MULTIBODY SIMULATION ANALYSIS OF A MONORAIL TRANSPORTATION SYSTEM

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Abstract

Multibody simulation enables engineers to examine and investigate the kinematic and dynamic motion of mechanical systems, allowing them to construct and develop virtual 3D models to simulate and illustrate motion, coupling forces and stresses. The purpose of this study is to analyse kinematic and dynamic characteristics of a monorail for urban transportation systems. The monorail will go through three simulations in Solidworks. The first simulation is motion analysis by moving along a straight and curved track under low-speed (10 m/s), medium speed (15 m/s) and high speed and (20 m/s). Next, static analysis due to weight of passengers and car body and finally the last simulation is dynamic analysis due to dynamic loads occurring at the stabilizing wheel. The collected result will then be compared with past studies to validate the multibody simulation. Most dynamic and kinematic characteristics show slightly similarity and some dynamic and kinematic characteristics turn out differently. The different characteristics are due to Solidworks errors during the simulation process.

Keywords

Multibody, Bogie, Kinematic, Dynamic, Load

Introduction

The primary objective of this study is to ensure that the monorail system operates at its optimum level in order to serve as an efficient public transportation service for citizens. To achieve this, it is crucial to examine the kinematic and dynamic characteristics of the monorail. The analysis of kinematic characteristics plays a vital role in determining key variables such as displacement, velocity, acceleration, and time associated with the monorail. This analysis is instrumental in helping analysts develop a comprehensive understanding of the monorail's motion. The second aspect of the study focuses on dynamic characteristics, specifically investigating the interaction between the monorail wheels and their behavior during motion. By studying the dynamic behavior of the monorail wheels, engineers can gain insights into their performance and make necessary improvements.

One common issue encountered in monorail systems is the behavior of the trains at different speeds: low, medium, and high. This factor holds great significance as engineers need to consider the allowable speed limits for both straight and curved tracks. Conducting motion analysis simulations will provide valuable solutions for determining these allowable speeds, which may differ from the operational speeds.

Additionally, another critical concern revolves around the impact of loading on the monorail components while in motion. Simulation studies involving static and dynamic loads on the components offer engineers insights into selecting appropriate materials and determining the lifespan of these components before reaching their finite life. By investigating both kinematic and dynamic characteristics, as well as addressing speed limits and loading effects, this study aims to provide valuable information for the development of an optimized monorail system that ensures efficient operation and longevity of its components.

2.0 TABLES AND FIGURES

2.1 Tables

Table 1: Monorail solidworks simulation parameters

Description	Unit	Value
Length of straight track, *l*	m	315
Radius of curve track, *r*	m	100
Load of passengers on bogie frame, F_{BF}	kN	32.45
Gravity, *g*	m/s^2	9.81
Dynamic friction velocity, μ_K	m/s	0.01016
Static friction velocity, μ_S	m/s	0.0001
Dynamic friction coefficient	-	1
Static friction coefficient	-	1
Motor speeds, lower, medium & upper limits	rad/s	28.27, 42.31 and 56.34

Table 1 above shows the monorail simulation parameters used in Solidworks motion analysis, static load analysis and dynamic load analysis.

Table 2: Summary of the simulation results for motion analysis of monorail bogie frame.

Parameters Recorded	Straight Track			Curve Track		
	Low Speed	Medium Speed	High Speed	Low Speed	Medium Speed	High Speed
Displacement	121 m	175 m	127 m	94 m	94 m	94 m
Maximum Velocity	10 m/s	15 m/s	20 m/s	10 m/s	15 m/s	16 m/s

Table 2 above shows the values from the straight track and the curve track which indicates there is loss of data from the simulation.

Table 3: Summary of the simulation results for static analysis of monorail bogie frame.

Passengers Load	Minimum			Maximum		
	Displacement	Stress	Strain	Displacement	Stress	Strain
131.2 kN	1 e^{-30} mm	5.243 e^{-04} MPa	4.493 e^{-09}	5.308 e^{-03} mm	1.477 MPa	5.199 e^{-06}
169.15 kN	1 e^{-30} mm	5.845 e^{-04} MPa	4.246 e^{-09}	7.277 e^{-03} mm	1.946 MPa	6.875 e^{-06}
210.35 kN	1 e^{-30} mm	5.845 e^{-04} MPa	4.246 e^{-09}	7.277 e^{-03} mm	1.946 MPa	5.199 e^{-06}

Table 3 above shows the values of displacement, stress and strain on bogie frame due to the different loads of passengers.

2.2 Figures and Graphics

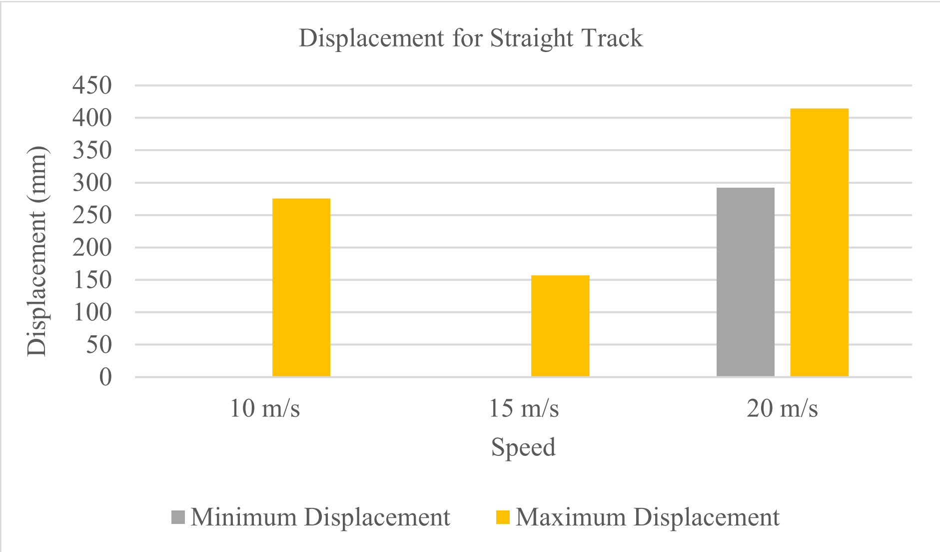

Figure 1: Displacement of stabilizing wheel along straight track.

Figure 1 indicates the minimum and maximum displacement of stabilizing wheel when the monorail moves along a straight track. The minimum displacement for low-speed and medium speed is too low compare to high speed. The highest maximum displacement occurs when the monorail travel at high speed.

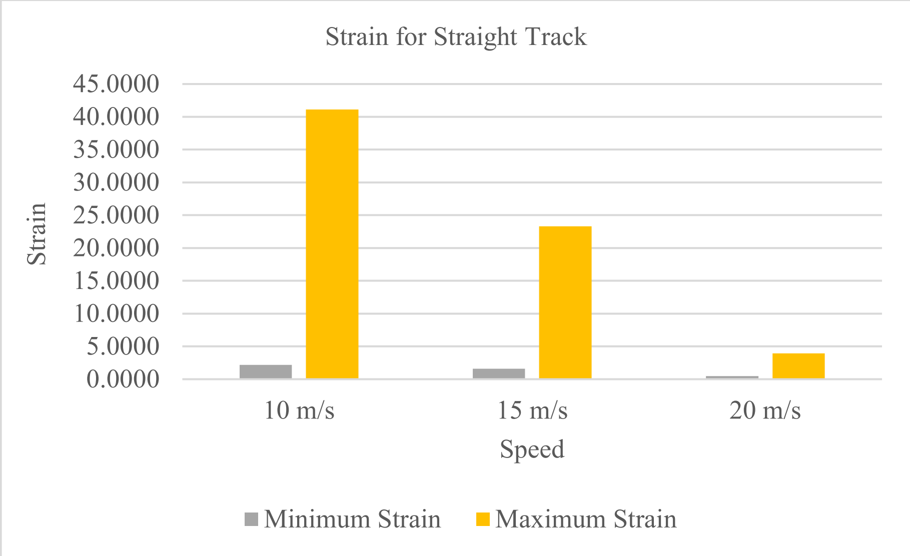

Figure 2: Strain of stabilizing wheel along straight track.

Figure 2 shows the minimum and maximum strain of stabilizing wheel when the monorail moves along a straight track. The minimum strain for low-speed and medium speed is same. As the speed of monorail increased, the maximum strain occurs decreased.

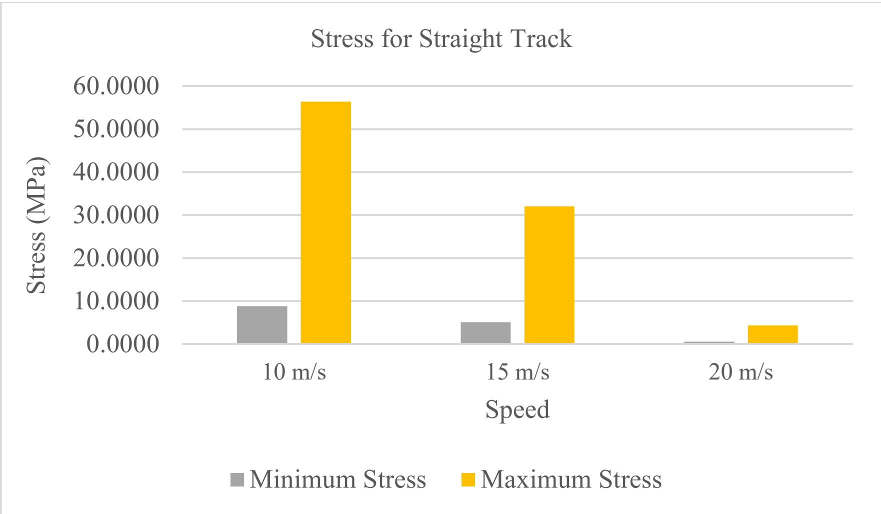

Figure 3: Stress of stabilizing wheel along straight track.

Figure 3 shows the minimum and maximum stress of stabilizing wheel when the monorail moves along a straight track. The minimum and maximum decreased when the speed of the monorail increased.

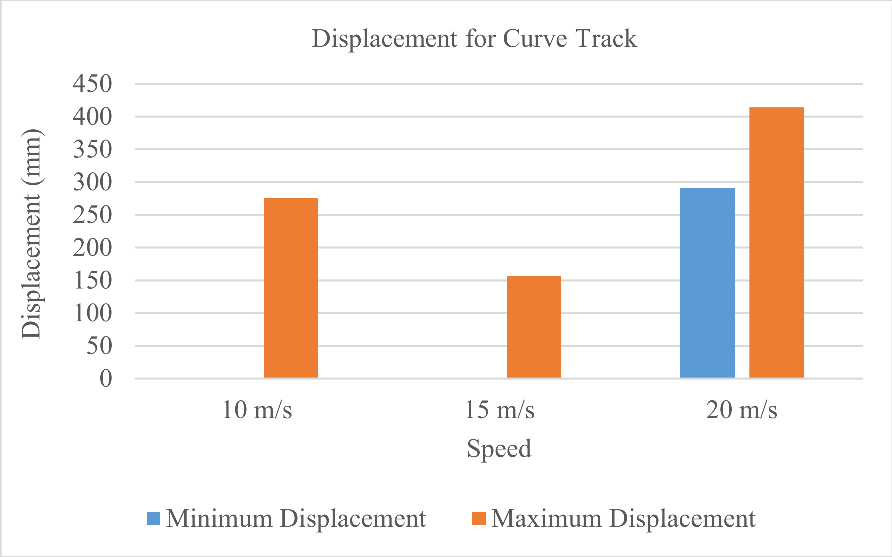

Figure 4: Displacement of stabilizing wheel along curve track.

Figure 4 shows the minimum and maximum stress of stabilizing wheel when the monorail moves along a curve track. The minimum displacement for low-speed and medium speed is too low compare to high speed and the highest maximum displacement occurs when the monorail travel at high speed same as the displacement for the straight track in Figure 1.

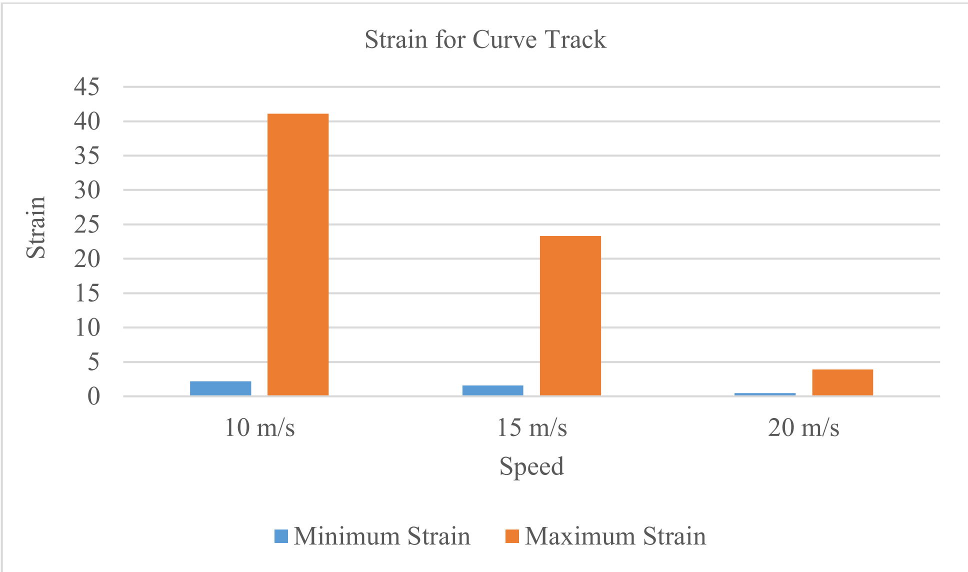

Figure 5: Strain of stabilizing wheel along curve track.

Figure 5 shows the minimum and maximum strain of stabilizing wheel when the monorail moves along a curve track. The minimum strain for low-speed and medium speed is same and as the speed of monorail increased, the maximum strain occurs decreased. This data shows similar trend compare to data from the straight track in Figure 2.

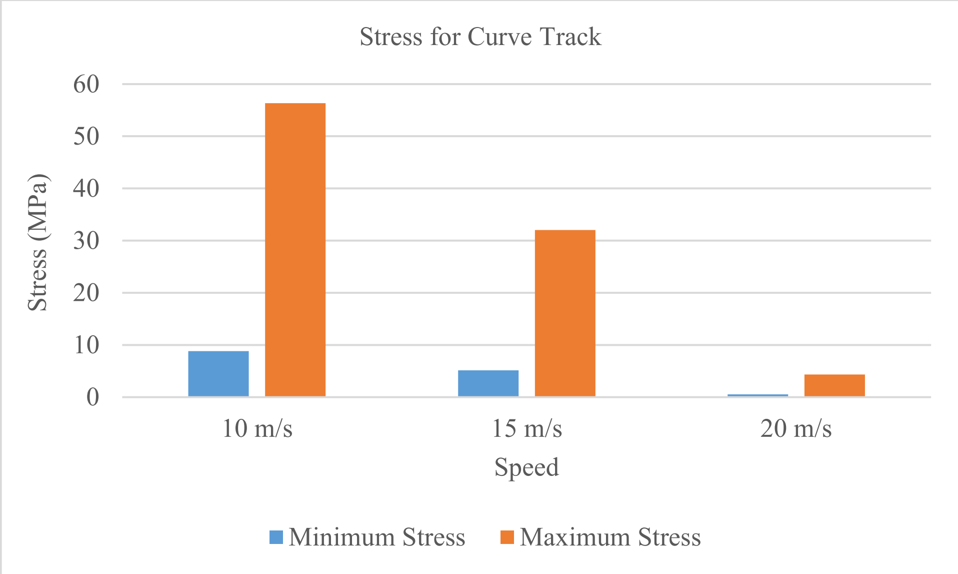

Figure 6: Stress of stabilizing wheel along curve track.

Figure 6 shows the minimum and maximum stress of stabilizing wheel when the monorail moves along a straight track. The minimum and maximum decreased when the speed of the monorail increased which is the trend is similar to data from the straight track in Figure 3.

CONCLUSION

The research conducted encountered challenges in achieving successful simulation results due to variations in motion study properties associated with different defined speeds and encountering errors or interruptions while running the simulation in Solidworks. However, several interesting conclusions can be drawn from this study. One finding is that the displacement of the bogie remains within an acceptable range when moving on a straight track at different speeds which is less than 300mm. However, when the bogie traverses a curved track, its displacement exceeds the acceptable range(>300mm). Another observation is that the bogie manages to reach its maximum velocity in all speed cases which is up to 20m/s or 72km/h. However, when traveling on a curved track at high speeds, it fails to attain the maximum velocity due the nature that the bogie needs to slow down to be able to be on the track. The study also reveals that the bogie frame is capable of withstanding the weight of the car body and passengers. The maximum displacement occurs at the centre of the bogie frame due to load concentration that act at the centre of the bogie. This lead to the highest levels of strain and stress at the connecting point between the bogie and the wheels which is can go up to 1.946 Mpa. The stabilizing wheel were also found to inadequately hold the dynamic loads of the monorail, both on straight tracks and curved tracks which possibly cause an accident at speed higher that 20m.s. The research highlights the limitations and challenges encountered during the simulation process while providing insights into the displacement of the bogie, the performance on curved tracks, the durability of the bogie frame, and the effectiveness of the stabilizing wheel.

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