Mobile Robot Tire Dynamics based on the LuGre Model

Student: Amanda McGivern
Nipissing University, Department of Computer Science
100 College Drive. North Bay, Ontario, Canada P1B 8L7

Professor: Dr Schreyer
Nipissing University, Department of Computer Science
100 College Drive. North Bay, Ontario, Canada P1B 8L7
bjs@nipissingu.ca

Background

A vehicle's motion is largely affected by the forces transferred to the road by the tires. Traditionally, a static tire model is used to simulate braking of a vehicle because it is highly efficient. It has been proven, however, that this is not always sufficient and that longitudinal tire forces can affect the wheel speed and tire oscillations [1]. Therefore, it is sometimes necessary to use a dynamic tire model to model these tire force fluctuations.

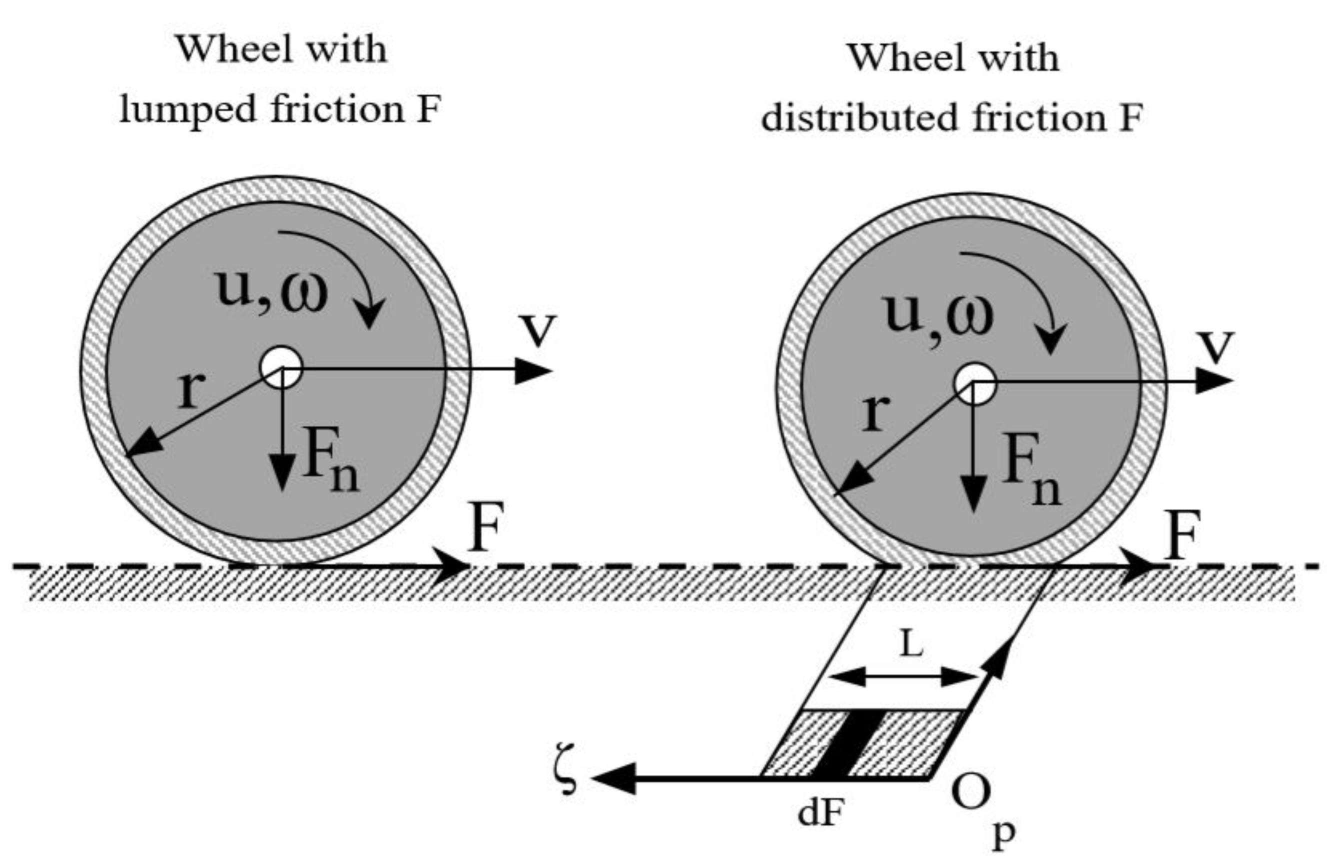

Figure 1. A brush tire model [3]

Dynamic Tire Model

A Matlab model of a dynamic tire system was created based on Deur's lumped tire model [1]. The tire force and slip were calculated. The natural frequency and damping ratio of the transfer function are also calculated. The resulting model was run using a variety of parameters and analysed.

Simulation Parameters

These parameters were adjusted throughout the different simulations, producing varied results.

- v_i = initial velocity; $\frac{m}{s}$
- L = length of tire contact patch; m
- N = number of bristles
- σ_0 = stiffness coefficient; $\frac{1}{m}$
- σ_1 = rubber longitudinal lumped damping; $\frac{1}{m}$
- σ_2 = viscous relative damping; $\frac{s}{m}$
- T = time constant
- T_0 = initial time constant = $\frac{\sigma_1}{\sigma_0}$
- K_w = constant = $\frac{L}{\kappa} \times \frac{1}{|v_i|}$
- K_v = constant
- a = rising slope of braking moment
- b = falling slope of braking moment

Initial Simulation Results

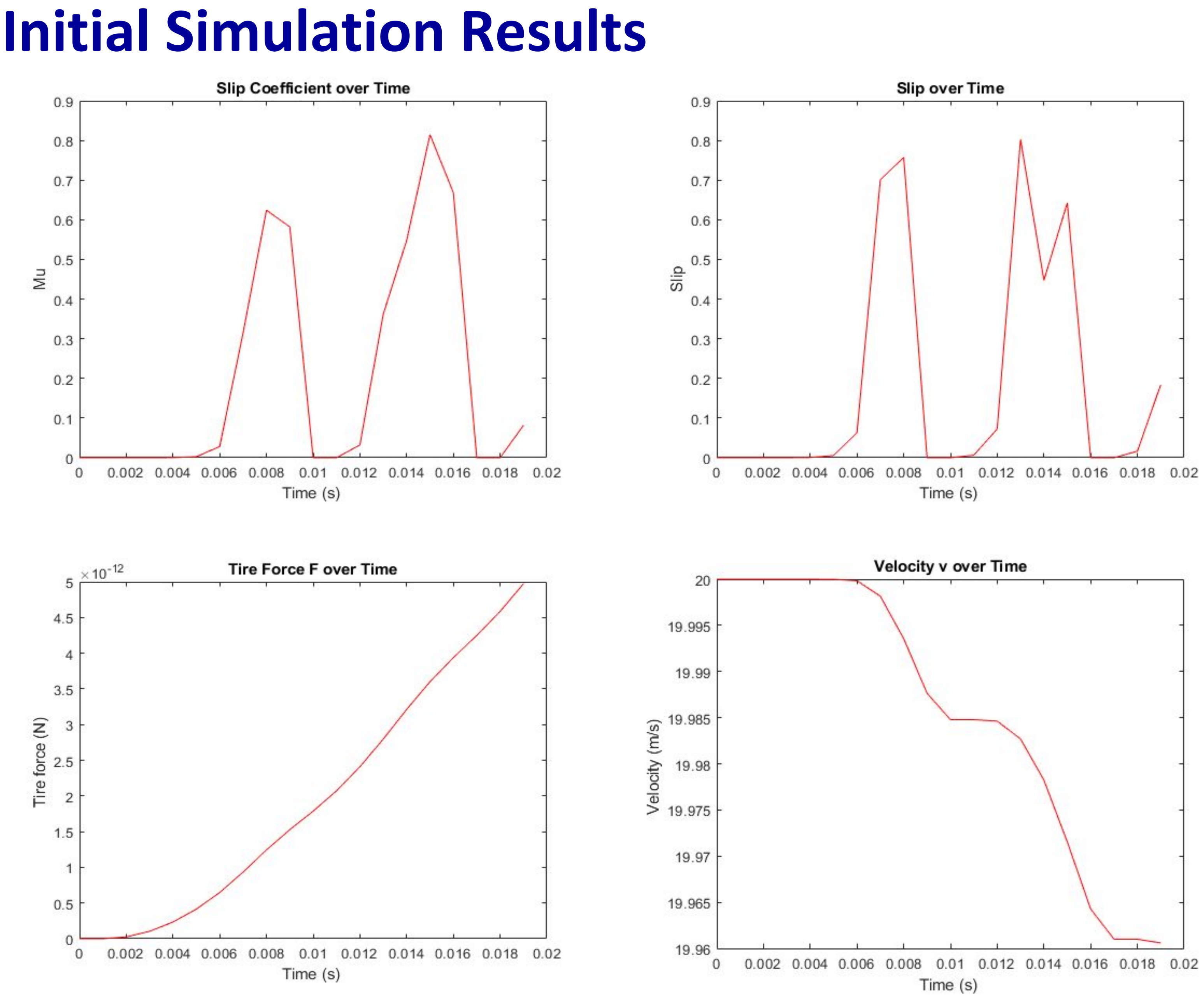

Figure 3. Simulation results with initial velocity of 30 $\frac{m}{s}$

Simulation with Increased Velocity

The following set of simulations changed the initial velocity from 20 $\frac{m}{s}$ to 60 $\frac{m}{s}$ The K_v value also had to be recalculated. To keep it within a reasonable range with this new initial velocity, the value had to be significantly less than 0.45. The value chosen for K_v was 0.05 in this simulation.

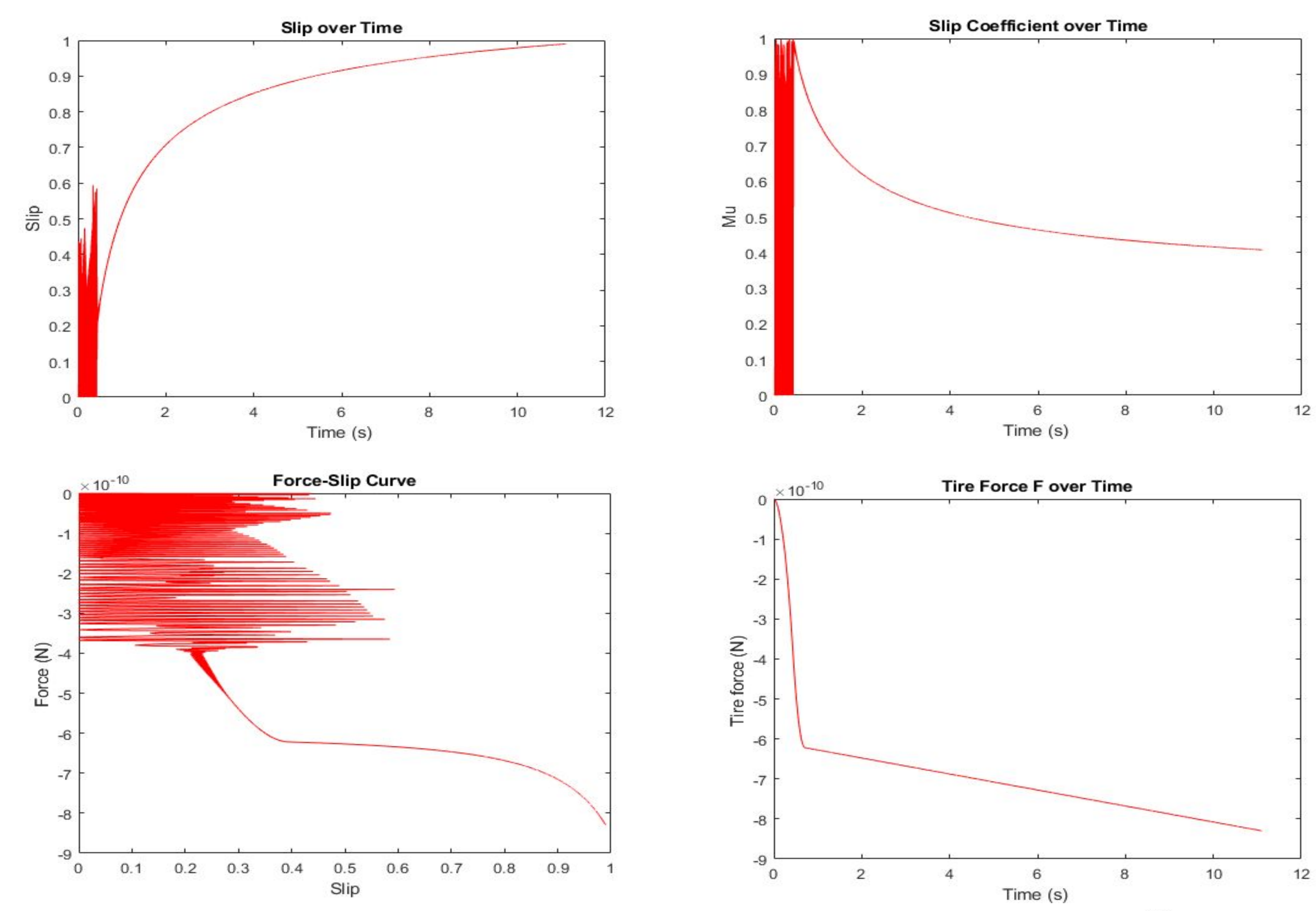

Figure 4. Results of the simulation with an initial velocity of 60 $\frac{m}{s}$

Simulation with Modified Damping Parameters

The damping parameters were modified so that σ_0=1000.0 and σ_1=125.0. While this had little effect on the slip, the tire force went from decreasing rapidly and inconsistently to much slower and linearly. This implies that the damping coefficients have a large effect on the tire force.

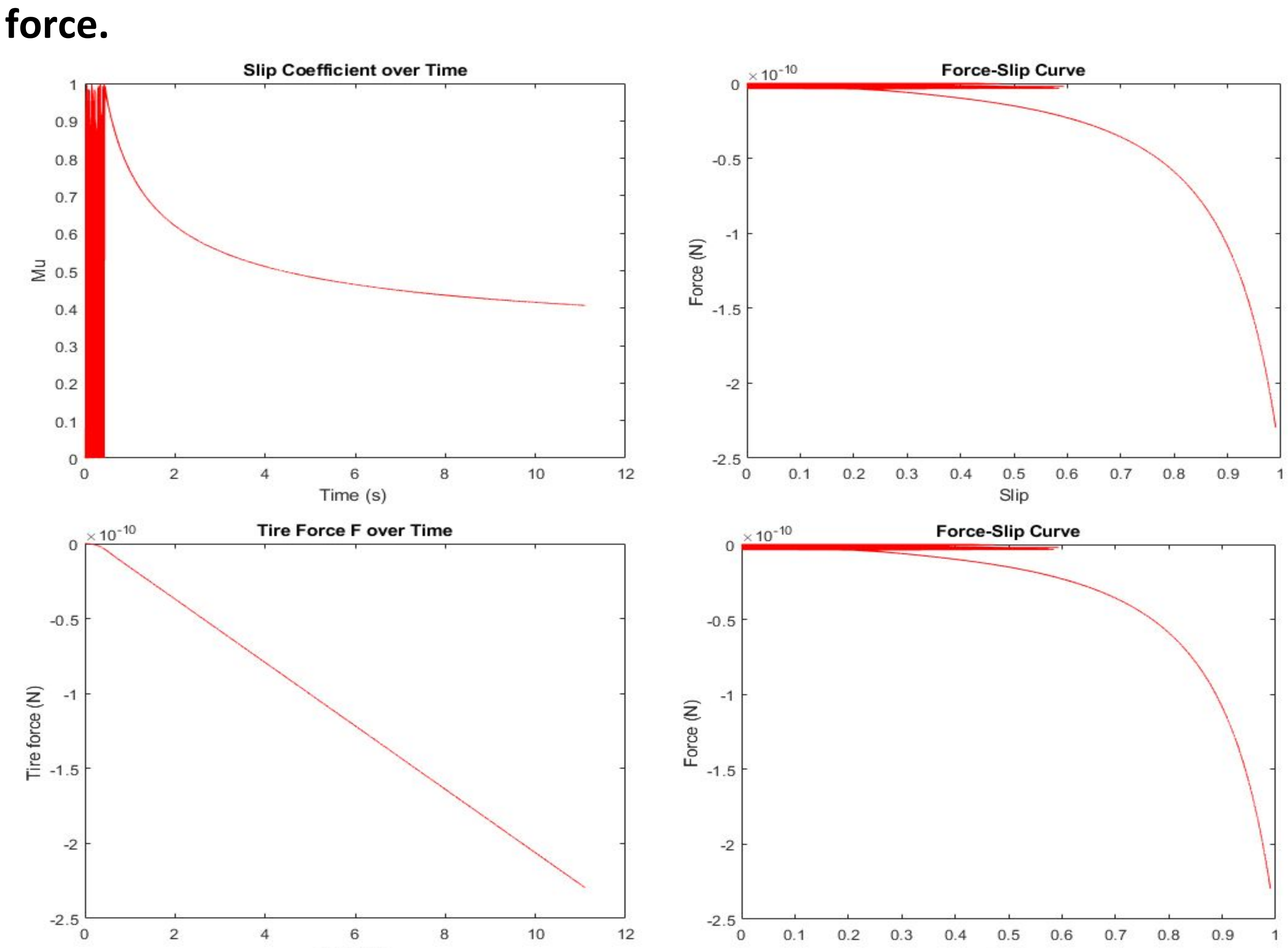

Figure 5. Results of the simulation with modified damping parameters

Conclusion

There are many factors that affect a tire's force and its stopping distance. The accurate modeling of a tire is important to determine the best way to apply ABS and stop the car safely without the wheels locking. More simulations can be done to determine the most accurate application of ABS while being able to model and consider the effects the longitudinal motion will have on the tire force.

References

[1] Deur, J. (2001). Modeling and analysis of longitudinal tire dynamics based on the LuGre friction model. IFAC Proceedings Volumes, 34(1), 91-96.

[2] Deur, J. (2002). A brush-type dynamic tire friction model for non-uniform normal pressure distribution. IFAC Proceedings Volumes, 35(1), 409-414.

[3] De Wit, C. C., & Tsiotras, P. (1999). Dynamic tire friction models for vehicle traction control. In Proceedings of the 38th IEEE Conference on Decision and Control (Cat. No. 99CH36304) (Vol. 4, pp. 3746-3751). IEEE.