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Studying the mathematical equations of rotational motion on vehicle by using labview simulation

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Abstract

This article presents a research on simulating the factors that affect the turning motion of a car using the Labview software. As the turning radius of a car requires many factors to be taken into account, such as motion conditions, the deformable characteristics of the elastic suspension hook, and the structural specifications of the car, relying on geometric relationships alone is not sufficient to guarantee the stability of the turning motion. Simulating the turning motion of a car with the Labview Control and Simulation tool therefore offers a more efficient and cost-effective alternative to manual calculations, as it allows for the consideration of all the factors that could affect the geometric relationship of the car and the turning radius.

Keywords: Equation; Labview; Rotational Motion; Cost-Effective

1. Introduction

The stability of a car is affected by various factors such as the weight of the car, the power of the engine, the design of the suspension, the type of tires, the road surface, and the weather conditions. The stability of a car is also affected by the driver's behavior and the type of driving that is being done. In order to evaluate the stability of a car, several tests are performed. These tests include the emergency lane change test, the brake test, the skid pad test, and the emergency steering test. These tests are designed to measure the car's ability to remain stable and to maneuver in emergency situations. The emergency lane change test is used to measure a car's ability to quickly and safely change lanes, without losing control. The test involves the driver making a sudden, sharp turn in order to change lanes. The car's ability to remain stable and to remain in the desired lane is evaluated [1-3].

The brake test is used to measure the car's ability to stop quickly and safely. The test involves the driver accelerating the car to a certain speed and then slamming on the brakes. The car's ability to stop quickly and safely is evaluated. The skid pad test is used to measure a car's ability to handle cornering and remain stable. The test involves the driver driving the car around a circular course at a constant speed. The car's ability to remain stable and to stay on the desired path is evaluated. The emergency steering test is used to measure a car's ability to handle sudden steering inputs. The test involves the driver quickly turning the steering wheel to make a sharp turn. The car's ability to remain stable and to remain on the desired path is evaluated [4-5].

Overall, the stability of a car is an important factor to consider when evaluating the safety and performance of a car. Knowing the car's stability in different driving conditions can help ensure that the car is safe and performs well in all conditions.There are many studies on the rotational motion of car [3] These studies only deal with the forces acting in circular motion. There is a topic that simulates the rotation of cars with GNSS/INS sensors [4] The article focuses on

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calculating the turning radius and lateral acceleration of a vehicle with a maximum weight of 3.5 tons (GVM) and cargo when navigating through curves. The calculation is based on the speed and turning radius of the vehicle. Although stability plays an important role in a car's performance, it is not the only factor to consider. Other important factors include braking performance, acceleration, handling, and suspension. All of these factors should be examined when evaluating the safety and performance of a car. Furthermore, regular maintenance and inspections should be performed to ensure that the car is in optimal condition [4-7].

However, to collect data and simulate the acceleration velocity affects the rotational motion, not much has been mentioned. Starting from that, the author implements the topic "Studying the equations of rotational motion on cars using LABVIEW" [5]. Describing the factors that affect a car's turning motion on a computer can save product development time and deliver reliable results. In addition, use simulation to provide insights into the operation of the system, which is not easily reproducible in a laboratory environment [6-8].

The project begins by studying the equations of motion, determining the parameters that affect the car's turning motion and then building a model of the car's motion. The equations of motion are written in the form of a system of linear equations. The parameters that affect the car's turning motion are the acceleration, velocity, and the radius of the turn. The model uses the LABVIEW software to create a graphical representation of the car's motion. The model is tested by simulating different scenarios of the car's motion. The simulations include varying the acceleration, velocity, and the turn radius. The results are analyzed to determine the effects of the different parameters on the car's rotational motion. The results show that the acceleration and velocity have the greatest effect on the car's rotational motion [9-10].

Finally, the paper discusses the implications of the results for product design. For example, the model can be used to determine the optimal acceleration and velocity for a given turn radius. The model can also be used to identify design problems that may lead to poor vehicle performance.Overall, this paper provides a comprehensive study of the equations of rotational motion on cars using LABVIEW. The study demonstrates how simulation can be used to provide insights into the operation of the system, which is not easily reproducible in a laboratory environment. The results have implications for product design and can be used to identify design problems that may lead to poor vehicle performance.

2. The trajectory of the car's motion

2.1. Motion trajectories of cars in flat model

The rigid car has a planar motion with three degrees of freedom: motion in the direction Cx, Cy and rotation about the axis Cz [11-12]. The Newton-Euler equation for a rigid vehicle in coordinates B mounted on the vehicle is as follows:

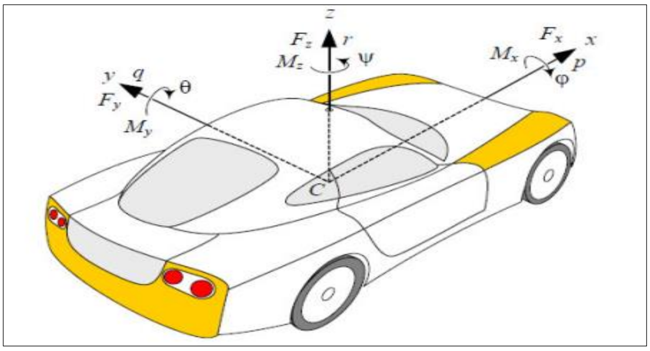

Figure 1 Vehicle moving in the plane

The speed vector of the vehicle is represented on the coordinate system mounted on the vehicle:

$$B_{V_c} = \begin{bmatrix} v_x \\ v_y \\ 0 \end{bmatrix}$$

- v_x : forward component (Cx axis),

- v_y : perpendicular part of v (Cy axis)

The velocity vector in the ground coordinate system is calculated according to the velocity vector in the coordinates attached to the vehicle

$$G_{v_c} = G_{R_B} B_{v_c}$$ ……………(2.1)

We have the transformation vector of the coordinate system in the form of a matrix

$$G_{R_B} = \begin{pmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$ ………………(2.2)

2.2. Theoretical rotational trajectory of the car

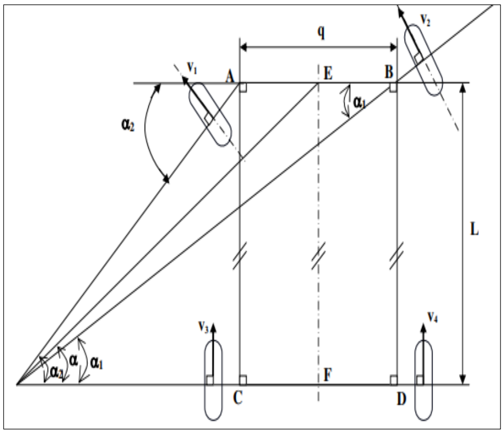

Figure 2 Diagram of the rotational kinematics of a car

On Figure 2, we can determine the relationship between turning radius R, wheelbase L and turning angle.

$$R = \frac{L}{tg\delta}$$ ……………(2.3)

$$x = a + R\cos(t)$$ ……………(2.4)

$$y = b + R\sin(t)$$ ……………..(2. 5)

We will have the theoretical orbital equation for the rotation of the car. The orbital equation for the rotation of a car is given by: angular position of car (θ) = angular velocity (ω) x time (t) + initial angle (θ0)

3. The labview application describes the rotation of the car

The system of differential equations describing the angular displacement and angular velocity of the vehicle body during the rotation of the vehicle is as follows [12]

$$\begin{bmatrix}\dot{\beta}\\ \dot{r}\end{bmatrix}=\begin{pmatrix}-\dfrac{C_{\alpha f}+C_{\alpha r}}{mv_x} & \dfrac{-a_1C_{\alpha f}+a_2C_{\alpha r}}{mv_x^2}-1\\ -\dfrac{a_1C_{\alpha f}-a_2C_{\alpha r}}{I_z} & \dfrac{-a_1^2C_{\alpha f}+a_2^2C_{\alpha r}}{I_zv_x}\end{pmatrix}\begin{bmatrix}\beta\\ r\end{bmatrix}+\begin{bmatrix}\dfrac{C_{\alpha f}}{mv_x}\\ \dfrac{a_1C_{\alpha f}}{I_z}\end{bmatrix}\delta \quad \text{.........................(2.6)}$$

Build a program to calculate the original body rotation β and body rotation angle, with input parameters being the stiffness of the front and rear hooks $C_{\alpha f}$,$C_{\alpha r}$; the mass of the car, the speed of the car when turning, the moment of inertia around the axle Z, and the steering angle δ.

Equation describing the orbit

$$x=\int(v\cos\psi-v\beta\sin\psi)dt \quad \text{............ (2. 7)}$$

$$y=\int(v\beta\cos\psi+v\ \sin\psi)dt \quad \text{...............(2. 8)}$$

With the body deflection and body rotation angles calculated in chapter In Figure 2, we proceed to describe the motion trajectory of the car revolving stably. Window Block Diagram program to simulate the vehicle's trajectory on LABVIEW. The survey vehicle is a four-seater tourist car with guided front-wheel drive and the following parameters that shown in Table 1.

Table 1 Vehicle Input Parameters

Loading mode	**a1 (m)**	**a2 (m)**	**m (kg)**
Not loaded	0,93	1,76	1000
Full loaded	0,93	1,76	2000
Moment of inertia about the axes			
Loading mode	Iyy (kg.m2)	Ixx (kg.m2)	Izz(kg.m2)
Not loaded	2484	512	2743
Full loaded	2969	585	3282
Tire rigidity (N/rad)			
Front wheel	40000		
Rear wheel	40000		

4. Result and discussion

Window Block Diagram program to simulate the vehicle's trajectory on LAB. The program will display a block diagram on the front panel of the system that will simulate the vehicle's trajectory on the lab. It will include a variety of blocks such as a timer, a data acquisition module, a controller, a motor control module, and a display module. The timer will be used to generate a time-based signal that will be used to control the acquisition and control of data. The data acquisition module will collect data from the vehicle's sensors and will send it to the controller. The controller will use the data to generate a control signal that will be sent to the motor control module. The motor control module will use the control signal to control the vehicle's motors and move it along the desired path. Finally, the display module will be used to visualize the vehicle's trajectory on the lab, Show on Front Panel Figure 3.

As shown in Figure 4, enter the three-car survey with the center-to-center distance parameters front axle (a1), the distance from the center of gravity to the rear axle (a2), the stiffness of the front and rear tires in three cars (caf, car) are the same, the car's load (m), the angle of attack driving is the same, we change the speed of each car differently as shown in figure (5.3), run a program to survey the trajectory of three cars. The program will display a block diagram on the front panel of the system that will simulate the trajectory of the three cars. It will include a timer, a data acquisition module, a controller, a motor control module, and a display module. The timer will be used to generate a time-based signal that will be used to control the acquisition and control of data. The data acquisition module will collect data from the vehicle's sensors and will send it to the controller. The controller will use the data to generate a control signal that will be sent to the motor control module. The motor control module will use the control signal to control the vehicle's motors and move it along the desired path. Finally, the display module will be used to visualize the trajectory of the three cars on the lab.

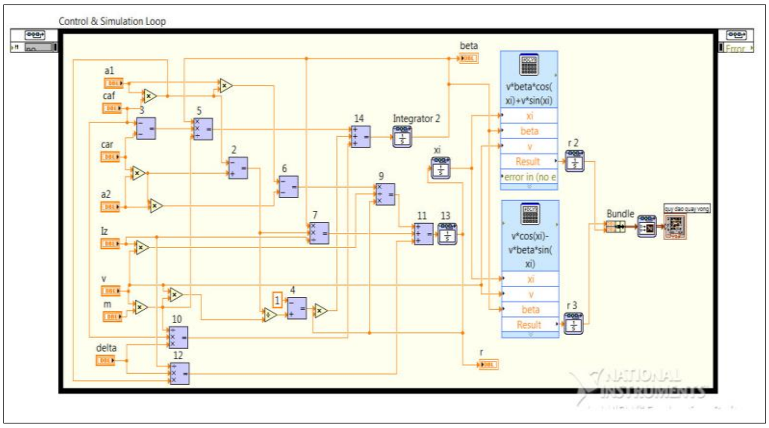

Figure 3 Programmable for rotation trajectory display

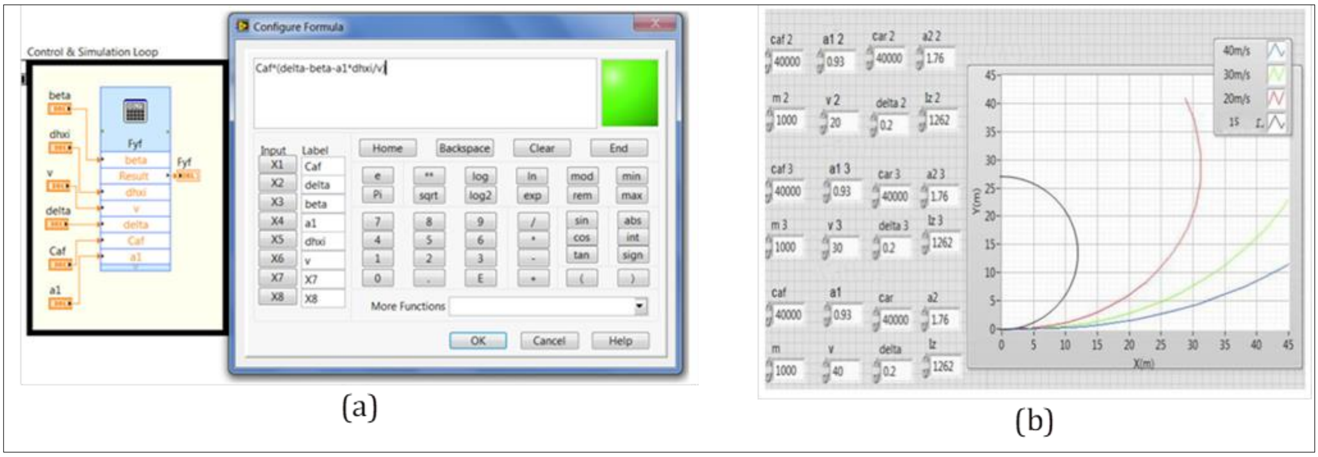

Figure 4 Vehicle Input Parameters

Centrifugal force is proportional to the speed of the car, leading to an increase in the speed of the car, the centrifugal force also increases and vice versa. Therefore, the case of speeding up or slowing down will affect the turning performance of the car in the same way as the load change. However, the speed is a power of two, so it will make the centrifugal force change faster, the turning performance of the car will change faster than changing the load.

5. Conclusion

The program will display a block diagram on the front panel of the system that will simulate the trajectory of the three cars. It will include a timer, a data acquisition module, a controller, a motor control module, and a display module. The timer will be used to generate a time-based signal that will be used to control the acquisition and control of data. The data acquisition module will collect data from the vehicle's sensors and will send it to the controller. The controller will use the data to generate a control signal that will be sent to the motor control module. The motor control module will use the control signal to control the vehicle's motors and move it along the desired path. Finally, the display module will be used to visualize the trajectory of the three cars on the lab. It will also include the parameters a_1, a_2, c_{af}, car, and m as input data to the controller.

Through the presented research contents and results, this paper has met the research objectives set out: Building differential equations describing the motion trajectory of the car through a surveying planar model and learned LabVIEW Control and Simulation tools use in simulate system of differential equations describing circular motion trajectory on a computer.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

All authors contributed positively to the writing of this manuscript and there no conflict of interest as agreed to the content of this research.

Statement of informed consent

Informed consent was obtained from all individuals respondents included in the study.

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