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Human Body Behaviour as Response on Autonomous Manoeuvres, Based on ATD and Human Model

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Abstract– In the near future active safety systems will take more control over the vehicle driving, even up to introducing fully autonomous vehicles. Nowadays, it is expected that the active safety systems will aid avoiding collisions much more efficiently than human drivers. These systems can protect not only the passengers, but also other road users. To mitigate collision, certain manoeuvres (e.g.: sudden braking, lane change, etc.) need to be done in a reasonably quick time. However, this may lead to low-g energy pulses. The latter fact, may cause unexpected and, in some cases, unwanted occupant body motion resulting even in out of position (OOP) postures. New patterns of occupant reactions in such cases are, to some extent, confirmed experimentally (Huber P., et al., 2014, Kirschbichler S., et al., 2014, Kirscht S., et al., 2014).

These paper evaluates limits of standard ATDs and chosen human models in well established manoeuvre scenarios. Obtained results are compared with experimental data available in the literature. Drawbacks identify new challenges for the near future simulation based safety engineering. One scenario with combined conditions of emergency braking during lane change has been used as an example of OOP posture after manoeuvre.

***Keywords*:** active safety systems, passive safety systems, autonomous manoeuvres, human body behaviour.

1. Introduction

In the near future active safety systems will take more control over the vehicle driving, even up to introducing fully autonomous vehicles. It is expected that the active safety systems can avoid collisions much more efficiently than humans. These systems can protect not only the passengers, but also other road users. To mitigate collision certain manoeuvres need to be done. It is important to keep in mind, that the passengers are unaware of autonomous manoeuvres.

More passengers than drivers are casualties in collisions (Regan M. A., Mitsopoulos E., 2001). There may be a few reasons for such a result. In order to be prepared for the collision Driver can instinctively protect himself by performing certain actions. Driver can prepare themselves for the collision by activating the muscles and taking the correct position. Passengers can only be prepared, if they know about the collision. Driver observes the road and knows earlier about the possibility of the collision, while the passenger usually does not do this, and their chances to prepare for the collision are smaller.

In the future, autonomous vehicles and small urban cars may change this pattern (Stein M., et al., 2014, Svensson M., et al., 2014). It is possible that occupants will be more often unaware of the impending collision, and will not prepare themselves for the crash. In such a situation, possibility of the *out of position* placement for the passive safety systems is higher.

2. Manoeuvres

The manoeuvres selected for the tests are: emergency braking from speed 50 kmph to 0, lane change with velocity 50 kmph and acceleration from 0 to 50 kmph. Scenarios are based on the tests procedures for active safety systems:

- Autonomous Emergency Braking (AEB) of Euro NCAP (European New Car Assessment Programme)
- Adaptive Cruise Control system (ACC) of ISO (ISO 15622:2002)
- Lane Keep Assistance (LKA) of ISO (ISO 17361:2007)
- Lane Change Assistance (LCA) of ISO (ISO 17387-2008) and eVALUE (eValue, 2010)
- Low Speed Following (LSF) of ISO (ISO22178:2009)
- Full Speed Range Adaptive Cruise Control of ISO (ISO/NP 22179)
- Lane Departure Warning (LDW) of NHTSA (Garrick J. et al.) protocols.

Scenarios have been built in the *PreScan* environment. Tests are prepared on both: straight road and bend road. The trajectory of the lane change manoeuvre was simulated by the Bezier Curve.

3. Methods

The acceleration of the host vehicle is the output from the simulations of selected PreScan scenarios. The selected car is Audi A8 equipped with the model of *Simple Dynamics* and the *Path Follower* controller (PreScan Manual). This combination allows to check the accelerations affecting the car. The mass and movement of the car's occupants have been omitted.

Some of the scenarios consist of combined conditions, e.g.: emergency braking, involved (caused) by vulnerable road user (VRU) protecting system during lane change performed by the driver (Figure 1.).

The accelerations from the *PreScan* simulation are applied to the *Anthropometric Test Device* (ATD) and *human model* in *MADYMO* environment. *MADYMO* model is a simplified car with the possibility of movement in X and Y directions and rotation around Z axis. In all simulations body behaviour has been calculated for the driver occupant with three-point seat-belt used.

There is no ATD dedicated for low-g acceleration and movement in both, X and Y directions, but for the simulations authors used *Hybrid III*, *ES-2 Q* and *US DoT-SID*. Also, a *passive human model* has been used in all simulations.

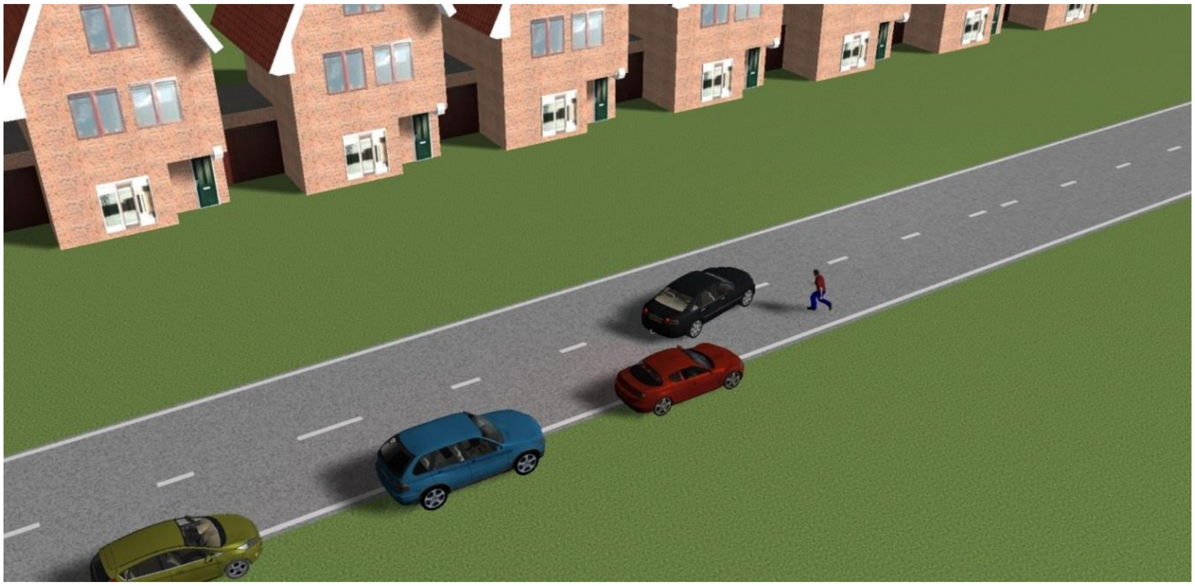

Fig. 1. Emergency braking caused by the VRU system during lane change executed by the driver.

4. Results

All test scenarios show some trend in ATD and human model behaviour. ATDs are too stiff, on the other hand, the human model is too flexible. However the simulations show some differences in model behaviour with pre-crash low-g acceleration and lateral impact (Jastrzebski D., et al., 2014). The pre-crash manoeuvres may move the occupant's body to the OOP. Combined conditions show the influence of the autonomous manoeuvre on the occupant's position (Figure 2). Every test shows occupant's movement to the side during lane change and to the front during emergency braking (Figure 3), which can lower airbag efficiency. The movement of ATD shows one of the smallest possible displacements of the occupant in compare to volunteer reactions (Kirscht S., et al., 2014) while Passive Human model shows one of the biggest.

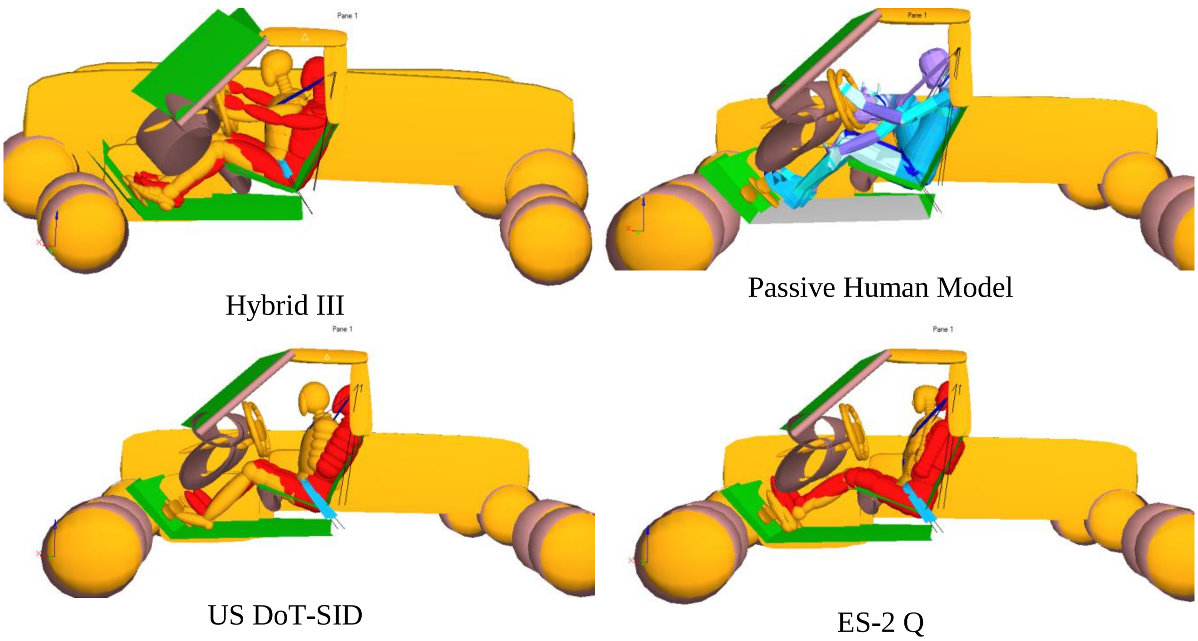

Fig. 2. Comparison of the responses of ATDs and Passive Human Model to the combined low-g acceleration of braking during lane change maneuver

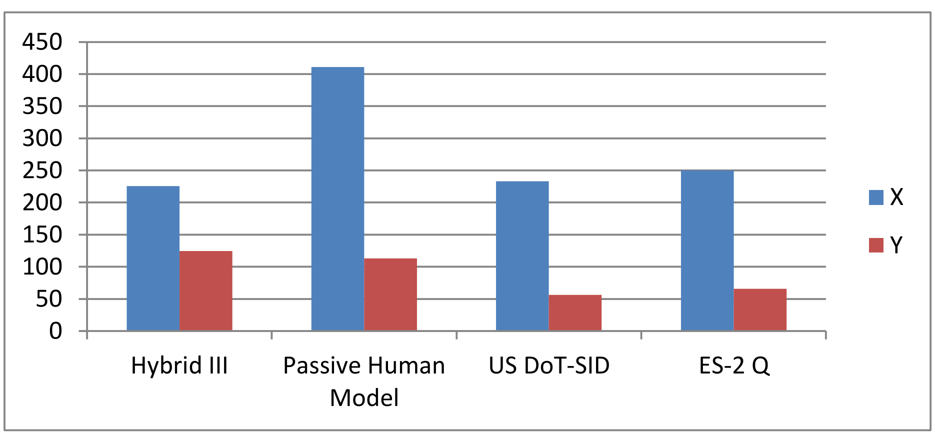

Fig. 3. Maximal movement to the front in X direction, and to the right in Y direction

5. Conclusion

The body movement may affect the efficiency of the passive safety systems, as the occupant can move to the OOP. Simulations compared with volunteer results shows the need for more tests, but also justify the reasonableness of research on efficiency of active and passive systems interaction. Based on the research, a new methodology of the occupant movement measurement needs to be created in different conditions. Moreover, it has to be compare with *Active Human Model* (Meijer R., et al., 2012). The forecasting of the collision should be combined with passive safety systems to increase the efficacy of both protections. There is a need for the comparison of the behaviour of the aware and unaware occupant during manoeuvres.

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