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ACTIVE FRONT STEERING FOR PASSENGER VEHICLE USING FUZZY PID METHOD

MOHD SAIFUL BIN MD. SUKARDI

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Mohd Saiful Bin Md. Sukardi

Master of Mechanical Engineering (Automotive)

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MOHD SAIFUL BIN MD. SUKARDI

A report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this report entitled "Active Front Steering For Passenger Vehicle Using Fuzzy PID Method" is the results of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Mohd Saiful Bin Md. Sukardi

Date : 18 April 2017

APPROVAL

I hereby declare that I have read this master project report and in my opinion this report is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Automotive).

Signature : .....

Supervisor : Dr. Mohd Khairi Bin Mohamed Nor

Date : 18 / 4 / 2017

DEDICATION

This final year master project report is dedicated to my beloved mother,

Mrs. Amidah Binti Mohd Ali and the revered father, *Mr. Md. Sukardi Bin Hashim*

and also to my siblings,

Shafina Binti Md. Sukardi, Normazila Binti Md. Sukardi and *Norazian Binti Md. Sukardi*.

My beloved wife

Nor Suraya Binti Mohamad

and also to my son,

Muhammad Sufi Syahmi.

Not to be forgotten also to my main supervisor,

Dr. Mohd Khairi Bin Mohamed Nor

for the support, encouragement and prayers from all of the peoples that involved directly or indirectly from the project start until it is success along the final project study development process.

ABSTRACT

This master project report for this final year project is about improving handling behaviour of passenger car by using active front steering. Active Front Steering (AFS) is a newly developed technology for passenger cars. It provides an electronically controlled superposition of an angle to the hand steering wheel angle that is prescribed by the driver. This additional degree of freedom enables a continuous and driving-situation dependent adaptation of the steering characteristics. At the heart of the new Active Steering system is the planetary gear set integrated into the steering column. An electric motor in the joint adjusts the front wheels' steering angle in proportion to the vehicle current speed. This active steering is evaluated by simulating different steering inputs. The active steering solution must be implemented in Matlab/Simulink. A vehicle model is also implemented in Matlab/Simulink. This master project fo cuses on comparison on both two systems: a conventional vehicle for passenger vehicle and a controlled vehicle. Simulation is made for a constant speed and a specific changeable road adhesion coefficient. The motivation for this work is to understand and characterize the response of a vehicle with a complementary steering system. Improved stability is obtained for the passenger vehicle due to side wind disturbances or slippery road driving. A passenger vehicle tends to lose its dynamic mobility when cruising on the roads that have side wind disturbances. This is due to the effect of the side wind force that reacts at the center of the vehicle body, which creates an unwanted yaw moment at the vehicle's center of gravity. In order to enhance the mobility performance of the passenger vehicle, a control strategy, i.e. yaw rejection control, is designed and test on a passenger vehicle model. The purpose of the control strategy is to maintain the directional mobility of the passenger vehicle by providing a steering correction angle to the pitman arm steering system. The control strategy proposed in this study consists of two main structures: yaw rate feedback control using a Proportional-Integral-Derivative (PID) controller using an adaptive Fuzzy-Proportional-Integral-Derivative (Fuzzy-PID) controller. The simulation results in terms of yaw and lateral motions were observed, and the proposed control strategy was shown to successfully improve the directional mobility of the passenger vehicle after cruising on the side wind road. The benefit of the proposed control strategy with Fuzzy-PID control is evaluated by comparing its performance to PID and Fuzzy-PID control strategies. Vehicle dynamic controls will continue to deliver safer, more pleasing products to consumers at greater value.

ABSTRAK

Laporan projek sarjana ini adalah untuk projek tahun akhir yang menjalankan penyelidikan mengenai kaedah untuk meningkatkan sistem pengendalian kereta penumpang dengan menggunakan 'Active Front Steering' (AFS). 'Active Front Steering' (AFS) adalah teknologi yang baru dibangunkan untuk kereta penumpang. Ia menyediakan kawalan tindihan secara elektronik dari setiap sudut pengawalan pemanduan melalui stering tangan yang ditetapkan sendiri oleh pemandu. Darjah sudut pemacuan bagi tahap kebebasan tambahan ini membolehkan adaptasi kebergantungan yang berterusan semasa memandu yang memberi nilai tambahan kepada ciri-ciri stering. Pusat pemacuan bagi sistem stering aktif pemacu depan ini mempunyai set gear planet yang bersepadu diletakkan ke dalam ruang pemacuan gear steering. Motor elektrik yang diletakkan di dalam gear penisbahan steering akan menyesuaikan sudut stereng roda depan yang berkadaran dengan kelajuan kenderaan semasa sedang memandu. Stering aktif pemacu depan ini dinilai oleh simulasi input stereng berbeza. Penyelesaian stering aktif mesti dilaksanakan di dalam Matlab / Simulink. Model kenderaan juga dilakukan di dalam Matlab / Simulink. Projek sarjana ini memberi tumpuan kepada perbandingan di kedua-dua sistem: kenderaan konvensional seperti kenderaan penumpang dan kenderaan yang mempunyai sistem kawalan steering aktif. Simulasi dibuat untuk kelajuan tetap dan untuk pekali lekatan jalan tertentu yang boleh berubah-ubah. Motivasi untuk kerja-kerja sarjana ini adalah untuk memahami dan mengenalpasti ciri-ciri respon kenderaan dengan sistem stereng aktif yang dipasang. Kestabilan pemanduan yang lebih baik telah diperolehi bagi kenderaan penumpang disebabkan gangguan angin lintang atau memandu di jalan yang licin. Kenderaan penumpang cenderung untuk hilang kawalan dinamik kenderaan apabila memandu di jalan yang ada angin lintang. Ini adalah disebabkan kesan daripada daya angin lintang yang bertindak pada pusat badan kenderaan yang akan menyebabkan daya momen rewang yang tidak dikehendaki pada pusat graviti kenderaan. Di dalam langkah untuk menambahbaik kawalan pemanduan pada kenderaan penumpang iaitu dengan strategi kawalan seperti contoh dengan menggunakan kawalan penghapus rewang di reka dan di uji pada model kenderaan penumpang. Tujuan strategi kawalan di dalam pembelajaran ini mengandungi dua struktur utama iaitu: kawalan maklum balas kadar rewang menggunakan kawalan 'Proportional-Integral-Derivative' (PID) menggunakan kawalan adaptasi 'Fuzzy-Proportional-Integral-Derivative' (Fuzzy-PID). Keputusan simulasi di dalam terma rewang dan pergerakan sisi mendatar di pantau dan cadangan strategi kawalan di tunjukkan untuk menjayakan pembaharuan arah mobiliti pada kenderaan penumpang semasa memandu di jalan yang mempunyai angin lintang. Kelebihan strategi kawalan yang dicadangkan dengan kawalan 'Fuzzy-PID' di nilai dengan membandingkan prestasi srategi kawalan 'PID' dan 'Fuzzy-PID'. Kawalan dinamik kenderaan akan berterusan memberikan keselamatan, produk yang menyenangkan pengguna pada nilai produk yang tinggi.

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LIST OF ABBREVIATIONS

3D	-	Three-dimensional
ABS	-	Antilock braking system
AFWS	-	Active front wheel steering system
DAQ	-	Data acquisition
DC	-	Direct current
DoF	-	Degree of freedom
EPS	-	Electronic power steering
PID	-	Proportional, integral, and derivative
SISO	-	Single input single output

LIST OF SYMBOLS

F_w	-	Side wind force
L_w	-	Distance side wind force to body centre of gravity
a	-	Distance between front of vehicle and *C.G.* of sprung mass
b	-	Distance between rear of vehicle and C.G. of sprung mass
t	-	Track width
δ_f	-	Front tyre angle from horizontal axis
a_x	-	Longitudinal acceleration
a_y	-	Lateral acceleration
β	-	Side slip angle
v_x	-	Lateral velocity
v_y	-	Longitudinal velocity
r	-	Yaw motion
G	-	Body centre of gravity
F_{xfl}	-	Longitudinal force for front left corner
F_{xfr}	-	Longitudinal force for front right corner
F_{xrl}	-	Longitudinal force for rear left corner
F_{xrr}	-	Longitudinal force for rear right corner
F_{yfl}	-	Lateral force for front left corner
F_{yfr}	-	Lateral force for front right corner

F_{yrl}	-	Lateral force for rear left corner
F_{yrr}	-	Lateral force for rear right corner
F_z	-	Vertical force
I_x	-	Moments of inertia of the sprung mass around x-axes
I_y	-	Moments of inertia of the sprung mass around y-axes

CHAPTER 1

INTRODUCTION

1.1 Project introduction

For the introduction of this project, firstly it will describes the general overview on the information related to the topic for active front steering and modelling along that connected with the project objectives. Brief literature is reviewed in this section, linking relevant topics to the research presented here. Finally an objective of the study and a brief description in problem statement are also presented. As for electronic controls in automotive has been evolved and spread from power to the body of the car and the technology has been evolvedwith time move on. The vehicle systems such as active suspension, antilock braking system, traction control and active steering for all of the active systems that have been evolve and develop on that want to improve a vehicle on handling system, vehicle stability and also the safety of the vehicle. All of the disturbances while braking forces, cornering and side wind disturbances makes the vehicle become in unstable conditions on the vehicle while driving. The active steering system will be greatly increased in use because of the performance on the vehicle stability system that equipped due to the increasing of the vehicle active system for such as suspension, antilock braking system, traction control and active steering and other capabilities that suitable to be control.

All of four tires must always in contact with the road surface to ensure the vehicle stability become improved on handling systems. If we looks more further,the improvement on vehicle handling and with ultimately ride experience will associated friction between the mediums that also plays a role in automotive technology. A uniform grip on the road must always contact with the road at all time while driving for four tires on a vehicle to be more stable. In conditions that will prevent success or developmentof this system is when the vehicle travel on the road condition that have water or loose gravel on the road because one or more tire may lose grip while driving because the vehicle will behave in the most erratic manner that will make the vehicle will twist and turn by itself and can cause skidding.

Recently the research in steering control is expanding rapidly with researches from all over the world with the different controller strategies. The main factor to improve the steering controller is to improve handling and vehicle safety for the vehicle to make sure that the enjoyment in driving experience. There is a lot of analysis in the vehicle dynamic system on the steering and the controller itself but for the improvement that achieve on it still difficult for us to rate the improvements.

The study of this research will develop a steering control solution and will be analysed using single track mathematical model with Fuzzy-PID logic controller strategy. A complementary for the steering control system on front-steered vehicle to be working efficiently we need to add or throw away a components that will give the signal for steering input that perform the move by the driver and the will give the output signal that will be evaluate within the suitable parameter according to the rules that have been creates. The angular movement on the steering wheel will be move from the driver and it will be the steering input signal. The component on the steering wheel will perform a move by the driver and then will resulting the steering angle that thus composed by the component that

will contributed on the steering system. Thus the input of the system came from the front wheel angle of the driver. There are many types of control strategy can be done to attenuate the final output whether using conventional controller such as PID or new controller strategy as Fuzzy-PID control. In this study, to control the active front steering system we have use Fuzzy-PID controller to overcome the road situation. The task for the project is to make a steering aid system and then implement the steering aid system that can help the driver to cruising when have the disturbance such as side wind disturbance.

1.2 Objective

The objective of the studies is to investigate and enhance the performance of an active front steering for yaw disturbance rejection control which has the capability in improving the desired travel direction of passenger vehicle due to side wind disturbance.

1.3 Scope

The scope for this project is shown below:

- Development of Vehicle Handling Model
- Develop Active Front Steering Model
- Performance evaluation

1.4 Problem statement

Road is known as the largest transportation system in the any country. Many dangerous situations and expected event may occur on the roads because the driver cannot

act fast enough at the beginning of skidding or rollover. Young and inexperienced driver have high tendency to over react on the unexpected condition during driving. Those reaction may occur an accident to the driver cause by instability of the car that controlled by the driver. The survey done by International safety committee found that 40% of the accident occurs from the loss of control by the driver during extreme condition. The condition of the road is the major factor that will influence the car especially for the tire. If the road condition is slippery and wet, it may increase the accident risk due to lack of the tire friction and it may cause the driver to lost control of the car and the steering system become unstable. The disturbance may come from wind gust disturbance and double lane change that need for controller to assist the driver to overcome those disturbances. The controller design must be able to overcome the instability within driver reaction time and reduce the time for system to achieve steady state condition. Usually for currently car without active front steering (AFS) will hard to control the car especially when driving with side wind force disturbance. This situation gives the unwanted yaw to the car. The driver will overcome the unwanted yaw by controlling the steering angle. This situation was r educing the car comfortable. For the new dimension in driving comfort due to handling and safety while driving, active front steering will give precision, agility and comfort in every driving situation on the road that you will experience.

1.5 Project Overview

For the overview of this study that want to makes active front steering using fuzzy PID controller for the passenger vehicle that want to make the vehicle more controllable so we must study and know the behavior of the vehicle dynamic and steering relation of function and what could go wrong when we are driving on the side wind disturbances.