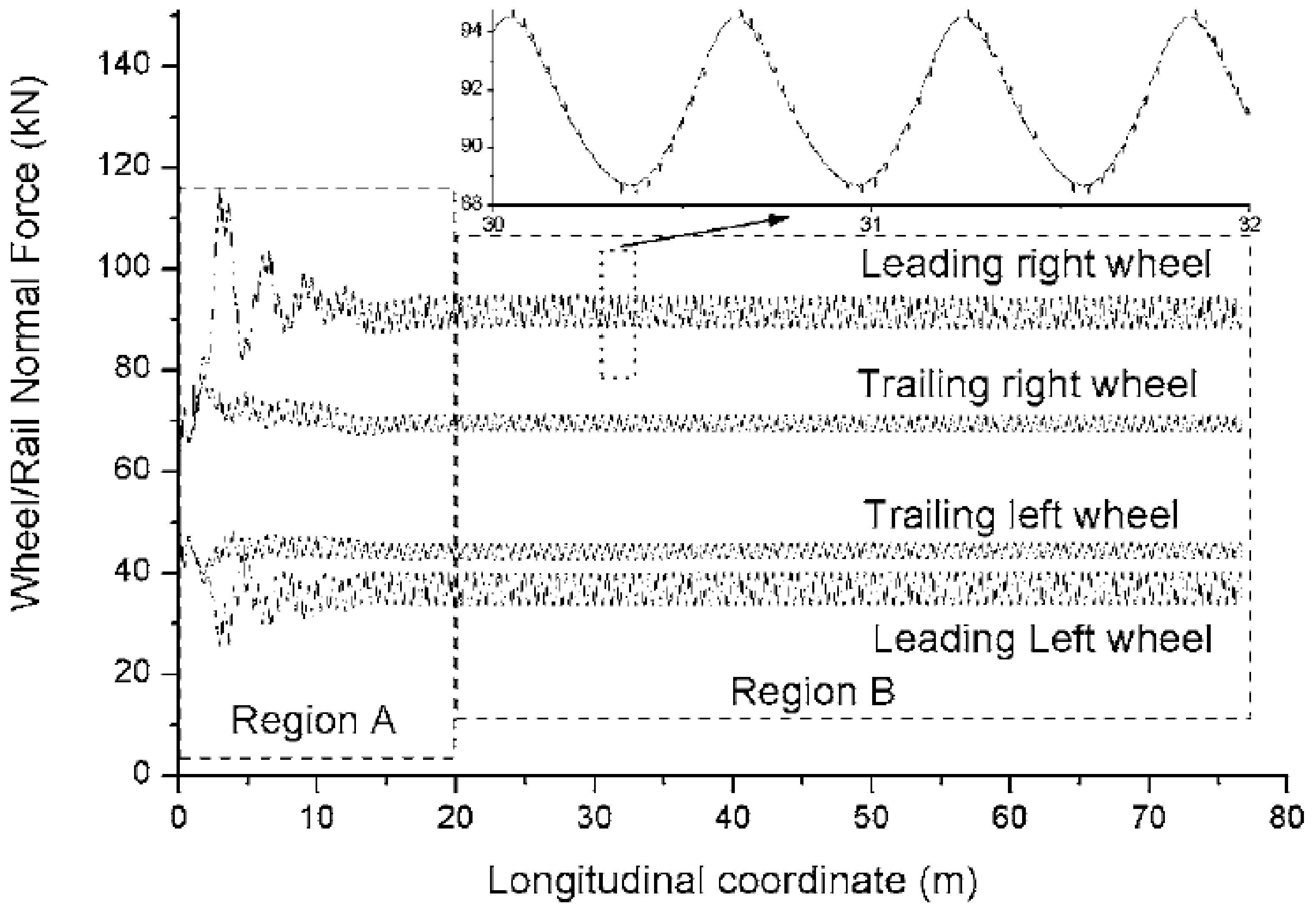
Observations

- The displacements, velocity and acceleration are all in phase for Rails, Sleepers, Ballast and Roadbed
- The signals for Sleepers are uniform denoting the uniform spacing between the sleepers
- The disabled fasteners lower the stiffness and damping coefficients of the tracks

The model from the research paper is explained in the report

Vehicle track system excitation model



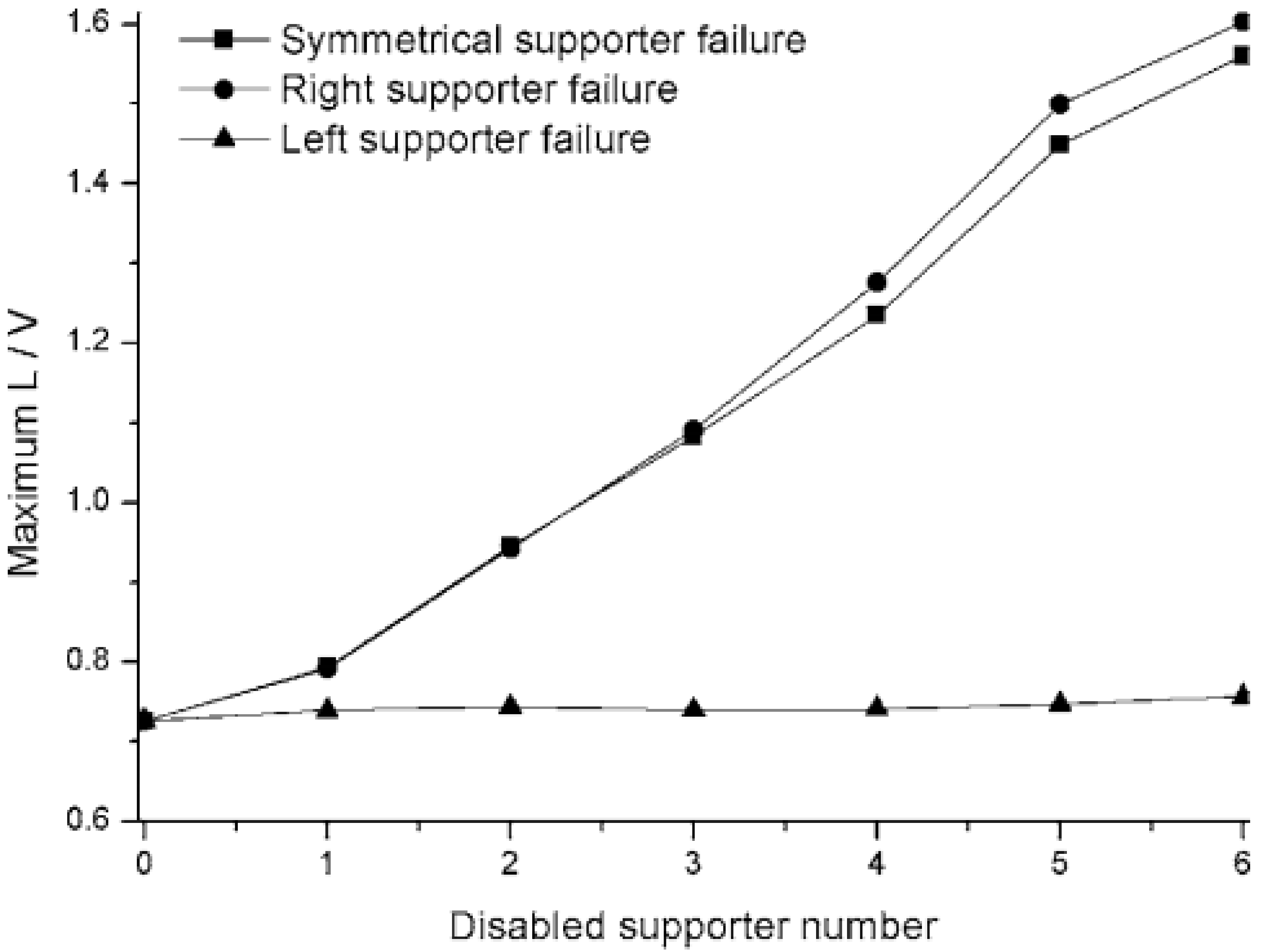


Normal Load without component failure

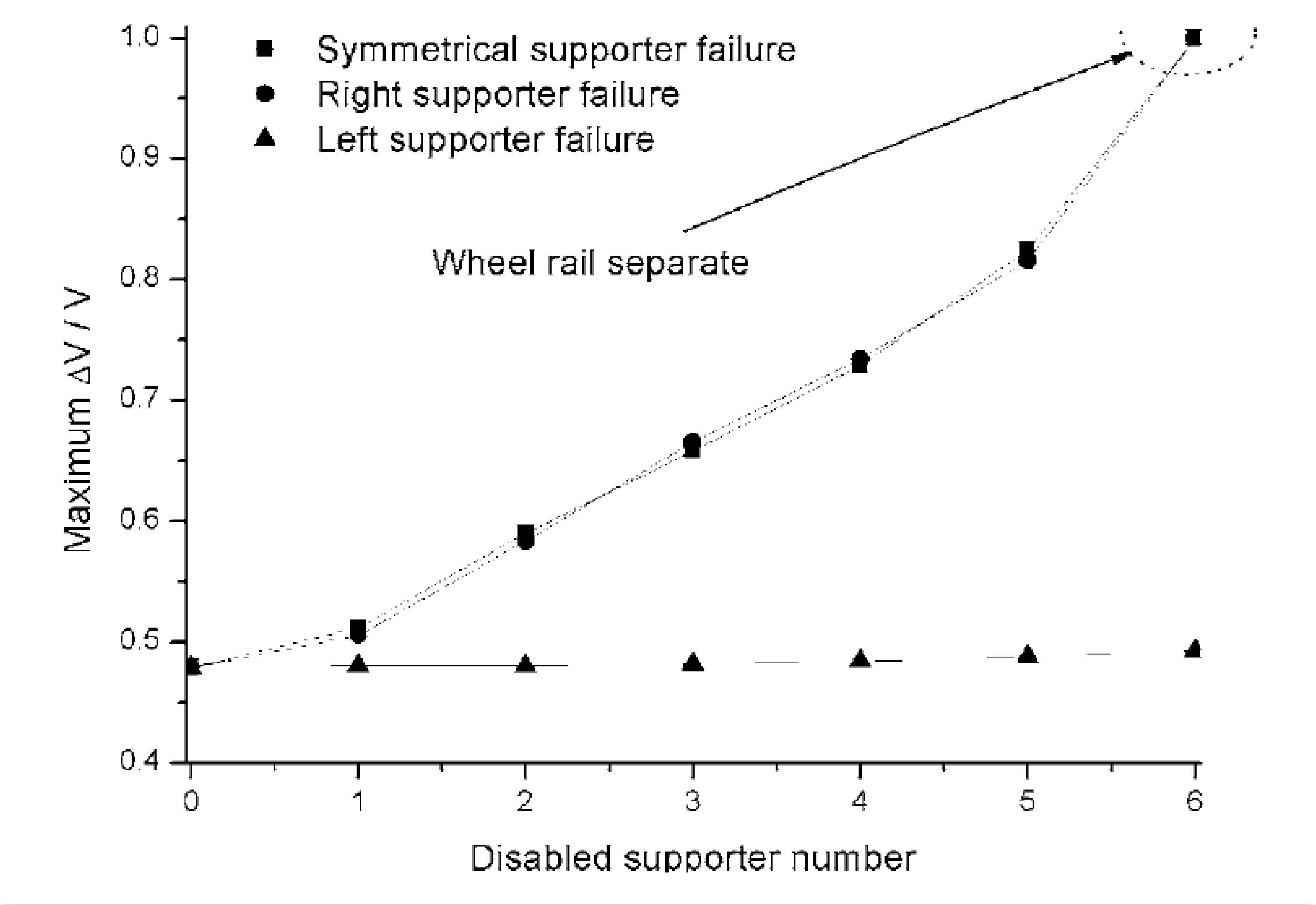
Table 4 Maximum track deformations that occurred

Disabled supporter	Gauge widening		Cross level		Turnover angle	
Number	Value (mm)	Increase (%)	Value (mm)	Increase (%)	Value (deg)	Increase (%)
1	2.064	63.680	0.224	9.804	0.439	9.476
2	3.506	178.033	0.258	26.471	0.540	34.663
3	5.683	350.674	0.276	35.294	0.691	72.319
4	9.191	628.866	0.374	83.333	0.850	111.970
5	12.790	914.274	0.584	186.275	1.042	159.850
6	22.124	1654.481	1.086	432.353	1.246	210.723

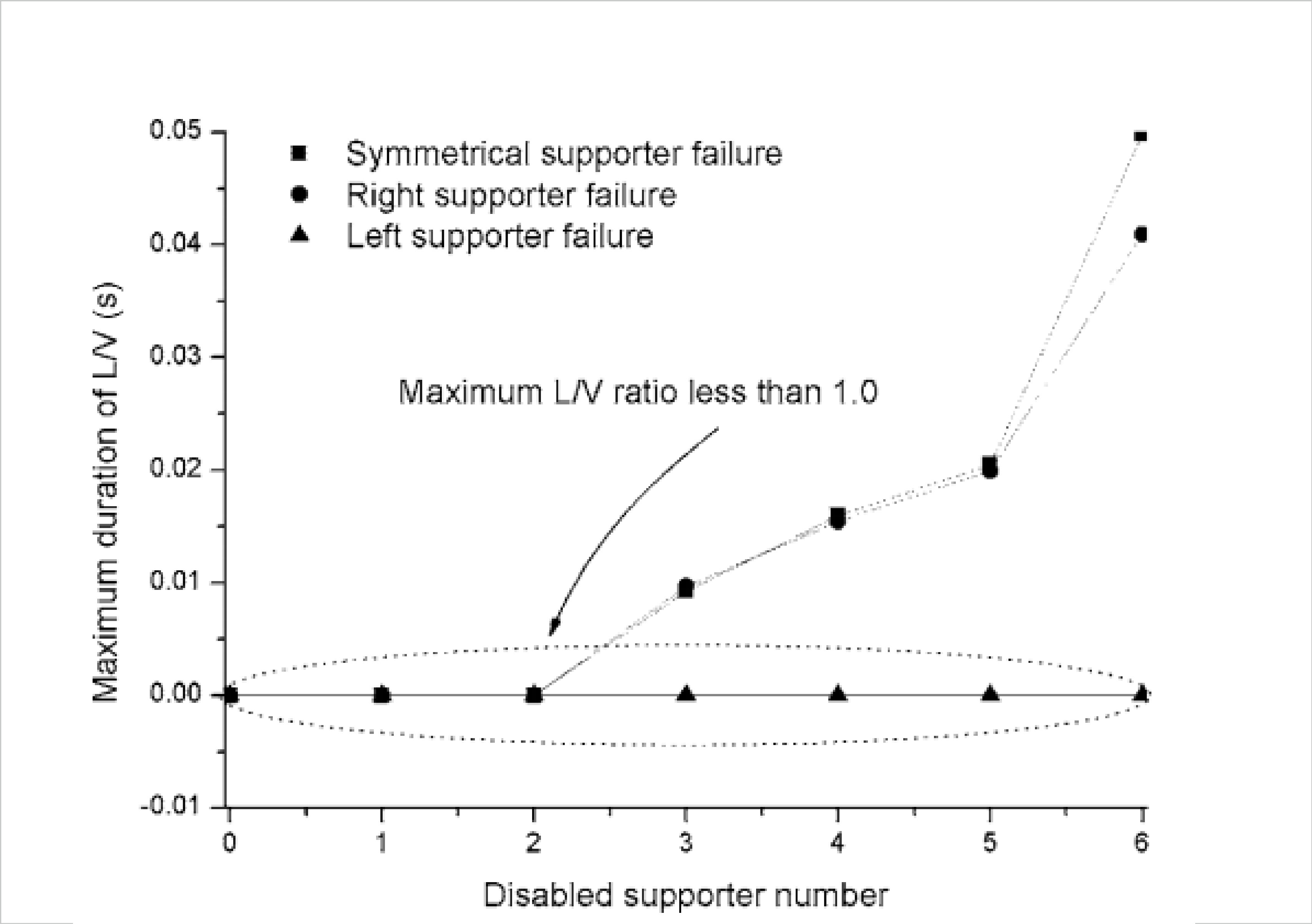
Results for Disabled fasteners



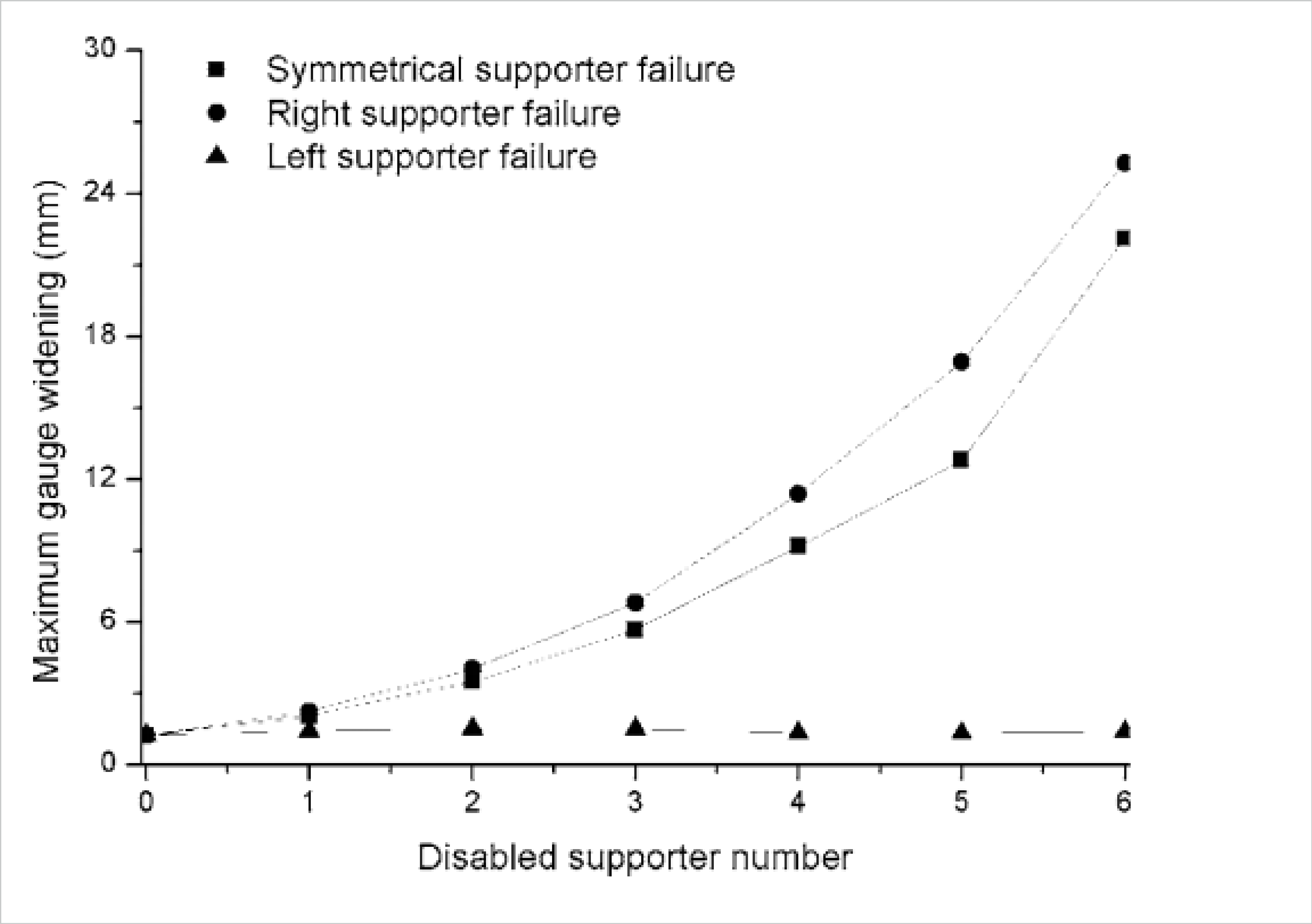
Maximum of L/V for disabled supporters



Maximum of $\frac{\Delta V}{V}$ for disabled supporters



Duration of L/V for disabled supporters



Maximum gauge widening for disabled fastener

Conclusion

- The disabled supports under the rails have significant effect on the derailment coefficients and contact situation of the wheels and the rails
- The derailment coefficients $\frac{L}{V}, \frac{\Delta V}{V}$ and the duration of $\frac{L}{V}$ increase quickly with the increasing number of symmetrical or right disabled supporters under the rails
- The track gauge widening increases quickly with increase in number of disabled supports
- The coupled multi DOF equations are solved with ODE-45 in simulink

References

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- Matlab help

Thank you