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ПРОДОЛЬНАЯ ДИНАМИЧЕСКАЯ МОДЕЛЬ ПОЛНОПРИВОДНОГО АВТОМОБИЛЯ

A LONGITUDINAL DYNAMIC MODEL OF ALL-WHEEL DRIVE VEHICLE

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В последние годы автомобильная индустрия стала свидетелем значительных достижений в области динамики и систем управления транспортными средствами, особенно в сфере технологий полного привода (AWD). В данной статье представлен продольный динамический модель полноприводного автомобиля, позволяющий провести всесторонние исследования динамики кузова и характеристик скольжения шин. Разработана компьютерная модель, которая годна для анализа продольной динамики автомобилей с полным приводом. Представлены результаты моделирования динамических процессов автомобиля при различных распределениях крутящего момента между активными осями. Показано влияние распределения крутящего момента на динамику автомобиля.

In recent years, the automotive industry has witnessed significant advancements in vehicle dynamics and control systems, particularly in the real of all-wheel-drive (AWD) technology. This paper presents a longitudinal dynamic model of all-wheel drive vehicles, enabling comprehensive investigations of body dynamics and tire slipping characteristics. The computer simulation model was developed and can used for analyzing the longitudinal dynamics of AWD vehicles. The simulation results of vehicle dynamic quantity in different torque distributions between active *axles were shown. The impact of torque distributions on vehicle dynamics was given.*

Ключевые слова: *полноприводный автомобиль, продольная динамика, моделирование, скольжение шин.*

Keywords: *all-wheel-drive, longitudinal dynamic, simulation, tire slip.*

INTRODUCTION

The advancement of automotive technology has placed a significant emphasis on improving vehicle dynamics, particularly in all-wheel-drive (AWD) vehicles. These vehicles offer enhanced traction, stability, and performance in various driving conditions, making them a preferred choice for both consumers and manufacturers [1]. The ability to accurately model and understand the longitudinal dynamics of AWD vehicles is crucial for optimizing their performance, safety, and overall driving experience.

The longitudinal dynamic model of a vehicle describes how forces generated at the tires are transmitted through the vehicle to influence its forward motion. For AWD vehicles, this involves a complex interplay between the drive torque distribution, wheel slip, differential operations, and drivetrain dynamics [2]. Previous studies have explored different aspects of vehicle dynamics, but a comprehensive model that fully captures the longitudinal behavior of AWD systems remains a subject of ongoing research [3].

This paper aims to develop a detailed longitudinal dynamic model of an AWD vehicle. By incorporating critical factors such as torque distribution, wheel dynamics with slipping, and road interactions, this model provides a holistic view of vehicle behavior under various driving conditions. The motivation for this study stems from the need to bridge the gap between theoretical models and real-world applications, ensuring that the model can be used for practical vehicle design and control strategies [4].

The methodology involves formulating the mathematical equations governing the longitudinal dynamics of AWD vehicles, followed by Newton-Euler rules. This approach ensures that the model not only represents theoretical dynamics but also aligns with empirical observations. Key parameters such as tire characteristics, drivetrain efficiency, and vehicle mass distribution are considered to enhance the model's accuracy [5].

Subsequent sections of the paper apply the developed model to various driving scenarios, such as acceleration, deceleration, and different road conditions, to analyze the impact of different parameters on vehicle performance. The results highlight potential areas for optimizing AWD systems, with implications for improving energy efficiency, handling, and safety.

LONGITUDINAL DYNAMIC MODEL OF VEHICLE ALL-WHEEL DRIVE VEHICLE

The reference object in the article chosen is the VinFast VF8 with technical specifications as shown in table 1 below.

Table 1 – Parameters of the reference vehicle [6]

Parameters	Value
Overall dimension	4750 x 1934 x 1667(mm)
Mass	2700 kg
Motor max. torque	250 N·m
Weight distribution	50:50
Motor max. power	260 kW
Air drug coefficient	0,25
Rolling resistance	0,016

The longitudinal dynamic model of an AWD vehicle is constructed based on the following key models: the dynamics model of the vehicle body and the tire model with slipping.

1. Vehicle body model.

Since lateral performance is neglected in this article, the vehicle dynamics model adopted here contains five degrees of freedom as seen in fig. 1, and the rotational movement of the four wheels. A single-wheel model is shown in fig. 1. According to the Newton's law, the motion equations of the vehicle can be expressed as [5]:

$$m \cdot \dot{v} = \left(F_{xf} + F_{xr}\right) - \left(F_{rf} + F_{rr} + F_{w} + F_{g}\right),$$

where F_{xf}, F_{xr} are the tractive force at the front and rear axle; F_{rf}, F_{rr} are the rolling resistance forces at the front and rear wheels; F_w is the aerodynamic drag force; F_g is gradient resistance.

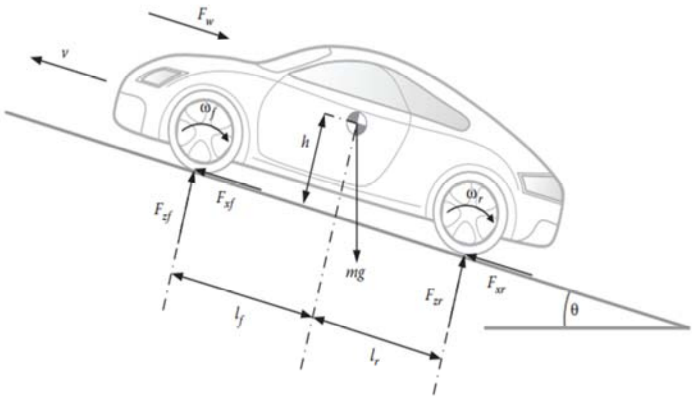

Figure 1 – Forces acting on the vehicle [7]

The dynamic vertical loads on the front and rear axles are composed of static vertical load and the transferred load comes from longitudinal acceleration, the corresponding equations are shown as follows [7]:

$$F_{zf} = \frac{m}{l_f + l_r} \cdot \left(g \cdot l_r - h \cdot \dot{v} \right),$$

$$F_{zr} = \frac{m}{l_f + l_r} \cdot \left(g \cdot l_f + h \cdot \dot{v} \right),$$

with m is the vehicle mass (kg); g is the acceleration due to gravity (m/s²); H is the height of the vehicle's center of gravity (m); v is the vehicle velocity (m/s); l_f and l_r are the distances from the front and rear wheel center to the vehicle's center of gravity (m), respectively.

2. Tire Model.

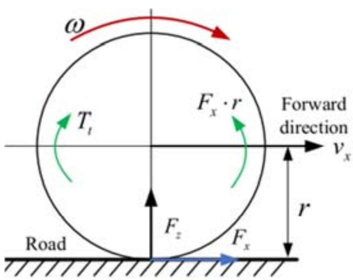

Figure 2 – Wheel rotation dynamic [7]

The dynamic model of the front-wheel is built according to the expression:

$$J \cdot \dot{\omega} = T_t - F_x \cdot r - T_b ,$$

with J is the torque of inertia of the wheel; ω is the angular velocity of the wheel; T_t is the torque at the wheel; F_x is the tractive force; T_b is the torque of the brake.

The tire slip rate is the key factor for tire longitudinal force calculation, the relationship between slip rate, wheel speed, and vehicle velocity can be expressed as follows [7]:

$$s = \left(1 - \frac{v}{\omega \cdot r}\right) \cdot 100\ \%,\ (0 < s < 1) .$$

Due to the elasticity of the tire, during operation, the tire is deformed in the radial and tangential directions. The force transmission between the tire and the road is compatible with the deformation of the tire, which is characterized by the velocity loss coefficient, or the slip coefficient expressed by the following formula [7]:

$$F_x = F_z \cdot \mu(s) .$$

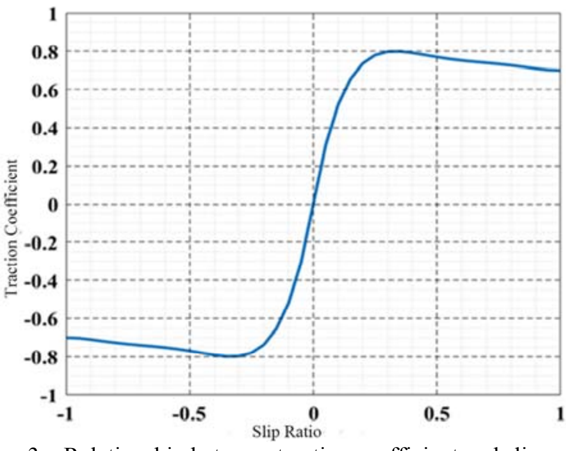

Figure 3 – Relationship between traction coefficient and slip rate [8]

RESULT AND DISCUSSION

The simulation scenario was built by torque distribution between the avtive axles of the electric vehicle. The following fig. 4–6 show the dynamic parameters as acceleration, distance, tires slip rate by time when vehicle moving from rets to velocity 100 km/h. The longitudinal quantity of acceleration process presents in the tabl. 2.

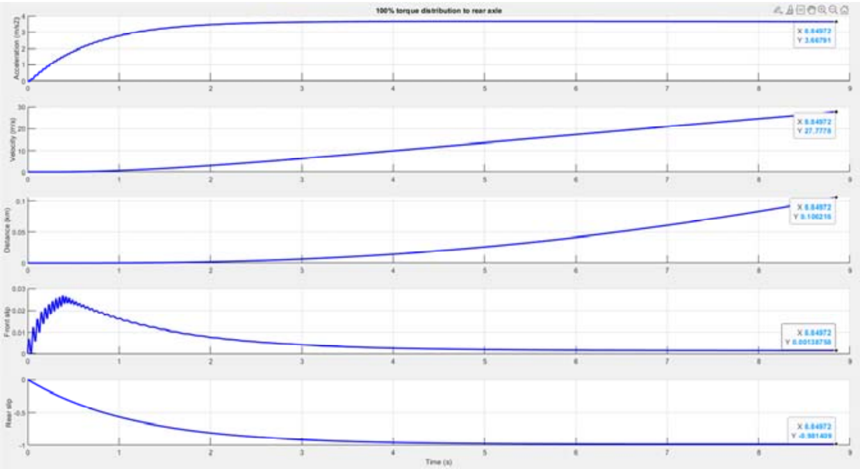

Figure 4 – Vehicle dynamics oscillations on acceleration with torque distribution 0:100

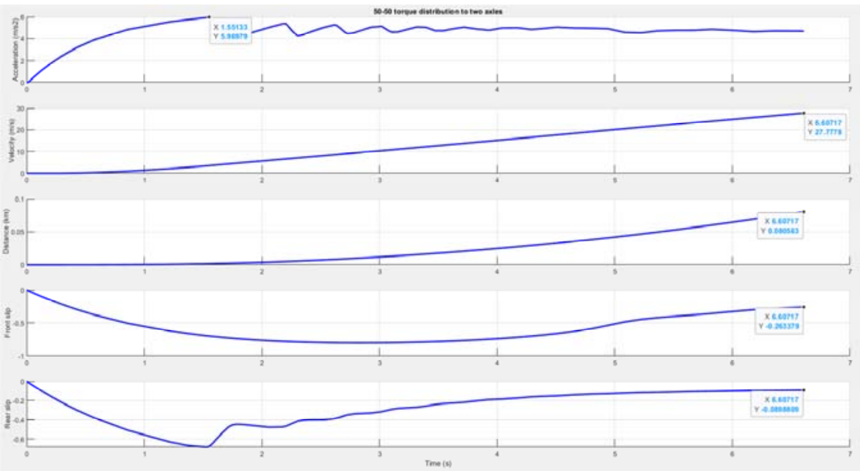

Figure 5 – Vehicle dynamics oscillations on acceleration with torque distribution 50:50

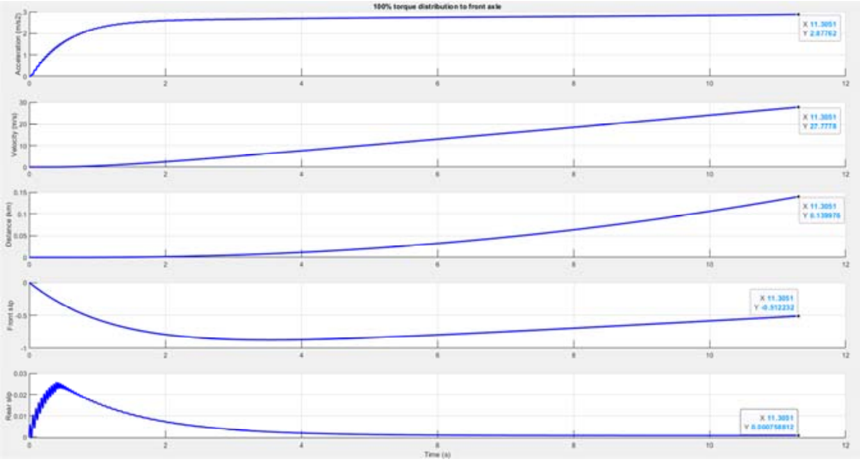

Figure 6 – Vehicle dynamics oscillations on acceleration with torque distribution 100:1

Table 2 – Vehicle dynamics quantity of acceleration process

Dynamics quantity	Torque distribution		
	0:100	50:50	100:0
Time, s	8,85	6,61	11,31
Maximum acceleration, m/s^2	3,67	5,97	2,88
Velocity, m/s	27,78	27,78	27,78
Distance, km	0,106	0,081	0,140

The simulation results in tabl. 2 show that, the vehicle dynamics quantity with the torque distribution 50:50 is better than the other options. The received results accurately reflect the physical laws of the ground vehicle theory.

CONCLUSION

A simulation model of the vehicle longitudinal dynamic on the VinFast VF8 car was successfully built. The developed model can be used for analyzing the vehicle longitudinal dynamics quantity of process as acceleration and deacceleration. The simulation results show that the torque distribution between active axles has a significant impact on the vehicle's dynamic parameters. The vehicle dynamics quantity with the torque distribution 50:50 is better than the other options.

REFERENCES

1. Genta, G. The Automotive Chassis / G. Genta, L. Morello. – Volume 1: Components Design. – Springer, 2009.

2. Rajamani, R. Vehicle Dynamics and Control / R. Rajamani. – Springer Science & Business Media, 2012.

3. Gillespie, T. D. Fundamentals of Vehicle Dynamics / T. D. Gillespie. – Society of Automotive Engineers, 1992.

4. Wong, J. Y. Theory of Ground Vehicles / J. Y.Wong. – John Wiley & Sons, 2008.

5. Milliken, W. F. Race Car Vehicle Dynamics / W. F. Milliken, D. L. Milliken. – Society of Automotive Engineers, 1995.

6. Vinfast : [сайт]. – URL: https://vinfastauto.us/vehicles/vf-8 (дата обращения: 15.05.2024).

7. Vo, V. H. Morden Vehicle Dynamic / V. H. Vo. – Vietnam Education Publishing House, 2020.

8. Crisostomi, E. Hybrid & Electric Vehicles / E. Crisostomi, R. Shorten, S. Stüdli // Electrical and Plug-in Hybrid Vehicle Networks: Optimization and Control. – Florida. – CRC Press, 2018.

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