Qualifying FE Human Body Models for Specific Load Cases: Assessing Uncertainties during the Validation Process

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I. INTRODUCTION

Finite Element (FE) Human Body Models (HBMs) have the potential to be used within the development process of active and passive safety systems in cars, especially for optimising their effectiveness and for evaluating their protective capabilities. The models thereby complement or already replace physical or numerical dummy models as they are capable of addressing new needs arising due to significant changes which are currently ongoing within the safety divisions of automotive companies. For example, future more advanced restraint systems are supposed (I) to protect a broader anthropometric diversity of human beings, (II) to be optimised for more complex loading conditions, such as oblique impacts, or (III) to evaluate potential new interior configurations like reclining seats [1-2]. Evidence of sufficient validity is needed not only to establish credibility of the models, but also to qualify them to be used for specific applications, such as for assessing deployable systems in the consumer testing protocol currently being developed for pedestrian protection. So far, there are no commonly agreed or standardised methods or procedures for the validation of the models to safeguard such proof. Especially uncertainties are often either not taken into account at all when evaluating simulation results or solely subjectively assessed. However, such uncertainties often result in a lower accuracy of predictive capability of simulation results. This paper presents a method of how to consider and objectively assess the results of a thorough uncertainty analysis within the evaluation process of validation results in order to create a base for defining a range the HBM can reliably be used within. Following such methodology should be part of any process which is to be followed when qualifying an HBM for a specific application.

II. METHODS

Two reference experiments with Post Mortem Human Subjects (PMHSs) were chosen from literature as a base to identify, investigate and classify different kinds of uncertainties arising during the validation process on two different validation levels. The experiments published in [3] represent a typical validation load case on the local level, solely involving the isolated human rib, the experiments published in [4] on the regional level, involving the complete head-neck-complex. Both experimental test setups were numerically modelled in the crash code LS-Dyna and relevant parts of the FE model THUMS^{TM} AM50 occupant model (Version 4.01) integrated. Uncertainties, which are inherent to the system resulting from the experimental boundary conditions, the numerical realisation of the test setup or from other load case specific parameters and which possibly influence the predictive capability of the results, were identified, classified and further investigated by reasonably varying relevant parameters in a justified range within different sensitivity studies.

Based on the findings, a method using the objective evaluation metric CORA (CORrelation and Analysis) [5] was developed to quantify and evaluate the scatter of validation results which resulted from altering relevant parameters in the sensitivity studies. This scatter represents the range the validation results can realistically vary in due to system-inherent uncertainties. Consequently, the demand on the validation accuracy needs to be lowered during the evaluation process of validation results. To address this, the method results in the adaption of commonly used rating schemes, such as the one of the ISO/TS 18571 [6].

III. INITIAL FINDINGS

By conducting two load cases with THUMS^{TM} AM50 occupant model (Version 4.01) as validation show cases on the local and regional level, respectively, three different types of uncertainties could be identified and classified, i.e. modelling-induced, experimentally-induced and load-case-specific uncertainties. Modelling-induced uncertainties result from the variety of possibilities to numerically model the experimental boundary conditions or constraints. Experimentally-induced uncertainties result from the experimental testing procedure or test setup. There are load-case-specific uncertainties when not only the structure of the FE HBM, which is to

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be validated, is part of the experimental procedure, but also other structures of the human model which validity cannot be relied on. The influence of all three types of uncertainties on validation results could be quantified by running sensitivity analyses. Experimentally-induced uncertainties resulted in a scatter of the validation results of almost up to 30%, modelling-induced uncertainties almost up to 8%. Load-case-specific uncertainties even led to more deviating results, not only altering size characteristics of time-history-curves, but also the shape and phase.

The method developed within this study is outlined in Fig. 1. As a first step, the influence of identified uncertainties on the validation results is to be quantified by varying relevant parameters in a justified range within sensitivity studies. Result curves of same validation parameters resulting from the sensitivity studies are to be comprised in one diagram, both boundary curves determined, each consisting of the upper and lower extreme values, respectively, and their average calculated. The CORA cross correlation metric is then to be computed to quantify the correlation of the average curve with both extreme curves, respectively, resulting in R^{Sensi1} and R^{Sensi2}. R^{Sensi} to be calculated by averaging both values. The sliding scale of the ISO/TS 18571 rating scheme can then be multiplied by this factor to lower the limits of the scheme. The correlation between the experimental and the numerical result curve can then be rated using the adapted rating scheme.

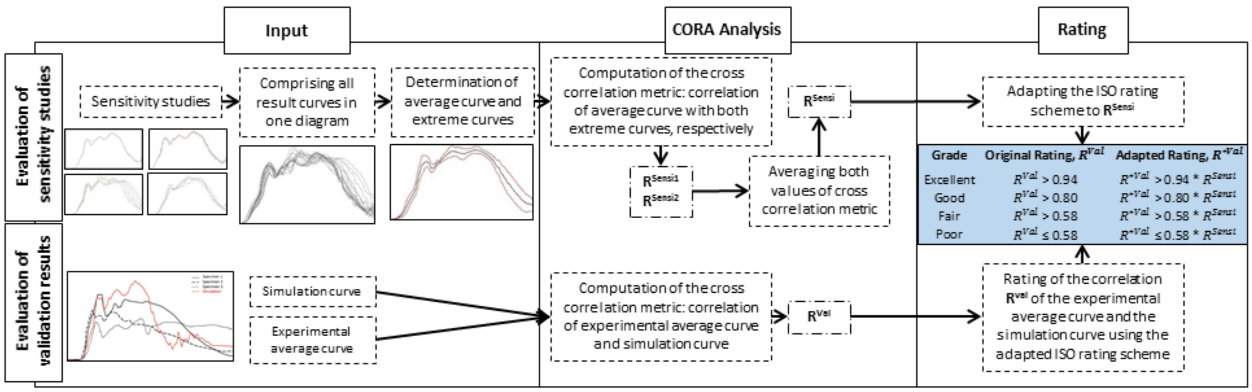

Fig. 1. Adaption of the ISO rating scheme to lower the demands on validation accuracy

IV. DISCUSSION, CONCLUSIONS AND OUTLOOK

A procedure of how to consider and objectively assess the results of a thorough uncertainty analysis within the evaluation process of validation results was developed. Such procedure is necessary as the predictive capability of a FE HBM cannot be expected to be more accurate than the accuracy of the factors, the response of the human model is sensitive to. A thorough assessment of uncertainties is not only crucial when evaluating validation results, but also when qualifying a FE HBM for specific load cases. Factors, such as anthropometric particularities, can result in a considerable scatter of simulation results which need to be taken into account when it comes to assessing simulation results. By further developing the method outlined in this paper, it is aimed to develop a procedure for defining a range, an HBM can reliably be used in, to account for such scatter. As the method was developed based on two validation show cases on the local and regional level, respectively, it can be expected that the spread of validation results becomes considerably higher when a validation on the global level is conducted. Lowering the validation accuracy would then lead to extensive low validation requirements- Consequently, the method has limited use here. However, it can be the basis to define a point where a personalised validation is obligatory to obtain reliable validation results.

V. REFERENCES

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