Passenger car – light trailer combinations – Cornering performance test

1. Scope

This standard specifies the cornering performance test procedure for combination vehicles of passenger cars or passenger car-type vehicles (hereinafter referred to as the "towing vehicles") and light trailers (hereinafter referred to as the "combination vehicles").

The light trailer herein refers to a trailer having a vehicle total mass of 750 kg or less, and is specified in the "Camping Trailers Structure Standards" stipulated by the Japan Automobile Manufacturers Association (JAMA) and the Japan Auto-Body Industries Association inc (JABIA). The light trailer herein also includes other equivalent trailers.

2. Normative reference

The following standards contain which, thorough reference in this Standard, constitute provisions of this Standard. The most recent editions of the standard indicated below shall be applied.

JASO Z117-1 Automobile – Steerability and safety test procedure – Part 1:Passenger car standard test conditions

3. Definitions

Definitions of main terms used in this standard shall be as follows.

a) Cornering radius

A curvature radius of a centerline of the cornering course to be used in the test. This is indicated by R (m).

b) Steering wheel angle

A rotation angle of a steering wheel of the towing vehicle. This angle is indicated by θ (°).

c) Towing vehicle and trailer lateral acceleration speed

A lateral acceleration speed at a position of the gravity center of the towing vehicle and trailer. These speeds are indicated by α (m/s^2) and α' (m/s^2), respectively.

d) Mean vehicle speed

A mean value of a vehicle speed of the combination vehicle within the measurement zone of the cornering course. This is calculated by dividing a length of a centerline of the measurement zone of the cornering course by a time required for the combination vehicle to pass through the zone. The mean vehicle speed is indicated by V (km/h) or v (m/s).

e) Centripetal acceleration

A component that is directed toward a cornering center direction of the acceleration vectors of the combination vehicle. This is indicated by A (m/s^2).

f) Centripetal acceleration influence coefficient

An inclination obtained by collinearly approximating a relation of the steering wheel angle and the centripetal acceleration during steady cornering at the centripetal acceleration of approximately 0-3 m/s^2. This coefficient is indicated by N [°/(m/s^2)].

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g) Roll ratio of towing vehicle and trailer

A roll angle of the towing vehicle and trailer which corresponds to the centripetal acceleration of 5 m/s^2 in a case in which a relation of the roll angle of the towing vehicle and trailer and the centripetal acceleration during steady cornering at the centripetal acceleration of approximately 0-3 m/s^2. This ratio is indicated by ϕ [°/5 (m/s^2)] and ϕ ' [°/5 (m/s^2)].

4. Test conditions

4.1 Vehicle conditions

The vehicle condition during testing shall be as follows.

a) A mass and an axial load of the towing vehicle in a non-hitched condition shall be as close as to a value specified in the specification under a condition in which test subjects and test equipment are onboard.

b) The total mass and axial load (such as a hitch load) of the trailer during testing shall be as close as to a value specified in the specification.

c) Tyres of the towing vehicle and trailer shall comply with **5.4.2** (Tyre) of **JASO Z117-1**.

d) Wheel alignment and play of a steering system of the towing vehicle shall be set to a value specified in the specification.

4.2 Test course and course form

A test course and course form shall be as follows.

a) Test course

A test course shall comply with **5.2** (Test course) of **JASO Z117-1**.

A friction coefficient of the road surface is not particularly specified, but the skid number or friction coefficient shall preferably be measured.

b) Test course form

Normally, a cornering course shall be such that a centerline is drawn on the circumference of the 30 m-cornering radius (*R*) as shown in **Attached Figure 1**, and at the both sides thereof, the signs for defining a 3.6 m-road width (*b*) shall be placed at the appropriate intervals along the total length of the cornering course. A cornering angle (*a*) in the measurement zone shall be 120 ° or greater. Both ends of the course shall preferably have a transit curve zone, in a tangential direction of the cornering circle, which corresponds to the entry zone and exit zone, respectively.

4.3 Test equipment

Test equipment shall be as follows.

a) Steering wheel angle measuring device

A device for measuring a steering wheel angle of the towing vehicle. The device shall comply with **4** (Measuring device) of **JASO Z117-1**.

b) Lateral acceleration measuring device

A device that is set at a position of the gravity center of the towing vehicle and trailer to measure a lateral acceleration speed of the vehicle. The device shall comply with **4** (Measuring device) of **JASO Z117-1**.

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c) Vehicle speed measuring device or timer

A device for measuring a mean vehicle speed or a test course pass time of the test vehicle. The device shall comply with **4** (Measuring device) of **JASO Z117-1**.

d) Sign

A fixture for defining a road width of the cornering course.

e) Other

Equipment necessary for taking measurements and recording data.

4.4 Wind speed

The test driving shall be conducted under a natural wind condition in which the wind speed is 3 m/s or less to minimize measurement variance.

5. Test procedure

5.1 Measurement preparation

Approximate values for characteristic values to be measured shall be checked and measuring equipment shall be adjusted and set. Prior to the test driving, drive straight and stop in that condition to set the zero position of the steering wheel angle measuring device.

5.2 Test driving procedure

The towing vehicle shall be driven at a speed as constant as possible along the centerline of the cornering course. The test vehicle speed shall be a value obtained by dividing, approximately by ten, the speed range from a very low speed to the maximum speed that allows safe driving without deviating from the course. The test driving shall be conducted once for each speed. The steering wheel angle shall be kept as constant as possible during driving. The cornering test shall preferably be conducted for both left and right cornering directions. However, if this is not possible due to course setting and other reasons, the test can be conducted in either one of the left and right directions.

5.3 Measurement

a) A steering wheel angle and a lateral acceleration speed in a zone including the measurement zone and the zones ahead and behind thereof shall be measured.

b) A pass time T_i (s) of the measurement zone shall be measured and recorded in **Attached Table 1**.

5.4 Course pass judgment

The test driving shall be considered invalid when any one of the following conditions applies: when the vehicle touches or knocks down the signs; and when a difference between vehicle speeds at the entry zone and the exist zone is 5 km/h or more by the visual measurement using a speedometer of the towing vehicle.

6. Recording and organization procedure

6.1 Record creation

Each item in **Attached Table 2** shall be checked and filled out prior to the test.

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6.2 Data organization and representation procedure

When the test is conducted in both left and right directions, the left cornering shall be indicated by j=1 and the right cornering shall be indicated by j=2, and data shall be organized in the following procedures. When the test is conducted only in one direction, the calculation of the mean value of the left and right cornering is not conducted.

a) Calculation of mean vehicle speed and centripetal acceleration

The mean vehicle speed (v_i) and the mean centripetal acceleration (A_i) for each driving cycle shall be calculated by the following equation and be recorded in **Attached Table 1**.

Mean vehicle speed	$v_i = L / T_i$	(m/s)	(1)
Mean centripetal acceleration	$A_i = v_i^2 / R$	(m/s^2)	(2)
However, cornering course measurement zone	$L = Ra / 57.3$	(m)	(3)

b) Reading of steering wheel angle

From the recorded waveform, a zone in which a steady cornering is achieved for three seconds or longer shall be selected, and an absolute value of the mean value of the steering wheel angle (θ_i) shall be read and entered in **Attached Table 1**.

c) Relation of centripetal acceleration and steering wheel angle

A relation of the centripetal acceleration (A_i) and the steering wheel angle (θ_i) shall be entered in **a)** of **Attached Table 4**, separately for each of left and right cornering. Also, the relation of the centripetal acceleration and the steering wheel angle shall be collinearly approximated by the least square method and entered in **a)** of **Attached Table 4**.

1) From θ_i and A_i in **Attached Table 1**, take out θ_i and A_i of the group k which fall under $A_i \leq 3$ m/s^2, and calculate $\Sigma\theta_i$, ΣA_i, and ΣA_i^2. Then, obtain an inclination (centripetal acceleration influence coefficient N_j) of collinear approximation of the data and a constant term (steering wheel angle Θ_j at very low speed cornering) by the following equation.

$$N_j = \frac{k\left(\sum \theta_i A_i\right) - \left(\sum \theta_i\right)\left(\sum A_i\right)}{k\left(\sum A_i^2\right) - \left(\sum A_i\right)^2} \qquad [°/(\mathrm{m/s^2})] \qquad (4)$$

$$\Theta_j = \frac{\sum \theta_i - N_j\left(\sum A_i\right)}{k} \qquad (°) \qquad (5)$$

2) Based on N_j and Θ_j obtained by the calculation above, express, as shown below, the equation for collinear approximation of the centripetal acceleration influence coefficient and the steering wheel angle for each cornering direction. In the equation, the steering angle shall be $\overline{\theta}_j$ and the centripetal acceleration shall be $\overline{A}_j$.

$$\overline{\theta}_j = \Theta_j + N_j \overline{A}_j \quad (j = 1, 2) \qquad (6)$$

However, $0 < \overline{A}_j \leq 3$ (m/s^2)

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d) Centripetal acceleration influence coefficient

A mean value (N) of the centripetal acceleration influence coefficient at the left and right cornering shall be obtained from N_j (j = 1, 2) obtained by the equation (4).

$$N = \frac{1}{2}(N_1 + N_2) \qquad [°/(m/s^2)] \qquad (7)$$

e) Representation of US-OS characteristics

A mean value of the steering wheel angle at the left and right cornering at a very low speed shall be obtained from Θ_j (j = 1, 2) obtained by the equation (5).

$$\Theta_0 = \frac{1}{2}(\Theta_1 + \Theta_2) \qquad (°) \qquad (8)$$

A relation of a ratio (θ_i / Θ_0) of Θ_0 and steering wheel angles (θ_i) for respective driving cycles (hereinafter referred to as "steering wheel angle ratio") and the centripetal acceleration (A_i) shall be indicated in **b)** of **Attached Table 4** separately for the right cornering (with a solid black circle) and the left cornering (with a blank circle). Also, values of Θ_0 and R shall be entered in **b)** of **Attached Table 4**.

Next, a representative value stability factor (K) of the US-OS characteristics shall be obtained by the following equation and recorded in **Attached Table 3**.

$$K_j = N_j / (57.3 \times l\eta) \qquad (s^2/m^2)$$

$$K = \frac{1}{2}(K_1 + K_2) \qquad (s^2/m^2) \qquad (9)$$

Wherein, l: towing vehicle wheelbase (m)

η: Overall steering ratio

f) Calculation of relation of centripetal acceleration and lateral acceleration and roll ratio

1) For each driving cycle, a mean lateral acceleration α_i (m/s^2) and α_i' (m/s^2) of the towing vehicle and trailer in a zone which can be considered from the recorded waveform that steady cornering is achieved for three seconds or longer shall be read and recorded in **Attached Table 1**.

2) A relation of the centripetal acceleration (A_i) and the lateral acceleration (α_i and α_i') of the towing vehicle and trailer shall be recorded in **c)** of **Attached Table 4** separately for the right and left cornering.

3) Based on the data which comprehensively include left and right cornering, a relation of the lateral acceleration and the centripetal acceleration shall be, within a range of $0 < A_i \leq 3$ m/s^2, approximated by a straight line that passes through the origin. A lateral acceleration of a point that corresponds to the centripetal acceleration of 5 m/s^2 on the straight line shall be read, and entered in **c)** of **Attached Table 4**, using α_0 (m/s^2) for the towing vehicle and α_0' (m/s^2) for the trailer.

4) A roll ratio shall be estimated by the following equation and entered in **c)** of **Attached Table 4**.

Roll ratio of towing vehicle $\quad \phi = \sin^{-1}\left(\frac{\alpha_0 - 5}{9.8}\right) \qquad (°/5\ (m/s^2)) \qquad (10)$

Roll ratio of trailer $\quad \phi' = \sin^{-1}\left(\frac{\alpha_0' - 5}{9.8}\right) \qquad (°/5\ (m/s^2)) \qquad (11)$

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g) Relation of lateral acceleration of towing vehicle and trailer

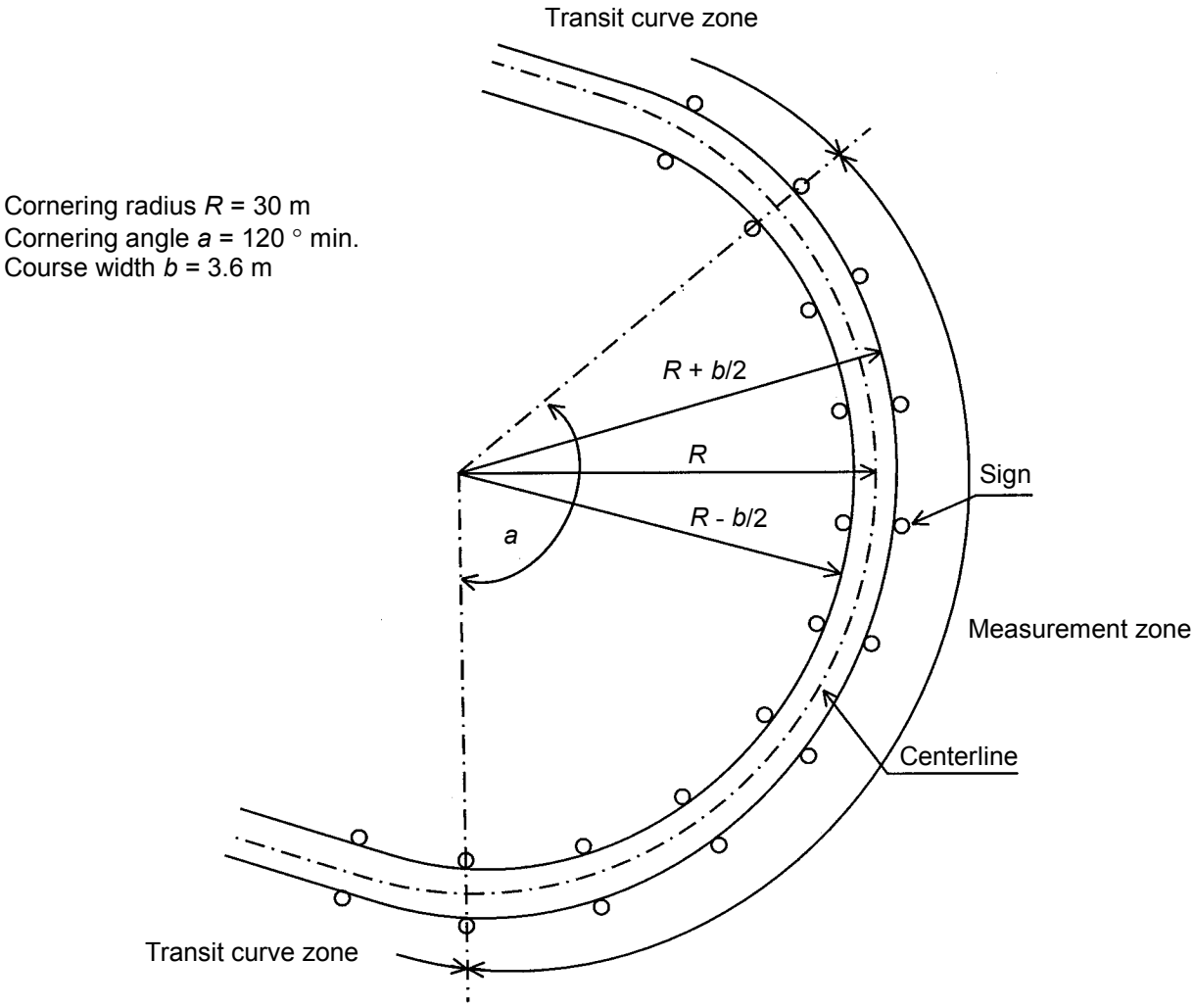
A lateral acceleration at the center of gravity of the towing vehicle and the trailer during cornering at the centripetal acceleration A_i (m/s^2) shall be obtained by the following equation. Alternatively, the lateral acceleration shall be obtained schematically using **c)** of **Attached Table 4** and entered in **d)** of **Attached Table 4**.

Lateral acceleration of towing vehicle $\beta_i = \alpha_i - (\alpha_0 - 5)\, A_i / 5$ (m/s^2) (12)

Lateral acceleration of trailer $\beta_i' = \alpha_i' - (\alpha_0' - 5)\, A_i / 5$ (m/s^2) (13)

6.3 Record

Results organized in **7.2** shall be recorded in **Attached Table 3**. Also, a maximum centripetal acceleration that allows stable driving on the course and a maximum lateral acceleration of the towing vehicle and trailer shall be entered. In addition, if any behaviours of the combination vehicle and phenomena specific to the towing vehicle and trailer that should be noted are identified, they should be entered in the remarks column.



Attached Figure 1 Sign placement and cornering course (Example)

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