A CAE Tool for Processes Optimization According to FMVSS201U

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ABSTRACT – Project work being conducted at P+Z Engineering has resulted in the need to develop a tool to aid in the FE-Simulation in accordance with Federal Motor Vehicle Safety Standard 201u commonly known as FMVSS201u. The task was to automate the alignment process of the Free Motion Head Form. The Free Motion Head Form is the test body for the interior impact testing.

Due to the large number of impact points on the vehicles interior that are required for testing, the determination of the impact points and the correct alignment of the free motion head form are extremely time consuming tasks. Priority was placed on developing an efficient process accompanied by a reliable tool to aid in the automation of this process.

ANSA has been and is currently being delivered with features which automate the alignment of the Free Motion Head Form on the vehicle interior trim. Additionally solver interfaces that export the necessary transformation cards allowing for quick and easy implementation of the alignment information into a full scale finite element model have also been incorporated.

This paper aims to shed some light on the complexity of the FMVSS201u standard and what aspects also need to be considered when setting up simulation models before hardware testing has started. The new features added into the ANSA FMVSS201 Safety Tool will also be described.

TECHNICAL PAPER -

1. INTRODUCTION

At the start of the last decade leading up to the turn of the century it became apparent that unrestrained occupants in automobile accidents were suffering major head injuries as a result of the impact against the vehicles interior. In order to ascertain the cause of these injuries The National Highway Safety Administration (NHSTA) began its work.

Results of studies carried out showed that impact occurred on points of the upper roof, upper side rails and pillar areas. In order to reduce the risk of severe head injury a legal requirement was developed with the objective being to commit automobile manufactures to setup the car interior as “energy absorbing” as possible. The standard FMVSS201U (Federal Motor Vehicle Safety Standard, Upper Interior) began on 1. September 1998 and became law, with exceptions, in the USA on 1. September 2002.

The FMVSS201U test procedure TP201U-01 involves the use of a modified Hybrid III 50%ile head form commonly known as the FMH (Free Motion Head Form) for use in high impact testing against vehicle interior components. The procedures describe how to position the FMH, how to find the required impact points inside the test vehicle and the impact speed required for the desired impact point. An accelerometer in the FMH measures the acceleration during impact and rebound. The HIC(d), Head Impact Criteria - dummy, is then calculated in order to measure the severity of the impact.

$$HIC = \max_{t_1,t_2}\left[\left(\frac{1}{(t_2-t_1)}\int_{t_1}^{t_2} a\,dt\right)^{2.5}(t_2-t_1)\right]$$

$$HIC_{dummy} = 0.75446 HIC_{FMH} + 166.4$$

In order to increase efficiency and aid in the all phases of a vehicle development program simulation teams are called upon, using the Finite Element Method, to help optimise many aspects of vehicle structural behaviour. FMVSS201U tests are currently being successfully carried out on virtual near to full vehicle finite element models. Together Beta CAE Systems S.A. and P+Z Engineering GmbH have developed and are continuing to improve a CAE tool which aids in generating the necessary data required for the "worst case" alignment, highest HIC(d) value, during impact of the Free Motion Head Form. This paper aims to shed some light on the complexity of this problem and show how new developments continually being incorporated in ANSA aid in finding the "worst case" impact for the FMH.

Motivation

The change in crash code from PAM-Crash to ABAQUS Explicit resulted in the need for new innovative tools to aid the automated generation of CAE models, their submission and reporting. ANSA having already a comprehensive interface for the features offered in ABAQUS Explicit was suggested as a basis to build upon. Current project work at P+Z Engineering provided the perfect opportunity to work together with Beta CAE Systems.

Due to the variability of the HIC(d) value that can be encountered when testing at any one point it is often necessary to vary the parameters used and in turn increase the number of tests carried out ant any one point. Parameters such as horizontal angle, vertical angle, although often fixed, and impact position in the Free Motion Head Form Impact Zone (FIZ) on the FMH and or interior components play a decisive role in the severity of the HIC(d) value. As mentioned previously it is required that the worst case HIC(d) value be found and therefore the worst case combination of the previously stated parameters.

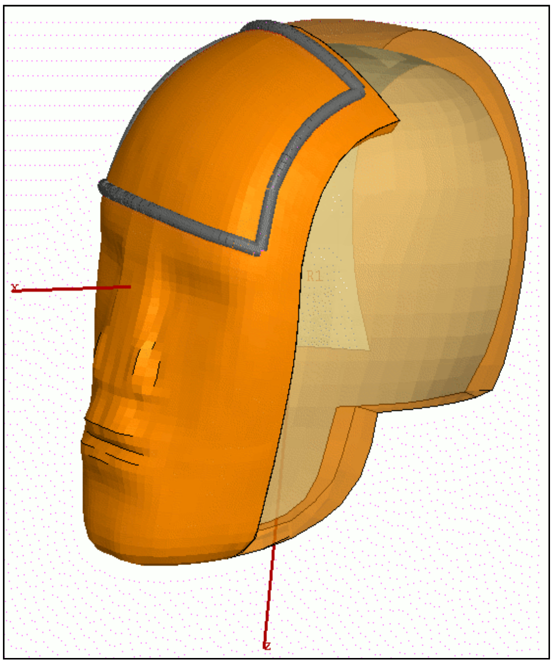

Figure 1.0 – Free Motion Head Form Front Impact Zone.

A standardised process was defined to increase efficiency during the creation of successive runs that are required to perform a full structural optimisation of the vehicle interior structure. Using this process it is possible to supply ANSA with the impact points on the interior vehicle trim surfaces and generate all required load cases and input decks. The user must not edit the input files himself.

Determination of the Impact Points in accordance with FMVSS201U

In order to generate complete documented procedure along with results, it is necessary to provide information gathered during the determination of the impact points. This information usually takes the form of a CATIA v5 / v4 format. Important is that the CG-F, CG-R and all impact points are clearly marked. The ANSA geometry engine currently possesses most of the features required for determination of the interior impact points. Work is currently being carried out in order to assess how much user input is required and how much of this input can be automated.

2. FMVSS201 SAFETY TOOL IN ANSA

FMH Alignment

Due to the complexity of modern motor vehicle interior structures the alignment procedure of the FMVSS201 Free Motion Head Form can become quite difficult and therefore needs to be described. The Figure below describes how to act when difficulties are encountered.

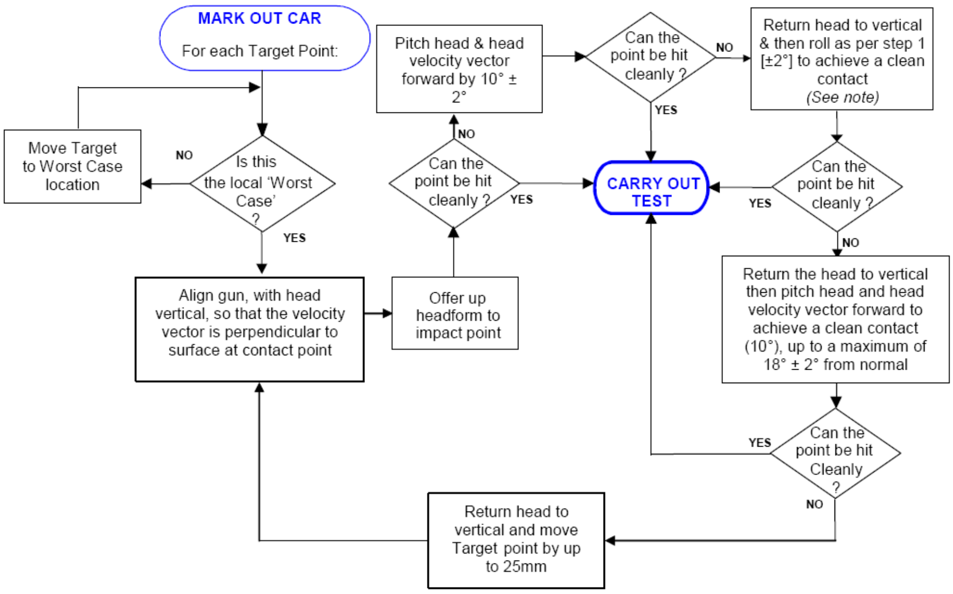

Figure 1.1: A free motion head form alignment procedure.

Finding the Horizontal Angle

As stated in table 1 of the FMVSS201U Laboratory Test Procedure seat belt mounting structures, door frame, A and B Pillars, the upper roof, rear most pillar all have predefined horizontal approach angle limits. The procedure defines a variable horizontal angle with an upper and lower limit. For the worst case HIC(d) value the corresponding horizontal angle must be found. The FMVSS201 Safety Tool developed and integrated in ANSA relies on an alignment algorithm to find the horizontal angle at which the midsaggital planes of the FMH and the interior trim surface line up. First contact between the Free Motion Head Form Impact Zone and the interior trim is, when combined with the previous step, also established. From this point onwards the vertical angle can also be calculated.

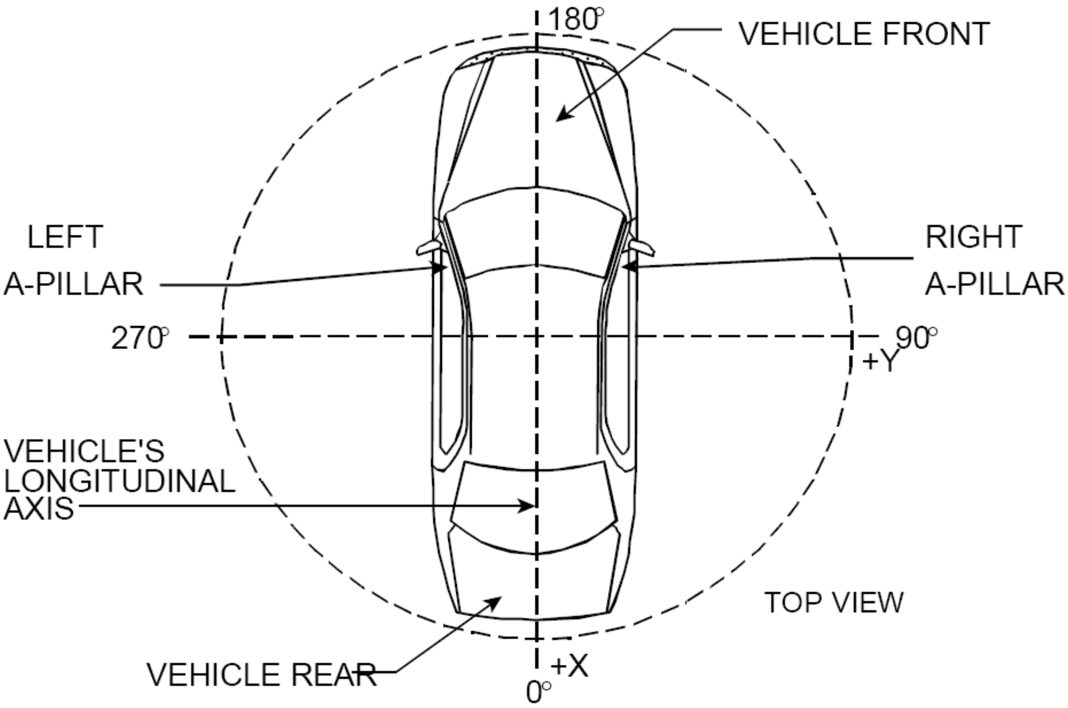

Figure 1.2: The vehicle horizontal angle reference frame.

Due to the complexity of the interior trim structure and the packaging behind, it is often required to use good “Engineering Judgement” in order to set the worst case for the horizontal angle. Based on the deformation of the trim structure and the subsequent impact against the BIW or packaging structure lining up the midsagittal planes of the FMH and trim at the impact point may not always represent the worst case. For this reason it is possible to manually set the limits of the horizontal angle so as to ensure good impact.

Finding the Vertical Impact Angle

The vertical angle at which the FMH is set to plays a key roll in influencing the HIC(d) value. As stated in the test procedure, the initial velocity of the Free Motion Head Form is always oriented in the positive local x-direction of the FMH, perpendicular to the skull base plate. The more the contact position is aligned with the initial velocity vector of the FMH the faster the interior trim structure will have to work in absorbing the energy during impact. Therefore it is imperative that the correct vertical angle be found. ANSA currently possesses the capability to find the vertical impact angle while staying contact with the impact surface.

Using Contact Algorithm

By setting the horizontal angle and moving the FMH from its original position to the impact point initial contact is made. From here it is necessary set the vertical angle so as to achieve the worst case HIC(d) value and adhere to the FMVSS201U standard. The vertical angle is taken about the local y-axis at the centre of gravity of the FMH. As a result of this rotation initial contact is lost between the FMH and the trim impact surface. It is easy to manipulate the FMH per hand however so as to hold the contact position. However in order facilitate automation and running in batch mode user intervention can be removed by allowing the software to generate a contact condition between the FMH front impact zone and the trim impact point surface. Using this method the software rotates the free motion head form about its local y-axis and adheres to a contact condition with the trim surface by translating the FMH in the local x-z plane. When a second contact is found between the trim surface and the nose or chin of the FMH of the vertical limit is reached the rebound angle is enforced.

Using Geometrical Relationships

Due to the complex geometry often encountered on the inner surface of modern automobiles it is quite often difficult to use a contact algorithm as the one and only criteria when determining the vertical impact angle. Using the impact position, the centre of gravity of the FMH and the desired arc along the FIZ (Front Impact Zone) it would be possible to set the vertical angle using the geometrical relationship if the contact algorithm were to fail. As an added function, to ensure quick and effective positioning of the Free Motion Head Form, work is currently being carried out in order to assess the feasibility of including such a feature.

Presetting the Vertical Angle:

As stated in the standard the horizontal angle is usually found first followed by the vertical angle. Whether or not the FMH be positioned in the vertical plane prior to finding the first contact must be left open to the user. It can quite often be the case that the geometry at the impact point is so complex that first contact with the FMH Impact Zone cannot be found. This option presents itself well when using automated positioning at the FH (Front Header) points. The FMVSS201 tool has an option that allows to user to set the vertical angle to an allowed value prior to finding first contact with the trim surface.

Initial Contact with other Interior Parts:

A common problem encountered when positioning the FMH is the collision between the FMH Impact Zone with other interior trim surfaces during alignment of the horizontal angle. This results in the FMH Impact Zone not being able to meet the desired impact point. Quite often the FMH can be obscured by other interior parts such as door trim, the sun visor or other interior trim surfaces. Although still in the experimental phase the version of ANSA used here is able to overcome these problems by recognising contact between other interior trim parts and the rest of the FMH. ANSA then attempts, in the correct order, different alignment angle combinations. When the FMH Impact Zone is able to make, in one step, contact with the impact point the vertical angle is set.

Outputting the Amount out of Position at the Impact Point:

Due to the geometrical form and complications encountered positioning the FMH it is often very difficult to ensure that the first point of contact between the FMH and the interior trim lies on the midsagittal plane of the FMH. For the purpose completeness it is required that the amount of "out of position" that occurs between the two points of contact be documented. For this reason an extra feature was built into the tool allowing contact based algorithm to output an exact value of the "out of position" that will occur during impact.

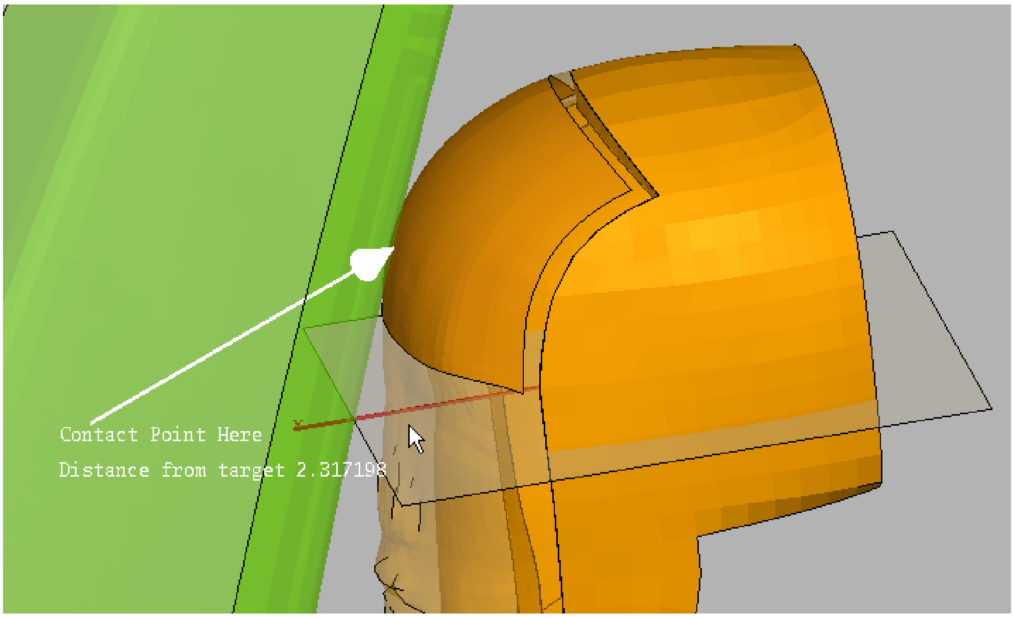

Figure 1.3: Determination of the "Out of Position" value.

Batch Mode

In order to assess the repeatability of the analysis inside the 1st and 2nd impact zones it is often required that several simulations at and around the same impact point of the interior trim be carried out. As it is clear that between 10 and 20 simulations will be required for each impact point an automated positioning process is required in order to save time. An automated feature using the FMH positioning process previously mentioned and template file defining the setup allows quick error free generation of the parameterised header files.

An ANSA_Transl file sets up the positioning data and recognises all associated FMH and interior trim data upon starting ANSA. The automated positioning is carried out using the "worst case" principal relying on lining up the midsagittal planes of the FMH and interior trim surfaces. Future versions will however allow the user to include their own horizontal and vertical angle limits. ANSA is able to run with the information regarding the impact points and the Free Motion Head Form. Batch mode produces the input decks ready for submission. The user interface of ANSA must not be opened and therefore no user interaction is required for this process. The input files can also be written back to their respective directory structure in order to avoid confusion.

Assessing the Vehicles Interior Structure

Additionally it may be necessary to relocate the desired impact point if the FMH impact zone, as a result of space problems and or the geometry of the interior trim surface, as it is unable meet with the desired impact point. In both cases creating a cross sectional view is necessary and will aid in finding the worst case position of the FMH. Therefore it is planned in a future version of ANSA to include this functionality.

3. CONCLUSION

To date ANSA's new Safety Tool, FMVSS201 incorporated has proven to be very useful when aligning the FMVSS201 Free Motion Head Form. Using the data generated the Occupant Safety project team within P+Z Engineering has been able to generate all data necessary without having to fall back on another tool. However, in order to achieve full automation extra work is still required.

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