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UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL & AUTOMOTIVE ENGINEERING TECHNOLOGY

BHA4224: Automotive Engineering

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Lane Changing

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1.0 Introduction

1.1 Advanced Driver Assistance System (ADAS)

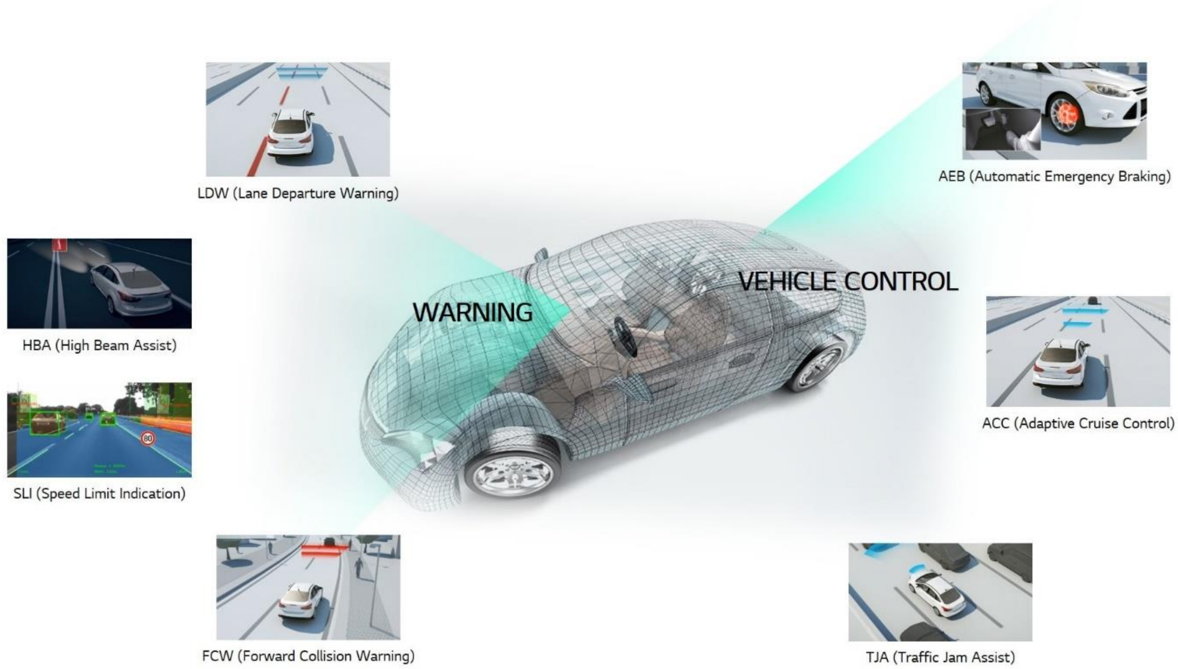


Figure 1.1: Advanced Driver Assistance System (ADAS).
(Source: https://www.lg.com/global/mobility/press-release/lg-to-supply-next-generation-adas-cameras-to-premium-german-automaker)

Figure 1.1 shows the Advanced Driver Assistance System (ADAS) in modern passenger vehicle nowadays. As shown in the figure above, the ADAS gives the features of Lane Departure Warning (LDW), High Beam Assist (HBA), Speed Limit Indication (SLI), Forward Collision Warning (FCW), Automatic Emergency Control (AEB), Adaptive Cruise Control (ACC), and Traffic Jam Assist (TJA). Advanced driver assistance systems (ADAS), which are intended to reduce or prevent crashes in passenger vehicles, are changing how we drive. Given the over 37,000 traffic fatalities recorded in the US in recent years, there is mounting evidence that ADAS are successful in lowering crash rates [1]. However, in order for society to fully benefit from ADAS's improvements to highway safety, drivers must not only embrace their vehicles' ADAS features but also comprehend their advantages and disadvantages in order to properly manage them. [2], [3].

Vehicle crashes can be reduced using ADAS. Forward Collision Warnings (FCW) on vehicles resulted in fewer and less serious collisions [4], yet the best results were seen in vehicles having both FCW and Automatic Emergency Braking (AEB) systems [5]. When combined with

AEB, FCW reduced rear-end struck crash rates in passenger cars by 50%, compared to 27% for FCW alone [6]. AEB also decreased crashes involving large trucks by more than 40% [7]. Blind spot monitoring [8] and cross-traffic alerts [9] also decreased collisions. This evidence demonstrates that ADAS technologies have the potential to significantly improve public safety.

Due to ADAS's limitations, automation must be under supervision. However, in subsequent NTSB-investigated crashes, the automation was found to have failed when the driver was not supervising it. Tractor-trailers crossed the path of the car in two of the tragic collisions, but neither the Level 2 ADAS nor the driver used the brakes [10]. These crash investigations are in line with a meta-analysis's conclusion that greater automation is linked to worse driver recovery from a system breakdown [11]. According to a recent study, owners of cars with adaptive cruise control (ACC) were no more knowledgeable about the system's limitations than non-owners [12]. Inadequate conceptual understanding of ADAS may deter drivers from investing in ADAS-equipped cars, deter drivers from using ADAS in their cars, and deter drivers from supervising ADAS in their cars.

1.1 Lane Changing Accidents

Figure 1.2: Accidents in Malaysia.
(Source: https://www.goodymy.com/mind50109276)

Based on Figure 1.2, there were few accidents that happened in Malaysia due to unsafe lane changing. According to study conducted by Confused.com, Malaysia was recently classified as the eighth most stressful country to drive in, and Malaysians shouldn't even bother trying to defend themselves. They are all aware that driving on Malaysian roads requires a very high level of tolerance and patience to deal with all the irritating things local drivers do. [13] From 2010 through 2019, the Ministry of Transportation recorded a constant rate of traffic accidents, with more than 6,100 fatalities in 2019. Malaysia's Movement Control Order reduced accidents in 2020 and 2021, although they were remained alarming. The statistics of accidents show us something very important: we must concentrate on preventing accidents because they can lead to fatalities, serious injuries, mental stress, and financial loss. External or environmental factors, including adverse weather, which are outside of our control as drivers, contribute to many accidents. However, subjective risks, or mistakes made by people, are what lead to most accidents. If necessary precautions have been taken, then these can be avoided. [14]

1.2 Objectives

The objective of this study is to analyze the vehicle’s dynamic behavior during lane changing at different speeds. The purpose of this study is to assess the vehicle’s behavior during lane changing, including steering angle, yaw angle, steering wheel torque and so on.

1.3 Scope of the project

The analysis vehicle model, which is based on the Vehicle Global Positioning System (VGPS), Universiti Malaysia Pahang (UMP) Test Car, ensures the accuracy of the simulation's results. All of the specs and parameters used in the numerical analysis match the VGPS UMP Test Car's real value. The vehicle's initial speeds are set at 60 km/h. the scope of this experiment is to determine how will the vehicle behave during lane changing with a constant speed of 60km/h. The test is being carried out in sunny conditions on a straight route.

2.0 Methodology

2.1 Location

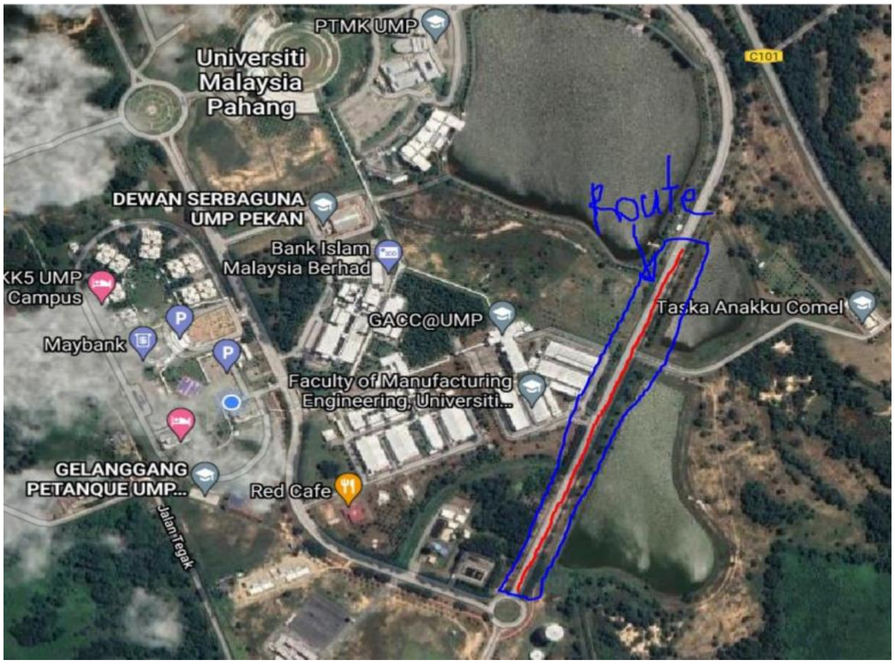


Figure 2.1: Route for lane changing test.

As shown in Figure 2.0, this is the route that has been used to carry out the lane changing experiment. This experiment is conducted in the Universiti Malaysia Pahang, Pekan campus, under a controlled traffic. It was held on the main road in front of the Faculty of Manufacturing and Mechatronic Engineering Technology (FTKPM), which has a very straight and long road, as shown in Figure 2.0, and is suitable to set up the cones and proceed with the test. During the test, the speed of the car is maintained at 60km/h, then 2 attempts were made for this speed. All the data was recorded by using Dewesoft software.

2.2 UMP Test Car

Figure 2.2: UMP Test Car.

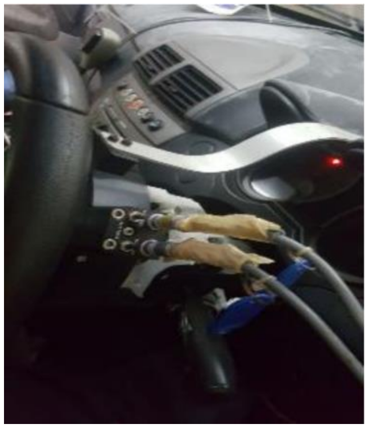
As illustrated in Figure 2.2, the experimental vehicle model used was the Proton Persona, which is the national automobile of Malaysia. The car is a sedan type with a 1.6-liter engine capacity with manual transmission. Several sections of the car have been changed to enable sensors, video, and data acquisition system (DAS) to be attached to the vehicle. Figure 2.2 shows the VGPS UMP Test Car that has been used as the analysis vehicle model in the numerical analysis. This vehicle is fitted with modern sensors to assess the dynamic motion of the vehicle. The Proton Persona 2008 model is used as the UMP Test Car. Because it is an older model, therefore it is not equipped with the Electronic Stability Control (ESC). Furthermore, it is equipped with power steering, which can help the driver to steer the wheels with less effort. It assists in turning the wheels by using hydraulic pressure, electric power, or a combination of both, in order to amplify the force applied by the driver. This technology allows for easier maneuverability, especially at low speeds or when parking, by reducing the physical effort required to turn the steering wheel.

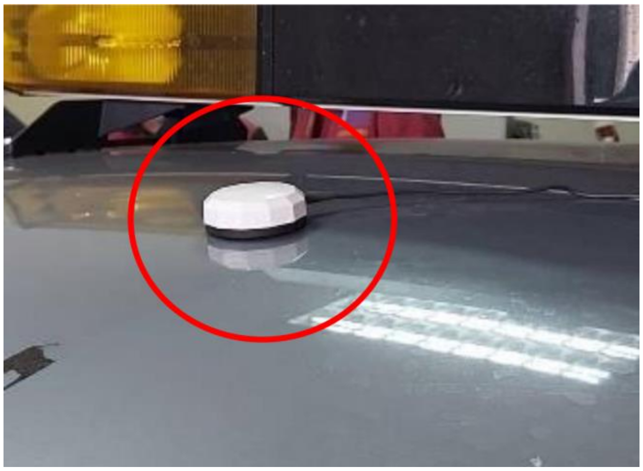
Parameter	Value
Drivetrain	Front wheel drive
Gearbox	5 speed transmission
Front Brake	Ventilated disc
Rear Brake	Drum
Tire Size	195/60/R15
Length	4.478 m
Width	1.725 m
Height	1.438 m
Front/rear track	1.476 / 1.471 m
Wheelbase	2.601 m
Unladed Weight	1195 kg

Table 1.0: Specifications of the Car.

Table 1.0 shows the specifications of the UMP Test Car. The Proton Persona is a compact sedan produced by the Malaysian automaker Proton. The 2008 model of the Proton Persona is part of the first-generation Persona lineup, which was manufactured from 2007 to 2016. The 2008 Proton Persona featured a stylish exterior design with a spacious cabin that could comfortably accommodate five passengers. It came equipped with various features such as air conditioning, power steering, power windows, central locking, and a stereo system. The engine options for the 2008 Proton Persona included a range of petrol engines, including 1.3-liter and 1.6-liter variants, offering decent performance and fuel efficiency.

2.3 Sensors and Equipment

No	Name	Function
1	Steering wheel sensor 	Use to measure steering wheel angle, steering angular velocity, steering torque, and rate of return.
2	Sport Camera 	Use to record the vehicle's windscreen view.
3	Brake pedal sensor 	Use to measure the braking force applied to the brake pedal.

4	Suspension accelerometer sensor 	Use to measure the displacement of the suspension and centrifugal force of the vehicle when cornering.
5	Gyro sensor 	Use to measure the yaw rate of the vehicle.
6	GPS sensor 	Use to measure the distance travelled and the velocity of the vehicle.

7	RV4 arm sensor 	Use to measure wheel position (x, y, and z) and orientation (steer and camber angle relative to vehicle chassis)
8	Wheel pulse transducer 	Measures rotational velocity, angular position and direction of rotation to determine wheel speed, acceleration, distance and vehicle speed
9	Data Acquisition Systems – Dewetron with built-in Dewesoft software 	Measures and records all data from the sensors and displays the data.

2.4 Dewesoft Software

Figure 2.3: Dewesoft software.

(Source: https://www.automotivetestingtechnologyinternational.com/supplier-spotlight/dewesoft)

Figure 2.3 shows the software that used to record all the data that acquired from the sensors which were installed around the car. Dewesoft is a software company that specializes in providing advanced data acquisition (DAQ) and analysis solutions. Their software, also called Dewesoft, is designed to acquire, visualize, analyze, and report data from various measurement sources. Dewesoft software is widely used in fields such as automotive testing, aerospace, industrial automation, research, and development. It supports a wide range of measurement devices and sensors, including analog, digital, thermal, CAN bus, GPS, video, and more. The software offers real-time data visualization, allowing users to monitor and analyze measurements in real-time. One of the key features of Dewesoft software is its flexibility and user-friendly interface. It provides a modular and customizable approach, allowing users to tailor the software to their specific measurement needs. Additionally, Dewesoft offers advanced analysis capabilities, including FFT analysis, order tracking, modal analysis, power analysis, and more. Overall, Dewesoft software provides comprehensive data acquisition and analysis capabilities, making it a popular choice for professionals in various industries who require accurate and reliable measurement solutions. This software (6.6.7 version) is installed inside a computer that is mounted inside the car. All the data from the sensors were acquired at a frequency of 500 Hz using the DAS from Dewetron. At this frequency, the DAS can capture the signal from the sensors every 1 s. The DAS is integrated with the Dewesoft software for real-time data processing, display, and recording. [15]

3.0 Experimental Procedures

3.1 Safety Precaution

It is necessary to adopt safety precautions in order to lower danger. The following set of safety measures must be strictly adhered to throughout the experiment.

a. Verify that no other vehicles are using the road at the time the experiment is being conducted.
b. Designate students to serve as traffic officers. In order to be easily visible from a distance, traffic control personnel are required to wear green safety vests. Their duty is to notify other road users to the flow of traffic.
c. Other students must always stay on the sidewalk if they are not participating in any activity during the experiment until the experiment is done.
d. Before starting the experiment, inspect the state of the road.
e. Prior to starting the experiment, inspect the vehicle.
f. The driver must use seatbelts while the experiment is being conducted.
g. Drivers must abide by traffic laws and speed limits.
h. Slow down and pull off to the side of the road when an emergency vehicle is present on the road during the trial.

3.2 Procedures of the Experiment

The procedures of the experiment are as follows:

a. Before the test, make sure the computer is properly linked to the Dewesoft software and that all of the sensors are calibrated and set to zero. All sensors are properly wired to the tested car. Place the cones in the proper order on the track; they should be 30 metres away from one another.
b. The tested car is driven to the testing track in front of FKP road during the test, and the GPS monitor registers 60 km/h. The experiment involves running a lane changing test between two lanes at a steady speed of 60 km/h while tilting the steering wheel. Up until the two turns, the entire experiment is done again. 4 seconds after the lane changing, the car and the measurements come to a stop. Measurements were made to make sure the measuring software and video captured the value required for the test.
c. The data is exported from the Dewesoft software and is analysed after the test, the test car is returned to the garage, and the vehicle is switched off.

4.0 Results and Discussion

4.1 Steering Angles

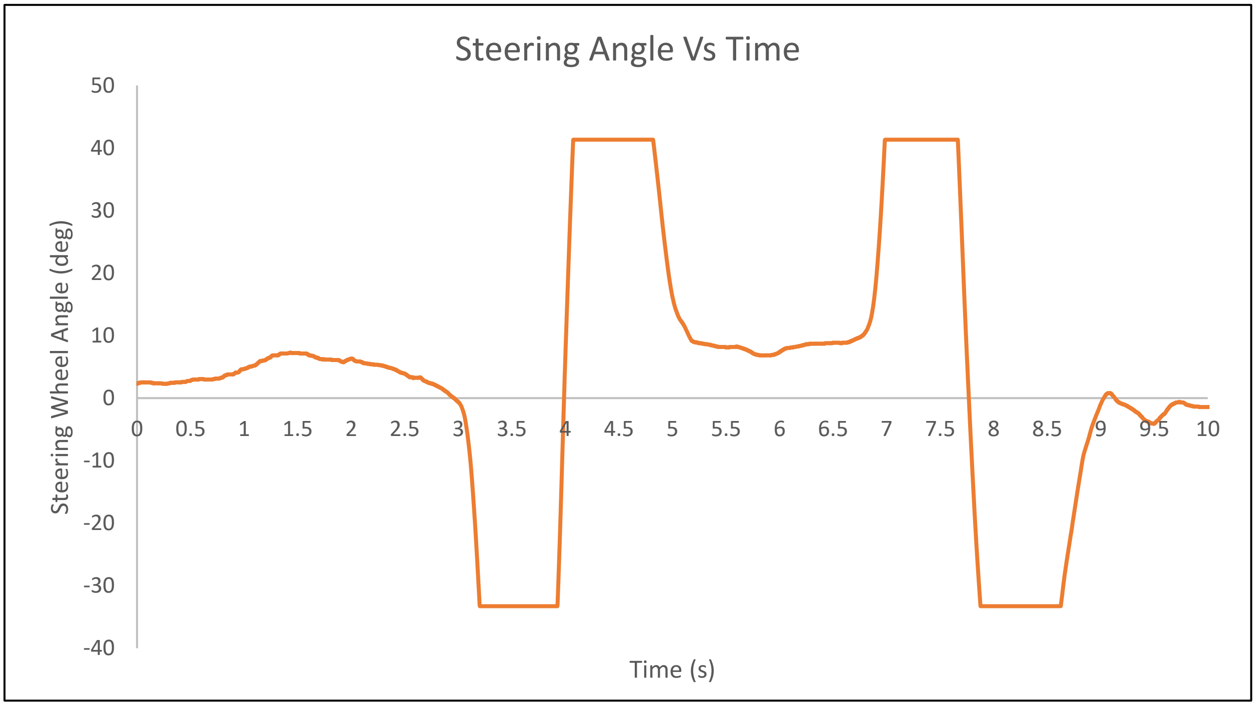


Figure 4.1: Steering angle vs. time.

Figure 4.1 depicts the value of steering angle over time where the lane changing was to happen. The speed of the vehicle was 60 kmh at the time for lane changing. Compared to study made by P.M. Heerwan [16] where the speed of the vehicle tested were 30 kmh and 50 kmh. Hence, by using the same vehicle and the same sensors, data for 60 kmh has been retrieved to compare the results. By comparing the 30 kmh and 50 kmh results of steering angle to 60 kmh, time base of 60 kmh speed vehicle is much smaller. Therefore, the change angle of 60 kmh vehicle was more abrupt. Hence, it can be concluded that it takes shorter time to lane change with faster vehicle speed.

4.2 Steering Torque

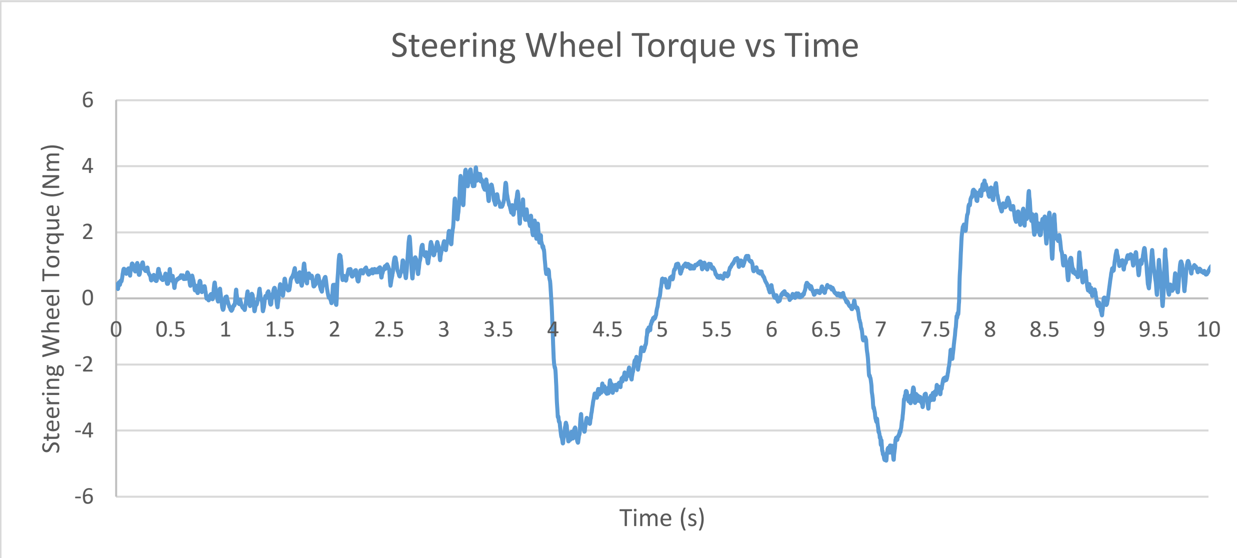


Figure 4.2: Steering wheel torque over Time.

From Figure 4.2, the steering torque requires to turn the steering wheel at 60 kmh is much less the same compared to 30 kmh and 50 kmh from study made by P.M. Heerwan [16]. At high speed, torque required to steer the wheel will be smaller because the steering angle will increase almost immediately when turning.

4.3 Yaw angles over time

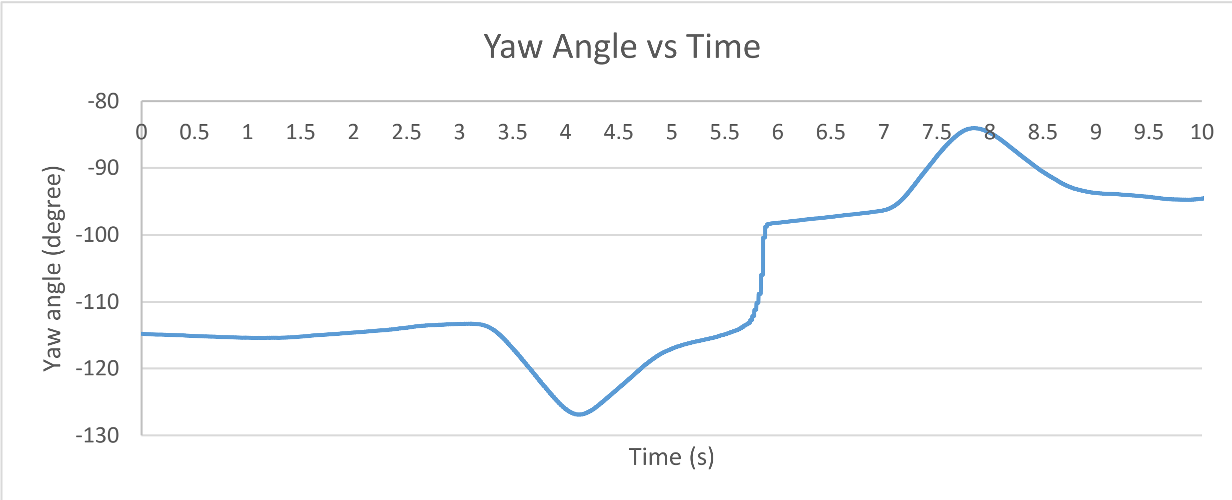


Figure 4.3: Yaw angles over time.

Figure 4.3 shows the yaw angle data that was collected from the experiment and compared to the previous study. The data curves were relatively similar in shape and pattern, since the method of changing lanes form left-right-left was the same to the previous study. The peak to peak value for speed of 60 kmh has relatively larger compared to the 2 speeds from the previous study. In order to clear the same distance while changing lanes, vehicle with faster speed need to turn more quickly compared to vehicle with slower speed. Inertia of the vehicle will be much bigger when the vehicle is faster, thus larger the yaw angle produced.

4.4 Displacements

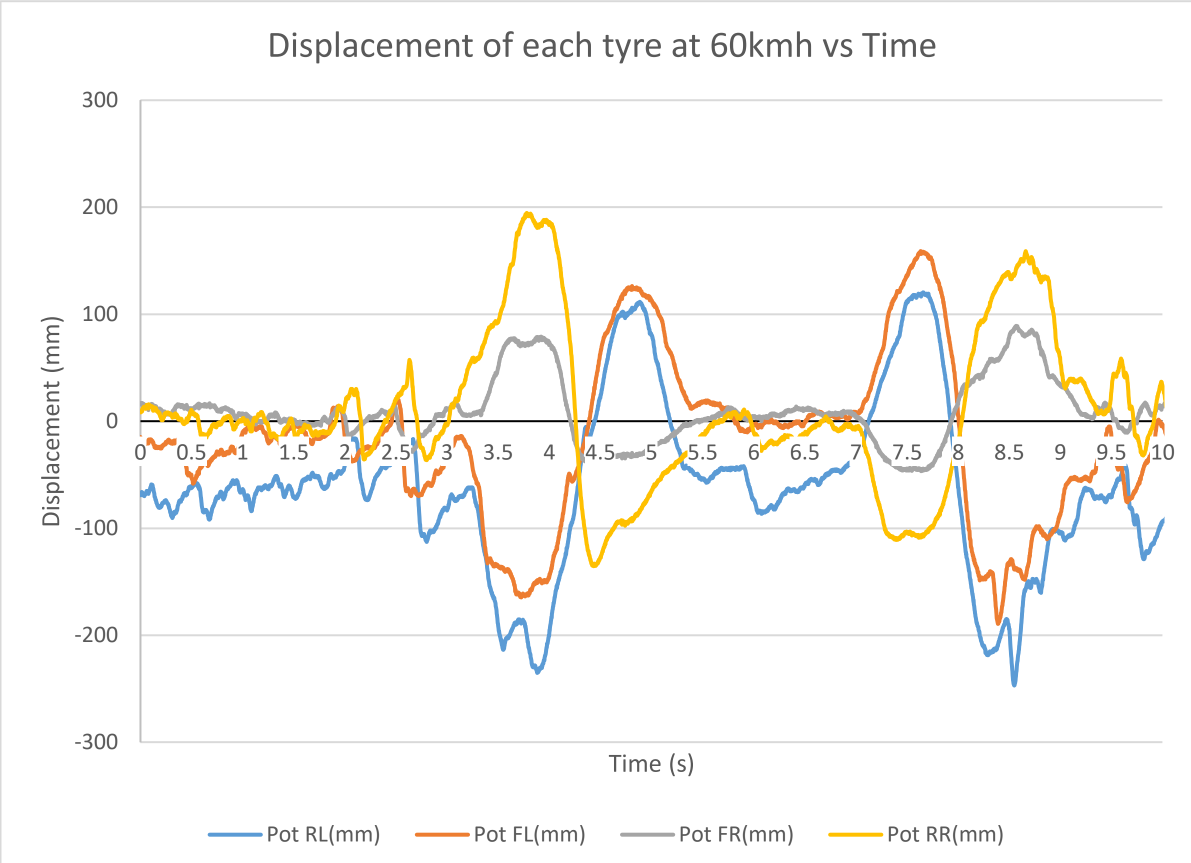


Figure 4.4: Displacement of each tire at 60km/h vs. time.

As shown in Figure 4.4, it can be clearly seen that the positive value of the graph means that the body weight of the vehicle is being shifted out since the displacement sensor indicates the absorber of the vehicles which measure the vertical position or direction of the vehicle at specific tire. On the other hand, negative values indicate the weight of the vehicle was shifted in, thus measure the negative vertical displacement. From Figure 4.4, as the vehicle turning left, the RR tire has the highest displacement since majority of the weight is shifted towards left tires and vice versa when turning right.

Tires of the vehicle are generating mechanical grip when turning where it pulls the vehicle inside the turn known as centripetal force. Furthermore, it also has reaction force which is the centrifugal force where it pushes the vehicle outside the turn. This centrifugal force is acting about the vehicle's center of mass. Turning force (rolling moment) were generated about the ground contact point since the center of mass is always above the ground contact point, thus becoming the pivot point. Rolling moment will be much larger when the center of mass is higher. This turning force causes the vehicle to roll, however it was restricted by the suspension.

Body roll should be avoided. When the weight of the vehicle is shifted towards outside of the turns, it can cause rolling. While on the inside of the wheel has less downward forces pushing it thus generated less grip. Handling of the vehicle will be affected, and understeer will occur. The whole car will roll over and crash when rolling moment too high because of the speed of the vehicle is too much or turn too tight. This is because, Resisting force of the suspension springs of outer wheels can no longer counter the rolling moment of the vehicle.

5.0 Conclusion

Behaviors of the vehicle while lane changing at 60 kmh is recorded and analyzed. From the data of the experiment and comparison with previous study, it is determined that higher yaw angle will be produced when lane changing at higher speed. At faster speed, the vehicle steering angle base will be lower and the steering angle changes is much more radical.

The Faster the vehicle is moving when lane changing, the level of dangerous situation will be much higher since the yaw angle produced more resulting the car to spin and loss control. by abruptly steering the wheel of the car, it can cause tires to slipping while it has less grip resulting in loss control of the vehicle. Understeer can occur for front wheel drive vehicle such the test car.

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