

Simulation Fidelity Improvement of H350 Lower Tibia Indices

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ABSTRACT

Finite element dummy models have been more and more widely applied in virtual development of occupant protection systems across the automotive industry due to their predictive capabilities. H350 dyna dummy model [1] is a finite element representation of the Hybrid III male dummy [2], which is designed to represent the average of the United States adult male population. Lower extremity injuries continue to occur in front crash accidents despite increasing improvement of vehicle crashworthiness and occupant restraint system. It is therefore desirable to predict lower tibia injury numbers in front occupant simulations. Though lower tibia loading/index predictions are not studied as much as the FMVSS 208 regulated injury numbers, the tibia indices are injury criteria that need to be assessed during IIHS and Euro NCAP frontal offset occupant simulations. However during front crash simulations, it is very difficult to achieve good correlations or predictions of lower tibia loadings. A common issue is that the simulations often over-predict lower tibia loading (forces and/or moments) and in turn generate unrealistically higher tibia indices. For this reason, safety CAE engineers are not yet confident in presenting correlations or predictions of the lower tibia loadings/indices. This paper employs Pugh Concept Selection to study the effects of dummy foot location and carpet to sled buck floor interaction on the lower tibia loading/index response. Based on the understanding gained, improvements in the simulation fidelity of lower tibia indices were achieved. Additionally, these findings demonstrate that overall dummy performance is affected by the lower tibia index differences.

CITATION: Li, W., Cheng, Y., and Furton, L., "Simulation Fidelity Improvement of H350 Lower Tibia Indices," *SAE Int. J. Mater. Manuf.* 8(3):2015, doi:10.4271/2015-01-0578.

INTRODUCTION

Finite element dummy models have been more and more widely applied in virtual development of occupant protection systems across the automotive industry due to their predictive capabilities. H350 dyna dummy model [1] is a finite element representation of the Hybrid III male dummy [2], which is designed to represent the average adult U.S. male. The dummy model has been proven via a rigorous validation approach [3] [4]. The approach consists of a series of stringent CAE tests at different levels, from material level, component level, sub-assembly level to full dummy level. Specifically, the dummy lower tibias were validated by 4 different tibia and foot impact CAE tests - tibia impact test, foot impact test with/without shoe [5] and 3 further validation tests - upper foot impact, lower foot impact with/without shoe as per Euro regulation [6].

In practice, safety CAE engineers find it difficult to obtain good correlations or predictions for the lower tibia loadings/indices in front impact occupant analysis even with this rigorous validation process and thus have lower confidence on the dummy model prediction capability. Not enough attention has been drawn to this issue because of two factors: a., the fact that lower tibia indices are not FMVSS 208 regulated dummy injury numbers, and b., the assumption that the lower tibia loadings/indices do not have significant effects on dummy performance, i.e. on other dummy injury numbers. Consequently, engineers have tended not to focus on tibia loadings/ indices.

Many factors affect lower tibia loading simulation fidelity. An attempt was made to improve the tibia index prediction by properly modeling the floor carpet with different material models and element types for different parts, and improved tibia index prediction was achieved [7]. However little effort has been seen in evaluating effects of other factors. In the following sections, the effects of two factors on lower tibia index simulation fidelity were explored, which have been ignored and attracted little attention from safety CAE community. These include how the interaction is modeled between the floor carpet and the sled buck, and the dummy foot location.

FACTORS AFFECTING LOWER TIBIA INDEX PREDICTIONS

1. Floor Carpet Modeling

The first factor analyzed is the way the floor carpet assembly is modeled. Fig. 1 shows a very general configuration of the passenger vehicle floor carpet. It can be seen that there are gaps between the floor carpet and the sled buck. It is currently common practice to model the bottom surface (red line in Fig. 1) of the floor carpet as rigid. The advantage of this method is that the model can be easily and conveniently connected to the sled buck. The disadvantage of this model is clear in that it eliminates all compliances between the floor carpet and the sled buck and the floor carpet assembly appears much

stiffer than in reality. This will increase the contact forces between the dummy feet and the floor carpet and in turn affects lower tibia index predictions.

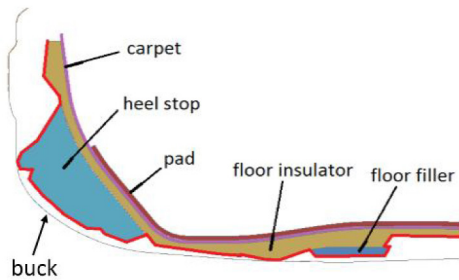


Fig. 1. configuration of a floor carpet model

To capture the appropriate compliances between the floor carpet and the buck in this study, the bottom surface is modeled as deformable and the carpet model is connected to the buck via a number of studs as per the design. A contact between the model and the buck is added in the sled model. This approach will more realistically reflect the floor carpet stiffness.

2. Foot Location

The second factor affecting tibia loading is the foot location. In FMVSS 208, Euro-NCAP and IIHS front impact tests [8] [9] [10], it is required to record many dummy-related measures prior to the tests, after the dummy setting and positioning procedures have been completed. Obviously there are no requirements to record any measures for the foot locations. Therefore test engineers usually do not record the locations of either the left or the right foot. Without any specific test set-up information, safety CAE engineers have to place the dummy feet as per the standard test procedures in the simulations no matter where the corresponding physical dummy feet are placed. As long as the foot location in a physical test is away from that specified by the standard procedures, the foot in the CAE simulation may interact with the floor quite differently and generate different tibia indices from those obtained in the physical test. For example, in Fig. 2, the z-section of the floor carpet shows that the front foot resting area of the floor carpet is curved. The left foot, when located in the position I or the position II, will interact with the floor differently in both contact force magnitude and contact timing, and consequently produce different tibia indices. The position I was achieved as per FMVSS 208 test procedure [11].

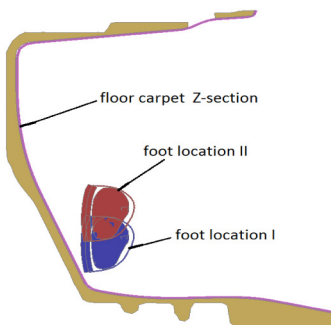


Fig. 2. Left foot locations

PUGH CONCEPT SELECTION

1. Baseline Model

The baseline model is built on a 50th unbelted 40 kph sled model as per GM modeling guideline, as shown in Fig. 3, and has the bottom surface of the floor carpet as rigid and the left foot placed in position I, which is achieved by standard FMVSS 208 dummy positioning procedure [11], as shown in Fig. 2.



Fig. 3. sled model used

2. Alternative Models

There are 3 concept models, defined as shown in table I:

Table I. Alternative Concept Models

Concept	Description
1	Deformable surf. & foot position I
2	Rigid surf. & foot position II
3	Deformable surf. & foot position II

Foot position II is believed to be closer to that in the physical test.

3. Evaluation Criteria

The left and right lower tibia indices are used as evaluation criteria for this study.

As the Pugh Matrix is not always able to judge which concept is the best one, the relative error is used to assist in such a case and the formulation used to calculate the relative error is shown below.

$$Relative\ error = 100\% * \left| \frac{(CAE - test)}{test} \right| \quad (1)$$

The maximum values in either CAE results or test results are used to calculate the relative errors.

4. Pugh Matrix

The simulation results for all four runs are shown in Fig. 4