Fuzzy Logic Based Adaptive Traction Control System

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***Abstract*—significant role is played by traction control system (TCS) in road vehicles, because slip occurs during driving on wet road or snowy surface. However, it is very dangerous to drive on the icy or snowy road without traction control system, because in that condition the vehicle can lose its path. In such condition, to control a vehicle is very difficult task for drivers. Drivers can regulate easily the traction torque of vehicle driving on difficult surface by using TC system. It also makes our journey safe. Owing to such system high way automation system can be made safer. In high way automation system it plays very crucial role as well. Therefore, TCS estimates the slip of each wheel and distribute traction torque between the wheels. Thus, it makes better the longitudinal performance of a given vehicle. In simulation it is analyzed that traction control system plays important role in road vehicles. So, there are four different cases of traction torque distribution shown while driving on different road conditions. Therefore, traction torque is distributed with respect to the slip of each wheel. In case of increasing slip in either of the wheel the traction torque will be distributed accordingly. Actually, in the given system a torque is distributed corresponding to the slip of each wheel. When a wheel loses its traction then traction control system activates and minimizes the torque of the given wheel. In contrast, it will involve maximum traction torque to opposite wheel. Similarly, it can be observed that traction torque will be reduced to the wheel which is spinning. Control system will observe the whole phenomenon of slip and distribute traction torque either high or low according to the value of slip. However in this research work cost effective and very simple techniques are adopted.**

***Index Terms*—Adaptive Traction Control system, Fuzzy Logic, slip, Traction Torque.**

I. Introduction

We are familiar to word traction which means the interaction between road surface and wheels of vehicle, without interaction we cannot be able to drive a vehicle [1]. It is a fact that if grip is lesser than slip is greater [2]. Thus, ATC system provides help that how should slip be reduced and driving be improved [3]. In past, drivers made use of gas pedals to avoid the slip of wheels but now a days electronic control systems are applied for the similar purpose [4]. The main aim of TC system is to make acceleration further better when more than desire slip occurs [5]. However, if condition of excessive slip occurs then system will automatically switch to controller, and it will operate in traction control mode [6].

In accordance with an international report, 90 percent accidents occur due to human error and less than 10 percent due to various mechanical faults [7]. In this regard TC ensures the safety of passengers on the worst road conditions [8]. In the report of National high way traffic safety administration (NHTSA), thousands of human lives can be saved by using TC system alone, in America such a system prevents many accidents in a year [9]. Therefore, it is necessary to develop such a vehicle system to make drivers, passengers life safer and comfortable. Thus, TC systems not only provide safety but also a comfortable journey[10].

Traction control (TC) system is an essential electronic control system, which provides help during driving on rough surfaces [10]. So, it will distribute a traction torque in accordance with slip of each wheel [4]. Again, if traction is lost by a wheel then automatically decrease traction torque to a wheel [7]. Besides, it will speed up the traction torque to the wheel on opposite sides [9]. Moreover, the TC system provides protection from slip while starting a vehicle on snowy or wet road surface [10]. In addition to, it decreases torque of traction to spinning wheel [10]. TC also detects slip of wheel during acceleration then it will decide about the distribution of traction torque for each wheel [11].

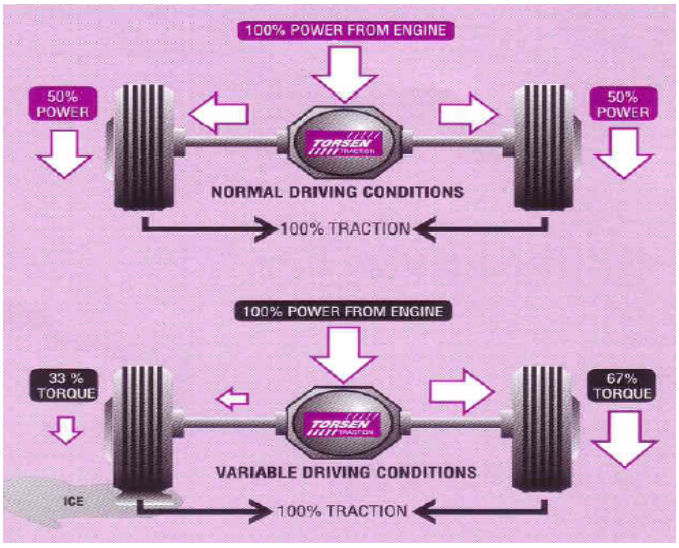

Fig. 1: distribution of torque according to slip of each wheel.

Due to, irregular surfaces of road it is very difficult task to design (TC) system, because of different values of wheel slip. Fuzzy logic controller is useful and essential approach towards the design of TC system. It is already discussed that slip is nonlinear function of velocity of wheel rotation and vehicle. This research paper focuses on an adaptive traction control

system using fuzzy controller that will provide friction torque on the basis of each wheel slip ratio.

II. MATHEMATICAL MODELLING AND SYSTEM ANALYSIS

Half vehicle model is classified in to three different categories; such as, Quarter vehicle model, half vehicle model, and full vehicle model. But in this research work we worked on half vehicle model. In half vehicle model we focused two major dynamics of vehicle: longitudinal dynamics and wheel rotational model. Half vehicle model consists of mass of vehicle and two wheels. And, tyre is connected to road with a spring but sometimes we use a damper to show dynamics of model.

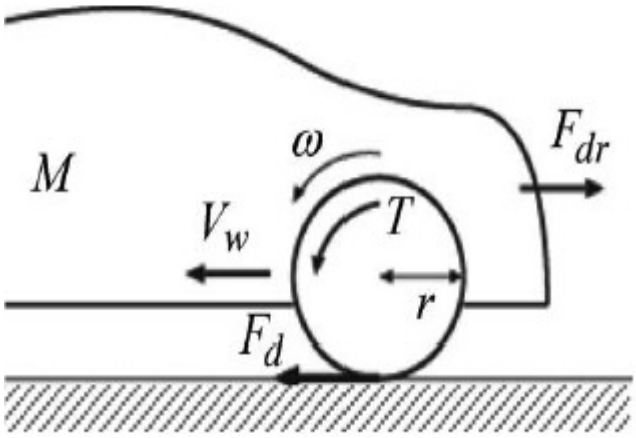

Fig. 2: Half vehicle longitudinal Model

Pacejka magic formula is applied for implementation of model of tyre. Generally given formula is used to describe the characteristics of tyre forces which are nonlinear. However, it is more useful and suitable for the purposes of simulation. Longitudinal frictional coefficient ( ) used in Pacejka magic formula is given below:

$$\mu_x = a(1 - e^{-b\pi} - c\pi$$

(1)

Where:
a, b, c = road friction coefficient
π = wheel slip

Main Equations of Vehicle Model are:

1) Velocity equation

$$mv = F_{xR} + F_{xL}$$

(2)

Where:

m = mass of vehicle
v = longitudinal velocity

$$F_{xR}, F_{xL}$$

= longitudinal forces of both left and right tyre

2) Right tyre angular rotation equation is given as

$$J_R \dot{\omega}_R = RF_{xR} - T_t \quad (3)$$

Where:

J_R = Inertia of right tyre
$\dot{\omega}_R$ = Angular speed of right tyre
R = Radius of wheel
T_t = Traction torque of tyre
F_{xR} = Longitudinal force of right tyre

3) Left tyre angular rotation equation is given as

$$J_L \dot{\omega}_L = RF_{xL} - Tt \quad (4)$$

Where:

J_L = Inertia of right tyre
$\dot{\omega}_L$ = Angular speed of right tyre
R = Radius of wheel
T_t = Traction torque of tyre
F_{xL} = Longitudinal force of left tyre

List of notations is given in the following table:

Parameter	Name	Value
Ω	Rotational Speed	Output Signal
N	Linear Speed	Output Signal
J	Inertia	1 Kg m^2
R	Wheel Radius	0.32 m
T_t	Traction Torque	Input Signal
F_x	Longitudinal Force	Calculated
Λ	Longitudinal Wheel Slip	Calculated
F_z	Vertical Force	Calculated
μ_x	Road Friction Coefficient	Calculated
M	Half Vehicle Mass	900 Kg
G	Gravitational Force	9.81 ms^{-2}

III. SIMULATION AND DISCUSSION

There are two sub blocks in this simulation where one shows the left wheel and other block shows right wheel of vehicle. These two blocks are connected with block of fuzzy logic controller as shown in figure (3)

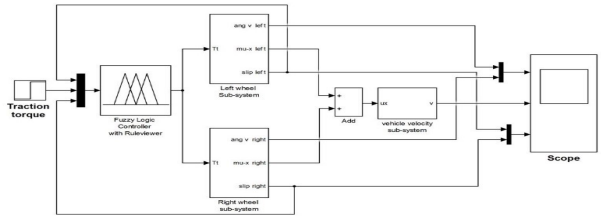

Fig. 3: Simulation of model with Fuzzy Controller.

IV. RESULTS

Case 01 When slip of both left and right wheel is high
Low traction torque is provided equally between each tyre by controller when the slip of both wheels is high as depicted in figure A.

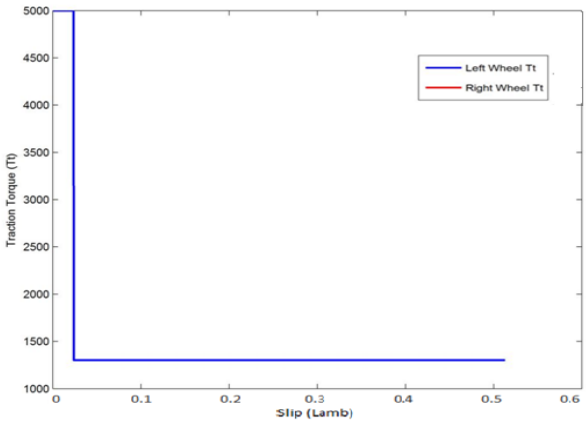

Fig. 4: A slip of both wheels is high.

Case 02 When slip of both left and right wheel is low
High traction torque is distributed equally among each tyre by the controller when slip of both wheels is low as shown in figure B.

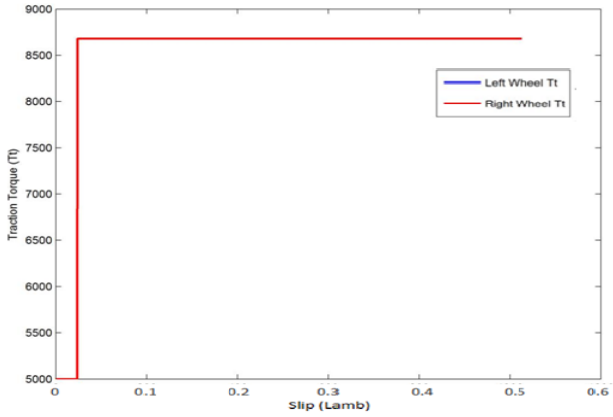

Fig. 5: slip of both wheels is low

Case 03 When the slip occurs high in right wheel and low in left wheel

Controller will distribute low traction torque to the wheel in which high slip occurs and high traction torque to the wheel in which low slip occurs as depicted in figure C.

Case 04 When the slip occurs low in left wheel and high in right wheel

Controller will distribute high traction torque to the wheel in which low slip occurs and low traction torque to the wheel in which high slip occurs as depicted in figure D.

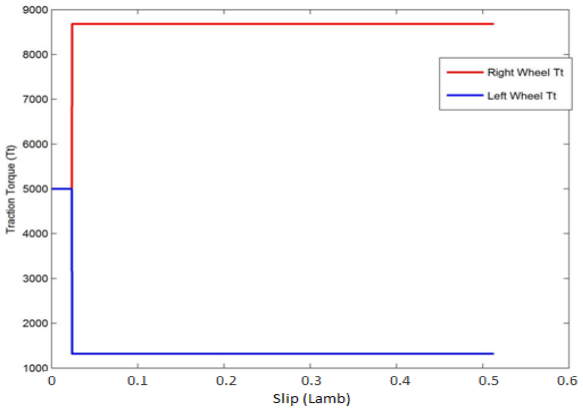

Fig. 6: slip of left wheel is high and slip of right wheel is low

V. CONCLUSIONS

The problem of vehicle traction plays an important role in vehicles. We have knowledge that slip is major issue due to which accidents occur frequently. Therefore, this desired

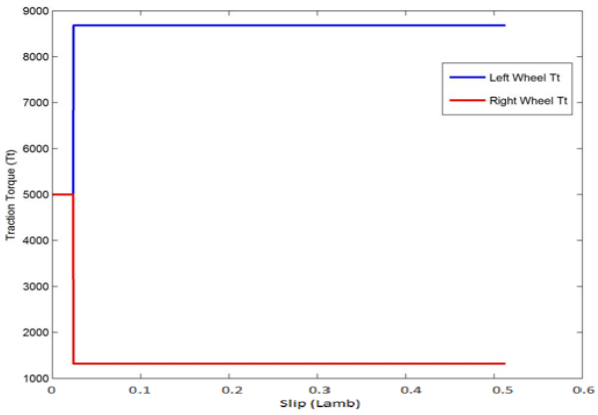

Fig. 7: slip of left wheel is low and slip of right wheel is High

Adaptive TC system will provide protection from accidents and guarantees safe driving as well. In this system, controller will automatically distribute traction torque depending on the separation of the obtained slip value. However, in this research work slip is measured through difference between wheels linear and angular velocity using pacejka formula. Here, no any sensor is used for measuring slip. Simulation results shows that how traction torque is distributed accordingly to slip ratio of each wheel. Fuzzy controller will decide about the distribution of traction torque. Thus, such a technique is very useful and cost effective because of no use of sensors.

VI. FUTURE WORK

It is worthwhile to work on adaptive traction control systems and its advanced dimensions. Moreover, in future work a half model can be modified to full vehicle model. To simulate four wheels of vehicle model it is recommended that in future we will also develop a combined engine torque and brake torque regulation Adaptive TC system. Similarly, it is very essential to make practical use of Adaptive TC system and prove its advantages.

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