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Research Article

Experimental Testing of Transient and Steady State Handling Characteristics of Passenger Vehicle

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Abstract

Handling generally refers to how a vehicle responds when it turn. Handling characteristics of the vehicles are closely related to driving safety. Handling characteristics of road vehicles refer to its response to steering commands and to environmental inputs, such as wind gust and road disturbances that affect its direction of motion. Many traffic accidents are caused by undesired and unexpected handling behavior of the vehicle. Hence it is necessary to understand the handling characteristics of the vehicle. The fundamental understeer/oversteer signature of a vehicle has evaluated through steady state circular skid pad testing according to one of the four methodologies outlined in the SAE J266 circle test. *These tests evaluate a vehicle's fundamental handling behavior, but are insufficient to fully establish its yaw stability and control characteristics and performance envelope. Transient testing of the vehicle is also necessary because vehicles are not operated under steady state conditions. This becomes of greatest importance in an emergency situation where a driver must respond quickly. For good handling and control, it is necessary for a vehicle to understeer in circular skid pad testing. Additionally, the vehicle must not become yaw unstable in a transient test (J-turn). In the present work, handling tests have been conducted on passenger vehicle Testing Laboratory.*

Keywords: *Steady State and Transient Test, Handling Characteristics, Handling Parameters, Four Wheeled Passenger Vehicle.*

1. Introduction

Vehicle handling has a long-established relationship to motor vehicle safety. A vehicle that is not stable in yaw up to its limit of performance is more likely to lose control. This can potentially lead to any number of accident scenarios including rollover, impact with fixed objects, impact with other motor vehicles, and impact with pedestrians. Traditional measures of vehicle handling are based on a combination of subjective driving evaluations along with some objective steady state testing. Pulse road test performed for a three-wheeled motor-vehicle due to its wide range of frequency and driver-vehicle system combination. The handling characteristics of a road vehicle refer to response to steering commands and to environmental inputs, such as wind gust and road disturbances that affects its direction of motion. There are two basic issues in vehicle handling: one is the control of the direction of motion of the vehicle; the other is its ability to stabilize its direction of motion against external disturbances. Handling characteristics of vehicles are related to vehicle active safety systems (Thomas D. Gillespie, 2001, J. Y. Wong, 2001). Stability and handling of the car can be predicted by conducting various directional tests.

Sudheer Kumar and V K Goel (2014), conducted a test and recorded data is used for evaluating handling parameters for a three-wheeled motor vehicle using MATLAB code. Some researcher have built multi-body dynamics model based on ADAMS software to compare with the mathematical model. Yan Chunali, (2010) has studied handling characteristics of a forest fire patrolling vehicle, two degrees of freedom mathematical and analytical model is built and steady state response characteristic is analyzed. Apart from the mathematical model, multi-body system dynamics model based on ADAMS software is built to compare with the mathematical model. Virtual experiments which include steady state turn and transient state response were simulated in order to analyze handling characteristics. The results showed that the results of mathematical method coincide with the results of virtual analysis method; the forest fire patrolling vehicle has understeering characteristics. Rajesh Raja Mani (2006) presented differential braking systems which utilize the ABS brake system on the vehicle to apply differential braking between the right and left wheels to control yaw moment. The vehicle model used to study differential braking based on yaw stability control system. Xinyu Wang *et al.* (2013) designed a steering controller which is based on multiple fuzzy logic inference engines. The simulation and experiments showed that the autonomous vehicle equipped

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with the underlying lateral control strategy can perform very well in different driving tasks, which verify the effectiveness of the proposed lateral control design methods.

2. Handling Characteristics Testing Methods

Three different test procedures can be performed during the vehicle handling characteristics evaluation testing namely constant radius test, constant speed test, Step steer test.

2.1. Constant radius test

This test is designed to measure the steady state understeer and/or oversteer characteristics of the vehicle. The tests are to be conducted as per ISO 4138:2012, on a closed skid pad around a 30 m radius circle. In this test, it is required that vehicle should begin at selected radius and run at different speed in left and right turn slowly and accelerate around the prescribed circle at less than 0.05 g until reaching the maximum speed attainable. In actual test, vehicle is running at 30 m radius for different selected speeds 10 km/h, 15 km/h, 20 km/h, 25 km/h, 30 km/h and 35 km/h.

2.2. Constant speed test

This test is used to measure the steady state understeer and/or oversteer characteristics of the vehicle. The tests are to be conducted as per ISO 4138:2012, on a closed skid pad around a number of marked circles of different radiuses 120 m, 100 m, 80 m, 60 m, 40 m and 30 m radius circles. In this test, it is required that vehicle should begin at selected speed and run at different radius in left and right turn slowly accelerate around the prescribed circle at less than 0.05 g until reaching the maximum speed attainable. In this test, vehicle is running at 25 km/h speed for different selected radiuses 120 m, 100 m, 80 m, 60 m, 40 m and 30 m radius.

2.3. Step steer test

This test is conducted as per ISO 7401:2003(E). In this test, vehicle is drive at test speed in a straight line. The Initial speed shall not deviate by more than 2 km/hr from test speed. Starting from a $0^{\circ}/s \pm 0.5^{\circ}/s$ yaw velocity equilibrium condition, apply a steering input as rapidly as possible to a preselected value and maintain at that value for several seconds after the measured vehicle motion variables have reached steady state. In order to keep steering input short relative to vehicle response time, time between 10% and 90% of steering input should not be greater than 0.15 sec. No change in throttle position shall be made, although speed may decrease. A steering wheel stop may be used for selecting the input angle. Take data for both left and right turns. All data shall be taken in one direction followed by all data in the other direction. Alternatively, take data successively in each direction for each acceleration level from lowest to highest level. Data shall be taken throughout the desired range of steering inputs and response variable outputs. Determine the steering wheel angle amplitude by steady state driving on a circle the radius of which gives the preselected steady state lateral acceleration in required test speed. The standard steady-state lateral acceleration level is 4 m/s^2. Additional levels of 2 & 6 m/s^2 may be used. Perform all test runs at least 3 times.

Table 1 Step Steer Test Input

Speed (km/h)	Steering Wheel Angle (degree)
10	30 for left turn
20	30 for left turn
20	90 for left turn
25	60 for left turn
25	90 for left turn
25	90 for right turn

3. Test Vehicle

The test vehicle used is a front engine, four wheel drive (4WD), front wheel steering, and two-axle passenger car. The front axle has Macpherson strut coil spring suspension and the rear axle has Double Wishbone coil spring suspension.

4. Instrumentation used for Testing

The following instruments are used to carry out testing of the test vehicle

4.1 Remote Wireless Handy Weighing Pad

To measure the weight distribution of test vehicle on each wheel & axle, the remote wireless handy weighing pads of Mechanical Systems used. The weight distribution will be used to calculate Center of Gravity (C.G.) of the vehicle.

Fig. 2 Handheld Display and Wireless Weighing Pad

Fig. 3 The test vehicle weight measurement on wireless weighing pad

From the above instrument, it is observed that weight on front right and front left wheel is 492 kg and 464 kg respectively, and weight on rear right and rear left wheel found 368 kg and 331 kg respectively. Rear axle weight is found 699 kg and gross weight of vehicle is 1655 Kg.

4.2 Systems for Motion Measurement

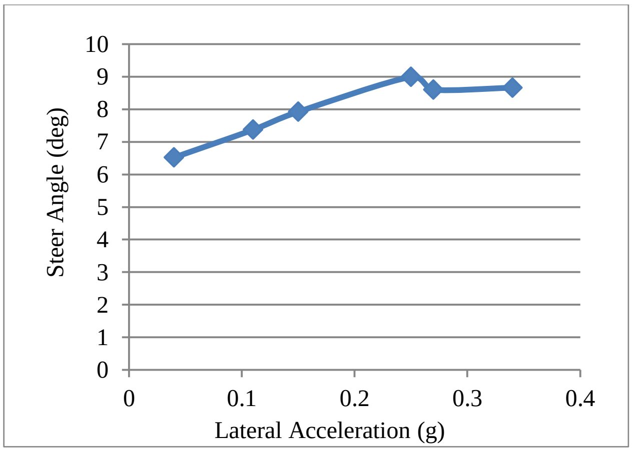
Inertial Measurement Unit is used for motion measurement during the testing. This unit provides highly accurate measurements of velocity, pitch, roll, and yaw, using three yaw rate sensors and three accelerometers. It is situated at the center of gravity (C.G.).

5. Results

The following data are acquired for constant radius test and constant speed test for left and right turn, steering ratio 16:1 is assumed for calculating steer angle.

Table 2 Steer angle & Lateral acceleration for Left Turn

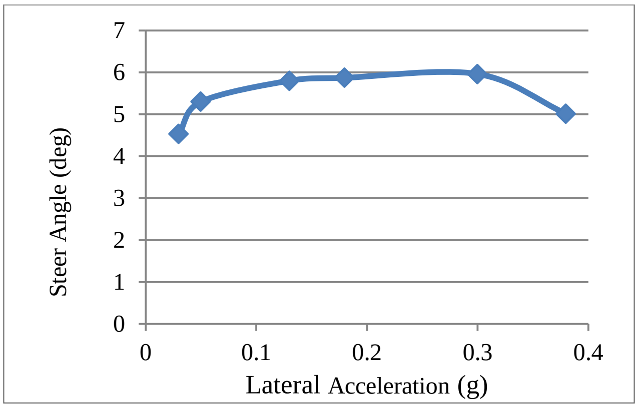
Steering Wheel Angle (deg)	Steer Angle (deg)	Lateral Acceleration (g)
104.36	6.52	0.04
118.05	7.37	0.11
126.83	7.92	0.15
143.96	8.99	0.25
137.66	8.6	0.27
138.67	8.66	0.34



Graph 1 Steer Angle Vs Lateral Acceleration at Constant Radius Test for Left Turn

Table 3 Steer angle & Lateral acceleration For Right Turn

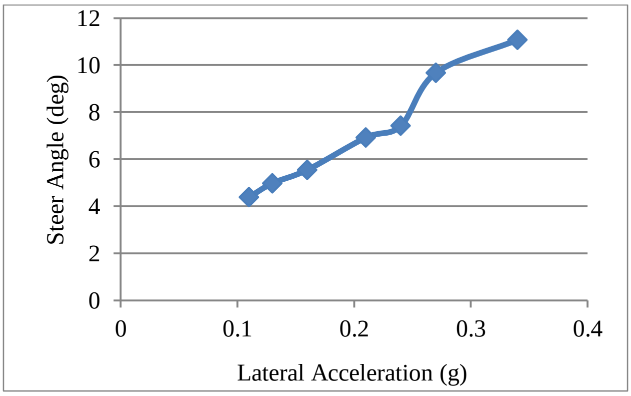
Steering Wheel Angle (deg)	Steer Angle (deg)	Lateral Acceleration (g)
207.11	4.53	0.03
84.9	5.3	0.05
82.92	5.8	0.13
78	5.87	0.18
85.91	5.96	0.3
87.6	5.01	0.38



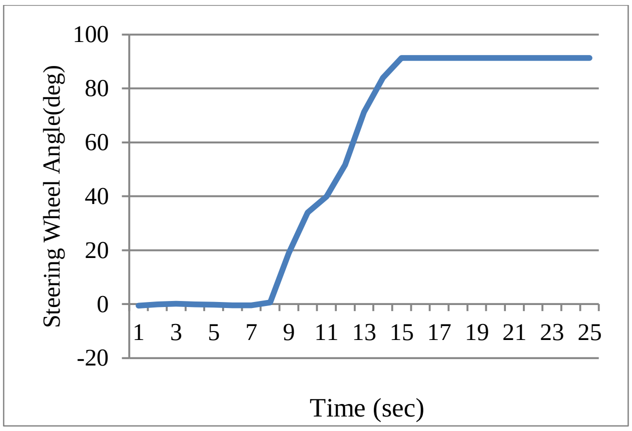
Graph 2 Steer Angle Vs Lateral Acceleration in Constant Radius Test for Right Turn

Table 4 Steer angle & Lateral acceleration For Right Turn

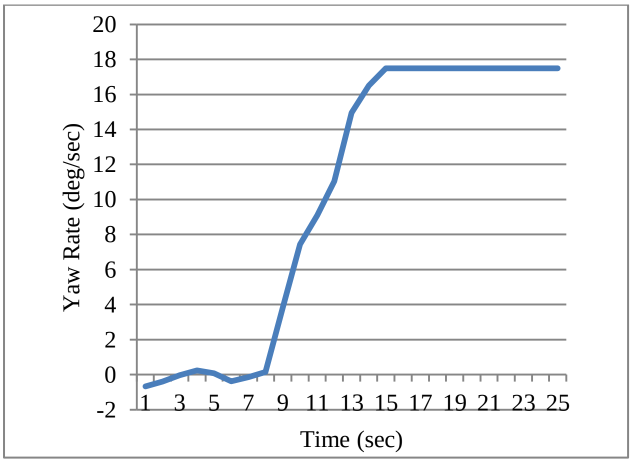
Steering Wheel Angle (deg)	Steer Angle (deg)	Lateral Acceleration (g)
70.24	4.39	0.11
79.81	4.98	0.13
88.85	5.55	0.16
110.86	6.92	0.21
118.72	7.42	0.24
177.17	9.67	0.27



Graph 3 Steer Angle Vs Lateral Acceleration in Constant Speed Test for Left Turn



Graph 4 Step Input of 90 deg SWA at 25 km/h



Graph 5 Yaw Rate for Step Input of 90 deg SWA at 25 km/h

Conclusions

From experimental results, following points concluded

1) From the graph 1 and 2, in both clockwise and counter-clockwise turns, the steer angle increases with the lateral acceleration up to about 0.25 g. Beyond 0.25 g, the changing of steering angle deviates from the linear pattern and starts to fall as lateral acceleration increases. Such a phenomenon manifest that the test vehicle is understeering when the lateral acceleration is lower than 0.25 g, then turns into limit oversteer beyond this lateral acceleration level.
2) From graph 3, in counter-clockwise turns, the steer angle increases with the lateral acceleration up to about 0.25g. Beyond 0.25 g, the changing of steering angle deviates from the linear pattern and starts to increase steadily as lateral acceleration increases. Such a phenomenon manifests that the test vehicle is understeering when the lateral acceleration is lower than 0.25 g, and then turns into limit understeer beyond this lateral acceleration level.
3) Step input test is performed for 25 Km/hr velocity and 90 degree steering wheel angle input is given. Response time of vehicle is calculated from step input test which varies from 4 to 6 Sec to get steady state of vehicle.

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