TOR (TOTAL OCCUPANT RECOGNITION) SYSTEM

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1. ABSTRACT

The TOR-system is based on a sensor combination using 2 different physical properties independent of each other, in order to realise an occupant detection system. Purpose of the system is to fulfill the NHTSA FMVSS 208 regulation for an automatic suppression system. It includes an additional feature for an automatic suppression zone of 15 - 20 cm around the airbag cover. The system consists of a force sensitive matrix-mat under the seat-cover and an EFD-system (Electrical Field Detection), with sensors in the seatplain, the backrest and the dashboard. Additionally, two sensors installed at the seat-frame provide the information on seat-position and backrest-angle.

2. INTRODUCTION

The widespread use of airbags in cars since the mid 90's has considerably helped to reduce the severity of occupants injuries in traffic accidents. In addition, some fatal casualities could be attributed to the deployment of airbags. Predominantly concerned are children, whether they were installed in child-seats or directly sitting on the passenger seat. For this reason the NHTSA issued a rule regarding smart airbag systems, which in a first step will have to perform an occupant classification, in order to control automatic airbag suppression. The TOR-system represents a solution to the FMVSS 208 requirements, and even offers additional information, which could be used to further improve airbag deployment strategies.

3. TOR-SYSTEM

The TOR-system uses 2 different sensor principles:

- Occupant Classification (OC®)
  Pressure on FSR™ elements leads to characteristic profiles.
- Electrical Field Detection (EFD)
  Capacitance depending on object conductivity on the seat is measured.
  Human tissue on sensor provides high signals.

The combined system therefore uses 2 physical properties independent from each other.

The complete system is suited for the passenger side. Some components could also be used on the driver side.
The OC®-sensor is integrated in the seatplain above the foam, and under an eventually present seat-heater. The EFD-sensors S* (see Fig 1) are installed in the seatplain, the backrest and the dashboard (airbag-cover). The capacitive sensors in the seat have to be located above the OC® sensor mat and heating pads. Seat-position and seat-inclination sensors provide additional informations.

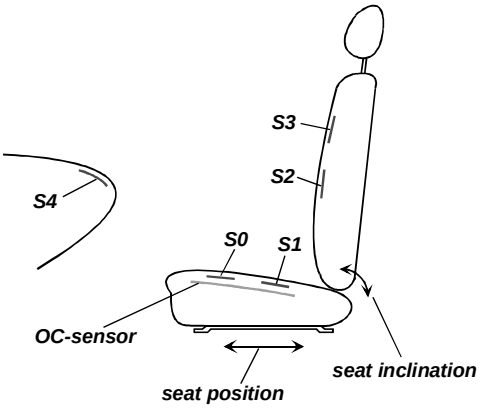

Figure 1. Schematic diagram of the TOR-system.

4. SYSTEM SENSORS

4.1. OC®-sensor

The OC®-sensor is a matrix of pressure sensitive FSR™-cells.

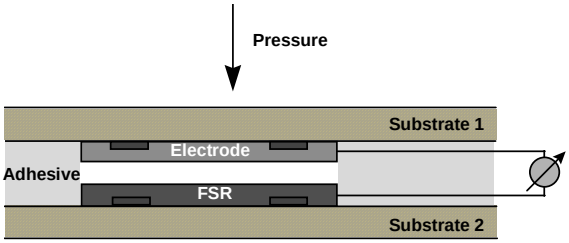

Figure 2. FSR™ sensor technology.

The FSR™-cell is composed of 2 carrier sheets laminated together with an adhesive spacer sheet. The electrical resistance varies as a function of the applied force (Fig 3).

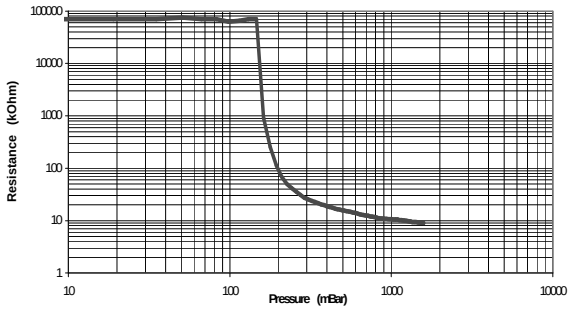

Figure 3. FSR™ sensor cell characteristic.

The signals from each single cell are read and evaluated in an algorithm in order to make a classification for persons/objects. The OC®-sensor also provides the information about the location of the occupants centre of gravity on the seatplain. The basic classification levels for a 2-class-OC® looks as follows:
Class 0: seat not occupied
Class 1: child-seat or small occupant
Class 2: adult occupant (weight ≥ 5%-female)

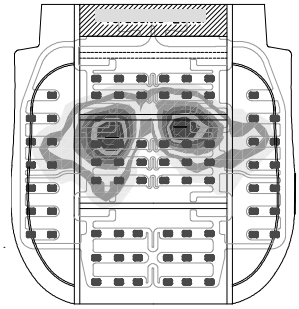

Figure 4. OC®-sensor with sit-in profile.

4.2. EFD-sensor

The EFD-sensor measures the capacitance between the sensor-electrode and the person/object in the seat.

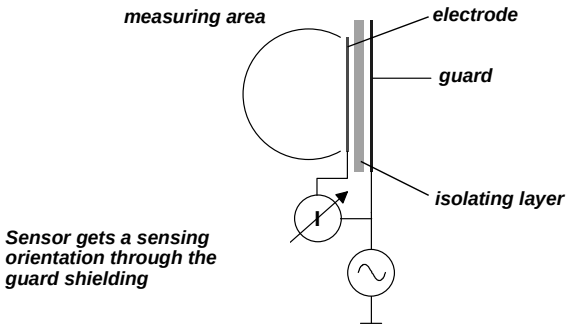

Figure 5. EFD-sensor principle.

The electrode and the guard are made up of a polyamid tissue, coated with a conductive material. A fleece material is used as isolating layer and as protective cover (not shown in Fig 5). This sensor sandwich is flexible, permeable to air, and survives seat-specific mechanical test cycles.
The EFD-sensor can be used in 2 different measurement-modes:

- loading mode (Fig 6): measures coupling-capacity between electrode and ground.

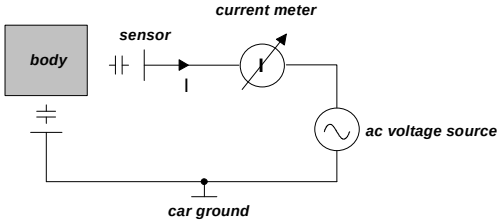

Figure 6. Schematic circuit diagram for loading-mode.

- coupling-mode (Fig 7): measures coupling capacity between two electrodes.

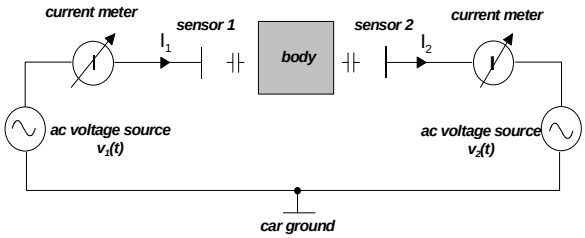

Figure 7. Schematic circuit diagram for coupling-mode.

5. SYSTEM PERFORMANCE

The system has 2 different applications:

- Child-seat discrimination and occupant detection.
- Monitoring of the automatic suppression zone.

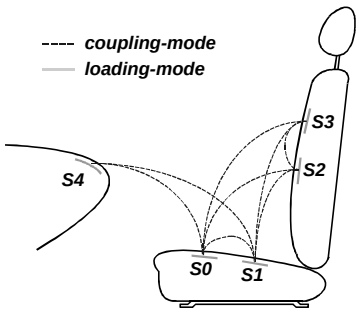

Figure 8. EFD-measurements in TOR-concept.

5.1. Child-seat discrimination and occupant classification

The EFD-system supports the OC®-sensor, and increases the reliability of the child-seat discrimination, as humans generally have a high capacitance, and child-seats a low one.
First the system selects the EFD values entering the algorithm. If the seat is occupied, the TOR-algorithm uses the EFD-values related to the sensor closest to the centre of gravity calculated by the OC®-sensor. If the OC® classifies the seat as not occupied, the system chooses the EFD-sensor with the highest signal.

■ OC®-Class = 0

If the OC®-sensor issues a Class 0 rating (see 4.1.), the algorithm displays, depending on the EFD-values on the seatplain, an empty seat, or a seat with a small conductive object on it (Fig 9).

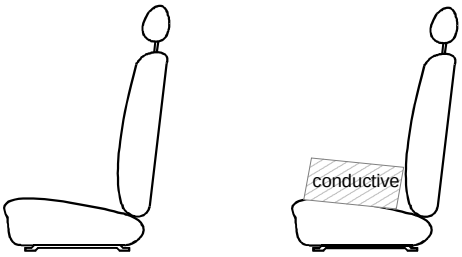

Figure 9. Possible TOR-status for an "empty" seat.

■ OC®-Class = 1

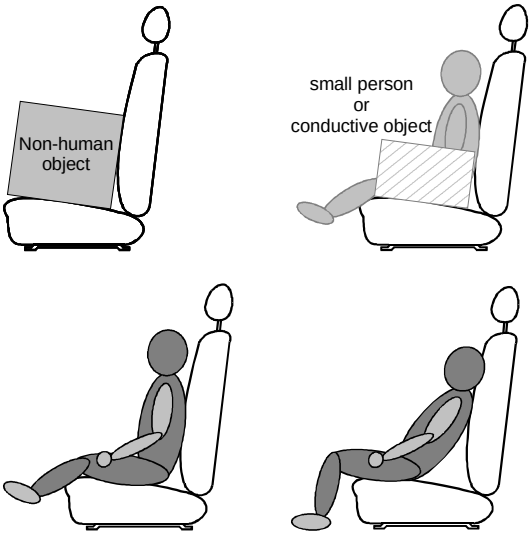

Figure 10. Possible TOR-status for an OC® "class1"-rating.

The TOR-system considers the EFD-values on the seatplain, the coupling between seatplain and backrest, and the OC®-pattern. An analysis of these values leads to one of the above decisions (Fig 10).

■ OC®-Class = 2

If the OC® detects a large coherent profile, the EFD-system back-checks if it is a non-conductive object. If an adult person is on the seat, we can detect if the occupant is leaned against the seatrest, or not. The algorithm displays one of the following pictures:

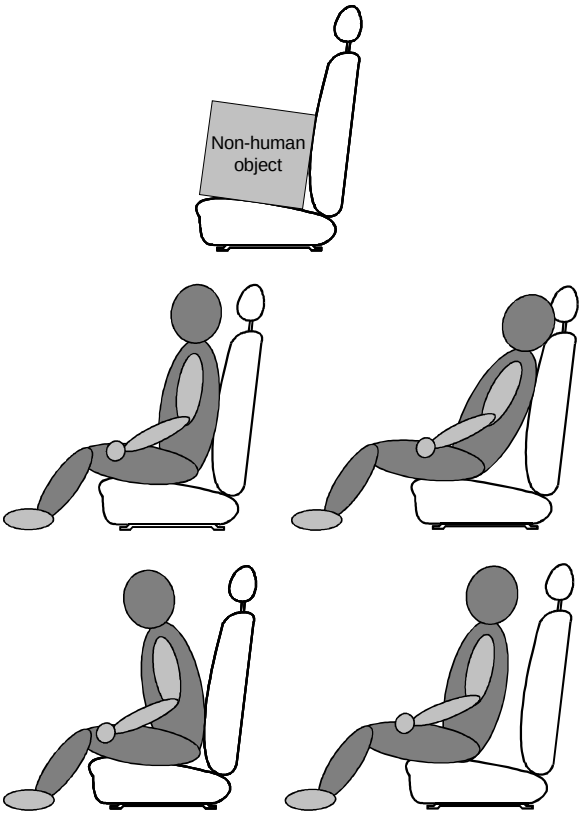

Figure 11. Possible TOR-status for an OC® "class2"-rating.

The EFD-system is not able to perform a detetion of the exact torso location in OOP-situations.
If the EFD-system detects a humidity influence above a critical level, the TOR-system can be reduced to the OC®-performance. The system-status can be transmitted to the driver by a tell-tale. If the humidity is down again to an uncritical level, the TOR-system can switch back to full performance.
The seat-position sensors provide an additional information about the occupants location relative to the airbag, which can be used for dual-stage airbags, e.g. if the seat is in a full forward position.

5.2. Monitoring of the automatic suppression zone (ASZ)

The sensor in the dashboard/airbag-cover can monitor an area of about 15- 20 cm (Fig 12). The range depends on the sensor size and the applied voltage. The volume of the conductive object has an influence on the sensor signal. A small volume close to the sensor creates a similar signal as a large volume slightly further away.

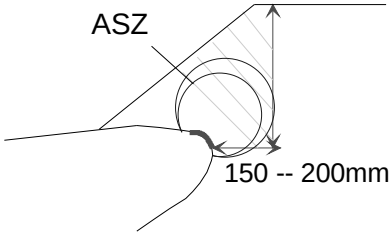

Figure 12. Schematic picture of an ASZ.

The information, that a conductive object enters the ASZ can be passed to the airbag control unit. The monitoring of the ASZ can be seen in connection with the occupant detection.

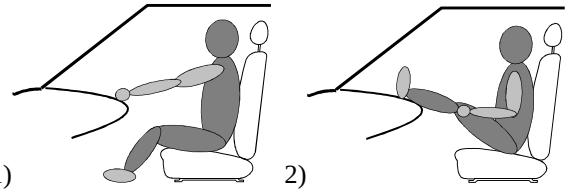

Figure 13. Situations 1 and 2 create similar signals.

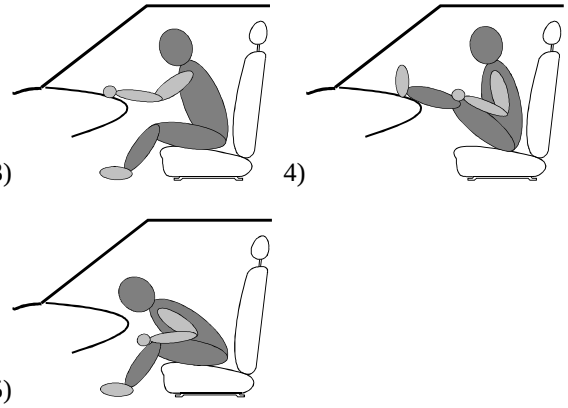

Figure 14. Situations 3, 4 and 5 create similar signals.

If the occupant is sitting properly, only the hands or feet can enter the ASZ (Fig 13). If the EFD-sytem has detected an occupant in an OOP-situation, it is no more possible to say whether hands or head or torso generate the dashboard-sensor-signal (Fig 14). The airbag deployment strategy in such a case would have to be manufacturer defined.

6. TOR-ALGORITHM

With the help of the seat position sensors, 5 seat track location zones and 5 backrest inclination zones can be specified. That means that there are 25 different distinguishable seat positions. For each of these positions a so called state machine (Fig 15) can be defined. Depending on the deployment strategy for the specific seat position and occupant detection, the airbag status can accordingly be issued.

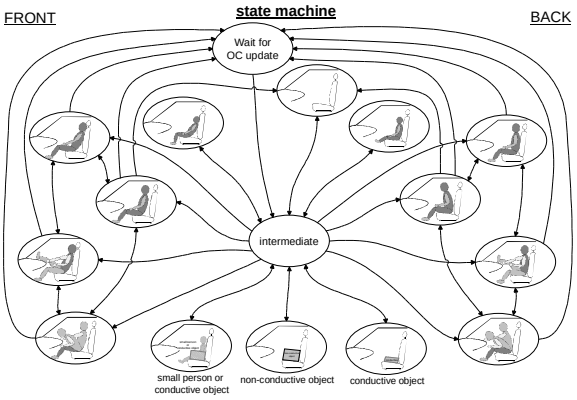

Figure 15. Schematic illustration of a state-machine.

7. CONCLUSIONS

The TOR-system shows how a combination of different technologies can be used for child-seat discrimination, occupant clasification and position detection. The system can deal with the increasing requirements regarding smart airbag systems and situation adapted airbag deployment strategies.