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Traction Control System using Computer Vision based Analysis

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Abstract - *The main forces responsible for braking, accelerating and maneuvering a vehicle are developed at the contact point between the tires and the road as a result of the difference in vehicle velocity and tangential wheel velocities. The normalized difference in vehicle and tire velocity is called slip and determines the magnitude of these tractive forces. The active braking and traction control system is therefore based on controlling the slip to maximize the tractive forces during braking and acceleration. Analysis of the tyre deformation at the contact patch can be related to the torque applied to create the deformation. This torque-deformation relation can be used to control traction. In this project a novel method is introduced to control traction by identifying the strain at the contact patch. Parameters like slip ratio, normal load, coefficient of friction of terrain can be measured. This method is most efficient in electric vehicles. The distinct advantage of the electric vehicle is its quick and precise torque generation. Helps in more accurate traction control system. Conventional traction control system works by attaining optimal slip ratio by calculating it through complex algorithms and calculation. The method described in this paper uses a camera is placed inside tyre and the displacement of the imprinted marks are measured using computer vision which gives strain. Raspberry pi board is used for image vision processing. Measuring the strain and corresponding torque, an algorithm is made for controlling the traction.*

Key Words: Traction, Slip ratio, compressive strain ratio

1. INTRODUCTION

The curves plotted in figure 1.1 and 1.2 illustrates why ABS and TCS increase traction and maneuverability. It is seen that the magnitude of the longitudinal force peaks at relatively low magnitudes of slip ratio thus far from wheel spin or locked wheels. Equally important is that the maneuverability (the lateral friction force) of the vehicle is significantly reduced during wheel spin and is complete lost if the wheels are locked as per Figure 1.2. Preventing this from happening will therefore increase the driving safety.

Slip ratio can be considered as an identification of wheel slip. For controlling the velocity of wheel for regaining traction, it is appropriate to control the applied wheel torque and make it similar to the required wheel torque which would assure traction.

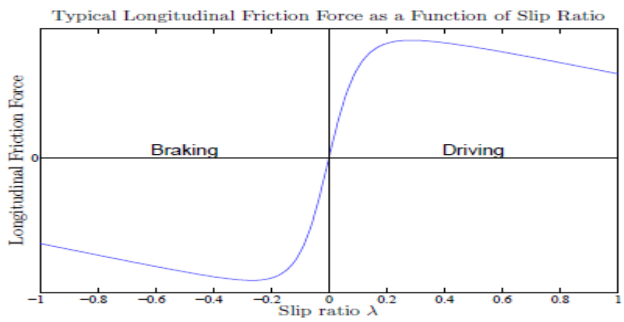

Figure 1.1 Longitudinal Friction Force vs Slip Ratio

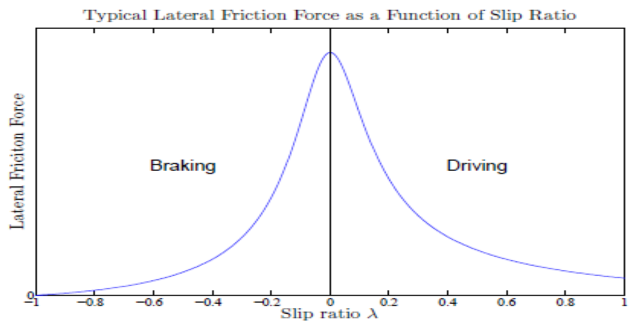

Figure 1.2 Lateral Friction Force vs Slip Ratio

1.1 METHODOLOGY

The novel method introduced in this project for controlling slip is by using the relation between the tractive torque and compressive strain ratio (rcompr), which is given by

$$r_{compr.} = (Ep + Ef)/ (Ep + Eb) \quad (1.1)$$

Ep is the strain in tyre due to the inflation pressure during the expansion. Ef, Eb are the compressive strain at the front and rear portions of the contact patch. Finding the ratio and finding the torque necessary to maintain traction, the traction is controlled. The torque controlling method is not cited in the project.

The parameters are measured using a camera installed inside the tire attached to the rim. Necessary shields are provided to protect electronic components under tire pressure. This camera is focused to two dots on the bottom surface of a tubeless tire and they both (camera and the dots) are relatively stationary at every instant during rotation of the wheel. Any differences in the position of these dots are detected and coordinates obtained are used to measure various parameters.

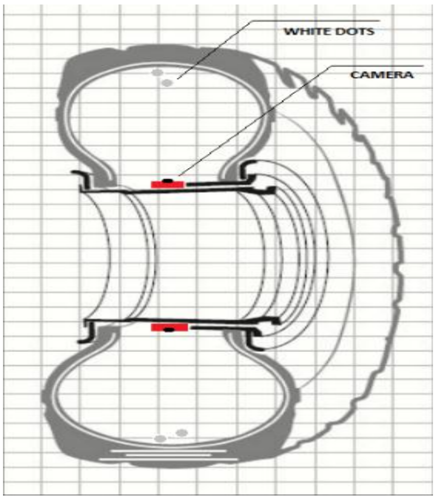

Figure 1.3 Installation of camera inside Tyre

For the testing purpose a rig is made. The availability of data from the contact patch can be measured is assured using the rig.

Relation between compressive strain ratio and torque, rpm and torque are obtained from the FEM model created by MRF tyres for their study purpose. Due to confidentiality, FEM model is not included in the report.

1.2 LITERATURE REVIEW

In vehicle dynamics, all the external forces (apart from aerodynamic forces) are generated at the tire-road interface. To fully understand the dynamics that govern these forces, parameters such as terrain profile, side-slip angle and longitudinal slip are critical. The ability to directly measure these parameters in real-time will aid and improve many drivers assist systems such as ABS and traction control, especially over rough terrain. Optimal torque for traction controlling is an important variable indispensable for some advanced automotive vehicle control systems. However, due to technical and economic reasons, this variable is often estimated rather than directly measured. In existing systems other variables are changed for regaining traction.

Matsuzaki, Todoroki (2008) developed a tire warning system by using measured data from an FEM model. The system can be used to warn the driver in case of loss of traction. The terrain friction coefficient is identified and the slip ratio. A relation between these two is used to find the slipping.

Matsuzaki, Todoroki (2005) developed an intelligent tyre sensing system using strain gauges. The properties are measured by this sensor. A battery less transmitting circuit composed of tuning circuit, transmitter, receiver.

Yi Xiong (2016) developed a multi laser-based tire sensor system to measure the in-plane deformation in tread and carcass part. Parameters like rolling resistance, Tyre forces are measured using the data. Different operational conditions of vertical force, inflation pressure and rotational velocity are considered.

Anderson, Wiben (2012) developed attraction control system for an electric vehicle based on slip measurement. The observer is based on sliding mode control theory and the estimated force is used in the slip controller to increase the robustness to unknown road conditions. The estimate of the friction force is also used to estimate the friction characteristics of the road surface during simulated driving using a recursive least squares algorithm. The estimated friction characteristics permits the calculation of an optimal slip reference to the controller.

Hyde (2014) developed of a traction control system for a parallel-series plug-in hybrid electric vehicle. Using the dynamic plant model, a slip detection algorithm capable of detecting slip on either axle or both simultaneously is developed. The algorithm uses six-wheel speed comparisons to determine the vehicle current slip scenario without requiring knowledge of the current vehicle speed. Next the traction control algorithm was developed to act independently on each axle if slip is detected. The system creates axle torque limits on the outputs of the operating strategy that reduce torque until wheel slip stops and then gradually reapplies the torque until the full driver torque request has been restored with no wheel slip.

Park, Kwak (2015) proposes a new slip controller which uses the brake and the throttle actuator simultaneously. To avoid measurement problems and get a simple structure, the brake controller is designed using Lyapunov redesign method and the throttle controller is designed using multiple sliding mode control. Through the hybrid use of brake and throttle controllers, the vehicle is insensitive to the variation of the vehicle mass, brake gain and road condition and can achieve required acceleration performance. Proposed method is validated with simulations based on 15 DOF passenger car model.

Sakai (1999) developed methods of motion control for an electric vehicle (EV) with four independently driven in-wheel motors. First, they propose and simulate a novel robust dynamic yaw-moment control (DYC). DYC is a vehicle attitude control method that generates yaw from torque differences between the right and left wheels. The results of simulations, however, identify a problem with instability on slippery, low coefficient of friction roads. To solve this problem, a new skid detection method is proposed that will be a part of traction control system (TCS) for each drive wheel. The experimental results show that this method can detect a skidding wheel, without any information on chassis velocity.

2. DRIVING AND BRAKING TORQUES

When driving or braking torque is applied, the ratio between forward and backward compressive strains changes. Braking torque increases the compressive strain in the rear area, E_b, where the rotation angle is positive, and decreases the compressive strain at the forward area, E_f as can be seen in Fig. 2.1. The compressive strain ratio between rear and forward areas is:

$$r_{compr.} = (Ep + Ef)/ (Ep + Eb) \qquad (2.1)$$

Ep is the strain due to inflation pressure. It is the strain occurring during the expansion on inflating.

Figure 2.2 shows calculated strain variation from the sensor at braking torques of 0, 144 and 342 Nm. As braking torque increases, the backward compressive strain increases, while the forward compressive strain decreases.

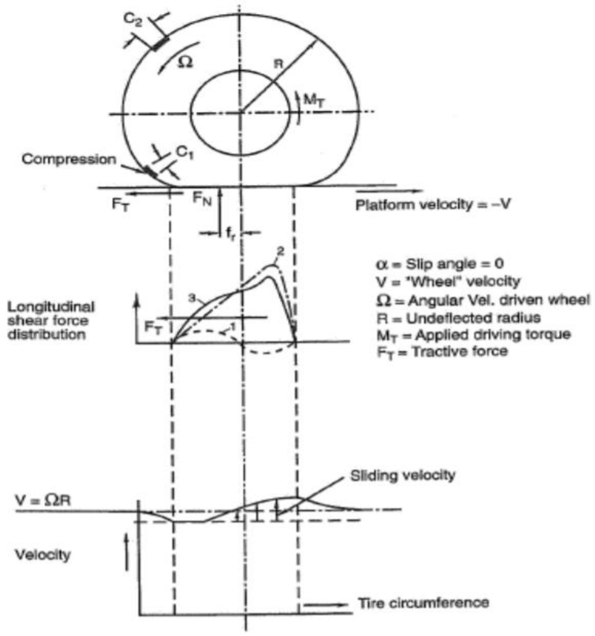

Figure 2.1 Distribution of forces and sliding velocity

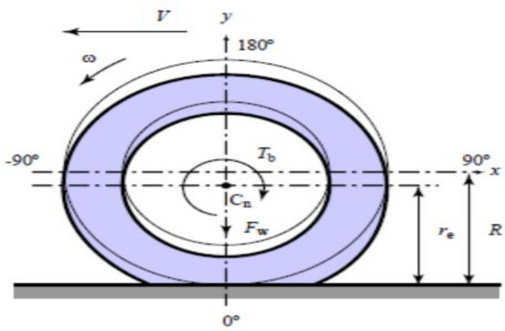

Figure 2.2 Tyre deformation on wheel

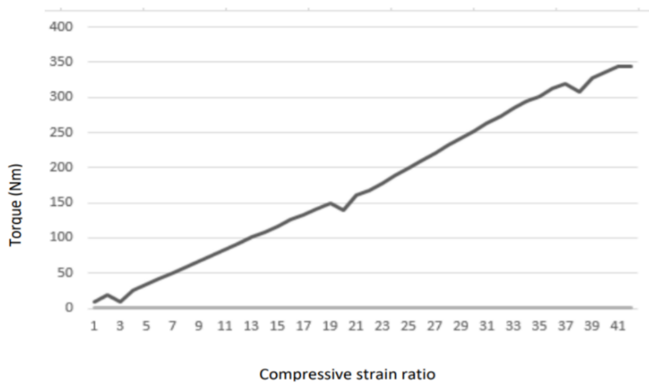

Figure 2.3 Torque in Nm (Y-axis) vs Compressive strain ratio (X-axis)

3. TRACTION CONTROLLING METHODOLOGY

A camera is placed over the wheel inside the wheel pointing towards the contact area. Deformations are identified processing the images generated. Using an optical encoder, the timing of capturing the image is made accurate to capture when the surveillance area is the contact area. In the test rig created the actual motion is generated by moving the terrain for convenience, on applying load on tyre which was discussed earlier. As the tyre is not in motion, use of optical encoder can be avoided in the test rig. But in actual case it is necessary. The charging and data transmitting in actual case is not discussed here. Optical encoders can be installed anywhere on the rotating portion.

The steps in controlling the traction is discussed below

3.1 IDENTIFYING SLIP

The angular velocity of one rear wheel (drive wheel) and corresponding front wheel (not in drive) is measured constantly. The angular velocity is measured by measuring the frequency of image captured. A change in velocity between the tyres corresponds to occurrence of slip in tyre. Strain is measured in the slipping wheel.

3.2 MEASURING STRAIN

Inside the tyre two markings are made for measuring strain as shown in the Figure 3.1. The two marks are symmetrically placed about a horizontal axis which is almost to be the through the centre of the contact patch when tyre is at rest. The distance between the dots are 200mm.

Fig 3.1 Dots made inside the tyre

On rolling of tyre, the longitudinal stress causes compressive strain on both side of the axis, one greater than the other depending on the direction of the rotation. Strain is measured using the equation

$$\text{Strain} = (Y(1) - 100) / 100 \qquad (3.1)$$

Y (1) is the distance of the mark from the reference axis after deformation occurs.

Compressive strain ratio is measured using the relation

$$r_{compr.} = (Ep + Ef) / (Ep + Eb) \qquad (3.2)$$

3.3 COMPRESSIVE STRAIN RATIO

It is measured using the displacement in the marking. If Y(1) and Y(0) are the displacement of each markings, measured from the centre line or horizontal axis

$$R_{compr} = (Y(1) - 100) / (Y(0) - 100)$$

3.4 FINDING OPTIMAL TORQUE

During slipping condition due to the elastic property of tyre, a strain is developed in the contact patch which corresponds to the longitudinal stress at the particular terrain and load conditions. This strain doesn't change when the tractive force exceeds the frictions force and slipping occurs. The corresponding torque is found using the relation between compressive strain ratio and torque. This is the optimal torque that would be applied to regain traction after slipping. This relation is different for different brands of tyres.

3.5 TORQUE CONTROLLING

Torque controlling can be done using many conventional methods. The rpm corresponding to the optimal torque is obtained from the torque vs rpm characteristics of the motor used. Reducing the rpm to required rpm regains traction. The distinct advantage of the electric motors is its quick and precise torque generation. Helps in more accurate torque generation. Identifying the motor used in vehicle, and using corresponding relation the optimal rpm can be found.

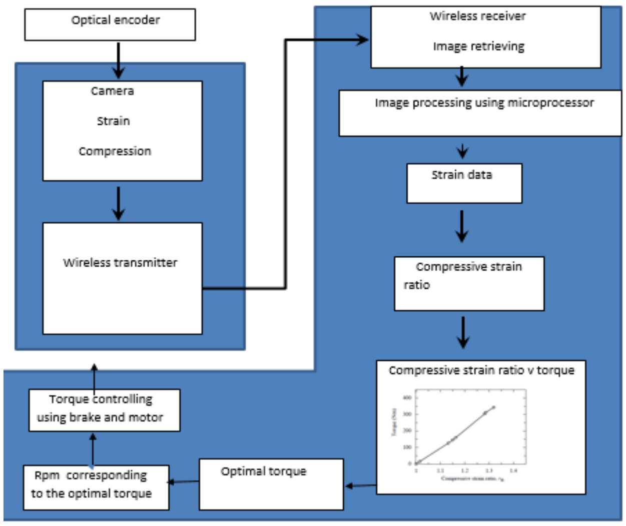

Fig 3.2 Torque control methodology

4. TEST RIG

4.1 FRAME

4.1.1 Construction

A frame that can withstand a load of more than the required load was designed, simulated and then fabricated. It is designed so as to house a standard tyre of a car. 1.5-inch square GI pipe was used for the outer frame. Elements were then arc welded.

Fig 4.1: Test rig frame

4.2 CAMERA INSTALLATION

The camera alone is installed on the wheel for convenience. The output is taken with a flexible printed circuit cable taken between the tyre and wheel. The inflation assures perfect sealing.

Fig 4.2 The pi cam attached over the wheel

4.3 APPLYING LOAD

The quarter model received a weight of approximately 200-250 kg. To load the quarter model a screw jack is used as shown in fig. 4.3

Fig 4.3 Applying load on the tyre

5. SIMULATION AND ANALYSIS

The Matlab model for traction controller is shown in fig 5.1. This model is used for simulation. The simulation is show in fig. 5.2

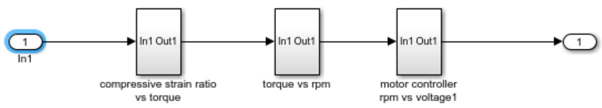

Fig 5.1 Model for traction controller

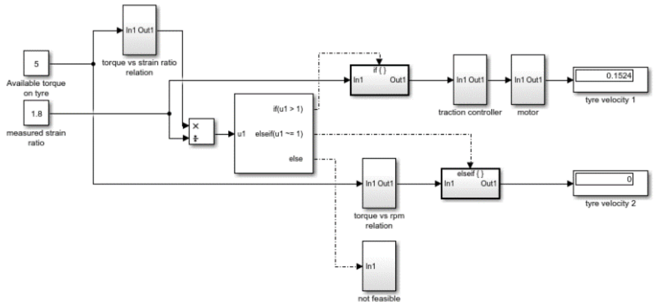

Fig 5.2 Simulation of a real condition

The inputs of simulation are the measured strain value and torque available in tyre. The two conditions of traction are defined in the simulation. It is checked by comparing the strain produced (measured) and the strain measured from torque strain relation. The controlled velocity after torque correction is shown as tyre velocity 1. If slip does not occur, the velocity is shown in tyre velocity 2.

6. CONCLUSION

The torque to be delivered to the wheels in order to maintain the optimal traction at the contact patches can be calculated implementing the described method. And the applied torque to the wheels can be controlled to match this optimum torque by varying the rpm.

REFERENCES

[1] Andersen, M. H. and Wiben, R. (**2012**). Design of slip based active braking and traction control system for the electric vehicle, Hindawi Mathematical Problems in Engineering.

[2] Bakwill, J. (**2017**). Perfomance Vehicle Dynamics, Butterworth-Heinemann, First Edition.

[3] Bastiaan, J. M. (**2015**). Design of a smart tire sensor system, SAE International.

[4] Gillespie, T. D. (**2013**). Fundamentals of vehicle dynamics, SAE International, Fourth Edition.

[5] Hyde, A. N. (**2014**). Development of a traction control system for a parallel series PHEV, University of Ohio.

[6] Matsuzaki, R. and Todoroki, A. (**2008**). Intelligent tires based on measurement of tire defomation, Journal of Solid Mechanics and Materials Engineering Vol2.

[7] Milliken, F. W. (**2015**). Race Car Vehicle Dynamics, SAE International, Sixth Edition.

[8] Park, Y. and Kwak, B. (**2015**). Slip controller design for traction control system, International Journal of Automotive Technology.

[9] Sado, H. and Hori, Y. (**1999**). Motion control in an electric vehicle with four independently driven in wheel motors, IEEE/ASME Transactions on Mechatronics, Vol. 4, no. 1.

[10] Wiegand, B. P. **(2015)** Notes on tire behaviour, 74th Annual International Conference of the Society of Allied Weight Engineers, pp 8-37.

[11] Xiong, Y. (**2016**). In plane tire deformation measurement using a multi laser sensor system, Doctoral Dissertations 89

[12] (https://en.wikipedia.org/wiki/computer_vision) accessed on 12 June 2019

[13] (https://en.wikipedia.org/wiki/open_cv) accessed on 12 June 2019