OPTIMISATION OF OCCUPANT SAFETY WITH COUPLING OF KINEMATIC AND OPTIMISATION TOOLS

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KEYWORDS –
Optimisation, Kinematic Tool, Dummy Positioning

ABSTRACT –

The idea for this project came up when knee mapping was introduced. Knee mapping is part of the EURO NCAP occupant safety test procedure. The knee mapping calculations take place in the Adult Occupant Safety Procedure in case of an instrument panel modifier. The goal of the optimisation tool described in this paper is to optimise the dummy and seat position procedure to finally find the optimum position of the dummy and the seat such that it meets the prescribed regulations by Euro-NCAP.
The optimisation tool consists of four steps and couples several programs. The pre-processor step (1) is performed by ANSA after which a numerical simulation (2) is performed in PAM CRASH 2008. The results are post-processed (3) by META post which forwards its outcome to the mathematical optimisation tool (4) DAKOTA. To demonstrate it's functioning the optimisation tool is applied to a knee-mapping test procedure.

TECHNICAL PAPER -

1. MOTIVATION

Nowadays, the positioning of a dummy becomes increasingly important for the test procedures. In detail for the protection of pedestrians in frontal impacts and for occupants in front-, side- and rear-impacts the dummy behaviour during the crash is evaluated and monitored. A correct positioning of the dummy is essential in these tests. The impact points in the pedestrian safety and knee-mapping procedure are not predefined to a fixed geometrical position. Instead, an impact zone is defined in which the certifying authority has the freedom to choose points which are potentially dangerous for the occupant's knees. The amounts of testing procedures in the different phases of the development of a car are substantial. The first step is to screen the predefined impact zone for impact points to be tested. Often this screening procedure has to be performed in every step of a cars development program. Automating this screening test by impacting the whole zone will result in an enormous amount of calculation time and resources. In some cases this screening is not even possible especially when the dummy is a complex kinematic system with multiple boundary conditions.
Knee-mapping is a good example of such a procedure in which the position of the dummy and the seat has to be changed for every modifier. An optimisation tool is developed to determine the optimal position of the dummy and seat.
The goal of the optimisation tool on the one hand is to detect harmful zones. On the other hand it should be able to answer the question how to position the dummy to fulfil the requirements of the test procedure.
The tool is a combination of the kinematic tool of ANSA to position the dummy and seat and a mathematical optimisation tool called Dakota which determines the optimal position with help of the numerical results.
This paper globally describes the working method of the optimisation tool. To demonstrate its functioning, the tool is applied to the knee mapping procedure of a passenger dummy. The regulations of the knee-mapping procedure have been updated in February 2009. This update has a major effect on the minimum knee displacement requirement. The knee mapping tests are performed with a sled on which the remaining parts are mounted, e.g. a

dashboard, centre console, airbags, air-conditioning module, seat belts and seats. The Euro NCAP requirement states that the acceleration of the sled equals the pulse measured at the B-pillar during frontal crash ODB.
To correctly position the passenger dummy, the following demands have to be fulfilled:

- A 95% male Hybrid III dummy shall normally be used. (5.3.1) (1)
- The vehicle seat should be adjusted according to the procedure of EURO NCAP frontal crash test protocol.(5.4.1) (1)
- The seat should be moved rearward by 30 mm (5.4.3) (1)
- The feet should be placed as flat as possible on the toe board parallel to the centreline of the vehicle (5.5.8) (1)
- The minimum knee penetration for all of the passenger femur load tests within main test program is based on the limit of the inspection zone. This is based on the penetration of the passenger knee obtained in the official Euro NCAP test including an additional 20 mm. (5.6.1) (1)
- The tests for the knee sliders are similar to the knee tests but are not considered in this example.

2. THE MODEL

In this numerical example a simplified model of a common car is used. At first the whole car model is monitored at the Euro NCAP ODB test. The resulting acceleration of the cars body is measured and filtered which results in the ODB acceleration curve. Figure 1 depicts the ODB acceleration curve and the acceleration curve of the Euro-NCAP standard acceleration curve.

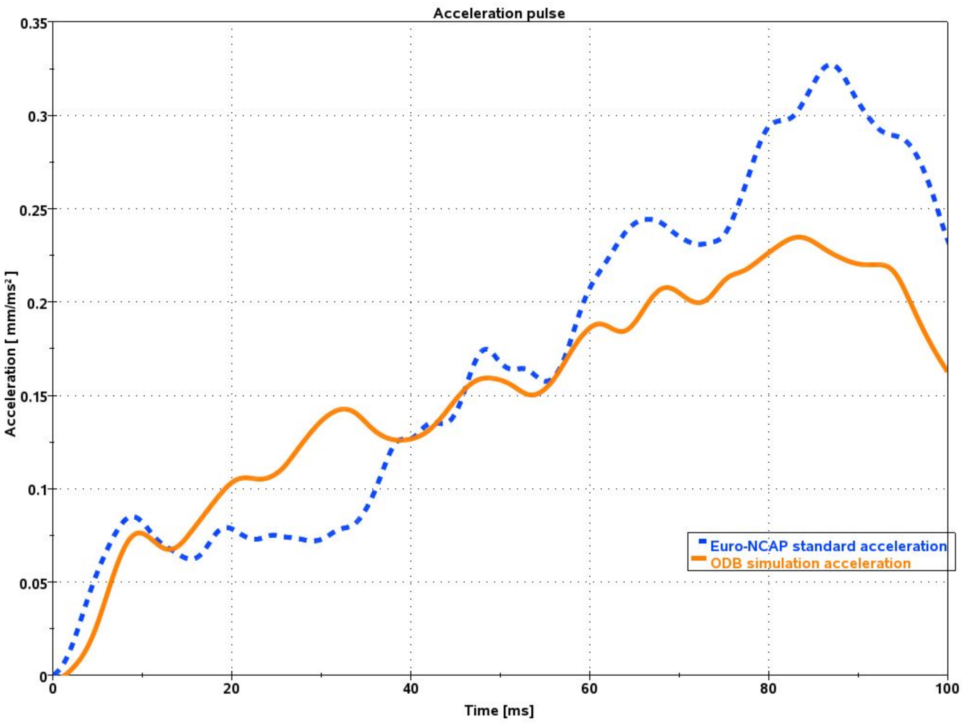

Figure 1 – Comparison of Euro NCAP standard acceleration and the acceleration of the model in the Euro NCAP Test procedure

The stable behaviour of the car during the simulation and the comparable performance between the ODB model and the acceleration curve of the Euro NCAP creates a sound basis for using sled tests. The sled test model includes parts of the body which are set to rigid. To achieve an acceptable calculation time, parts like the driver's door and seat, which do not have any influence in the test, are removed.

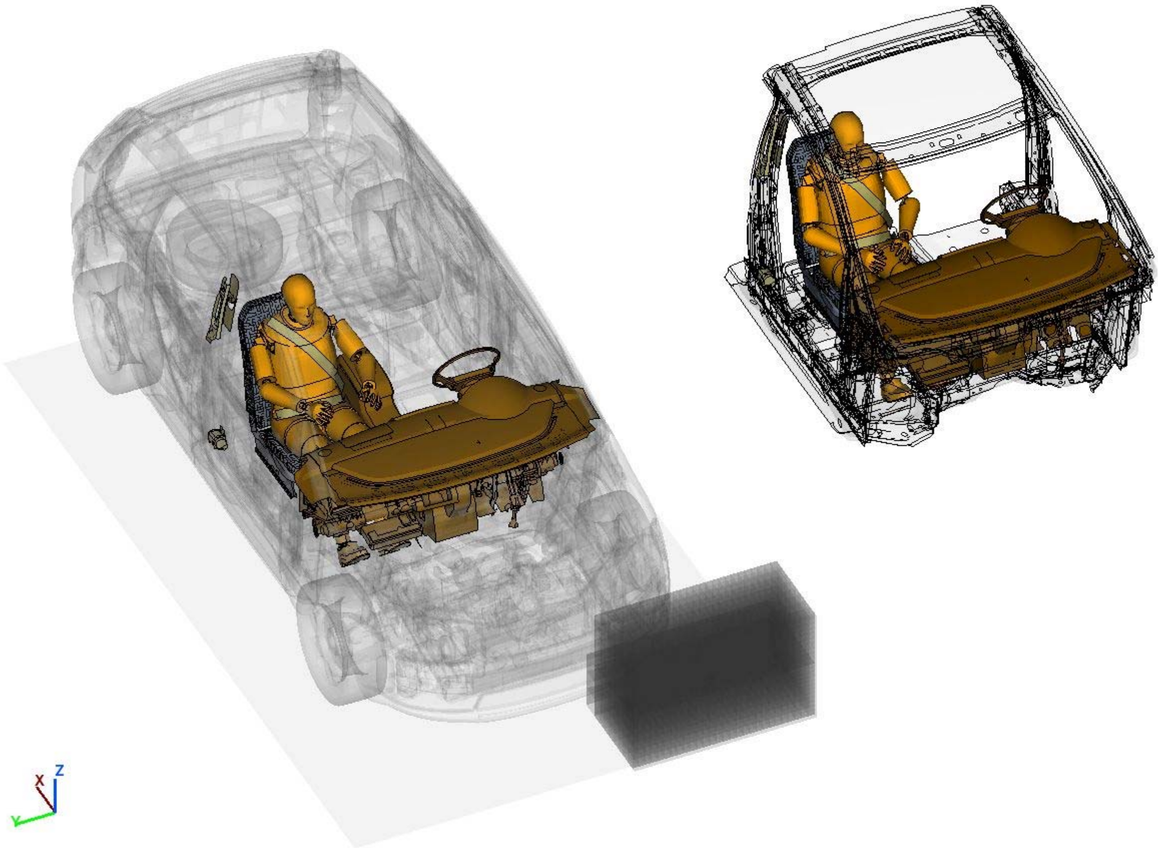

Figure 2 - Model of Euro NCAP ODB front crash and sled test model

To create a realistic intrusion of the knee into the dashboard, special attention is given to the modelling of the seat, dashboard and components situated in the interior of the dashboard. The whole model has an initial velocity of 64 km/h. The negative acceleration from the ODB test is applied to the whole body to realise a comparable behaviour compared to the ODB test of the interior parts.

The dummy and the seat are mapped with the kinetic model of ANSA. To make sure that the dummy and the seat behave realistically during the optimisation cycles, the joints are assigned a maximum and minimum value. Some of the kinematic joints are locked to prevent the movement of the upper body of the dummy.

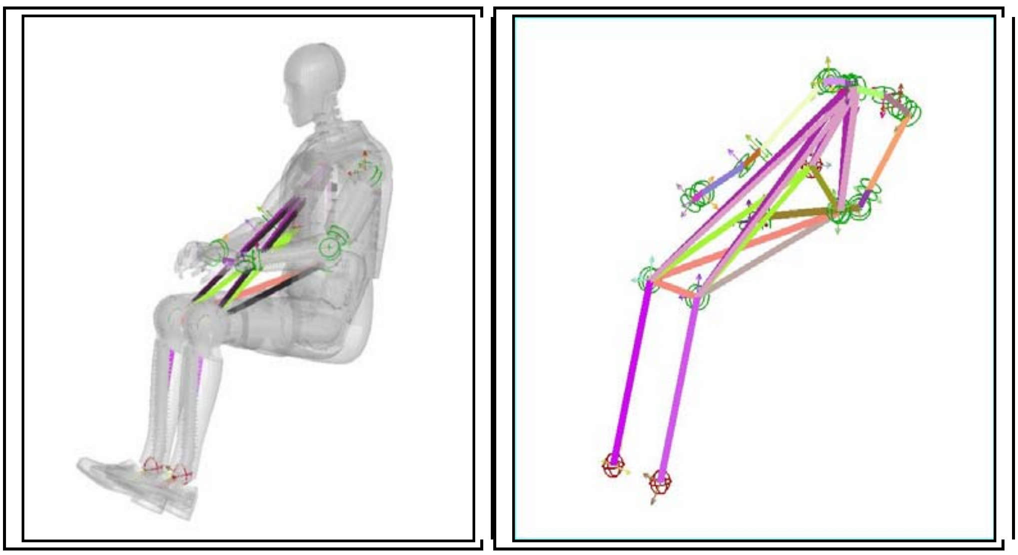

Figure 3 – Dummy mapped with the kinematic tool of ANSA 13

In this test only the slider of the seat is mapped with the kinematic tool to move the seat back and forward. A possible extension is to vary the position of the seat in vertical direction so that whole testing area can be covered. To constrain the number of influencing factors in the test, the latter influencing factor is set constant.

Another important influencing factor in the positioning of the dummy is the definition of the contact between the feet and the toe board. It is mandatory to place the feet as flat as possible on the toe board and parallel to the centreline. The contact detection is use to ensure that there are no intersections or penetration of the dummy and its surroundings. A limitation of the ANSA optimisation tool is the absence of a tool that allows for a vectorial movement. For example, the movement of a foot in which a vector is defined from the heel to the tip of the foot which then is rotated and translated so that the vector is parallel to the centreline of the car.

3. IMPLEMENTATION

In general the optimisation tool consists of a cycle of four steps: pre-processing, solving, post processing and optimisation of the parameters.

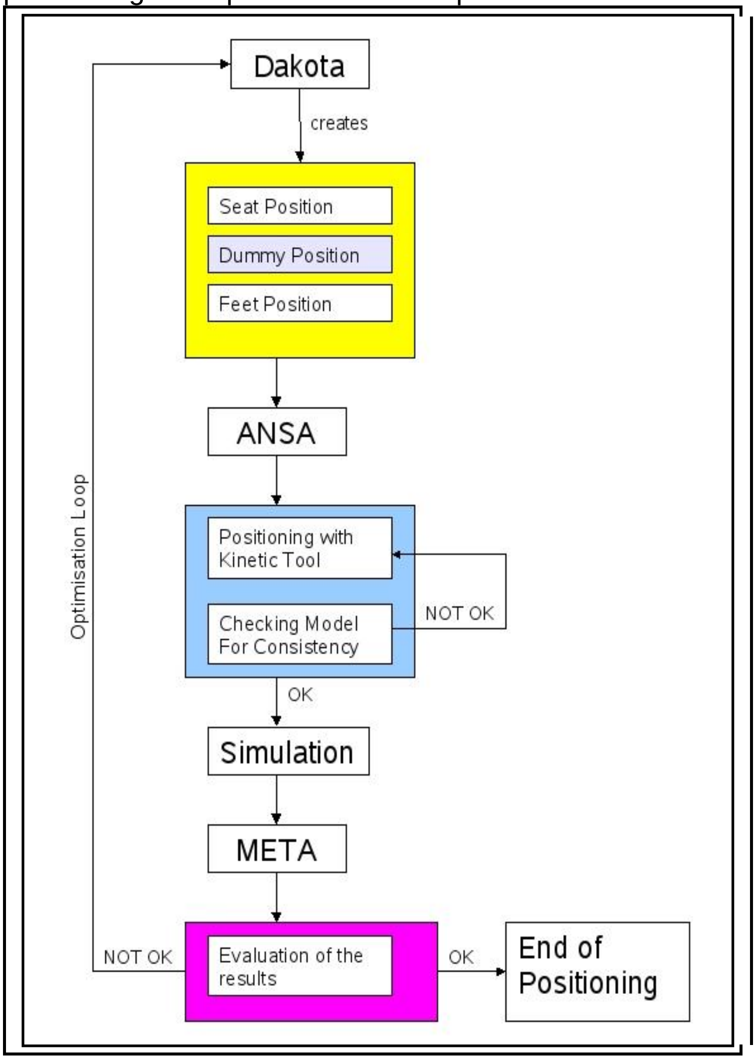

Figure 4 – Scheme of the optimisation cycle

In the pre-processing step the model is initially mapped with pre-defined parameters. The resulting model is then solved in PAM CRASH 2008. The outcome of this numerical calculation is analysed by META post processor. In this post processing step the focus is laid on the intrusion of the knee into the dashboard. The movement of the knee is measured relative to the total movement of the sled. Another measurement is made between the knee and the dashboard. Initially, a gap exists between the knee of the dummy and the dashboard. This movement does not result in any intrusion and has to be excluded from the

results. Once the knee contacts the dashboard, the relative movement of the knee to the sled equals the intrusion in the dashboard. If the knee gets in contact with the dashboard and detaches again the cycle is useless because of its unstable character. The regulation states namely that the knee has to have a stable contact to the dashboard. Finally the resulting intrusion curve of the post-processing step is then forwarded to the optimization tool
For optimisation the Design Analysis Kit for Optimization and Terrascale Applications (DAKOTA) is used. It handles the incoming intrusion curve and forwards the optimized position for the dummy. DAKOTA is free software and contains a large number of different optimisation algorithm strategies such as linear, nonlinear and genetic optimisation. The tool is easy to integrate because of the ASCII input and output format. (2)

4. THE RESULT

As explained in chapter 3, the optimisation tool is applied to the knee-mapping procedure in which the dummy is initially positioned according to the standard position described in the regulations for the ODB frontal impact test procedure. The one dimensional problem still demands a considerable amount of calculation time. The number of optimisation cycles is therefore limited to 15. The optimisation tool proved to be able to come close to the optimal position of the seat and the dummy. In detail this means that the intrusion of the knee is at least 20 mm and the force on the femur remains low. The next step in the optimisation would be to optimise the design of the interior components of the dashboard such that the forces acting on the dummies knee remain below 3 kN.

5. SUMMARY AND FUTURE WORK

The optimisation tool presented in this paper is a combination of the ANSA kinematic tool, the META post-processing tool and the mathematical optimisation tool DAKOTA. The four step procedure is applied onto a knee-mapping example. This tool proves to be an efficient and convenient procedure to optimise the position of the dummy with regard to the prescribed regulations by Euro-NCAP. It decreases the amount of pre-processing work considerably and the optimum position of the dummy and the seat is found within an acceptable amount of optimisation cycles.
Although this tool is specifically tested and described for the knee-mapping procedure in this paper, it can easily be applied to other test procedures because of its black box character. An example could be the use in ‘out of position’ tests in which uncommon positioning procedures of the dummy must take place. In this case the whole dummy and seat have to be mapped and all joints of the limbs and adjustable parts of the seats need to be limited.
Also the numerical testing of side airbags can be improved by applying this optimisation tool. Not only extreme seat positions and standard positions can be tested, but the whole airbag can be checked for weak points by moving the dummy and seat within certain pre described limits.

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