Table Top Test – Influence of Rib Cage Shape of 5th Percentile Female on Thoracic Response using Human Body FE Model

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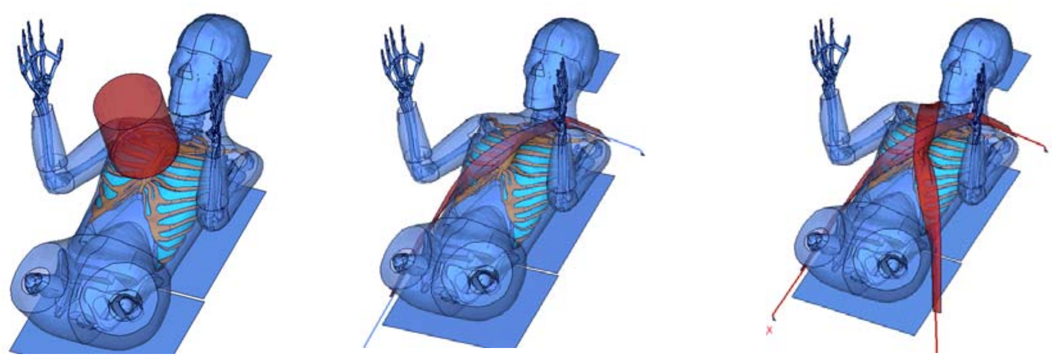
I. INTRODUCTION

The thoracic region is a critical body region from the perspective of occupant protection. The increasing use of FE human body models (HBMs) for evaluating new safety systems require these models to be biofidelic for multiple number of loading scenarios. Table top tests [1] comprise of different loading conditions which highlights the limitations of blunt impact tests. Significant work has been conducted on developing and validating models for these tests for 50th percentile FE HBMs. However, a lot less information is available related to the use of these tests for 5th percentile female validation, and for studying the effect of variations in rib cage shapes when subjected to these tests. Current research tries to address some of these aspects.

II. METHODS

The THUMSD_F05 model was previously validated for ISO 9790 sled and pendulum impact tests [2] and it was observed that differences in thoracic response existed with changing rib cage geometries [3]. Therefore, to gain further insight related to the influence of geometry on thoracic response at system level, table top tests were conducted on this model. The following steps were undertaken in the research work.

1. ***Validation Load Case***: The validation of THUMS-D AF05 was conducted based on load cases identified by [1]. The validation excludes distributed loading conditions in the current study. In the current work only non-injurious tests were targeted for the validation of the model.



Hub Loading Single Diagonal Belt Double Diagonal Belt

Fig. 1: Full Body Testing Load Case – Table Top Test Load Case Description

2. ***Anthropometric Comparison***: In [1] experiments were conducted on seven male and eight female subjects. The female PMHS in the dataset which was closest to 5th percentile female had a stature of 157 cm and mass of 65.3 kg (PMHS ID: 182). This female was considered for validation of THUMSD_F05 FE model. However, the chest depth (200 mm) and chest breadth (320 mm) were different from that of THUMS_F05 model (chest depth – 160 mm and chest breadth – 260 mm).
3. ***Corridor Development:*** [4] had proposed a method for creating corridors of the 50th percentile male. The same technique was used to derive the corridors for the 5th percentile female. Force data was scaled to the 5th percentile female using scaling factors as given by [5]. The scaling factor for the elastic modulus (λ_E) was

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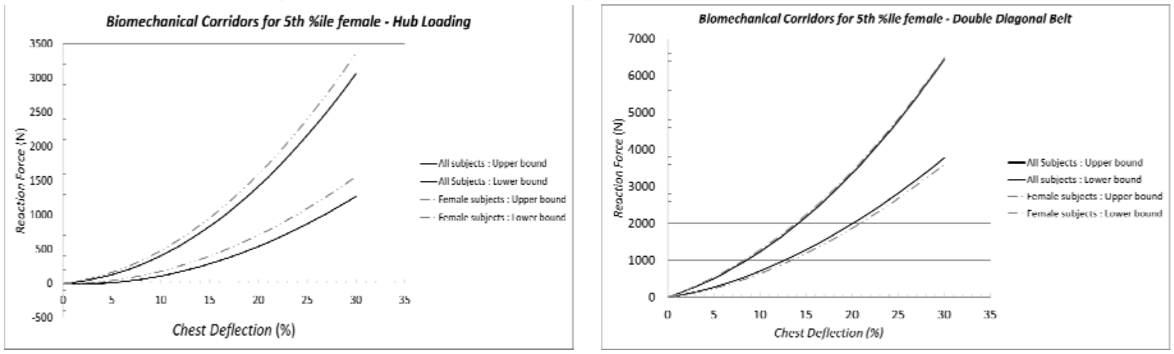
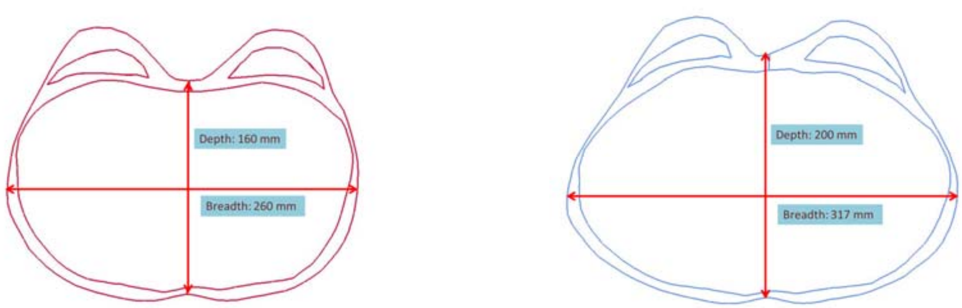
not reported by [5] and was considered as 1. The corridors were created considering all PMHS data (15 subjects) as well as data of only female subjects (eight subjects) as illustrated in Fig. 2 below. The maximum deviation between the two corridors was 30% for hub loading case, however, for single (1.8%) and double belt loading (6.3%) was less than 10%. These deviations were computed at 20% chest deflection values. The corridors developed, considering female subjects only, were used in the current study as high variation (30%) was observed for the hub loading corridor if developed using all subject data.



Hub Loading Double Diagonal Belt Loading

Fig. 2: Biomechanical Corridors for 5th percentile female

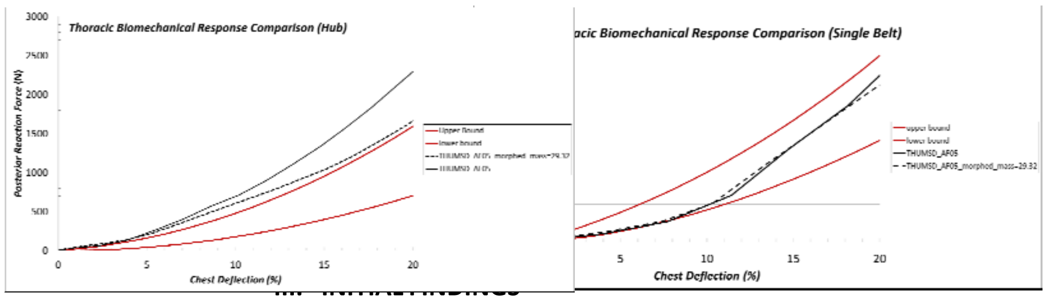
4. ***Model Validation and Influence of Thoracic Geometry***: The biomechanical response of THUMSD_F05 when simulated for single and double belt load cases gave a fairly good response, however, for hub loading it was outside the developed corridors. No CORA analysis was conducted in the current study. The model showed a stiffer response for the hub loading (out of corridors) and good response for single and double belt loading (in the corridors). These results contradicted in the manner that any modifications done for improving the hub loading response would essentially worsen the response of the other two load cases. This contradiction was an indicator that influence of geometry might change the biomechanical response as was established previously by [3]. The existing thorax of THUMSD_F05 was then morphed to the dimensions of PMHS 182. The morphing of the ribcage was conducted using the morph box tools available in the commercially available software ANSA. Morph boxes were created at different sections of the thorax as illustrated in Fig. 4. The sections were decided based on dimensional measurement locations illustrated in the CAESER report. The morph boxes were then modified in a way so that the overall profile of the modified ribcage was similar to that of the original one. The mass of the thorax was kept the same as the original model, which was approx. 30 kg. The original and the modified ribcages are illustrated in Fig. 3 below. These changes in thoracic geometry led to a less stiff response for the hub loading load case. This indicated that changes in geometry definitely effect biomechanical response. Fig. 5 below illustrates the curves for the hub and single belt load cases for the original and modified thoracic region.



Original Thoracic Geometry of THUMSD_F05 Modified Thoracic Geometry as per PMHS 182

Fig. 3: Original and modified thorax geometries

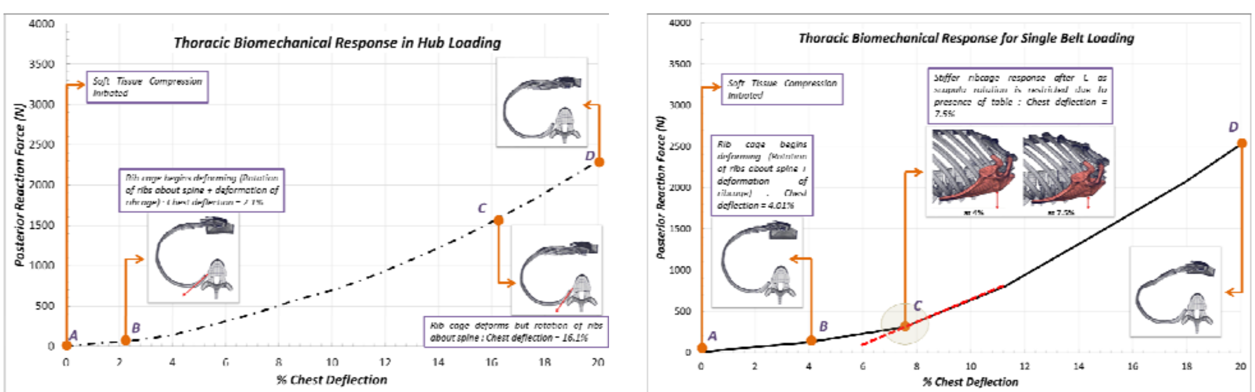
Fig. 4: Method of morphing the ribcage



III. INITIAL FINDINGS

The above numerical load case evaluation indicates that the response of the thoracic region varies between hub loading and belt as shown in Fig. 6. The main difference in the hub and belt load cases is the engagement with the clavicle. The motion of the clavicle and scapula drives the force-deflection response for belt loading because the clavicle starts to move on experiencing loads from seat belt. This leads to movement of the scapula and hence, initially the thorax gets pushed against the table until the time the complete thorax comes in contact with the table (at approx. 7.5 % chest deflection for single diagonal belt – Fig. 6(b)). This phenomenon does not occur in the case of hub loading. Therefore, single and double diagonal belt systems show a more stiff response once the scapula completely rests on the table.

Another effect which differs between the hub and seat belt is rotation of the ribs about the vertebrae. In case of hub loading from 2% chest deflection to 16% chest deflection, the ribcage deforms while the ribs rotate about the vertebra. This rotation of the ribs stops after 16% chest deflection and therefore, an increase in stiffness was observed in region C-D (Fig. 6(a)) compared to B-C. The above explained phenomenon observed in the simulations explicitly segregate the hub loading from belt loading conditions. It has also been mentioned in [1] that a difference in structures engaged by various loading conditions have an influence on the force-deflection response of the system.



(a) (b)

Fig. 6: Thoracic behavior of THUMSD_F05 in hub loading and single belt loading conditions

The geometric modifications conducted on THUMSD_F05 showed different behaviour in hub and belt (single and double diagonal) loading conditions. The change in geometry lowered the stiffness of the thoracic regions (Fig. 5) and was closer to the biomechanical corridors. However, for belt loading cases no significant improvement in thoracic stiffness was observed. This might be due to the differences in mechanisms of loading (discussed above).

IV. DISCUSSION

In the current research, an attempt to create biomechanical corridors for the thoracic region based on work done by [1] was done. These corridors show good coherence to the data generated in the experiments. Moreover, the influence of geometry on the response of the thoracic region was checked. The initial observations suggest that geometry does have an influence on biomechanical response, but, it is also dependent on load case. Further geometric shapes of the ribcage needs to be analysed for understanding different behaviour in the hub and belt loading conditions. The role of costal level on the response of rib cage has been addressed in [6], but, has also highlighted the importance of rib cage inclination.

V. REFERENCES

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