

Construction of an ISO 26262 C Class Evaluation Method for Motorcycles

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ABSTRACT

For applying ISO 26262 to motorcycles, controllability classification (C class evaluation) by expert riders is considered an appropriate technique. Expert riders have evaluated commercial product development for years and can appropriately conduct vehicle tests while observing safety restrictions (such as avoiding the risk of falling). Moreover, expert riders can ride safely and can stably evaluate motorcycle performance even if the test conditions are close to the limits of vehicle performance.

This study aims to construct a motorcycle C class evaluation method based on an expert rider's subjective evaluation. On the premise that expert riders can rate the C class, we improved a test procedure that used a subjective evaluation sheet as the concrete C class evaluation method for an actual hazardous event. The evaluation sheet included the C class table, in which the classifications are defined by the percentage of representative riders who could avoid harm, and a table of supplementary descriptive items indicating the background behind the C class evaluation result.

Using this method, four expert riders evaluated the C class in tests that reproduced various hazardous events. This study introduced examples of C class evaluations for scenarios involving "unintended acceleration on a straight road" and "insufficient braking force during deceleration".

The C class evaluation results of this and previous studies were summarized for each hazardous event. From these results, we concluded that the C class evaluation method considered in this study is appropriate for motorcycle C class evaluations.

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INTRODUCTION

The international standard for electrical and/or electronic (E/E) systems of road vehicles (ISO 26262) was published in November 2011[1]. The scope of the current standard is limited to passenger cars, but motorcycles are expected to be included in the second edition (to be released in 2018). Future motorcycle development is expected to be compliant with the standard. The class of controllability (C class) is used in determining the Automotive Safety Integrity Level of each hazardous event based on ISO 26262. C class evaluation for passenger cars has been reported in a previous study[2]. In addition, the method for C class evaluation of a motorcycle is under development.

A motorcycle maneuver is highly affected by the rider's control, such as leaning control, body balance, or weight shifting. In addition, a risk of accident exists when an experiment is conducted. We therefore suggest that the C class evaluation be performed by expert riders because they have the well-developed skills necessary to conduct the experiments safely.

In a previous study[3], three tests were conducted: the steady-state circular test, the lane-change test, and the brake test, assuming normal riding conditions. This study also investigated the differences between the skill levels of expert riders and ordinary riders during certain riding maneuvers. The expert riders were professional test riders; the ordinary riders were accustomed to riding the same kind of motorcycle as the test vehicle. The results of this study showed that the distribution range of the skill level of the expert riders during maneuvers in normal riding conditions was similar to that of the ordinary riders. The results also showed that the expert riders were able to control the motorcycles more appropriately in situations involving high-difficulty test conditions. The results demonstrated that the expert riders could perform as representative riders for the purposes of the given tests.

On the basis of the results of the study in [3], the following study[4] introduced a motorcycle C class evaluation method based on the subjective evaluations of expert riders. This study sought to construct an evaluation method more suitable for practical use than that in the previous study. The evaluation method was reviewed so that it was easier for the expert riders to understand how to evaluate their experiences. Further, examples of the C class evaluation in actual vehicle tests are presented.

For this study, the test plans were reviewed and approved in advance by the Research Ethics Committee of the Japan Automobile Research Institute.

C CLASS EVALUATION METHOD BY EXPERT RIDERS

The C class evaluation method using the subjective evaluation sheet and the test procedure that was reported in the previous study[4] was improved to be detailed for practical use.

Designation of the Riders

The category of expert riders, who evaluated the C class in the actual test, and the category of representative riders are described below. Note that the representative riders are the subjects of the evaluation, but for the safety-related purposes of this test, the expert riders evaluate from the viewpoint of them.

Expert Riders

- Are professional test riders.
- Can operate safely under test conditions involving difficult test conditions.
- Are trained in subjective evaluation and can reliably evaluate the given situations from the perspective of representative riders.

Representative Riders

- Accustoming to riding the same size motorcycle as the test vehicle.
- Not novice.

Test Procedure

Figure 1 shows the C class evaluation test procedure that the riders follow. First, the experimenter instructs the expert riders in the test contents including the intent of the standard, the purpose of the test, and the expected vehicle responses caused by malfunctions. In addition, the experimenter explains the assumptions for the test scenario including the traffic situation and the existence of other traffic participants, the way to ride, and the evaluation technique, including the evaluation sheet (see below). After a preliminary ride, the tests are conducted, and the riders rate the C class for every ride.

Following the C class rating, the riders rate the supplementary descriptive items and comment on these ratings for every ride. Supplementary descriptive items concerning recognition, judgment, and operations that compensate for a malfunction are noted in describing the reasoning that produced the C class rating. The riders' comments are used so that the rider confirms the transition in his ratings. These ratings are then collected to extract vehicle behavior and compensatory control actions indicating how riders responded to hazardous events.

During the test, consideration should be given to the following points.

- To prevent one rider's rating from being affected by another rider's rating, it should not be possible for the riders to see each other's C class ratings for the same test.
- The degree of difficulty of the test conditions should be kept at a low level in order to establish vehicle behavior and to maintain safe conditions at the time of malfunction.

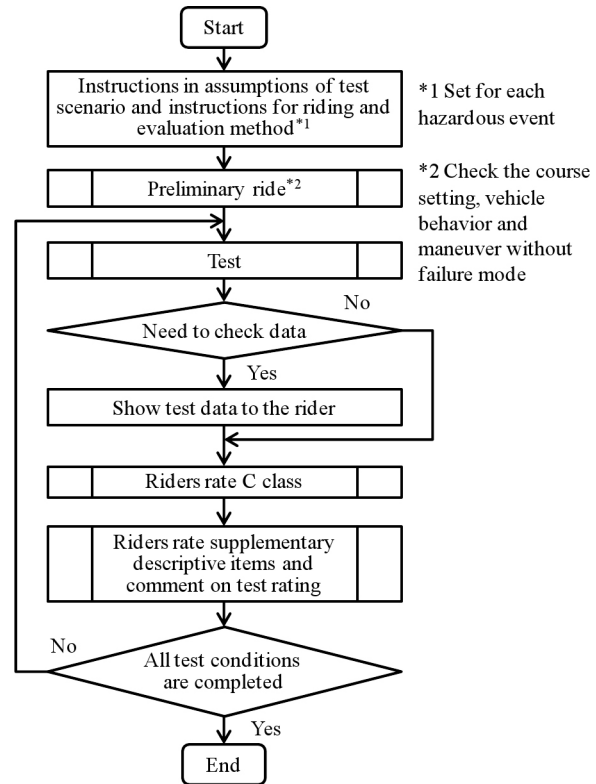


Figure 1. C class evaluation test procedure

Evaluation Sheet

The evaluation sheet includes items concerning the C class as well as the supplementary descriptive items. Table 1 shows the criteria for judgment that expert riders used during the C class evaluation tests. C class is defined by the percentage of representative riders who could avoid harm, i.e., could achieve the task, with reference to ISO 26262[1] and a publicly available specification of motorcycle functional safety[5]. The task was set depending on the kind of hazardous event of interest in the evaluation.

The C class was rated as one of four classifications: C0, C1, C2, and C3, in accordance with the ISO standard. In the study, if the expert riders evaluated the C class as falling between two classifications, for example C0 and C1, they were allowed to choose a rating in units of half a point.

The supplementary descriptive items were rated on a scale of four points in units of half a point. These descriptions are shown in Table 9 in the appendix.

Table 1. Controllability classification

Percentage of representative riders who can avoid harm		
	Description in standard[1]	Description in PAS[5]
C0	Simply Controllable	Controllable in general*1
C1	Simply Controllable	99% or more of all riders can usually avoid harm
C2	Normally Controllable	90% or more of all riders can usually avoid harm
C3	Difficult to Control or Uncontrollable	Less than 90% of all riders can usually or barely avoid harm*2

*1 C0 does not imply that nothing happens or that the riders do not execute any control actions. It simply means that the riders can deal with malfunctions within the range of normal operation, even though an unusual phenomenon occurs because of the malfunctions.

*2 “Barely able to avoid harm” is the level at which the expert riders believe that half of the representative riders cannot avoid harm.

C CLASS EVALUATION TEST

Using the improved C class evaluation method, C class evaluation tests reproducing specific hazardous events were conducted with an actual vehicle.

Tests were selected from among the hazardous events related to E/E systems concerning riding, turning, and braking while riding. This study investigated examples of the C class evaluation for “unintended acceleration” caused by the malfunction of the electronic throttle control system, and “insufficient braking force” caused by the malfunction of the anti-lock braking system (ABS).

Four expert riders participated in these tests (Table 2). Before the tests, all participants were informed verbally and in writing about the test details and protection of personal information. Their consent for participation in the test was obtained in writing.

Table 2. Participants in the tests

	Height [m]	Weight* [kg]	Age [-]
A	1.82	86	48
B	1.71	85	48
C	1.82	86	49
D	1.84	87	44

* Protective riding gear included.

Test of Unintended Acceleration on a Straight Road

The test of unintended acceleration on a straight road was assumed to increase the risk of colliding with the preceding vehicle because of acceleration that a rider does not intend (Figure 2).

The previous study[4] conducted the test at 30 km/h using the same assumptions as those for this test scenario. In this study, it was conducted at 60 km/h with the assumption of driving on a typical main road (Figure 3).

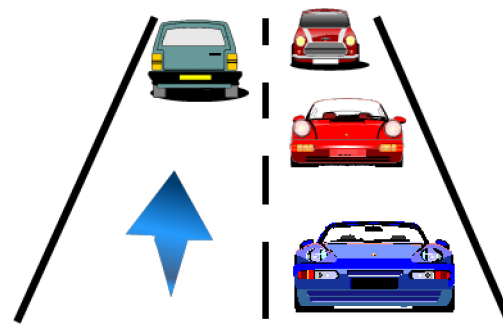


Figure 2. Assumptions for the test scenario in the test of unintended acceleration on a straight road.



Figure 3. Experiment scenery in the test of unintended acceleration on a straight road.

Figure 4 shows the motorcycle designated as Test Vehicle 1 that was used in the test; a measurement system to acquire data on vehicle behavior and riding maneuvers at a frequency of 100 Hz was installed. For failure mode reproduction, the test vehicle’s throttle plate opening angle was controlled automatically by operating a switch to initiate the failure mode (Figure 5). The time-to-control was set to 11 s as the period during which the expert riders could sufficiently understand the vehicle behavior and implement the appropriate control action for the failure mode. In addition, a mechanism that enabled riders to interrupt the failure mode was available for the riders’ safety.



Figure 4. Test Vehicle 1

Table 3. Specifications of Test Vehicle 1

Length [mm]	2,070
Width [mm]	715
Height [mm]	1,130
Seat height [mm]	835
Wheelbase [mm]	1,415
Weight [kg]	206
Displacement [cc]	998
Caster angle [deg]	24°00'
Trail [mm]	102

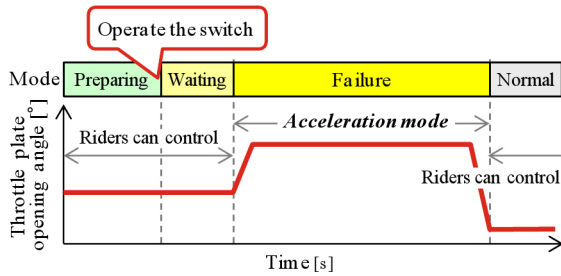


Figure 5. Throttle plate opening angle control for failure mode reproduction.

Test Conditions

The test conditions were determined by a combination of the imposed acceleration, speed, gear-shift position, and the distance between the test vehicle and the preceding vehicle at the start of the triggered failure (Table 4). The imposed acceleration was restricted to certain acceleration levels, and it was determined by a velocity increase lasting 4.0 s after 0.5 s from the start of acceleration while riding straight ahead, without any control action (Figure 6). Distance between the test vehicle and the preceding vehicle was set three levels (16.7 m: short, 25.0 m: medium, and 33.3 m: long) to confirm the effect to the C class rating.

Table 4. Test conditions for the test of unintended acceleration on a straight road

Speed (gear-shift position)	Distance between the test vehicle and the preceding vehicle	Acceleration level	Imposed acceleration
60 km/h (4 th gear)	16.7 m	1–8	0.5–2.5 m/s ²
	25.0 m	3–12	1.1–3.0 m/s ²
	33.3 m	4–12	1.5–3.0 m/s ²

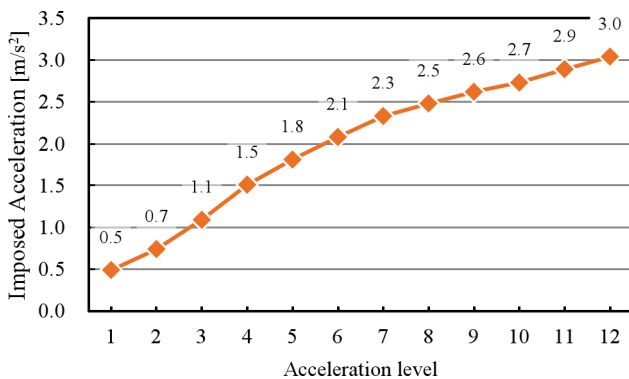


Figure 6. Distribution of imposed acceleration

Test Environment Setup

The test environment is described below and in Figure 7.

- Test field: Dry asphalt with approach, test, and escape sections.
- Preceding vehicle: Placed in an adjacent lane in consideration of the riders' safety.
- Lane width: 3.50 m (test lane), 5.50 m (adjacent lane) separated by a lane line and pylons.

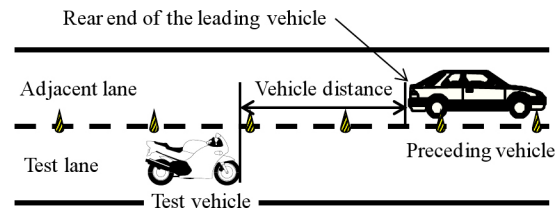


Figure 7. Course setup for the test of unintended acceleration on a straight road.

Test Procedure

The test was performed following the procedure in Figure 1. The instructions to the expert riders (assumptions for the test scenario, target task for evaluation, and instructions for riding) are described below.

Assumptions for the Test Scenario

- On a straight road, following the preceding passenger car, with oncoming cars driving in the adjacent lane (Figure 2).
- Unintended acceleration occurs, caused by the malfunction of the electronic throttle control system.
- The risk of collision with the preceding car is increased.

Target Task for Evaluation

The target task for evaluation is “not to reach the rear end of the preceding vehicle” (Figure 7). However, the riders are not necessarily instructed to achieve the task.

Instructions for Riding

- Follow the preceding vehicle with the gear shift in the indicated position and at the specified distance between vehicles.
- Operate the switch to start the failure mode when the indicated vehicle distance is achieved.
- After the test vehicle accelerates, deal with the failure mode if necessary, considering the target task. Only braking is allowed as a control action, and using the same control action as the representative riders would perform is not necessarily required.

Results of the Experiment

For each vehicle-distance condition, the results of the C class rating for each expert rider were arranged by imposed accelerations (Figure 8, Figure 9, and Figure 10). The legends labeled A, B, C, and D in the figures below represent each of the expert riders.

For the 16.7 m vehicle-distance condition, the C class was rated as C0 for acceleration values less than 0.5 m/s² and as C3 for acceleration values of 2.5 m/s² or more (Figure 8). For the 25.0 m vehicle-distance condition, the C class was rated as C1 for acceleration values less than 2.1 m/s². Furthermore, acceleration values of 3.0 m/s² or more were rated as C3 by three of the four riders (Figure 9). For the 33.3 m vehicle-distance condition, three riders rated acceleration values less than 1.5 m/s² as C0 and values of 3.0 m/s² and more as C3 (Figure 10).