Triangle Wave

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

Note: This standard uses terminology related to the directional control of vehicles as defined by SAE J670.

1.1 Purpose. The purpose of this test procedure is to measure the steering feel and lateral response properties of a vehicle at several discrete steering input frequencies. Steering feel properties are derived from steering wheel torque, steering wheel velocity and lateral acceleration measurements. A more detailed discussion of the relationship between subjective characteristics and this test can be found in SAE 2014-01-0148.

1.2 Applicability. This test procedure can be applied to all pneumatic rubber tired highway vehicles with hand wheel steering control at any load condition.

1.3 Remarks. A standard test will have data segments at the discrete frequencies of 0.5 Hz, 1.0 Hz, 1.5 Hz and 2.0 Hz.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ISO 9001 ISO 15037-1 SAE J670

2.2 GM Standards/Specifications.

None

2.3 Additional References.

SAE Technical Paper 2014-01-0148, Ibrahim A. Badiru, “Customer Focus in EPS Steering Feel Development”, Citation: *SAE Int. J. Passeng. Cars – Mech. Syst.* 7(3):1009-1015, 2014, doi:10.4271/2014-01-0148.

3 Resources

3.1 Facilities. This procedure requires a minimum two-lane straight roadway that is at least 800 m (0.5 mi) long with an adequate berm or run off for safety. Three (3) lanes are preferred.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. Each test vehicle is to be equipped with sensors and a Data Acquisition System (DAS).

3.2.1 Steering Wheel Angle Transducer.

3.2.2 Steering Wheel Torque Transducer.

3.2.3 Vehicle Speed Sensor. Vehicle velocity and side slip is typically measured with Global Positioning Satellite (GPS)/Inertial sensors (e.g., Oxford Technologies RT3000 series). Alternatively, vehicle velocity and sideslip can also be measured with an optical sensor placed at the front-center or rear-center of the vehicle, or radar based sensors, or sonar based sensors. Sensor outputs are transmitted simultaneously to the data acquisition

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system and the instrument panel mounted display. The instrument panel mounted display allow the driver to accurately monitor vehicle speed.

3.2.4 Multi-Axis Inertial Sensor. A multi-axis inertial sensing system is used to measure fore/aft and lateral accelerations and yaw rates (e.g., Oxford Technologies RT3000 series). The position of the multi-axis inertial sensing system must be accurately measured relative to the total vehicle Center of Gravity (CG) or centroid of the vehicle in its test configuration. These data points are required to translate the motion of the vehicle at the measured location to that which occurred at the actual centroid to remove roll, pitch and yaw effects. Alternatively, a motion box package may be used to measure lateral and fore/aft acceleration and yaw rate.

3.2.5 Roll Height Sensors. Height sensors are used to measure left and right side vertical displacements for the calculation of vehicle roll angle by using one (1) ultrasonic or laser ranging module mounted on each side of a vehicle. With these data points, roll angle is calculated during post processing using trigonometry.

3.2.6 Data Acquisition System (DAS). See 3.5 and 4.1.1 for more information about the data acquisition method.

3.3 Test Vehicle/Test Piece. Any vehicle with two (2) axles and pneumatic rubber tires at any load condition.

3.4 Test Time.

Calendar time:	1 to 2 days
Test time:	1 to 4 hours
Coordination time:	1 to 4 hours

3.5 Test Required Information.

3.5.1 DAS Channels and Full Scale Values. See Table 1.

Table 1: DAS Channels and Full Scale Values

Channel	Value
Steering Wheel Angle	1440 degrees
Steering Wheel Torque	40 Nm
Vehicle Speed	150 km/h (93.2 mph)
Vehicle Sideslip	10 degrees
Lateral Acceleration	10 m/s^2
Yaw Velocity (Rate)	10 degrees/s
Roll Angle	10 degrees

3.5.2 Additional Channels. May be used as required.

3.5.3 Sample Rate. All data is to be sampled at 100 Hz. Typical anti-aliasing filter frequency is 25 Hz.

3.6 Personnel/Skills. Operator must be qualified and documented as capable to run this test as required by ISO 9001.

4 Procedure

Note: This standard follows the general conditions that apply when vehicle dynamics properties are determined, as specified in ISO 15037-1.

4.1 Preparation.

4.1.1 Installation.

4.1.1.1 The DAS must be will restrained inside the vehicle. The front passenger seat is a typical and acceptable location.

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4.1.1.2 The multi-axis inertial sensor must be installed and securely mounted at or near the total vehicle center of gravity (centroid or CG), with the location recorded on the Test Vehicle Description (TVD) sheet (or similar). Refer to Appendix B, Data Sheets B1 and B2 for a sample TVD sheet. The CG of a vehicle is typically located in the area between the front driver and passenger seats. Interior components such as the center console may need to be removed in order to mount the multi-axis inertial sensor in a suitable location.

4.1.1.3 The roll height sensors must be securely mounted on the left and right side of the vehicle. Typically the sensors are installed at the end of a bar that can be strapped securely to the front of the vehicle. The fore/aft location of the sensors and the lateral distance between the sensor heads should be recorded in the TVD sheet.

4.1.1.4 If an optical speed sensor is used, it should be mounted at the front or rear of the vehicle and centered laterally. If the sensor cannot be mounted at the precise lateral center of the vehicle, the magnitude and direction of offset from center should be documented and reported to the appropriate test engineer.

4.1.1.5 If a motion box package is used, it should be installed in a level position as close to the centroid as is practical. The front passenger seat foot well is a typical and acceptable location. The for/aft location of the motion package should be recorded on the TVD sheet.

4.1.1.6 All ballast inside the passenger compartment of the vehicle must be secured in place. Water dummies must be secured with straps in addition to the seat belts. All loose equipment should be removed from the passenger compartment, including tools, extra transducers and personal belongings.

4.1.2 Vehicle Preparation.

4.1.2.1 The test vehicle should be inspected to ensure that the proper tires and suspension components are installed, and that all chassis components are in good mechanical condition.

4.1.2.2 The vehicle suspension should be aligned to nominal specifications.

4.1.2.3 With the fuel tank full, the vehicle test weights should be determined and recorded.

4.1.2.4 Vehicles equipped with a “tilt-wheel” steering column should be adjusted such that the alignment of the column is as straight as possible.

4.1.3 Tire Preparation.

4.1.3.1 Tire pressures should be set to the requesting engineer’s recommended cold pressure for each tire, unless otherwise stated on the test request.

4.1.3.2 Note the condition of the tires. New tires should be broken in by driving 10 km (6.21 mi) at 100 km/h (62.1 mph), including moderate cornering and several heavy brake stops (without inducing skidding). Obviously worn tires should be noted and the appropriate wear state checked on the TVD worksheet.

4.1.4 Operator Precautions.

4.1.4.1 Seat belts must be worn during testing. Lock all doors and close all windows prior to testing.

4.1.4.2 The test operator (driver) must inform any others at the test site of their presence using the appropriate site-specific communications protocol.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 There should be no standing water or ice patches on the roadway, however, a damp roadway is acceptable.

4.2.1.2 The wind speed component perpendicular to the direction of travel should be no more than 15 km/h (9.32 mph).

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 Turn on all instrumentation and data acquisition equipment and allow at least 5 minutes to warm up.

4.3.2 Establish the straight-ahead setting on the steering wheel by driving in a straight-ahead direction at 100 km/h (62 mph). Mark the 12 o-clock position on the steering wheel with a piece of tape. If the steering wheel transducer is equipped with a protractor to reference steering wheel zero and steering amplitudes, line up the steering wheel protractor zero degree mark with the pointer when the steering wheel is directing the vehicle in a straight-ahead direction.

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4.3.3 With the vehicle at rest, the steering wheel in the straight-ahead position and hands off the wheel, record the balance and calibration data. If the steering wheel transducer is equipped with a digital readout, zero the steering wheel angle and torque outputs.

4.3.4 Drive at selected test speed (set cruise control if available) and input approximated triangle wave steer with an amplitude of 10 degrees and desired target frequency. A standard test will include separate segments with steering input at a discrete frequencies of 0.5 Hz, 1.0 Hz, 1.5 Hz and 2.0 Hz. Figure 1 shows an example of a satisfactory steer input at 0.50 Hz.

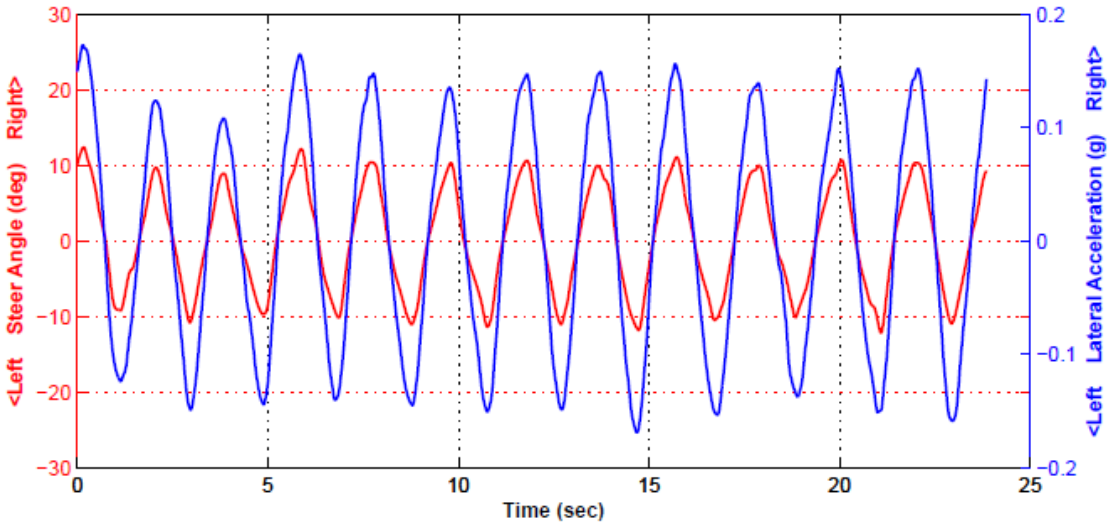

Figure 1: Sample Steer Input

4.3.5 Given the fixed steering peak amplitude and varying input frequency of each segment, the peak amplitude of lateral acceleration will vary between segments.

4.3.6 Begin data acquisition/storage at a steering angle peak after at least one (1) complete steering cycle. Record data for a complete 25 s data segment.

4.3.7 Using the DAS time trace, check that the steer amplitudes do not vary any more than 2 degrees from target in either steer direction. Verify that the frequency of the steering angle input is within 0.10 Hz of the target frequency. The steer angle trace should appear triangular, not a square wave or sine wave. There should be no extraneous peaks in the signal (excluding noise). Steering wheel torque and speed signals should be present and free of noise. See Figure 2.

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