THE UNIVERSITY OF PARDUBICE

FACULTY OF TRANSPORT ENGINEERING

BACHELOR THESIS

2022 PARTH OZA

The University of Pardubice

Faculty of Transport Engineering

Overview of kinematic variables for typical road vehicle maneuvers

Bachelor Thesis

2022

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University of Pardubice
Faculty of Transport Engineering
Academic year: 2020/2021

ASSIGNMENT OF BACHELOR THESIS
(project, art work, art performance)

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Work topic:	**Overview of kinematic variables for typical road vehicle maneuvers**
Assigning department:	**Department of Transport Means and Diagnostics**

Theses guidelines

The aim of the work is to determine the characteristic courses of quantities during various precisely defined maneuvers of a road vehicle. The work is of an experimental nature with ERCT equipment and technology, experimental vehicles are also available. The student is expected to have a systematic approach, the ability to sort and process the measured data and then interpret them appropriately.
Student should incorporate the following points in the thesis:
1. Introduction
2. Test maneuvers of road vehicles.
3. Methodics of measurement of choosen maneuvers.
4. Reailization of experiments (test maneuvers).
5. Evaluation of measurement.
6. Recognition of elemntar maneuvers from normal driving based on measured data.
7. Conclusion

Extent of work report: **35 pages**
Extent of graphics content: **according to supervisor's instructions**
Form processing of bachelor thesis: **printed/electronic**
Language of elaboration: **English**

Recommended resources:

[1] HEYDINGER, Gary J. a J. Gavin HOWE. *Analysis of vehicle response data measured during severe maneuvers*. Warrendale: Society of Automotive Engineers, c2000. SAE Technical paper series, 2000-01-1644.
[2] DUKKIPATI, Rao V. *Road vehicle dynamics: problems and solutions*. Warrendale: SAE International, c2010. ISBN 978-0-7680-2051-9.
[3] MILLIKEN, Douglas L. *Race car vehicle dynamics: problems, answers and experiments*. Warrendale: SAE International, c2003. ISBN 0-7680-1127-2.

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In Pardubice February 15, 2021

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TITLE

Overview of kinematic variables for typical road vehicle maneuvers

ANNOTATION

The aim of the work is to determine the characteristic courses of quantities during various precisely defined maneuvers of a road vehicle. The work is of an experimental nature with ERCT equipment and technology, experimental vehicles are also available. The student is expected to have a systematic approach, the ability to sort and process the measured data and then interpret them appropriately. Suitable work for those who are interested in the real behaviour of the vehicle in relation to the measured data.

KEYWORDS

Maneuvers, Sensors, Steering Wheel Deviation, Acceleration, Kinetic Parameters

TÉMA PRÁCE

Přehled kinematických veličin pro typické manévry silničních vozidel

ANOTACE

Cílem práce je stanovit charakteristické průběhy veličin při různých přesně definovaných manévrech silničního vozidla. Práce má experimentální charakter s využitím zařízení a technologie VVCD, kde jsou k dispozici i experimentální vozidla. Od studenta se očekává systematický přístup, schopnost třídit a zpracovávat naměřená data a následně je vhodně interpretovat. Jde o vhodnou práci pro ty, které zajímá reálné chování vozidla ve vztahu k naměřeným údajům.

KLÍČOVÁ SLOVA

manévry, snímače, natočení volantu, zrychlení, kinetické parametry.

CONTENTS

LIST OF ILLUSTRATIONS AND TABLES

INTRODUCTION

The major purpose of this study is to determine the characteristics courses of the kinematic variable quantities during precisely defined maneuvers of a road vehicle.

This study includes the study of different road vehicle maneuvers such as Turning of vehicle in left or right direction, changing of lanes, turning a sharp turn with acceleration, sudden braking, and Slalom maneuvers.

I measured the vehicles characteristic changes in kinematic quantities such as velocity, acceleration in different direction, height (for roll over of vehicles), breaking, steering wheel behaviour etc. and comparing these parameters with each other during each maneuver to see how they change when vehicle is driven through a certain course with the help of ERCT equipment and technologies using an experimental vehicle made available by the university.

With choosing specific methods of measurement for a chosen maneuver and choosing a location to implement the corridor for testing. Results are obtained from severe maneuvers are then studied to gain understanding of vehicle response in these cases.

1. TEST MANEUVERS OF ROAD VEHICLES

As producers are pushing their innovative work toward more recreation based and PC helped techniques, vehicle elements demonstrating and recreation become more significant than any other time. Modern cars have implemented event data recorder (EDR), which monitors from most of the sensors that I have chosen for my work. To understand what exactly happened before the impact or accidental crash of the vehicle it is necessary to understand the parameters and graphs from sensors The test lies in how to use the Methodics of measurement to its fullest, conveying the most ideal evaluation and presentation of given specific maneuvers

1.1 Selecting of appropriate maneuver

To understand vehicle response in different driving conditions by understanding the driver's ability and to determine kinematic variable quantities during driving in a critical or non-critical conditions in the everyday situations the appropriate maneuvers are selected.

Based on the above the basic requirement for suitable maneuver selection was determined.

- The maneuver must be able to describe kinematic variable quantity changes in the vehicle.
- Simulate required situations as precisely as possible.

It is not possible to evaluate this information with one single maneuver, so combination of maneuvers is selected.

In the following chapters only the selected types of driving test when maneuvers are presented in practice the range of tests used is much wider and its description will require further independent work.

1.1.1 Straight drive maneuver

In the straight drive maneuver the driver tries to keep the vehicle in a straight line as much as possible keeping the steering wheel still, the speed of the vehicle may or may not be constant. Measured parameters include the velocity in a straight line, longitudinal acceleration, the height of the vehicle from the ground and the steering wheel angle using different types of sensors which we will come across in the upcoming chapters.

The main purpose to perform this maneuver was for the taring of parameters. From this straight drive maneuver, you should take stable part of data (where parameters do not change a lot) and make an average from them and offset measured data about this average. Processed data then should start at “0” level.

1.1.2 Sudden braking maneuver

In this maneuver the testing vehicle is driven with an acceleration and sudden breaking is applied to stop the vehicle. In the actual situation this maneuver is observed during critical condition such as accident or occurrence of a sudden obstacle in front of the vehicle.

I measure the driver’s response time after applying of the brakes and the changes in the other kinematic variable quantities.

1.1.3 Double Lane change maneuver

In the lane change maneuver to the right the driver initiates maneuver by turning the steering wheel to the right with steering angle within typically 0.5 seconds followed by a counter steering action within 0.5 seconds and turns the steering angle to the central position movement. In the lane change maneuver to the left the driver performs similar action in the opposite directions.

The combination of both that is the double lane change maneuver the driver turns the steering wheel simultaneously in both directions with brake pedal activation. Measured Parameters include the height of the vehicle from sides, the steering wheel angle, along with changes in velocity and acceleration.

1.1.4 Cornering (right turn) maneuver

This maneuver is a simple right turn where measured quantities includes the steering wheel angle, the changes in velocity, acceleration and the angular velocity of the vehicle while performing the turn in the implemented corridor for testing.

1.1.5 Slalom maneuver

The slalom test consists of seven lined up cones, separated by 17 m. The vehicle is driven through the course, in a slalom pattern an S-shaped winding of zig zag course. The test is generally performed to measure the driver's reaction time and to measure the vehicle stability through the course.

1.1.6 Round-about turn maneuver

In this maneuver the vehicle is driven going through round-about with a left turn about 270° turn following circular path having a constant radius implemented for the test corridor. Measured values include the steering wheel angle, change in velocity, longitudinal and lateral acceleration, and angular velocity of the vehicle during the turn.

2. METHODICS OF MEASUREMENT OF CHOSEN MANEUVERS

2.1 Design of the test methodology

2.1.1 Test track

The test track must allow testing of both the avoidance maneuver according to, as well as steady turning. It must therefore meet the space requirements of these maneuvers with sufficient reserves to create safety escape zones. The width of the test track should therefore be at least twice the required track width to perform the maneuver.

In the study the test track chosen was located at the Pardubice Airport, Czech Republic in the FIG. 1.

Figure 1 : Test Track located at the Pardubice Airport, CZ

2.1.2 Test vehicles

The test vehicle was the Skoda Superb Sportline 2016 with turbocharged petrol engine 2.0 TSI / 200 KW4×4 with automatic seven speed DSG transmission. The geometric parameters of the vehicles are shown in the FIG .2.

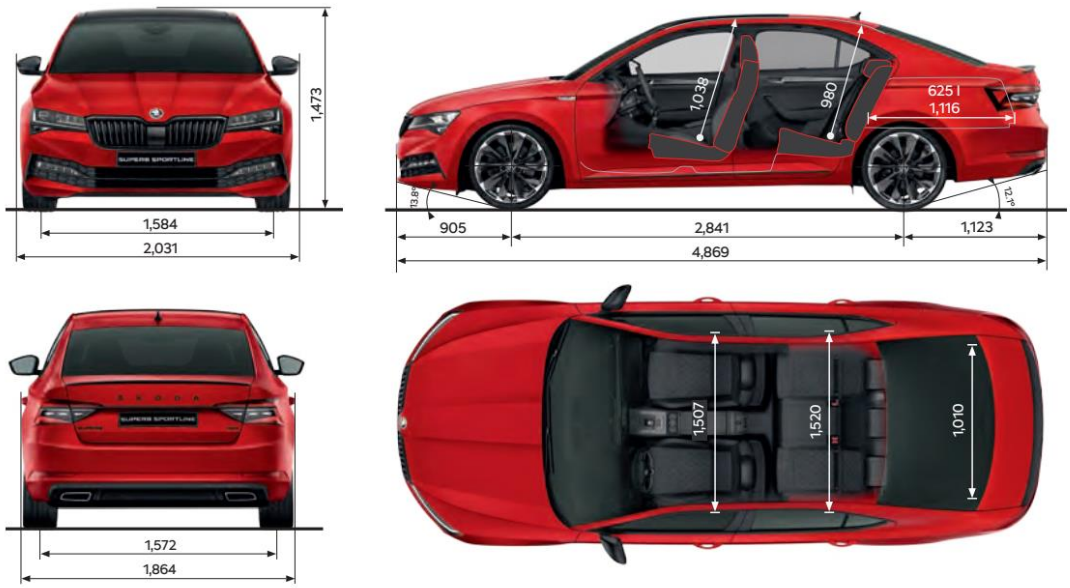

Figure 2 : Geometric parameters of the test vehicle (SUPERB SportLine 4x4 Wagon Brochure).

2.1.3 Test vehicle tires

The tires used during testing where the Zenith measuring 235/45 R18 Y XL (extra load radial tubeless) having maximum inflation pressure 350 kPa in Max load 750 KG mounted on wheels 8J × 18 ET 44.

Figure 3 :Zenith 235/45 R18 Y XL (SUPERB SportLine 4x4 Wagon Brochure).

2.1.4 Test Driver

The test driver was Mr. Petr Jilek who is your assistant professor at the add Faculty of Transport Engineering at The University of Pardubice.

2.2 Measured Quantities and Measuring Devices

The main quantities measured during the testing were:

- Longitudinal vehicle speed [km / h]
  Sensing device: Correvit S-CE with gyroscope, manufacturer Corrsys-Datron, year of manufacture 2002, serial number: 31522, registration number: DHM 005341, sampling frequency: 100 Hz.

- Steering wheel angle [deg]
  Sensing device: cable steering wheel angle sensor, manufactured by Micro Epsilon Czech Republic and KDPD DFJP University of Pardubice, year of manufacture 2010, sampling frequency: 100 Hz.

- Lateral acceleration [g]
  Sensing device: Accelerometer ADXL 311, manufacturer Analog Devices, year of manufacture 2003, sampling frequency: 100 Hz.

- Directional deviation [deg]
  Sensing device: Correvit S-CE with gyroscope, manufacturer Corrsys-Datron, year of manufacture 2002, sampling frequency: 100 Hz.

- Angular velocity [deg/s]
  Sensing device: Correvit S-CE with gyroscope, manufacturer Corrsys-Datron, year of manufacture 2002, sampling frequency: 100 Hz.

The additional quantities served only as a support for data evaluation, i.e., for a secondary description of the vehicle's behaviour during maneuvers.

An optical gate sensor FIG. 4. was used to determine the beginning and end of the corridor, consisting of special reflecting surfaces located at the beginning and end of the corridor and a Balluff BOS 36K-PA-1QH-S 4-C optical sensor located on the vehicle. The sensor was set at a sampling frequency of 1000 Hz with artificially extended pulses.

Figure 4– An optical gate sensor: Balluff BOS 36K-PA-1QH-S 4-C

The height sensors located on both sides and in front of the vehicle to measure the change in course of the height from the ground.

Figure 5–Height sensor

Cronos control panels and Cansas were used to collect data from individual sensors shown in FIG. 6. The manufacturer of this system is imc Berlin. Data transfer from the Cansas module to the Cronos unit takes place via the CAN bus. The data transfer from the Cronos unit to the PC then took place via the Ethernet interface. The measurement was triggered by a manual trigger. The data recorded by both control panels were stored on the internal flash memory in the Cronos control panel. After a series of rides, the data from this memory was copied to the laptop's hard drive, where it was further processed.

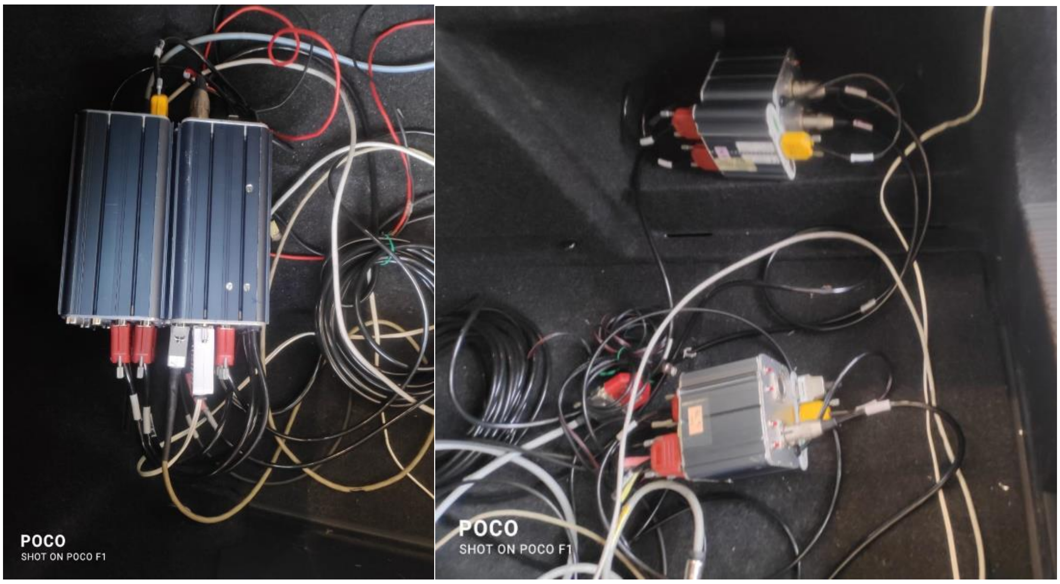

Figure 6- Cronos measuring center (left) with Cansas module (right)

The measuring notebook MSI Megabook VR 6, was used for communication with the measuring control panel and data collection.

The Ergoline BMI band of 50 m was used to delineate the test tracks.

2.3 Location of Measuring Equipment

The acceleration sensor was placed in space below hand rest on the right side of the driver’s seat. Shown in the FIG .7.

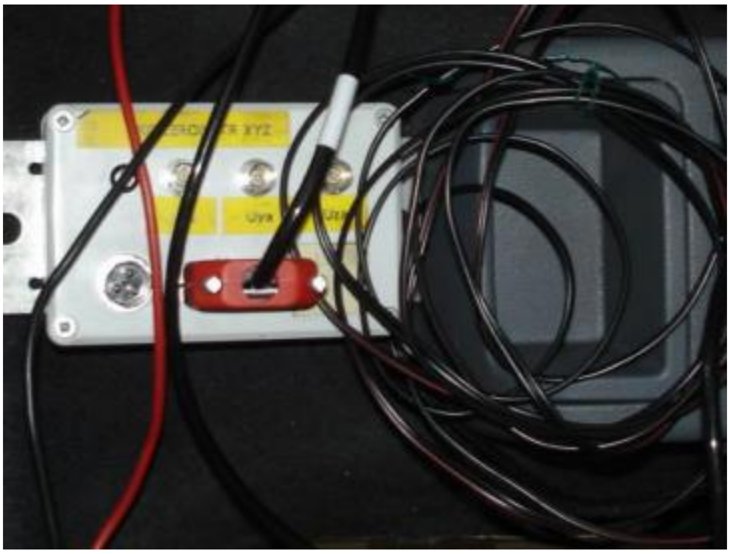

Figure 7– Acceleration sensor: Accelerometer ADXL 311 (Lichorobiec, 2012).

The cable part of the steering wheel angle sensor was placed on the inside of the windscreen in front of the front passenger.

The two Correvit sensors were placed both at the front and the back end of the vehicle shown in the FIG. 8.

Figure 8– Correvit Sensors attached to the test vehicle.

The control panel including the batteries was in the trunk of the vehicle perfectly tide with ropes with safety measures. Shown in the FIG. 9.

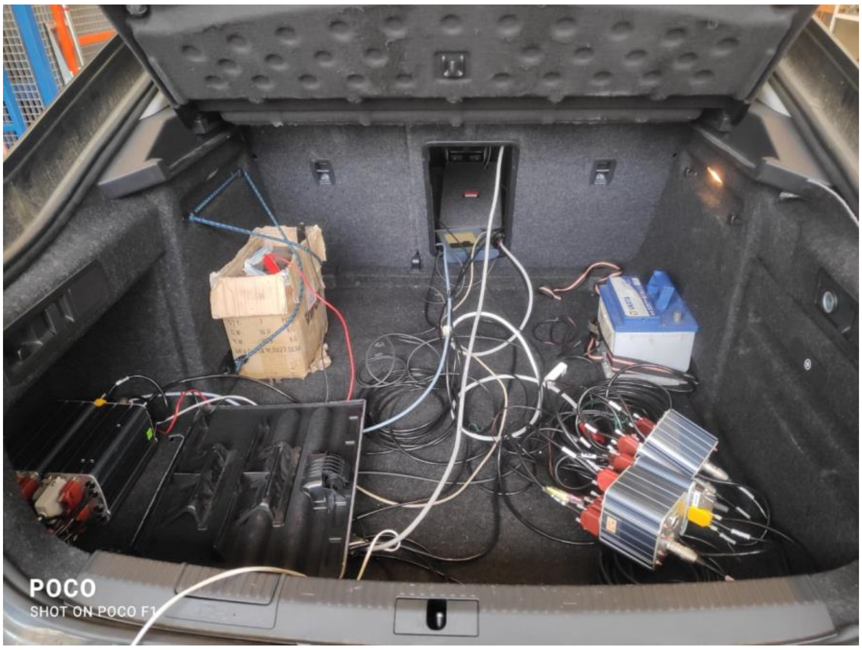

Figure 9– The control panel including the batteries

2.4 Atmospheric conditions

Air temperature [11° C to 16° C], wind speed [11 -13 kph],

Test track surface: slightly wet. Dated [May 15th, 2021]

3. REALIZATION OF EXPERIMENTS (TEST MANEUVERS)

After the sensors were installed on the test vehicle the control panel was connected, test track was laid out.

3.1 Implementation of Test Corridors for Straight drive maneuver

The test and corridor for this maneuver was road track at a short distance from the airside road surface drainage channel used as a reference straight line to keep the vehicle in straight track while driving as shown in the FIG .10.

Figure 10- Test Corridors Straight drive maneuver

3.2 Implementation of Test Corridors for Sudden braking maneuver

The test vehicle was driven with high speed and then followed with sudden applied brakes measuring the reaction time of the driver and the height of the front side of the vehicle decreasing when the brakes are applied.

3.3 Implementation of Test Corridors for Double Lane change maneuver

This maneuver requires a double lane corridor. The test track has cones placed in the manner as shown in the FIG .11. the driver initiates the maneuver by steering slightly left changing the lane for the first time and then followed with the counter steer to right to get back to the same lane with the brake pedal activation. The FIG .12. shows the track corridor implemented during the test.

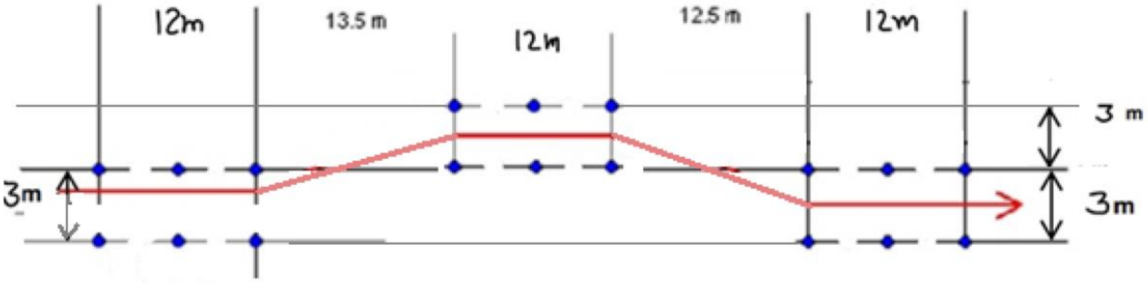

Figure 11- Shape and dimensions of test corridor for Double lane change maneuver (Lichorobiec, 2012).

Figure 12 - Actual test corridor for the double lane change.

3.4 Implementation of Test Corridors for Cornering (right turn) maneuver

This maneuver is performed on an implemented right turn corridor in a steady driving condition with an average velocity around 27 to 30 kmph. The FIG. 13. shows the actual corridor track.

Figure 13 Actual test corridor for the Cornering (right turn) maneuver.

3.5 Implementation of Test Corridors for Slalom maneuver

This maneuver was performed on a straight track corridor with cones placed in centre of the track in straight line with a 12-metre distance between them, the test vehicle is then driven through the cones in a S-shape winding in zig zag way. The FIG. 14. shows the actual corridor track.

Figure 14- Actual test corridor for the Slalom maneuver

3.6 Implementation of Test Corridors Round-about turn maneuver

The test vehicle is driven through circular track with constant radius performing a steady left turn through a roundabout, the radius is about 10 metres for the turning track. The track was marked by to circles of cones that formed the corridor for the vehicle the cones were arranged in the radius of 6-metre inner at 14 metre outer circle approximately. The diagram of the test path including dimension is shown in the FIG. 15.

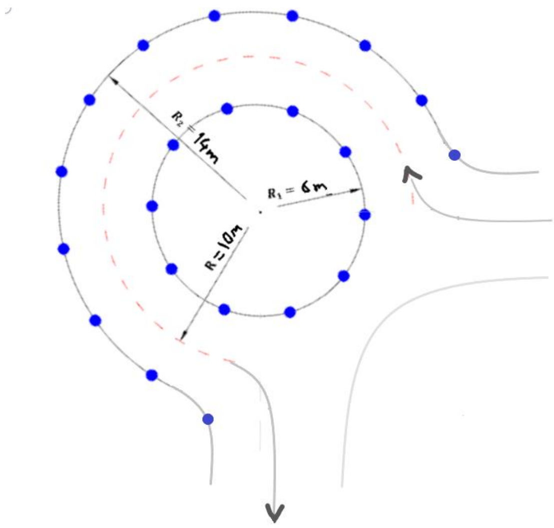

Figure 15 - Shape and dimensions of test corridor for Round-about turn Maneuver (Lichorobiec, 2012).

4. EVALUATION OF EXPERIMENT

The program FAMOS was used to evaluate the measured data 10.2 and Microsoft Excel 2016.

For every test maneuver approximately 8 or more tests were performed out of which I have chosen the best suitable test results for the evaluation of each maneuver.

4.1 Evaluation of Straight drive maneuver results.

The following evaluation shows, as the driver tries to maintain a straight and study drive the course of velocity remains almost in a constant range with an average velocity of 25.8 kmph.

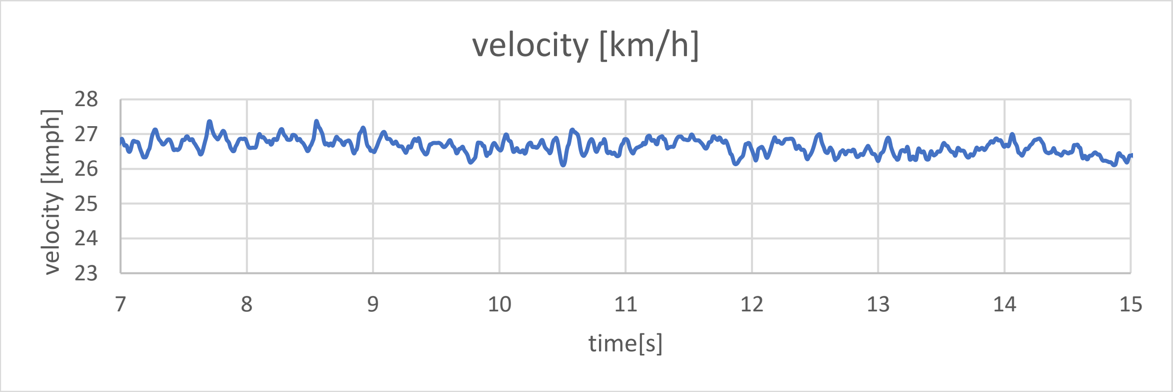

Figure 16 – course of velocity in the straight direction during Straight drive maneuver

Similarly, the course of steering wheel deviation the value almost remains constant with an average value of 0.176 meters, the longitudinal and lateral acceleration has a constant range of values throughout the drive with an average value of (-0.11153 g, -0.16096 g)

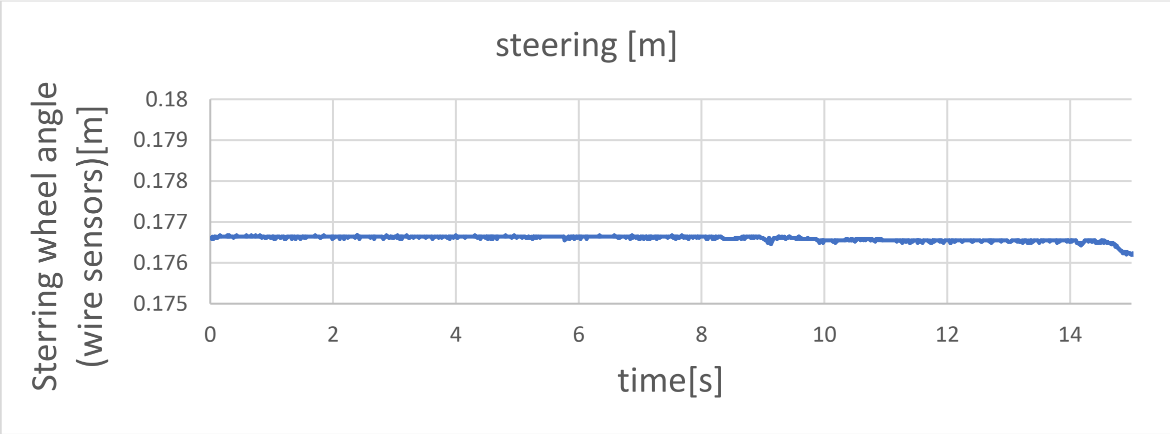

Figure 17- course of the steering wheel angle during a Straight drive maneuver

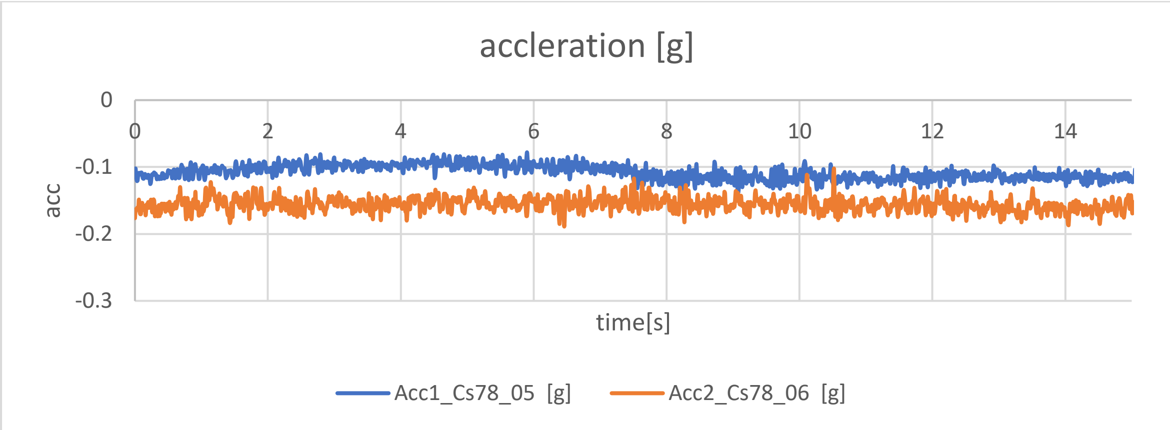

Figure 18- course of longitudinal acceleration of the vehicle during an Straight drive maneuver

As mentioned above the purpose of straight drive maneuver is to find the average value of the parameters from straight drive maneuver and taring of parameter of other maneuvers during the thesis so the data processed for them starts from a zero reference.

4.2 Evaluation of Sudden braking maneuver results.

In the sudden breaking maneuver, the test corridor begins at the 4th second where the velocity is past 50 kmph and you can see a flat line in the course for the velocity which is not pressed due to setting the correvit sensor. In the 14th second of the corridor when the brakes are applied the velocity as well as the acceleration decreases, and the vehicle stops at almost 16th

second.

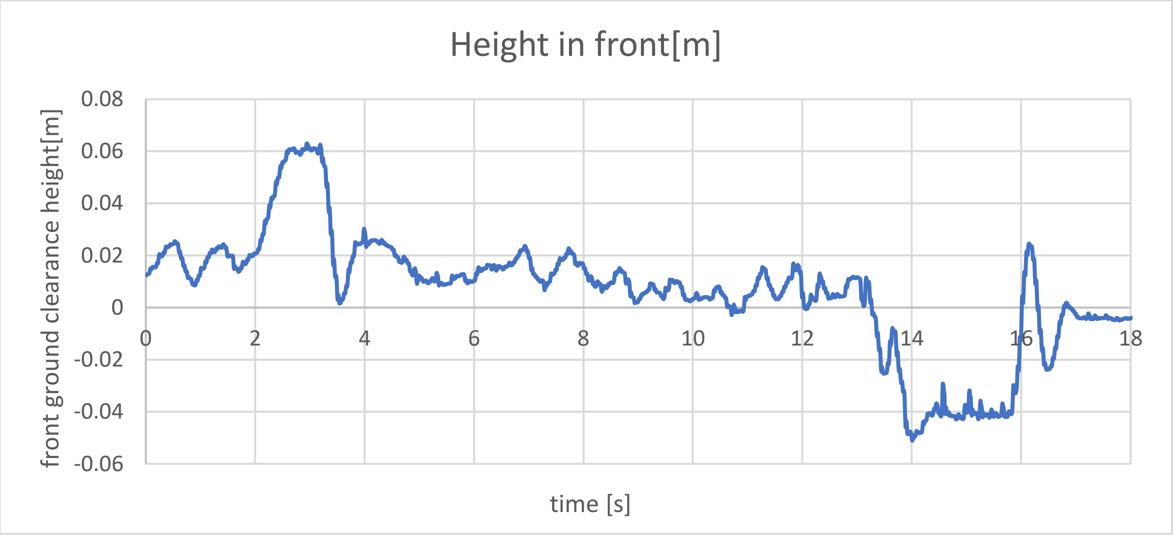

Figure 19– course of change in height during Sudden braking maneuver

In the course of the height sensor when the break begins to apply the height of the vehicle in the front starts to decrease is at its lowest when the vehicle stops then comebacks to its normal position with an increase in the value.

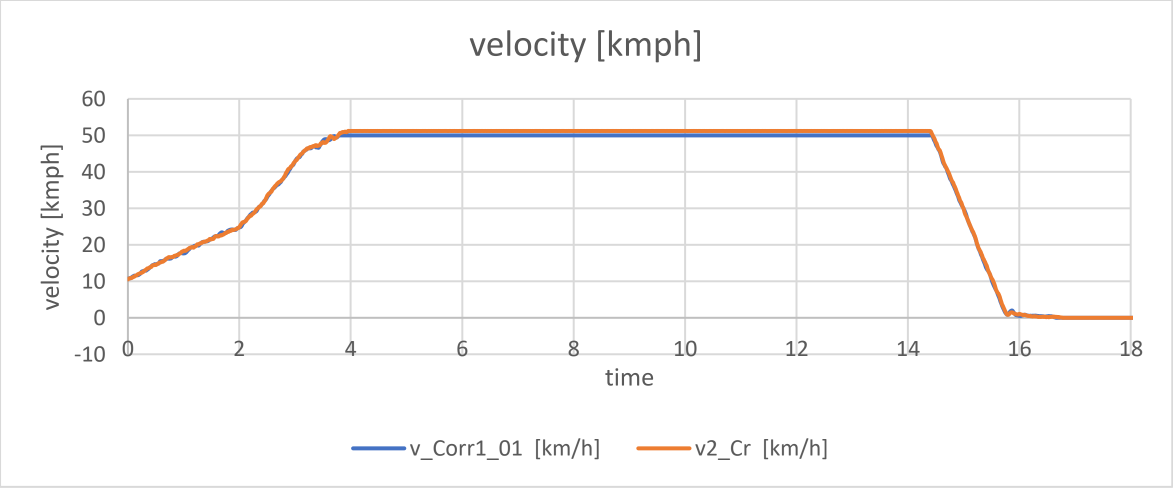

Figure 20- course of velocity in the straight direction during Sudden braking maneuver

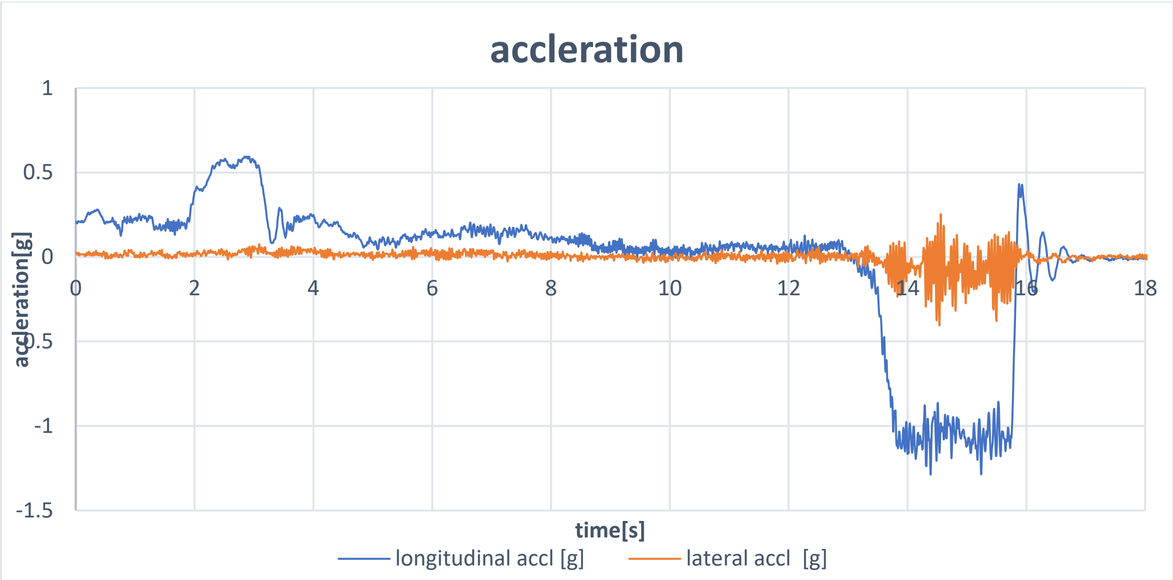

Figure 21– course of lateral acceleration and longitudinal acceleration of the vehicle during an Sudden braking maneuver

4.3 Evaluation of Double Lane change maneuver results.

In a double lane change maneuver what's the driver initiates the turn for changing the lane from right to left with a slight steering turning which we can observe in the course of steering where the value has an increase and then come back to the initial best steering comes back to normal position now in the second half of the maneuver the driver changes its lane from left to right in the similar fashion and you can see the opposite tilt of the graph.

During the course of driving between 4^{th} and 6^{th} second there are changes in the graphs for steering wheel angle and acceleration, as the vehicle is steered to change a single lane room left to right rotating the steering wheel slightly anticlockwise following with clockwise rotation and in about 2 seconds, in the first half of the turn to the left the value of steering wheel angle reading increase from 0m to 0.22m (max at 4.9^{th} sec) at the same time in the course of acceleration the lateral acceleration reading is increased to (-0.674g) on the graph and then steered back to the original position. And in the second half when the vehicle is steered to right (clockwise) the steering wheel angle reading on the graph in decreased to (-0.23m) at 5.5^{th} second of the course, the lateral acceleration at this point is elevated to +0.62g on the graph.

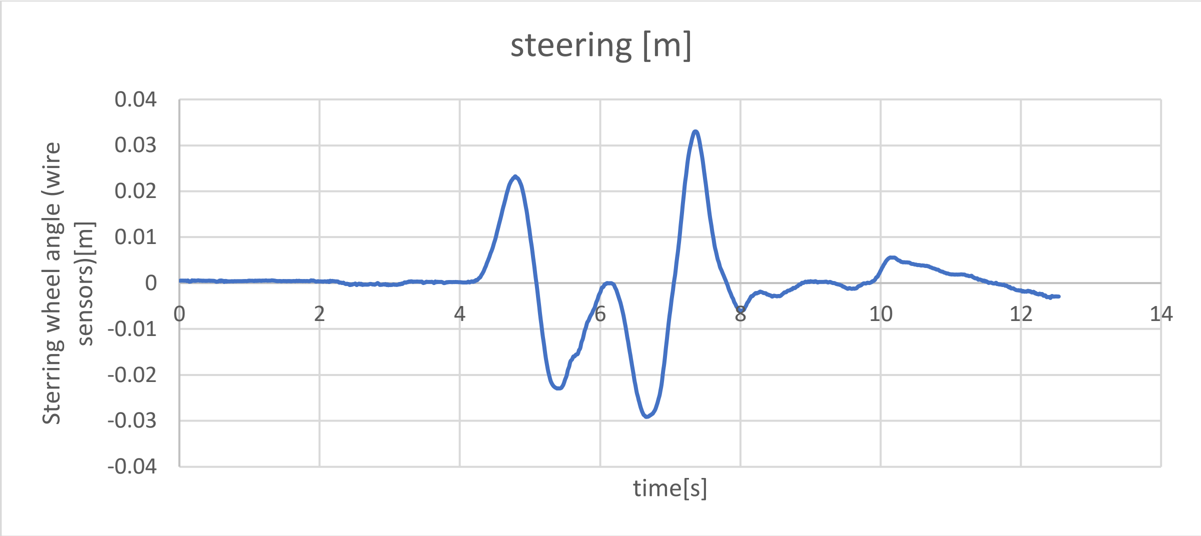

Figure 22 - course of the steering wheel angle during a Double Lane change maneuver

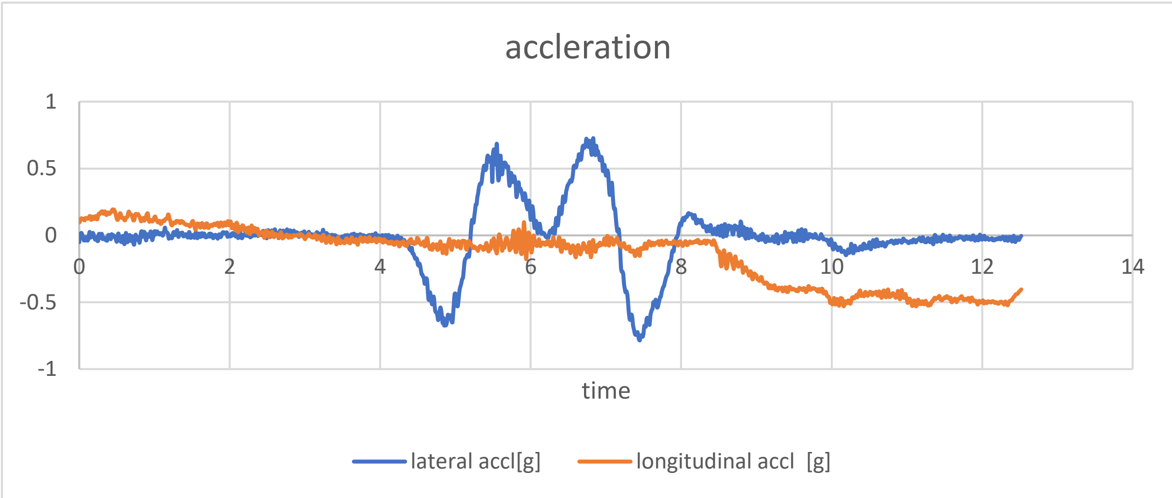

Figure 23- course of lateral acceleration and longitudinal acceleration of the vehicle during a Double Lane change maneuver

The test corridor begins at the 4th second and ends at 9th second you can see the course of the lateral acceleration changing accordingly with the turning. Whereas the longitudinal acceleration that is the acceleration in the straight direction remains almost within a constant range. Similarly, the course of height of the vehicle on the sides which represents possibility of rollover of a vehicle change accordingly with the turning.

During the movement of vehicle when steered to the left the height sensor parameter graph (HP2_Cs78_02) attached to vehicle on the right side has its volume dropped from 0m to -0.05m (min at 4.9th sec) and increases to 0.053m (max at 5.7th sec) as the vehicle is steered back to the right direction. Similar course of behaviour is seen on every lane change of the vehicle.

The vehicle maintain stability throughout the test due to the adhesion force which prevents rollover

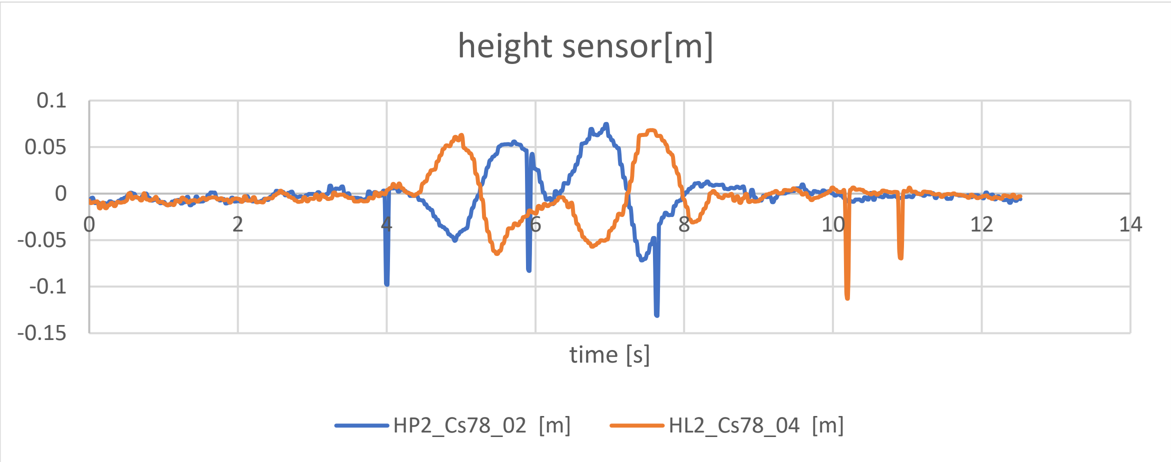

Figure 24- course of change in height during Double Lane change maneuver

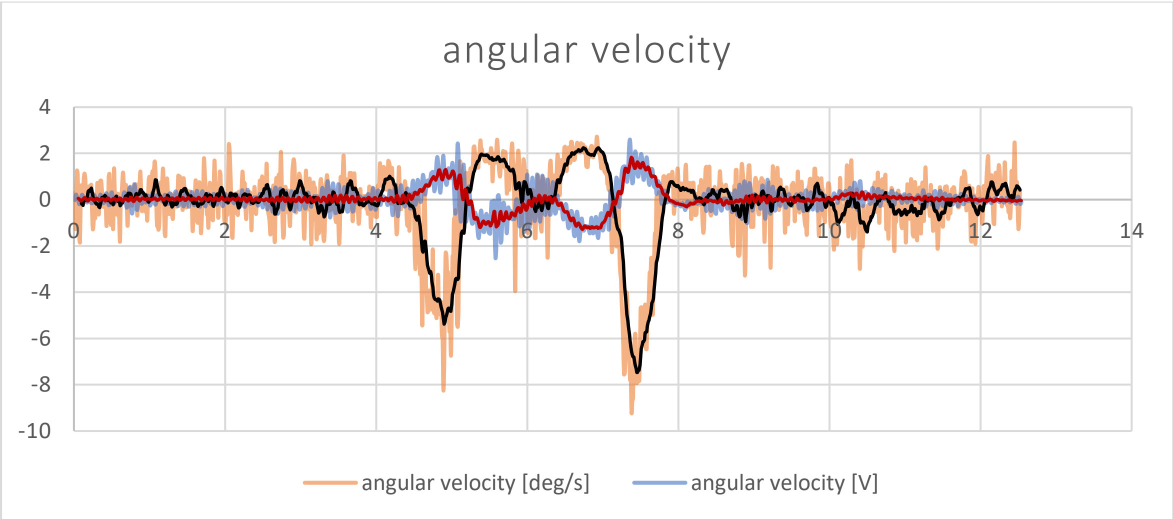

Figure 25- course of vehicle angular speed during Double Lane change maneuver

The above figure shows a course of angular velocity which changes according to the turn but in the opposite fashion of the turn.

4.4 Evaluation of Cornering (right turn) maneuver results.

The cornering right turn maneuver was performed with an average velocity of 29kmph. As the turn is initiated at 5.6th sec steering wheel is rotated clockwise hence the reading on the graph falls from almost 0m to -0.073m at 8.6th sec So it can be said that steering was rotated clockwise for 2 seconds and then back anticlockwise for another 2 seconds when the value is 0m in the graph again at 10.6th sec that is vehicle travelling in straight direction. During this the height on the right side is increased from 0 to approximately 0.02m and on the left side decreased to -0.035m as seen in the graph.

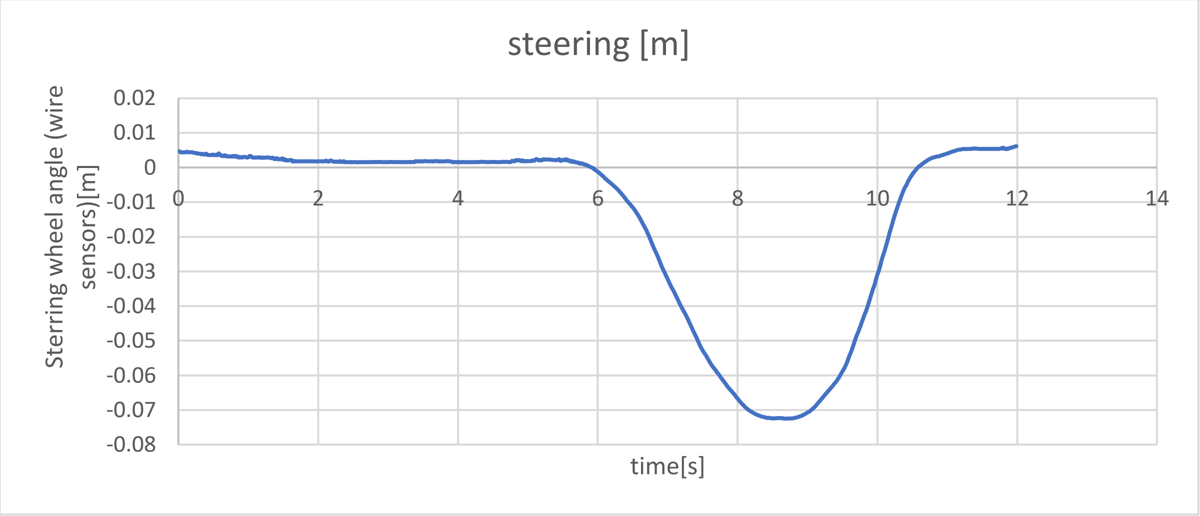

Figure 26- course of the steering wheel angle during a Cornering (right turn) maneuver

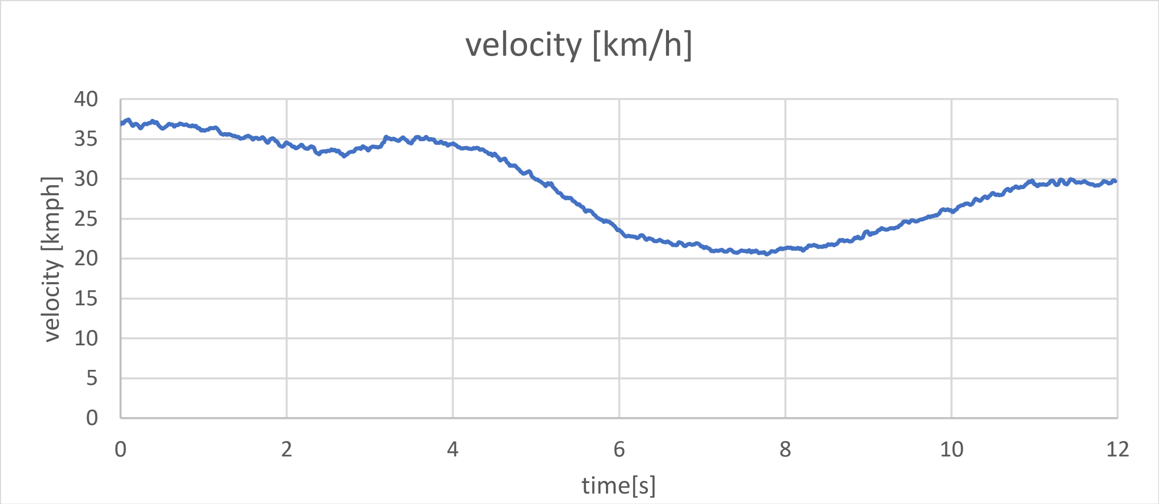

Figure 27- course of velocity in the straight direction during Cornering (right turn) maneuver

To study the rollover of the vehicle we can see the vehicle turns towards right and a centrifugal force act on the vehicle in the outer direction of the turn which results in increase of the height on the right side of the vehicle and decrease in the left as shown in the course of the height. At 8.65th sec when the vehicle is completely steered the height on the right side is increased from 0 to approximately 0.02m and on the left side decreased to -0.035m and then back to the initial value at the end of the course as seen in the graph.

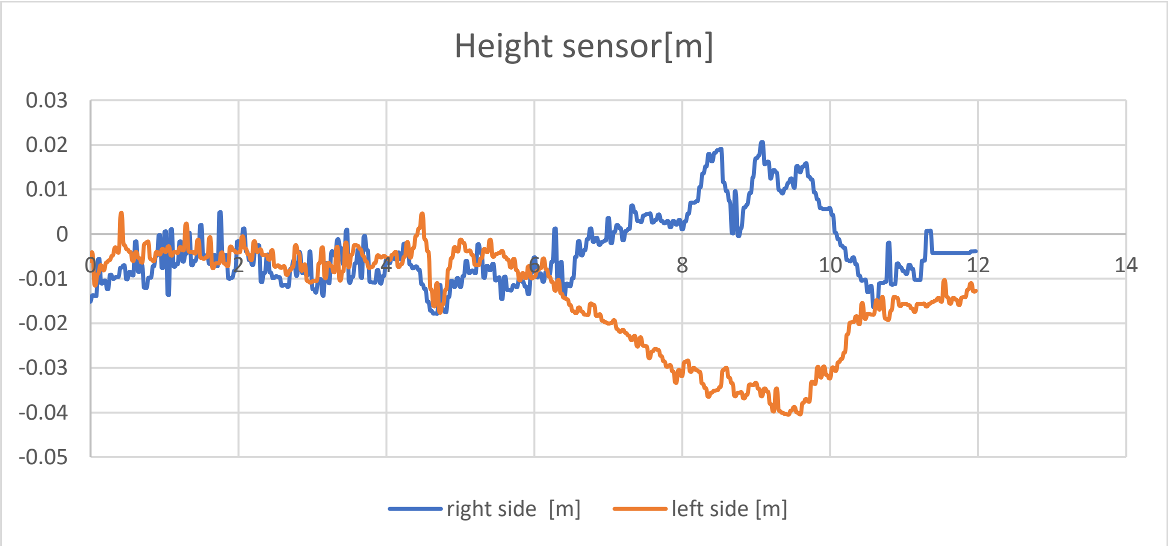

Figure 28- Course of change in height during Cornering (right turn) maneuver

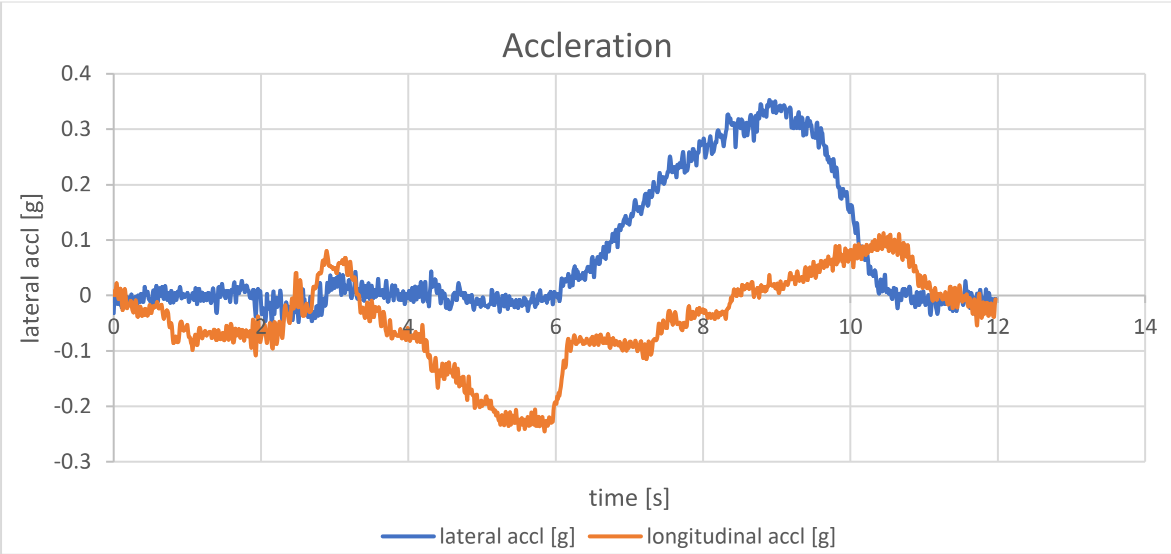

Figure 29 - Course of lateral acceleration of the vehicle during a Cornering (right turn) maneuver

During the turn you can see the velocity also decreases whereas the lateral acceleration that is the acceleration in the perpendicular direction of the arc of the turning increases. When the steering is completely turned clockwise at 8.7th sec the lateral 0 again as the velocity starts increasing and steering is turned anticlockwise again increasing the longitudinal acceleration.

4.5 Evaluation of Slalom maneuver results.

In the slalom maneuver as the vehicle travels following zig zag path, we can see the steering deviation follow the turning.

The vehicle travels with an average velocity of 27.2 kmph. Time the vehicle initiates the turn the course of velocity increases and decreases accordingly similarly the lateral acceleration increases and decreases within a range of -0.6g to 0.6g where is the longitudinal acceleration remains in a shorter range of -0.2g to 0.2g.

It took around 2.5 secs to pass a single cone with the steering wheel rotated clockwise followed by an anti-clockwise rotation.

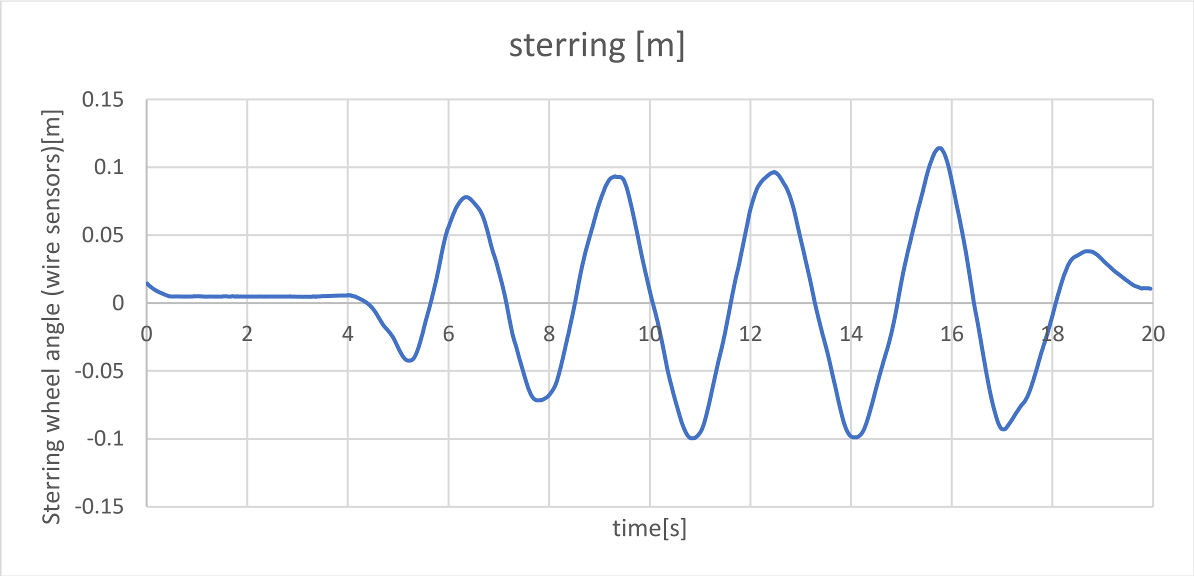

Figure 30 - Course of the steering wheel angle during a Slalom maneuver

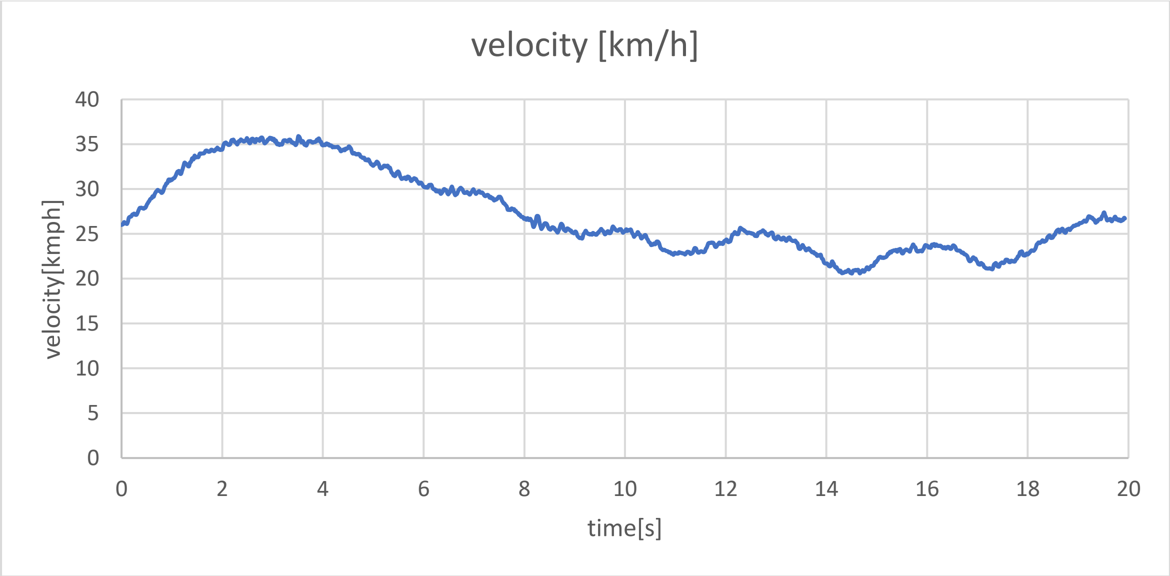

Figure 31- Course of velocity in the straight direction during Slalom maneuver

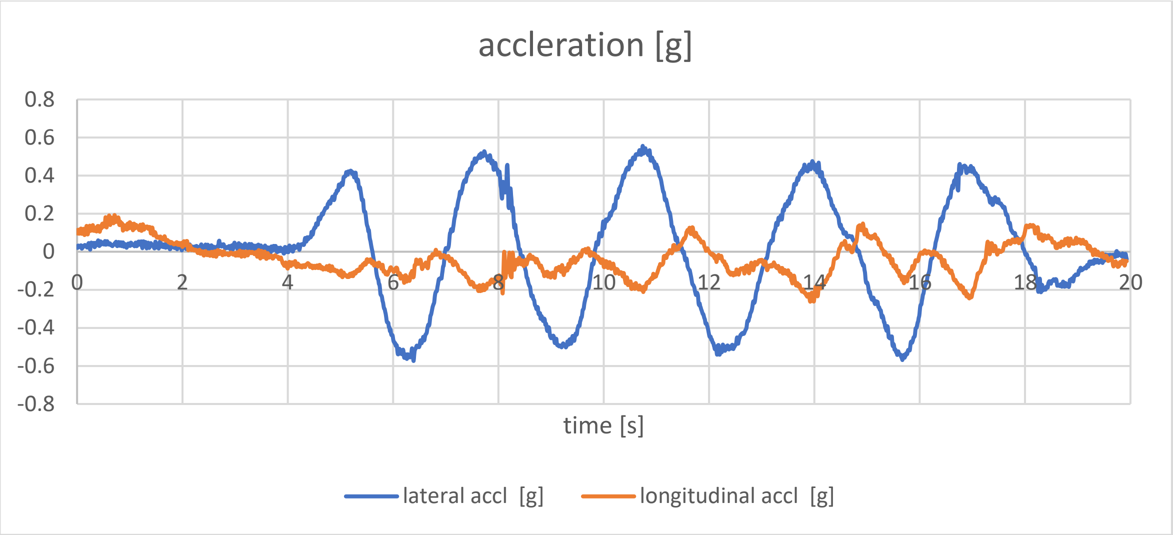

Figure 32- Course of lateral acceleration and longitudinal acceleration of the vehicle during a Slalom maneuver

As the vehicle initiate right turn the height on the right increases and the height on the left decreases, And the opposite happens when the vehicle initiates a left turn as seen in the course of change in height both sides within a range of -0.05m to 0.05m.

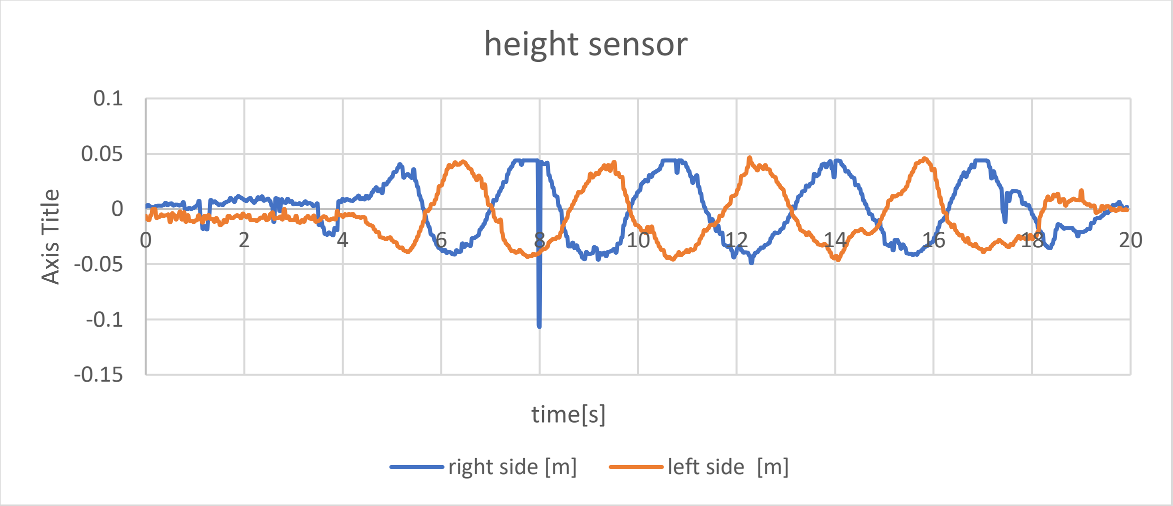

Figure 33- course of change in height during Slalom maneuver

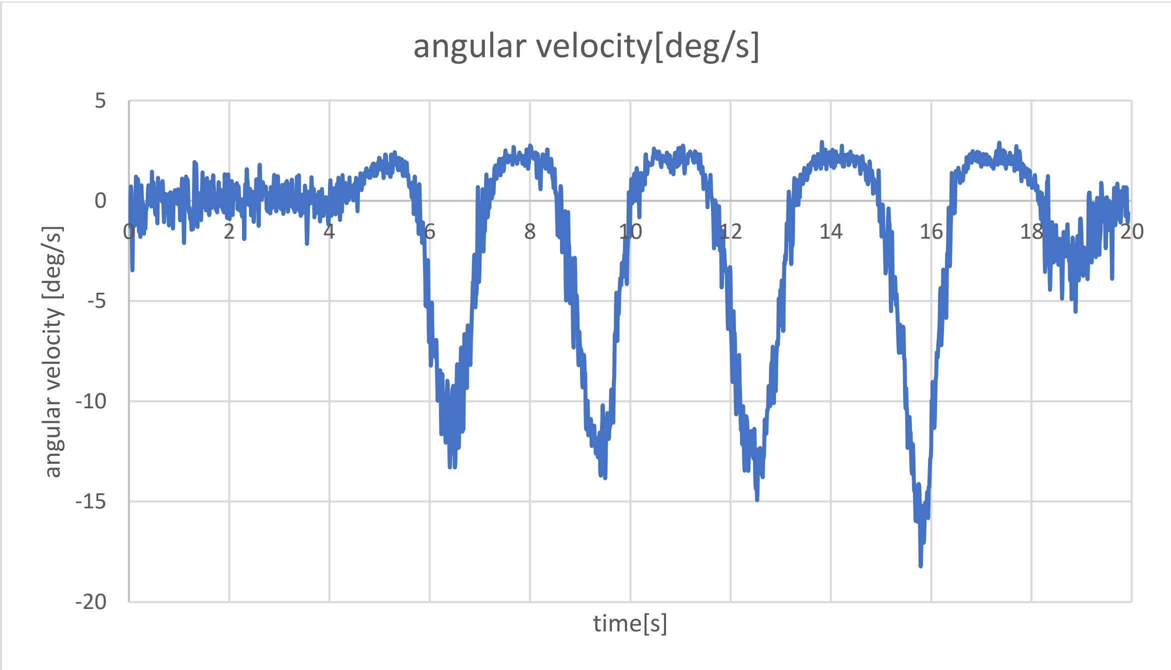

Figure 34 – course of vehicle angular speed during Slalom maneuver

4.6 Evaluation of Round-about turn maneuver results.

In the Round-about turn maneuver as the vehicle initiate the turn towards the left you can see an increase in steering wheel angle value. The turn initiates at the 10th second of the corridor when is completed at the 22nd second.

The steering is slightly rotated to the right clockwise for 2.5 secs and the value for steering wheel angle in the graph is decreased to -0.023m, then the steering is rotated anticlockwise for a large left turn for next 4 seconds where is the reading in the graph is increased to 0.1m (max at 16.3th sec) and again rotating the steering wheel back to original position for next 4 secs when the value is -0.02m and then a small clockwise rotation for 2 seconds to bring the vehicle back to the straight direction in the lane.

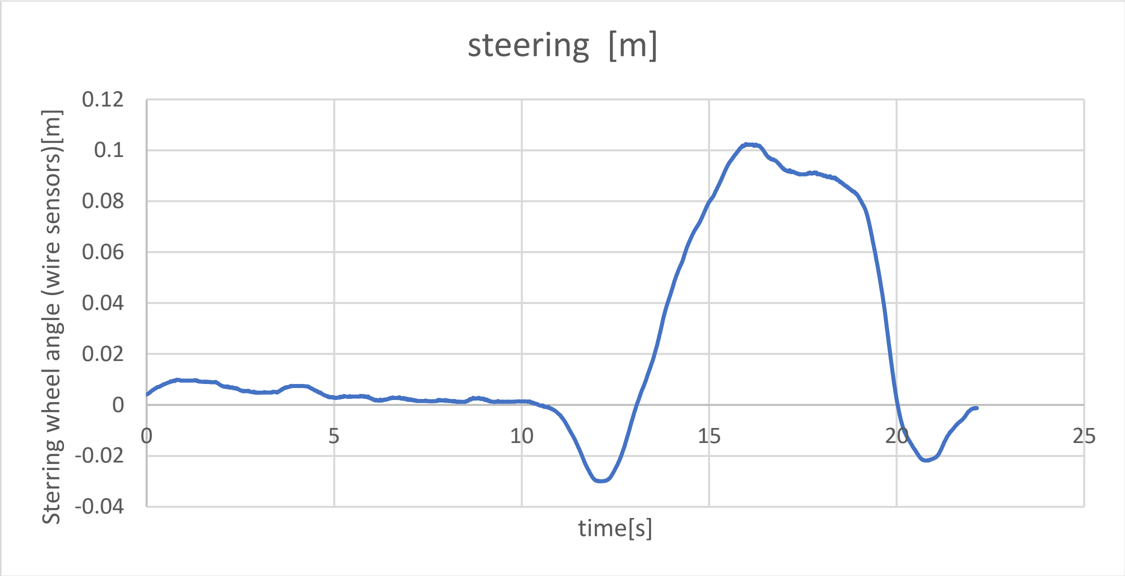

Figure 35 - course of the steering wheel angle during a Round-about turn maneuver

The vehicle travels with an average velocity of 31.2 kmph. You can see the change in the value of lateral acceleration during the turn in the first half the value is increased when the vehicle performs right turn and decreased to negative when turned left.

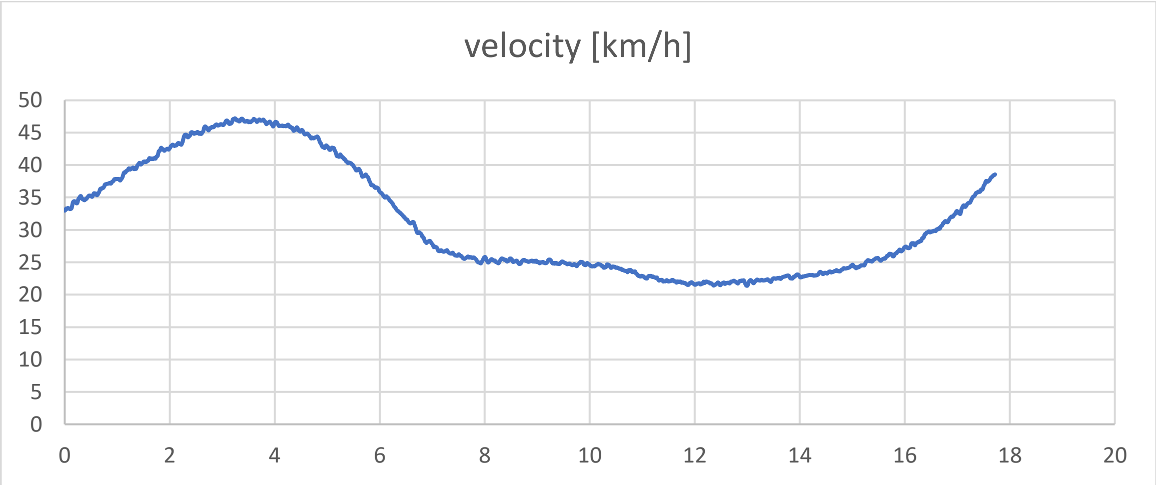

Figure 36 - course of velocity in the straight direction during Round-about turn maneuver

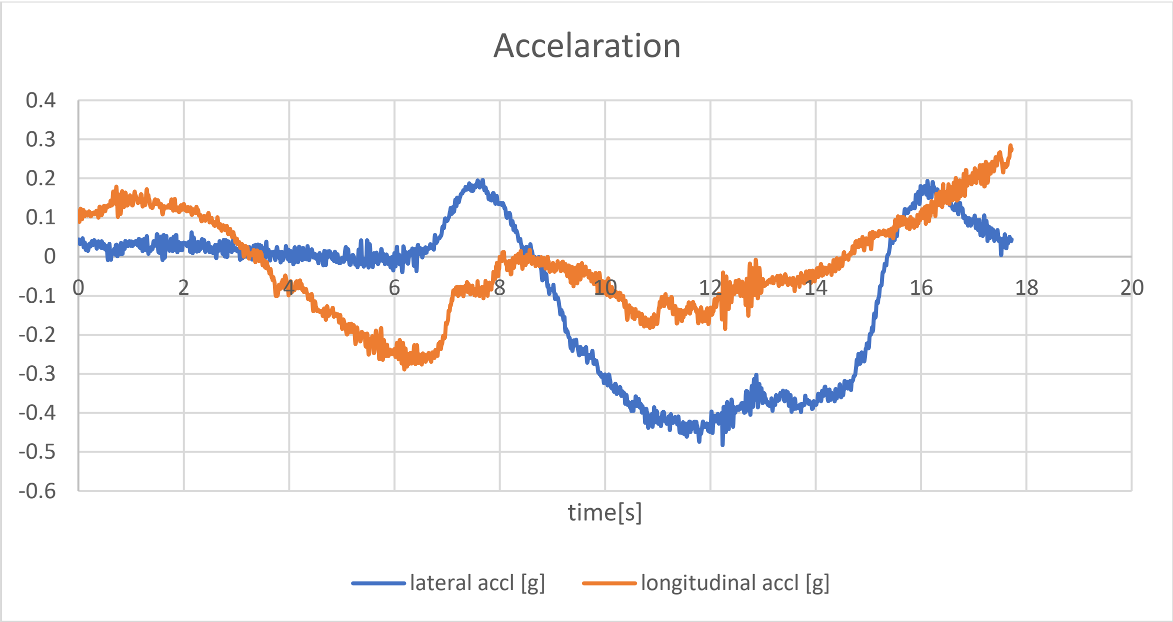

Figure 37 - course of lateral acceleration of the vehicle during a Round-about turn maneuver

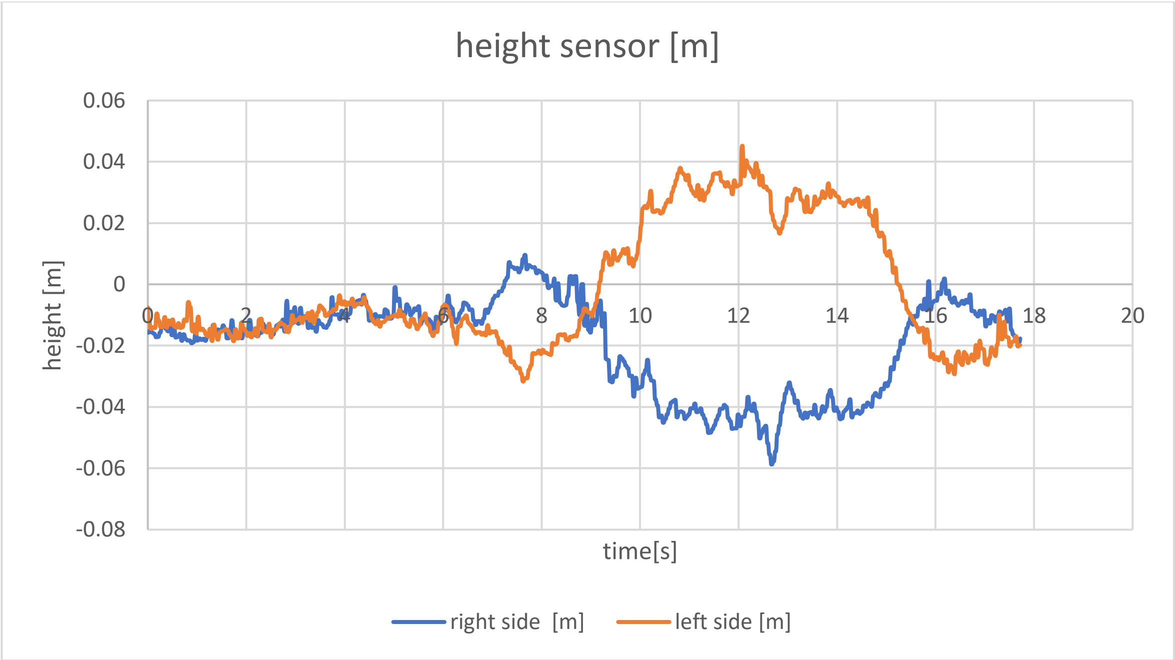

Figure 38 - course of change in height during Round-about turn maneuver

As the vehicle initiates left turn the height of the left side of the vehicle increases.

5 CONCLUSIONS

Throughout the course you are successfully able to determine the characteristic course of the kinematic variable quantities during various typical road vehicle maneuvers and were able to process the measured data and interpret them accordingly.

The study is of an experimental nature with ERTC equipment and technology, which requires a lot of time. To begin with selecting the vehicle, setting up the measuring devices and control panel and computer to record the measurement, then selecting a proper location to implement the test corridors and perform the test with all the safety measures.

I realized that to get to an ideal result a various number of tests for each maneuver were performed. And selected the ones closest to the ideal. Other tests were rejected due to technical or operator errors such as loosening of wire connections, draining of batteries, unfavourable weather conditions etc.

I studied that during each maneuver as the vehicle performs the test there is a change with measured quantities i.e., the vehicle speed in different direction, the steering wheel angle, the lateral and the longitudinal acceleration of the vehicle, angular velocity, the height of the vehicle body from each side. All these parameters are linked with each other, I have observed during the study that as the vehicle is turned to a certain direction at the same time the lateral acceleration of the vehicle along with height on both sides is changed, turning the vehicle right the lateral acceleration value increases in a positive direction, and it decreases in the negative as the vehicle is turned right. I measured the parameters for the maneuvers by obtaining average values for each course of driving parameter from the straight drive and then taring parameters for other maneuvers. All this with the help of various sensors used.

During driving in each maneuver, the time for performing task is observed such as time required to apply brakes to high-speed travelling vehicle, to change a lane, to perform a sharp or a roundabout turn. And what exactly happens during these time intervals to the other parameters.

I can further expand our research to study different aspects affecting the course of measurement which can include wind speed, air resistance, vehicle condition such as tire inflation pressure, etc and including different types of vehicles as well.

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