

Examination of Hazard Analysis and Risk Assessment and Exposure Research in the Real Traffic Situation of ISO 26262 for Motorcycles

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ABSTRACT

ISO 26262, an international functional safety standard of electrical and/or electronic systems (E/E systems) for motor vehicles, was published in November 2011 and it is expected that the scope will be extended to motorcycles in a second edition of ISO 26262 going to be published in 2018. In order to apply ISO 26262 to motorcycle, proper estimation of Exposure, Controllability, and Severity are key factors to determine Motorcycle Safety Integrity Level (MSIL). Exposure is a factor to indicate the probability of the state of an operational situation that can be hazardous with the E/E system malfunction. And it is not easy to estimate the motorcycle Exposure due to less availability of back ground data in actual operational situation compared to motor vehicle. Therefore real traffic situation should be investigated in order to provide rationales for MSIL determination. In this study, we examined Hazard Analysis and Risk Assessment (HARA) for motorcycle in accordance with ISO/PAS 19695 and identified motorcycle-specific operational situation. Then we executed field survey for the acquisition of actual operational situation data and estimated Exposure. This paper shows motorcycle-specific issues for HARA and example of motorcycle travelling data useful for Exposure estimation.

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INTRODUCTION

ISO 26262 [1], an international functional safety standard of electrical and/or electronic systems (E/E systems) for motor vehicles, was published in November 2011 and it is applied to passenger car. And it is expected that motorcycle will be included in its scope at the next revision scheduled in 2018. Prior to its revision, Publicly Available Specification, ISO/PAS 19695 [2] was published in 2015 and this PAS specifies the unique requirements to adapt ISO 26262 to motorcycle. It is foreseen that the elements of ISO/PAS 19695 will become the main contents of the revision of ISO 26262 regarding motorcycle inclusion.

Motivation of this study is to examine Motorcycle Safety Integrity Level (MSIL) determination in accordance with ISO/PAS 19695 for the application of functional safety standard to motorcycle. Also example of back ground data and method of its measurement to estimate Exposure which is necessary for MSIL determination are presented. There are few case studies of MSIL determination available even though many case studies of Automotive Safety Integrity Level (ASIL) for passenger car are available.

The factors to determine MSIL in accordance with ISO/PAS 19695 are Exposure (E), Controllability (C) and Severity (S). We previously studied estimation procedure for Controllability and Severity [3][4]. And research of Exposure example in the real traffic situation should

be effective to support expert judgement to estimate Exposure, whose back ground data in actual operational situation is less available compared to motor vehicle.

In this study we examined Hazard Analysis and Risk Assessment (HARA) for motorcycle in accordance with ISO/PAS 19695 and identified motorcycle-specific operational situation. Then we executed field survey for the acquisition of actual operational situation and estimated Exposure. Namely, we executed HARA for items of Fuel Injection (FI) system, Anti-lock Brake System (ABS), Combined Brake System (CBS) and Throttle-By-Wire (TBW) system, which connect to the basic factors of motorcycle motion; "braking, accelerating and turning" and getting popular E/E systems of motorcycle, and examined potential concerns.

As a result, we assumed that Exposure of follow-up running situation should be different between motorcycle and motor vehicle, which is necessary to estimate it when we examine TBW system malfunctioned situation. Therefore we chose the inter-vehicle time between motorcycle and motor vehicle while motorcycle follow up a preceding passenger car at constant speed on the urban road as a research target and analysed follow-up running Exposure using video data acquired by five video cameras on one of the heaviest traffic road in Japan.

FUNCTIONAL SAFETY STANDARD FOR MOTORCYCLE

ISO 26262:2011, an international functional safety standard of electrical and/or electronic systems for motor vehicles is intended to be applied to passenger car. Though it is expected that motorcycle will be included in its scope at the next revision, it is considered that there is a difficulty to apply existing ISO 26262 to motorcycle as it is, because motorcycle have different characteristics from passenger car. One of that kind of characteristics which should be taken into consideration is the required level of safety measures to avoid unreasonable risk defined by MSIL, and another is estimation method of Exposure, Controllability and Severity in order to execute HARA for motorcycle. Therefore ISO/PAS 19695 was created as functional safety standard for motorcycle ahead of the revision of ISO 26262.

Hazard Analysis and Risk Assessment (HARA)

HARA is a method defined by ISO 26262 and ISO/PAS 19695 to identify and specify the hazardous event caused by malfunctioning behaviour of E/E system and determine ASIL and MSIL and safety goals. MSIL is determined by combination of Exposure, Controllability, and Severity of the corresponding hazardous event of each items composed of several E/E systems. Exposure indicates a probability of the state of an operational situation that can be hazardous with the E/E system malfunction. Controllability is an ability to avoid a specified harm through the reactions of the persons involved. Severity is an estimate of the extent of harm to individuals that can occur in a potentially hazardous situation. These three factors of MSIL are considered to have a huge difference between motorcycle and passenger car in terms of estimated class because of its vehicle characteristics and operational situations, and therefore ISO/PAS 19695 shows motorcycle-specific example of these factors' classification in Annex A.

To estimate Exposure, it is assumed that it is not appropriate to apply same Exposure class as that of passenger car to motorcycle because back ground data effectively support expert judgement is less available compared to motor vehicle. Concerning Controllability and Severity, those are also assumed not appropriate to apply because of difference of vehicle characteristic in motion and feasibility of evaluation test for Controllability, and availability of injury data based on Abbreviated Injury Scale (AIS) used for passenger car for Severity. Therefore motorcycle-specific methods were proposed as mentioned previously.

In this study, we attempted to estimate motorcycle Exposure class with acquiring motorcycle travelling data in the real traffic situation.

EXAMINATION OF HARA FOR MOTORCYCLE

Following HARAs were conducted in accordance with ISO/PAS 19695 Clause 5 and Annex A. FI system, ABS, CBS and TBW system were selected to the target items from a viewpoint that the items connect to the basic factors of motorcycles motion; "braking,

accelerating and turning" and getting popular E/E systems of motorcycle. The results are described in following sections.

HARA for FI System

Item Definition for FI System

At the initiation of HARA for FI system, item definition was executed. This activity is to understand the target item properly and to enable to conduct subsequent phase activities smoothly. The following is the result of item definition for FI system.

Target Systems

* FI system and related systems such as engine start system. See [Figure 1](#).

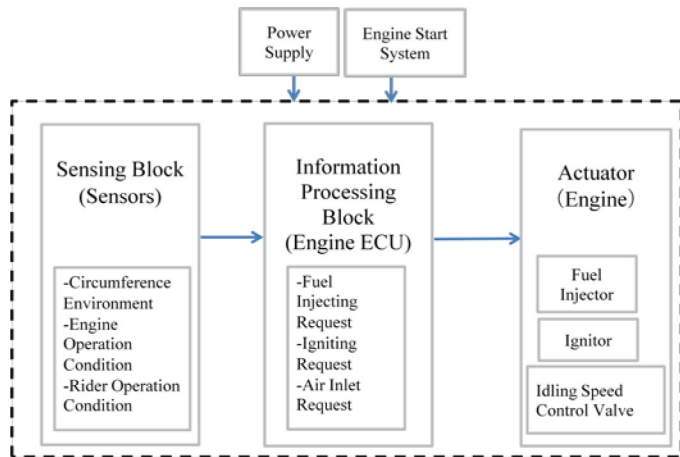


Figure 1. Functional block diagram of target FI system

Functionality of the Item

* To detect rider operation and vehicle condition, and to control necessary devices to generate adequate engine torque

Equipped Vehicle Specification

* Specification of vehicle equipped with defined item as in [Table 1](#).

Table 1. Fundamental specification of the vehicle equipped with FI system.

Engine Displacement	250 cm ³
Number of Cylinders	Two
Engine Cooling	Water Cooled
Transmission Type	Manual
Throttle-by-Wire	Not Applicable

Identification of Representative Failure Cause, Hazard and Hazardous Event

As a next step representative failure cause occurred in FI system and hazard were examined. Failures could occur in any functional blocks and elements described in [Figure 1](#), thus failure causes are numerous. It is considered to be more important to examine what vehicle behaviour would happen as an output from actuator because hazard is an unintended behaviour of item resulting from failure which is the root of harm. As a result, representative hazards were classified as follows.

1. unintended loss of propulsion force
2. unintended loss of additional propulsion force
3. unintended generation of propulsion force

- Case 1. a possible hazardous event is losing the propulsion force and motorcycle speed decreases during travelling urban road, and collided by following vehicle.
- Case 2. a possible hazardous event is losing the additional propulsion force and motorcycle speed does not increase during attempting to overtake preceding vehicle on urban road, and colliding to the oncoming vehicle on the opposite lane.
- Case 3. a possible hazardous event is generating the propulsion force and motorcycle speed increases during travelling urban road, and colliding to preceding vehicle.

MSIL determinations for above representative hazardous events are shown in below.

MSIL Determination

For the estimation of Exposure, Controllability and Severity to determine MSIL, it is important to know how much acceleration and deceleration could occur caused by concerned hazard. Our study together with motorcycle manufactures is shown as below;

- Case 1. a possible maximum deceleration is caused by engine stall and it is still equivalent to the deceleration occurred by engine braking during normal riding and rider could easily and safely stop or evacuate from the lane, and following vehicle driver could stop or avoid as well. (C class: C0 [3])
- Case 2. rider could easily recognise that motorcycle would not accelerate as intended and cancel the overtaking manoeuvre (C class: C0).
- Case 3. a possible maximum acceleration caused by FI system without TBW system is what rider could easily control by brake (C class: C0 [3]).

As a result representative HARA results are as shown in Table 2. In each cases Controllability class was estimated as C0 and estimation of Exposure or Severity was not required.

Table 2. Examples of FI system HARA

Hazard	item	scenario	Rep. MSIL
1. unintended deceleration	FI system	unintended deceleration by engine stall during urban travelling and collided by following vehicle	No MSIL (QM) (E: N.A., C0, S: N.A.)
2. unintended loss of acceleration	FI system	unintended loss of acceleration during overtaking manoeuvre and colliding to oncoming vehicle	No MSIL (QM) (E: N.A., C0, S: N.A.)
3. unintended acceleration	FI system	unintended acceleration during urban travelling and colliding to preceding vehicle	No MSIL (QM) (E: N.A., C0, S: N.A.)
* note 1: In case at least one of factors estimated class 0 (zero), no MSIL is assigned to the corresponding hazardous event. * note 2: Above results are representative examples in a variety of examined numerous scenarios.			

HARA for ABS/CBS

Item Definition for ABS/CBS

The following is the result of item definition for ABS/CBS.

Target Systems

* ABS, CBS shown in Figure 2.

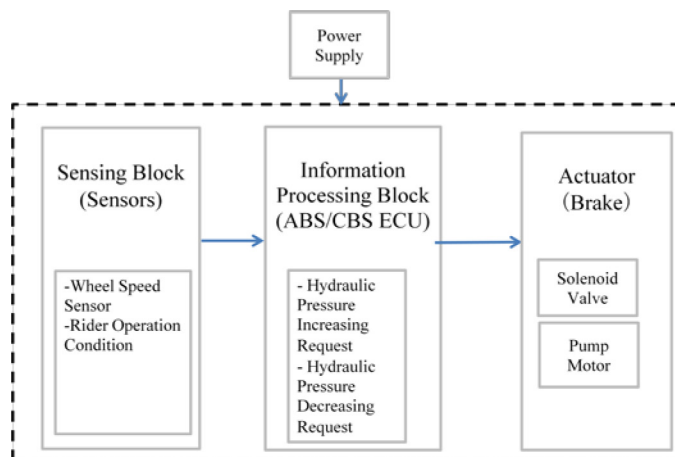


Figure 2. Functional block diagram of target ABS/CBS

Functionality of the Item

* To detect rider operation and vehicle condition, and to control necessary devices to generate adequate brake force

Identification of Representative Failure Cause, Hazard and Hazardous Event

Representative failure causes occurred in ABS/CBS and hazard were examined. Basic idea is same as FI system examination and representative hazards were classified as follows. In this paper situations under which ABS/CBS would be activated, or effect of ABS/CBS malfunction would be large, were chosen as representative situations.

1. unintended reduction/loss of front wheel braking force
2. unintended reduction/loss of rear wheel braking force
3. unintended reduction/loss of braking force of both wheels
4. unintended loss of front wheel ABS function
5. unintended loss of rear wheel ABS function
6. unintended loss of ABS function of both wheels
7. unintended generation of braking force
8. unintended loss of CBS function

- Case 1. a possible hazardous event is losing the front braking force and motorcycle speed does not decrease during braking on urban road, and colliding to preceding vehicle stopping at traffic light.
- Case 2. a possible hazardous event is losing the rear braking force and motorcycle speed does not decrease during braking on highway, and colliding to preceding vehicle stopping with traffic congestion.