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DEVELOPMENT OF OCCUPANT CLASSIFICATION SYSTEM BASED ON DISTRIBUTED SYSTEM INTERFACE

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ABSTRACT–According to the United States FMVSS 208, every passenger car on the market after September of 2006 must install a safety system, which can deploy the airbag with different intensity or suppression based on the passenger type, to reduce infant and child injuries from airbag deployments. The Weight Classification System, which has been developed by Hyundai Autonet, is a system that classifies the person occupying the passenger seat. To overcome sensing problems due to the weight sensors small voltage, the Distributed Systems Interface is adopted.

KEY WORDS : Occupant classification system (OCS), Weight classification system (WCS), Distributed system interface (DSI), Weight sensor, Strain gauage, Advanced airbag, Belt tension sensor (BTS), Electric control unit (ECU), Rear facing seat (RFCS)

1. INTRODUCTION

In order to protect the passengers, the existing airbag system deploys regardless of whether or not there is a person in the passenger seat, of if there is an infant or child in it (Chan, 2002; Barnard *et al.*, 2000). Even though the law prohibits sitting infants and children down in a front passenger seat, there is still some possibility to sit them down for convenience. Thus injuries from airbag deployment is increasing. According to a survey by the National Highway Traffic Safety Administration (NHTSA), 158 people died of airbag deployment by April 1st 2000. This number contains 92 children, 60 drivers and 6 adult passengers. As the airbags, which were meant to protect the passengers, became a cause of infant and child injuries, needs for a system that can protect these children arose. For this reason, the Advanced Airbag, which is an improved airbag system, has been developed. And by the law, FMVSS 208, all cars in sale after September 2006 must have the Advanced Airbag system installed.

Also, in order to protect the infants and children that sit in the front passenger seat, a system that can divide them from the adults is required. The Occupant Classification System has been developed for these purposes. This system is one of the systems that plays a main assisting role in the Advanced Airbag system (Lu *et al.*, 2002).

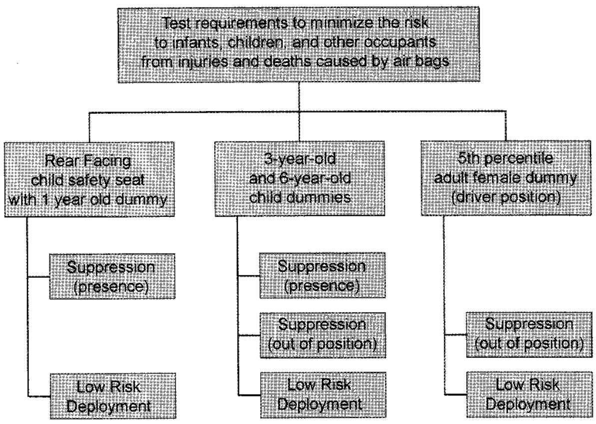

Figure 1. Conditional demands of airbag deployment for infants and children.

Based on the law established by the United States Federal Motor Vehicle agency, the conditions of the airbag deployment is shown in Figure 1 (NHTSA, 2005).

As shown in Figure 1, airbag deployment is prohibited when there is an infant or child in the front passenger seat. But if it must deploy, it must have a system that minimizes the damage inside the car. Also, it states that a system that can protect the small framed, female drivers from airbag injuries must be installed.

At present, many kinds of Occupant classification systems are being developed. There are systems that can

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recognize the passenger's head's size and shape, systems that can measure the passenger's weight, systems that measure the force impressed on the car seat, and systems that can measure the passenger's size and volume by using cameras (Scholpp, 2005). This paper describes the development and classification algorithm of the Weight Classification System (WCS), a system that can measure the passenger's weight using Strain gauge sensors.

2. STRUCTURE OF THE WEIGHT CLASSIFICATION SYSTEM

The Weight Classification System is made by connecting 4 Weight sensors and 1 Belt tension sensor to the Weight Classification Systems Electric control unit (ECU).

Using the data sent from each sensor, the ECU calculates and sends the occupant classification information to the Airbag ECU.

2.1. Weight Sensors

The weights sensors have linearity, as shown in Figure 3, which is a unique quality of the Strain Gauge sensors.

Because signals from the Strain Gauge sensors are very weak, an electronic circuit that amplifies and changes them into digital signals is attached. The Distributed System Interface (DSI) device sends these digitally changed signals to the Weight Classification system.

2.2. Distribution System Interface

The Distribution System Interface is an airbag related communications rule, proposing the Electric Control Unit to control remote sensors and actuator. This method connects many kinds of sensors and actuators together with the using the same bus. Because power can be supplied by a communication bus, to the sensors and actuators on the same time, increasing the wires efficiency. Also, as information about communication errors

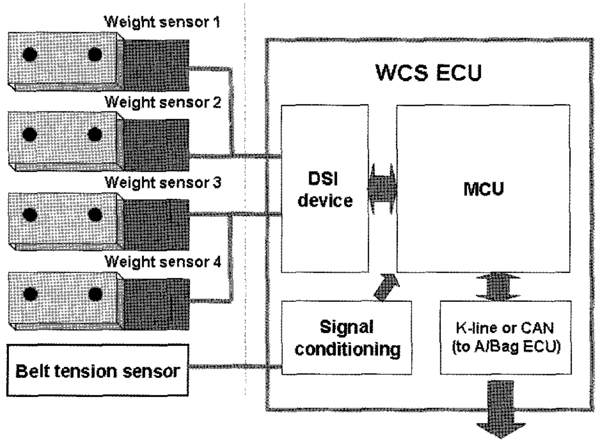


Figure 2. Structure of weight classification system.

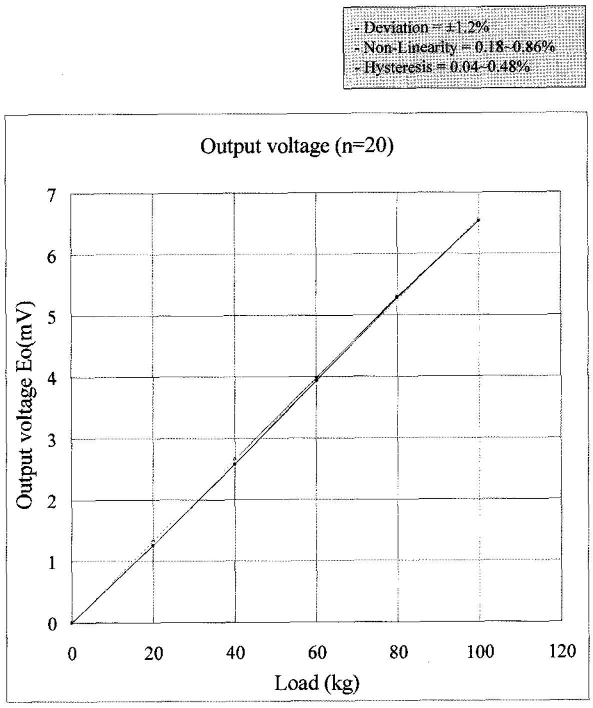


Figure 3. Output characteristic of the weight sensors.

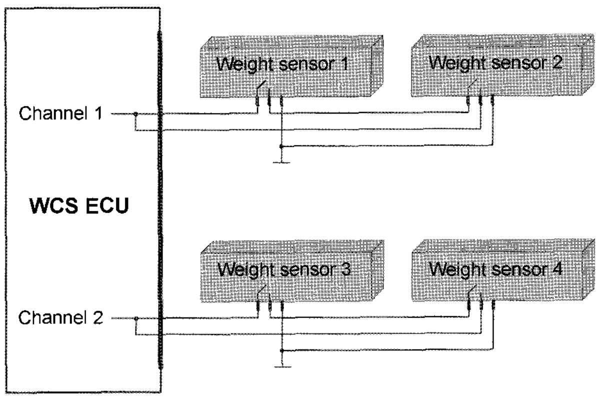


Figure 4. Connective structure of the distributed system interface.

are provided, the reliability increases too (McHenry, 1999).

The Occupant Classification System is provided with the passenger's weight information from 4 Electric Control Units. But because the weight sensor's output voltage is low and current is weak, it is vulnerable to surrounding factors, like noise, and the accuracy of the passenger's weight information is low.

In order to overcome these weaknesses, this paper proposes the Distributed System Interface, and by this method the reliability of the passenger weight information has been increased.

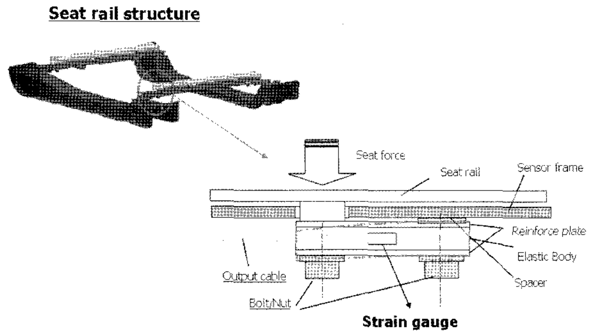


Figure 5. Install positions of weight sensors.

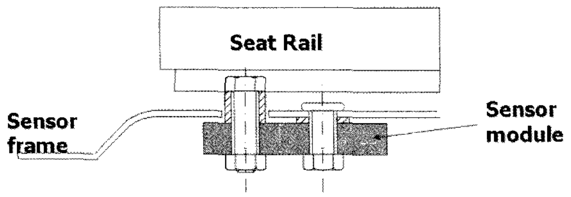


Figure 6. Install method of weight sensors.

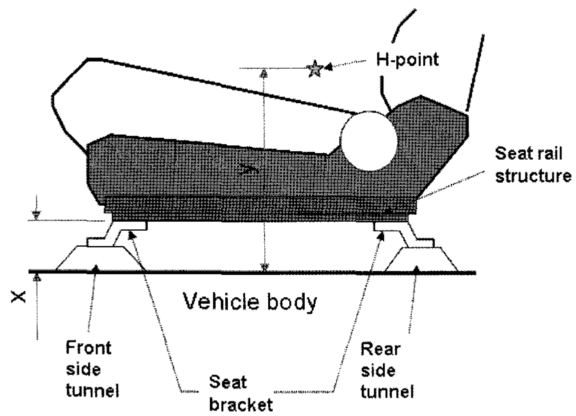


Figure 7. Structure of car seat without weight sensors installed.

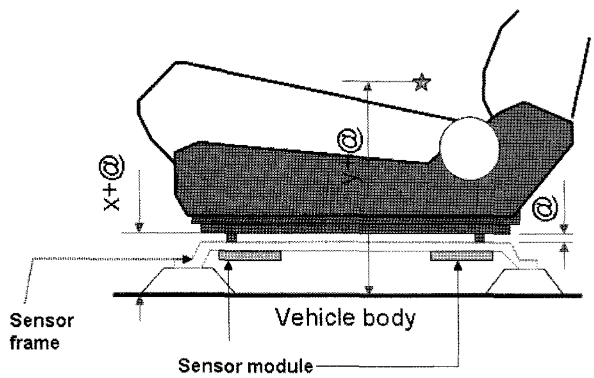


Figure 8. Structure of car seat with weight sensor installed.

Table 1. Occupant classification table.

Class	Occupant	Weight (Kg)	Airbag Status
0	Empty	≤ 5	Suppression
1	Child seat or New born and Children (1,3,6-year-old)	8.0~25.6	Suppression
2	Adult	≥ 46.7	Activation

2.3. Install of Seats with Weight Sensors

The process of installing weight sensors on the car seats is as shown in Figure 5 and 6. The sensors are installed by sticking weight sensors on each 4 of the seats lower rails.

There are fixed points and action points on the weight sensors. The fixed points are used to as strength support points by joining the Sensor frame, and the action points are stuck to the car seat lower rail structure. If weight is impressed to the action points, the weight sensors begin activation.

There is a difference between the existent, weight sensor non-installed, car seats and the car seats with weight sensors installed. The existent car seat has a Bracket, which is used to attach the seat to the car. But in the seats with weight sensors installed, the brackets are

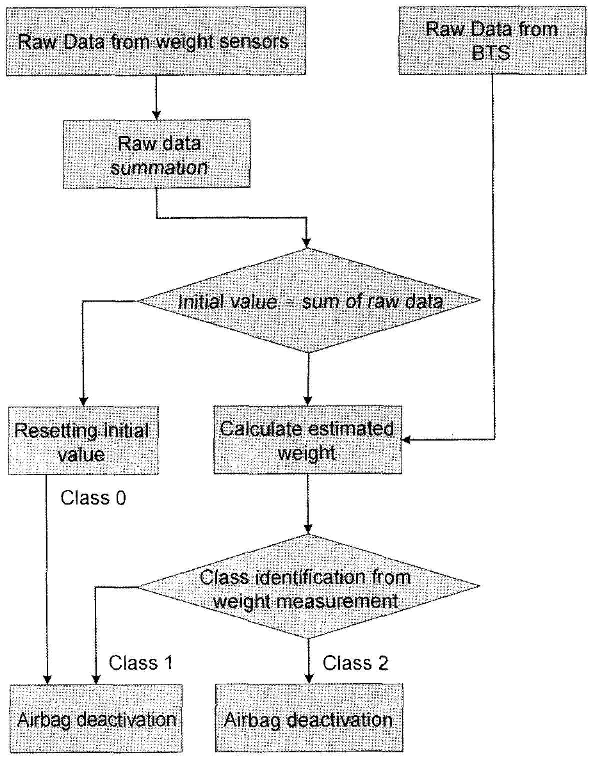


Figure 9. Algorithm structure.

substituted with the sensor frames. Therefore the weight sensor installed seat's H-point increases. But by designing the car seats structure, it can become a minimum (Figure 7, 8).

3. OCCUPANT CLASSIFICATION ALGORITHM

Normally, 3 grades are used to classify the passengers by weight. The unit of classification is Class, and is divided into 3 parts. Details of Occupant Classification are described at Table 1.

Normally, the passengers are classified by their measured weight. By using data measured from the weight sensors, the current occupant's weight is predicted, and by comparison with the classification standards, the occupant's class is determined. Also, by calculating the passenger's weight and measuring the seat-belt tension sensor values at the same time, the weight is corrected. Therefore, when a child seat is installed in the car, the seat-belt must be fastened with a regular force. By doing this, the child seat's weight increases because of the seat-belt's tension. Therefore, weight calculation must be corrected by measuring the tension sensor's values.

4. VERIFICATION OF THE PROPOSED ALGORITHM

Performance of the proposed Weight Distributed System is verified by an experiment. Experiment targets and conditions are as following, 3 adults (2 adult men (64 kg, 86 kg) 1 adult woman (50 kg)), 1 Rear facing child seat (RFCS). Instead of a real infant, weights, with a similar weight of an infant (10 kg, 15 kg) have been used. The experiment has been progresses in normal temperature.

The experiments with the adults where divided to 2 types, a normally posed experiment, and an unnatural but probable posed experiment. These experiments where performed repeatedly, each with different car seat posi-

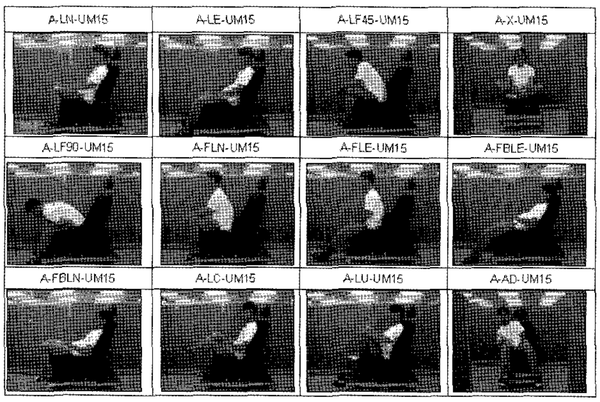
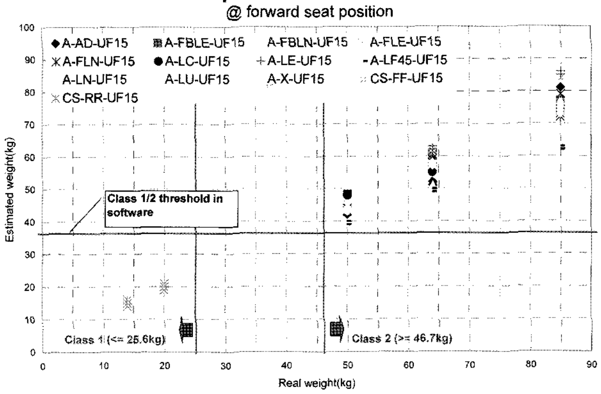
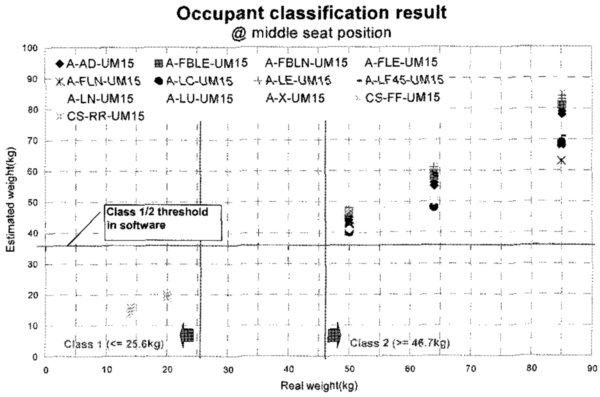


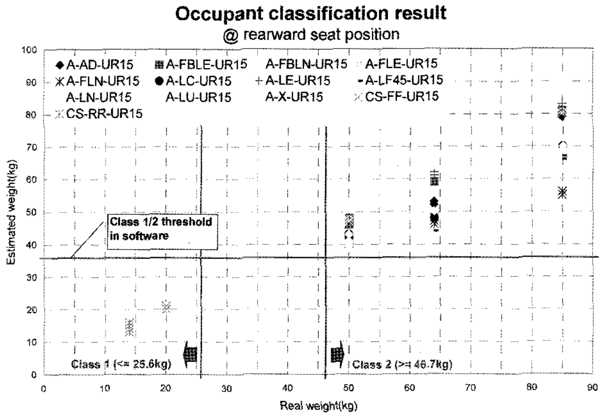
Figure 10. Passenger experiment poses.



Graph 1. Occupant classification experiment result-forward positioned seat.

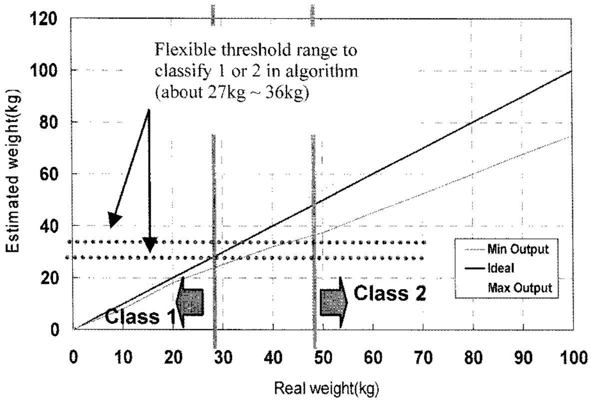


Graph 2. Occupant classification experiment result-middle positioned seat.



Graph 3. Occupant classification experiment result-rear positioned seat.

tions. The car seats were positioned in 3 forms, when the seat is in the front side, middle side and rear side. Experiments for the Rear facing child seat has been



Graph 4. Performance features of the weight classification system.

performed, by following the experiment procedures presented by the United States Federal Motor Vehicle agency.

Results of the adult passenger experiment, using the poses shown in Figure 10, have been made into a graph divided by the car seat's position. By this graph, the fact that the car seat's position does not have effect on the Weight Classification System can be verified. Also, the measured weight values of each passenger shows many distributions, but the actual passenger weight shows a linearity result (Graph 1, 2, 3).

As seen in the experiment results, car seat positions do not have effects on the Weight Classification System. But the occupant's pose, especially the position of the leg, does slightly decrease the measured weight. However these changes have little effect in the regulated classification range. By these results, the proposed Weight Classification System's performance features have been clearly noted (Graph 4).

As presented by the United States Federal Motor Vehicle agency, the range between the seat-measured weight of a minimum weighing adult and a maximum weighing child is quite far. Thus, the Weight Classification System has advantages of easily classifying the occupants.

5. CONCLUSION

In the formation of the Occupant Classification System, which is one of the main sub-systems of the Advanced Airbag System, the Weight Classification System, which has the unique quality, linearity, of a Strain Gauge sensor, has many advantages. For example, it is less effected by the passenger's pose, and it can show equal output amounts, regardless of the seat's position. Also, the car's seats are easy to install in the vehicle, and the maintenance is relatively easier than other systems.

However, because the Weight Classification System cannot distinguish the occupant's position in the passenger seat, measuring the distance between the airbag and the passenger is impossible. To overcome this feature, additional sensors must be used. Also, the measured weight value decreases with the passenger's sitting position, thus the leg position. This feature does not have a big effect on the passenger classification of adults and children, but if the Advanced Airbag System is more developed hereafter, and a more detailed classification is demanded, this feature must be improved. In order to do so, an algorithm that can detect the passenger's sitting pose must be developed. Supporting sensors must be developed to improve the system also.

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