Application and CAE Simulation of Over Molded Short and Continuous Fiber Thermoplastic Composites: Part II

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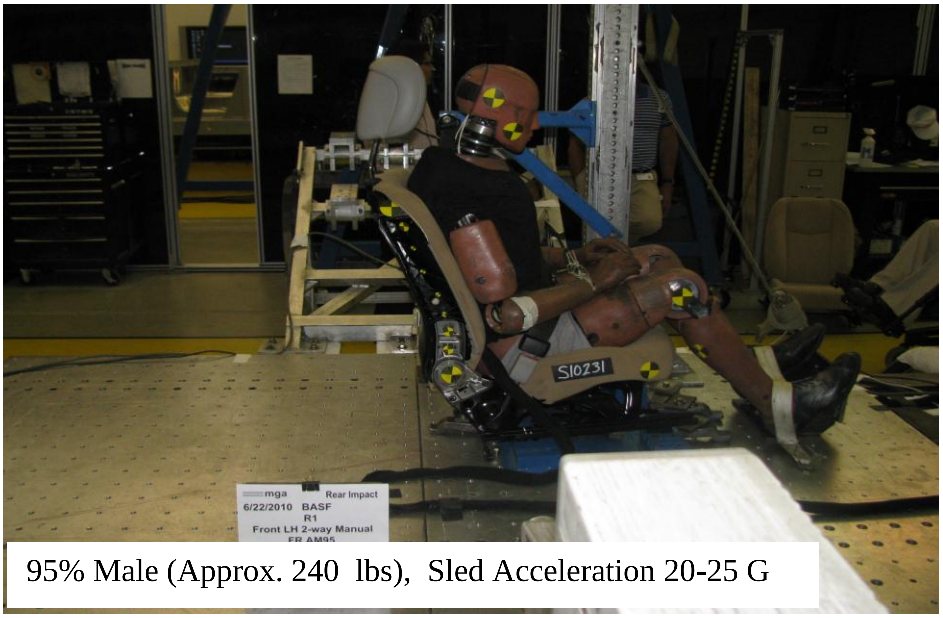
Abstract

Automotive seating back frames for front row are mostly constructed from high strength steel in order to meet very rigorous crash requirements. The main requirements are meeting the rear impact and luggage retention behavior as specified by the standards. In this paper, seating back frames constructed from over molded Short Fiber Reinforced Thermoplastics (SFRT) on Continuous Fiber Reinforced Thermoplastics (CFRT) inserts are described. One of the challenges is accurate CAE simulation of the static and dynamic behavior of such parts. CAE tools using LSDyna were developed to model accurately the rear crash and luggage retention behavior. Designs validated through CAE analyses were used to cut the tool and build prototype parts. Physical tests on Prototype parts confirmed good correlation between the tests and FEA. They met all the required criteria without requiring any design changes.

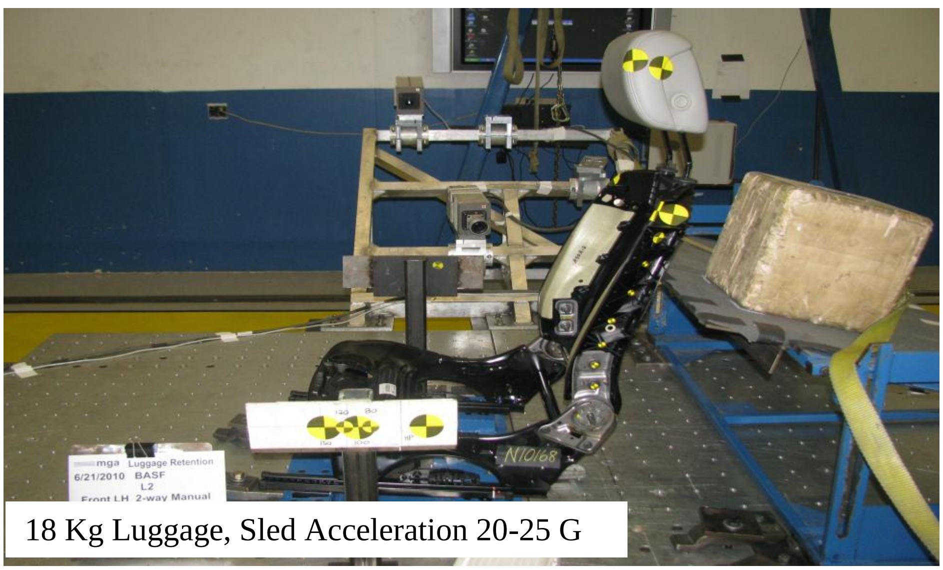
Introduction

In a previous paper [1], material modeling of short glass fiber reinforced thermoplastics (SFRT) and continuous glass fiber reinforced thermoplastics (CFRT) laminates were described. SFRT modeling uses an anisotropic material model based on fiber orientation and is an outcome of ULTRASIM® technology [2],[3]. This is implemented as a USER DEFINED MATERIAL LAW in LS-DYNA. For CFRT laminates, MAT_58 in LS-DYNA is used. The material models were verified through application to various parts in [1]. Automotive front row seating has been one of the more difficult applications to penetrate for plastics due to the stringent requirement of crash safety standards. Two of the critical safety standards to be met are rear impact test (FMVSS 301 [9], Figure 1), and Luggage retention test (ECE-R17 [10], Figure 2). Application of over molded SFRT on CFRT inserts to Automotive seating is described in this paper. It combines the directional stiffness & strength of CFRT layers with the flexibility and versatility of molding SFRT over it. Two examples with CAE analyses and testing are detailed here and they confirm the viability of such applications. CAE analyses with LS-DYNA has proved to be very valuable in the development process in terms of predictive capability and cutting down the number of prototypes for physical testing.



95% Male (Approx. 240 lbs), Sled Acceleration 20-25 G

Figure 1 Rear Impact Test Set Up (FMVSS301)



18 Kg Luggage, Sled Acceleration 20-25 G

Figure 2 Luggage Retention Test Set Up (ECE-R17)

Seatback Example I

One of the seat frames which were converted into a composite frame is shown in Figure 3. The composite equivalent of the seat frame is shown in Figures 4 & 5. The CFRT members provide stiffness & strength required to withstand a rear impact. The over molded

SFRT (polyamide 6) provides additional stiffness through ribbing and stability to the CFRT part. It also forms the frame for consolidation and incorporation of other features for holding the trim. The CFRT part is thermoformed from a layered kit and then placed in the injection molding tool. The polyamide 6 (SFRT) is over molded around the CFRT part in the tool. Extensive tests were conducted to assess the bonding strength between the CFRT and SFRT. The finite element analysis (FEA) model involved building a mid-plane shell model for each part separately. Material models as described in [1] are used. The two parts are coupled together by tied contact definition in LS-DYNA. Appropriate contact definitions are also defined for other contacting parts. After the initial design was established, a series of iterations, mainly FEA, were carried out to improve the design. This was mostly done on a component level basis. Some prototypes were also built to validate some of the CAE findings. Some buckling failures were identified and design was improved through reinforcements as shown in Figure 5. The prototype tool was modified to incorporate all the changes. The rear impact test was carried on the final part. Figure 6 shows the set up for the rear impact test for both the FEA and the physical test. Figure 7 shows the deflection of the seatback for the FEA and the physical test and the deformations are similar. Predicting initial failure and/or damage accurately in FEA was one of the main goals. Figure 8 shows excellent correlation of the local cracking of the boss in the physical test and the FEA. This is critical for developing parts without going through extensive and costly prototyping phase.

Figure 3 Front Row Seatback Frame made of Steel

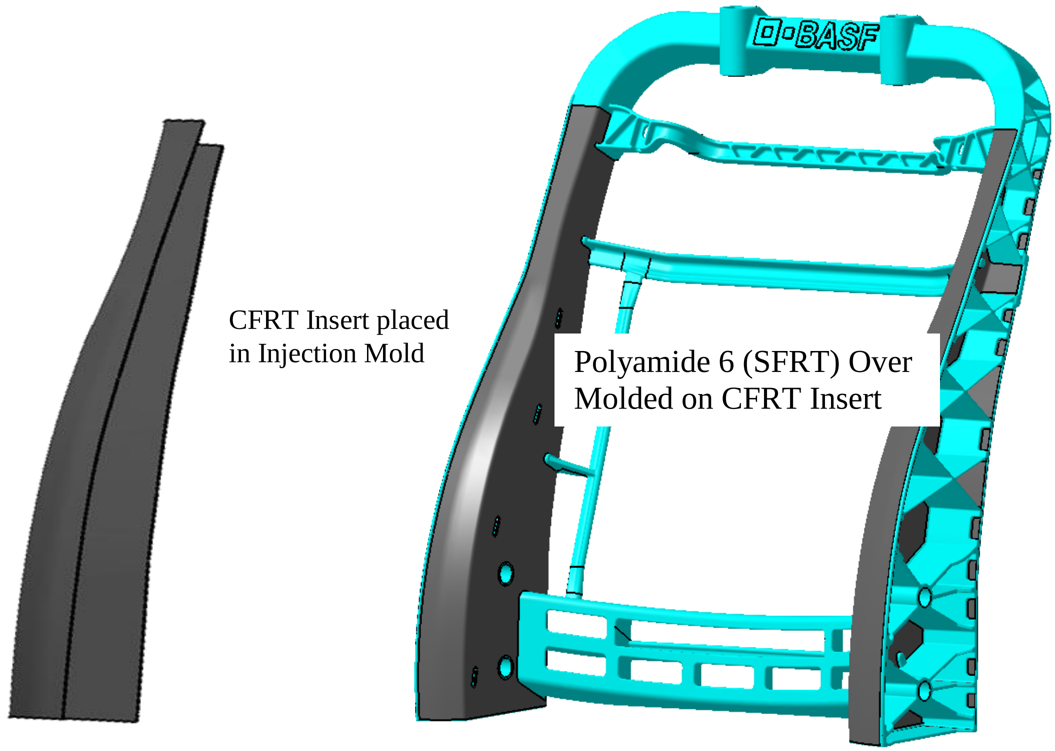


Figure 4 CFRT Insert and Composite Seatback

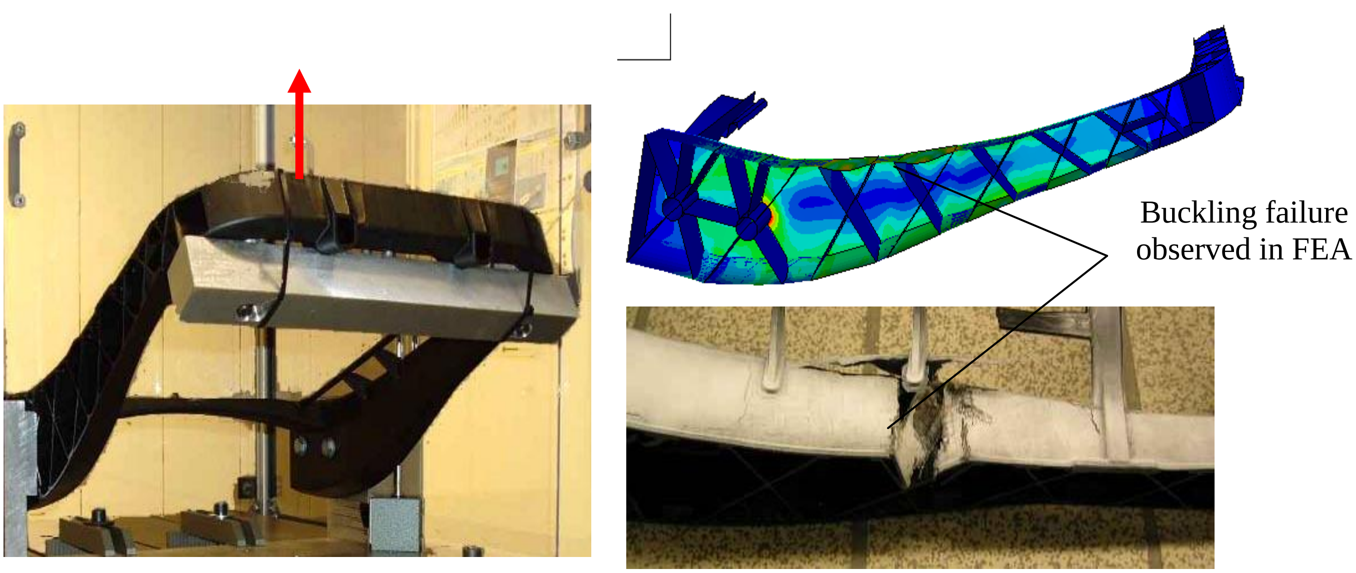


Figure 5 CAE Simulation and Component Level Testing to Identify Weak Locations

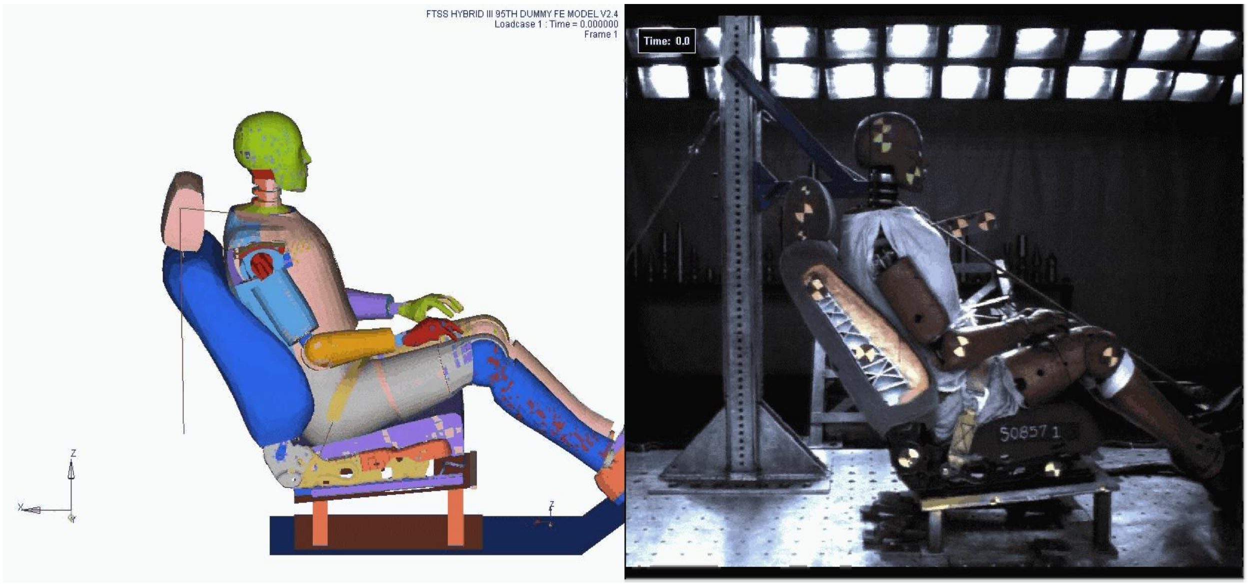


Figure 6 CAE and Test Set Up for Rear Impact Test

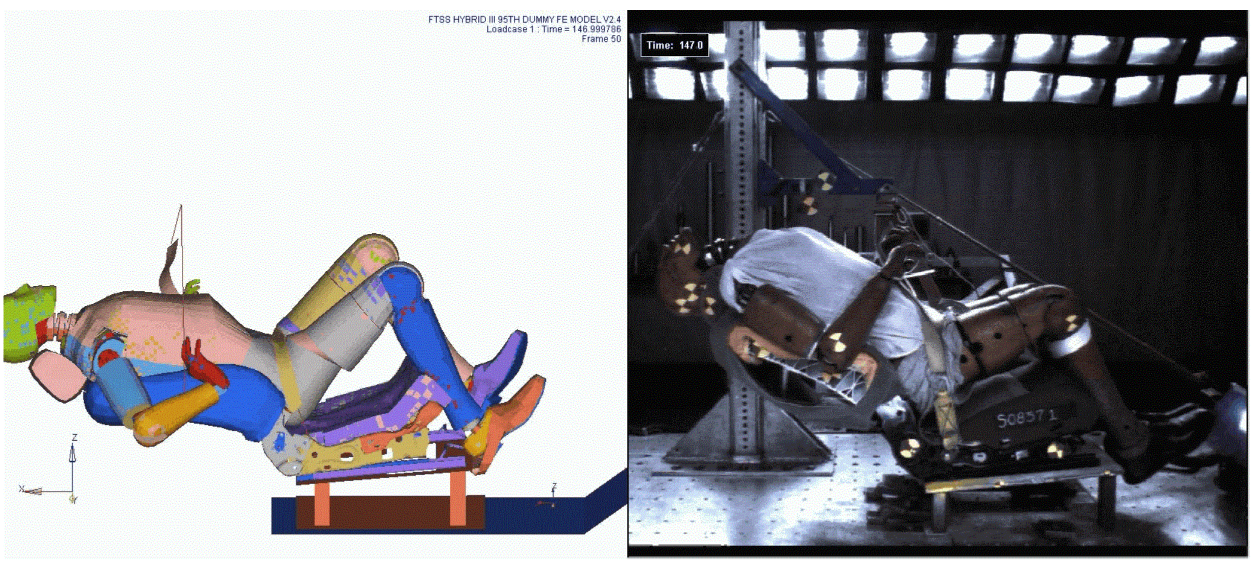


Figure 7 Seatback Deflection from Test and FEA

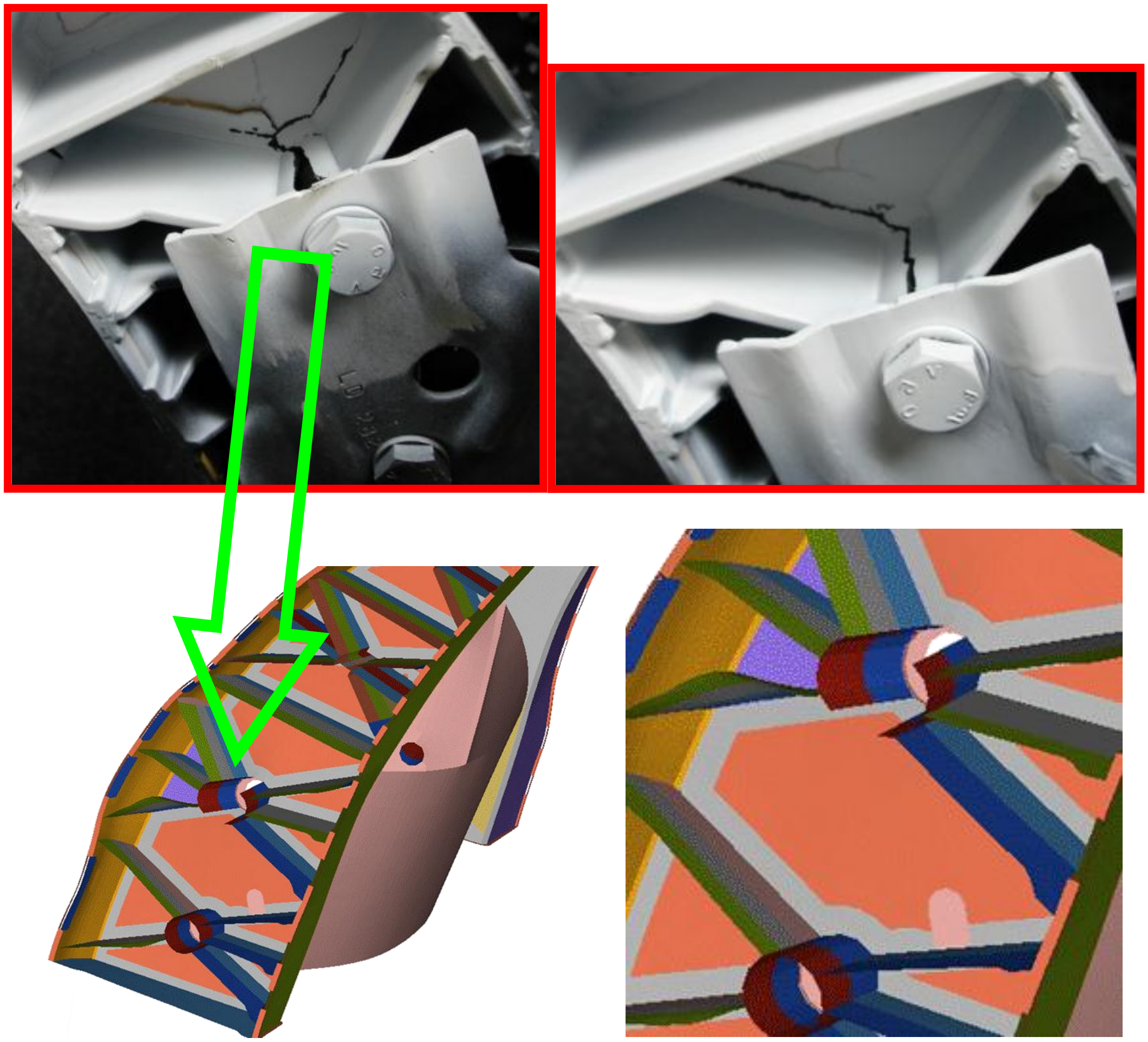


Figure 8 Comparison of CAE Simulation and Testing

Seatback Example II

Another seatback was considered as shown in Figure 9. This seatback was designed as a substitute for an existing steel design. Based on the learning from the previous example, this was designed to withstand both rear impact test and the luggage retention test. The two side members are reinforced with CFRT inserts. The rest of the part is over molded with SFRT (Glass Filled Polyamide 6). Steel brackets are also included in the design in order to attach to the recliner. A moldflow analysis was conducted to optimize the gating conditions and to generate the fiber orientation information. This information was used to generate the

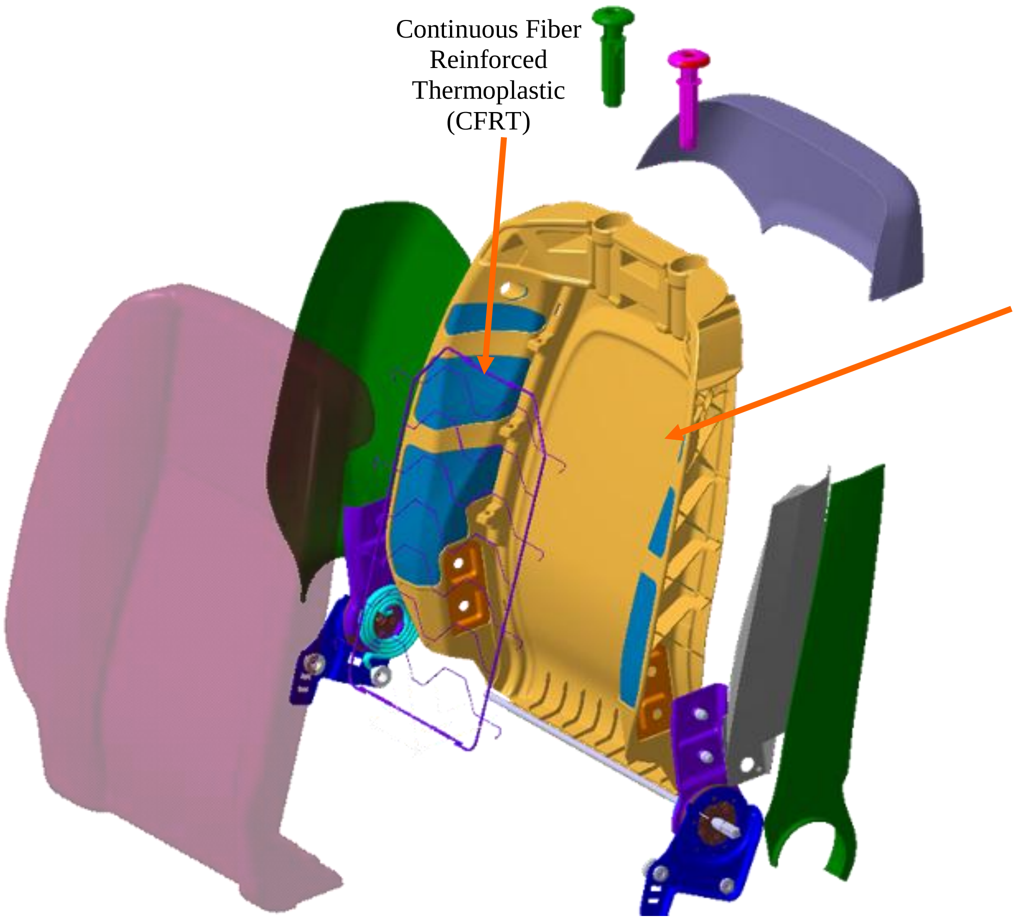


Figure 9 Comparison of CAE Simulation and Prototype Testing

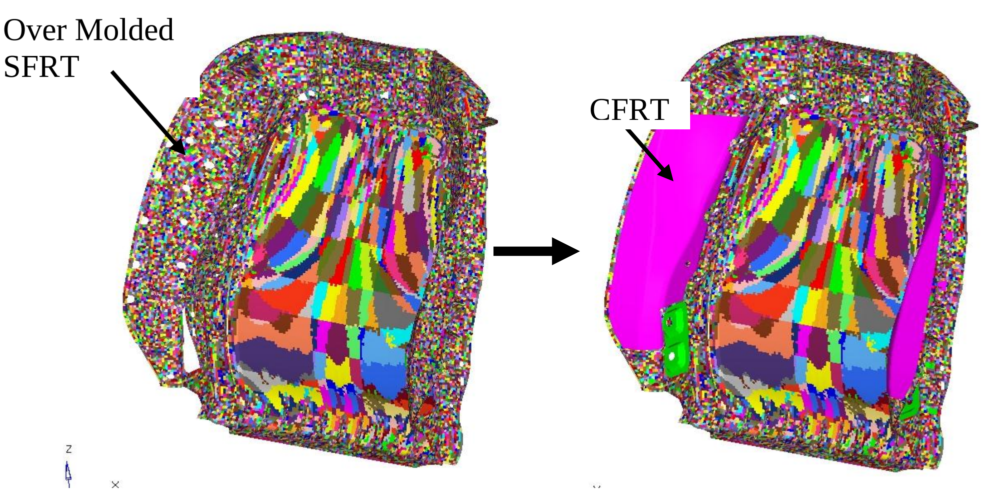


Figure 10 FEA Model of Seatback

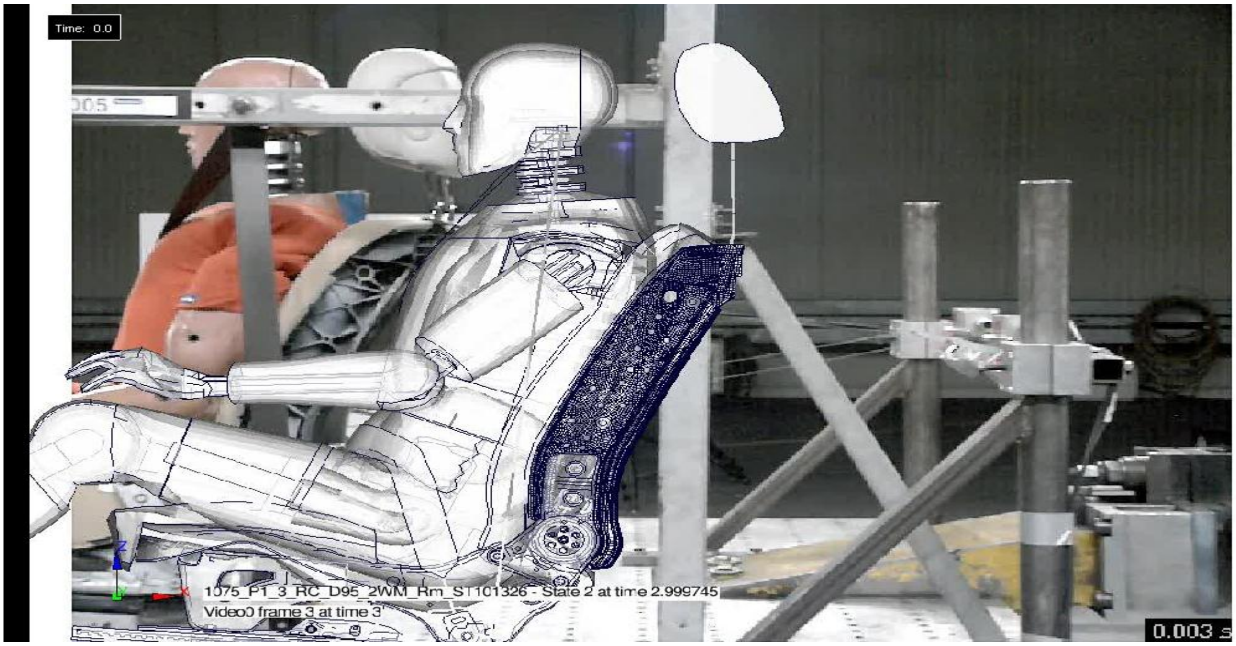


Figure 11 Rear Impact Test Set Up, Overlayed with FEA Model

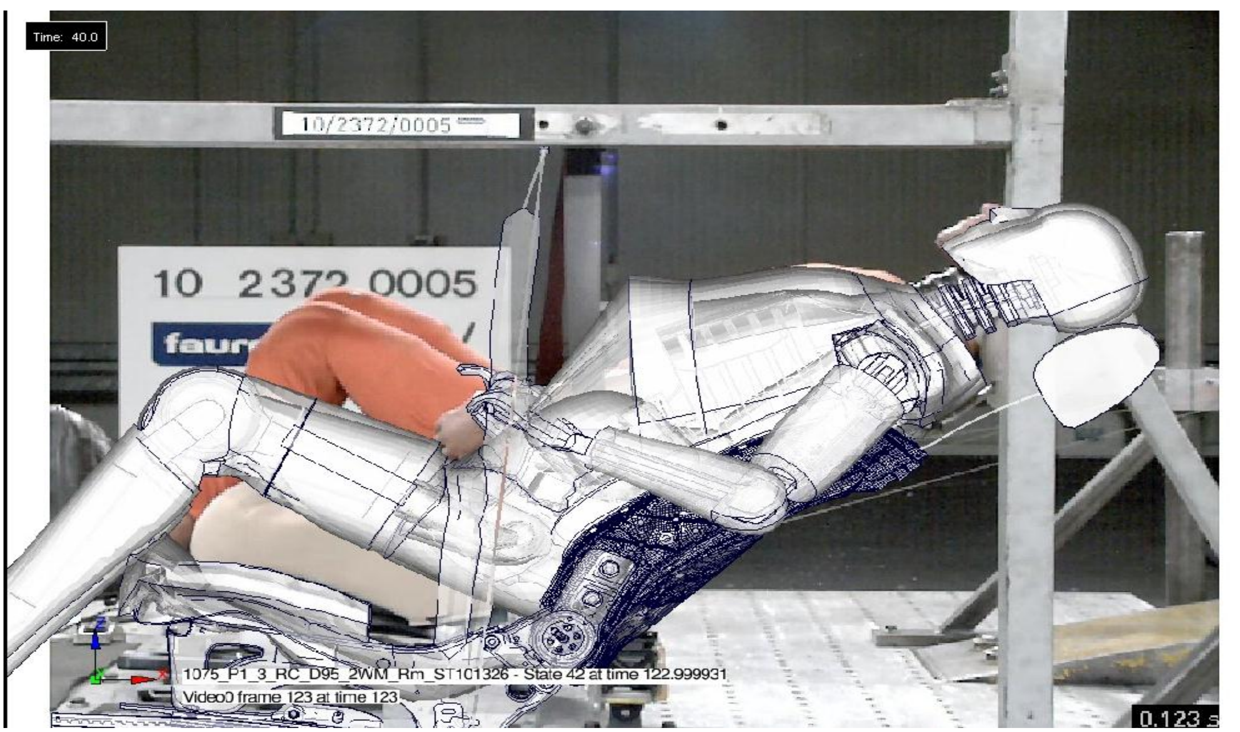


Figure 12 Overlay of FEA and Test for Rear Impact Test

Table I Dynamic Deflection Comparison

Dynamic Deflection	Test	FEA
Door	36^0	31^0
Tunnel	33^0	31^0

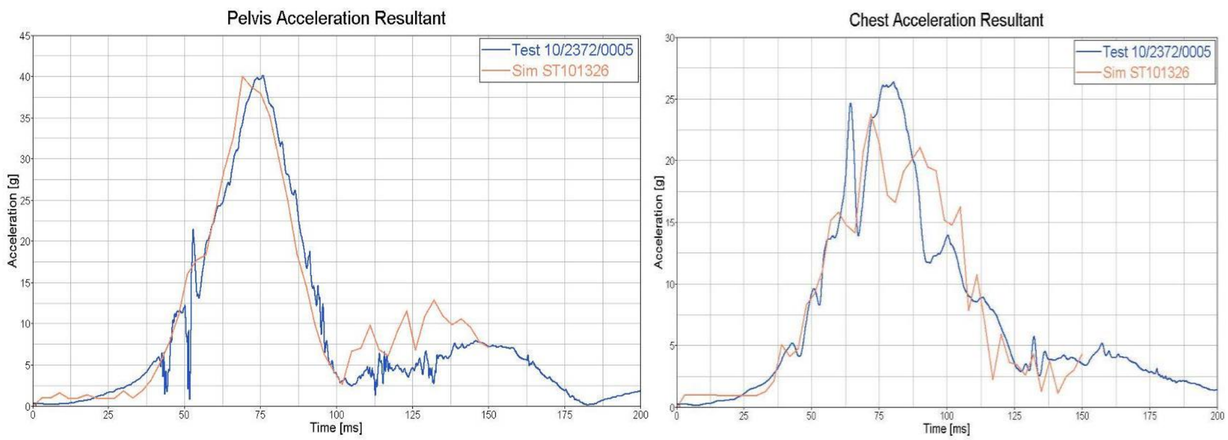


Figure 13 Comparison of Pelvis and Chest Acceleration from Test and FEA

anisotropic material model for the SFRT (Figure 10). It also shows the inclusion of the CFRT insert and the steel bracket in the model. Tied contact definition is used to couple the CFRT and the SFRT. The seatback frame is set up with the rest of the model for rear impact simulation (Figure 11). Figure 12 overlays the CAE simulation and the test and shows very good correlation. The dynamic deflection comparison is given in Table I. The correlation of the pelvis and chest acceleration is also very good and is given in Figure 13. The luggage retention test was also performed on the seatback. Figures 14-15 show the comparison of the CAE and the test result and they compare quite well. The main goal of the FEA was to identify any weak locations and improve the design before any prototype tool was cut. Some of this was achieved through component level simulations. Only after satisfactory results were obtained in the FEA for the rear impact and the luggage retention simulations, a prototype tool was cut. The seat back frames passed both the rear impact test and the luggage retention test in the first attempt without requiring any tool changes. This reinforces the value of the FEA tools to design and develop composite seatback frames to a point where costly prototype parts are minimized or eliminated.

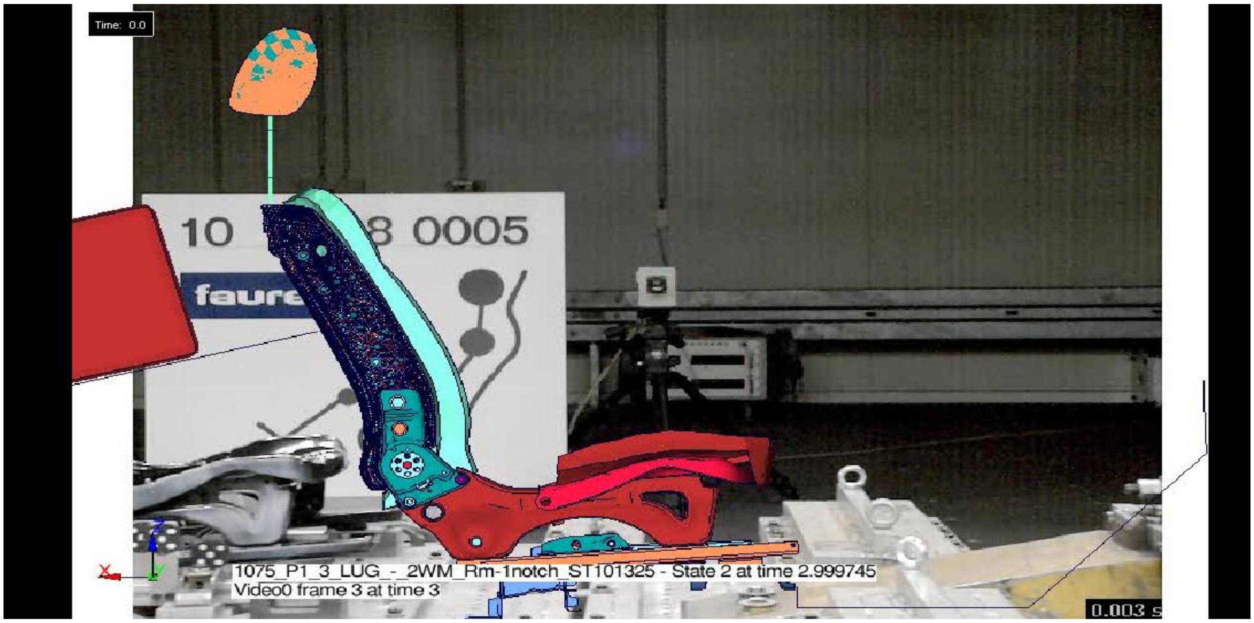


Figure 14 Luggage Retention Test

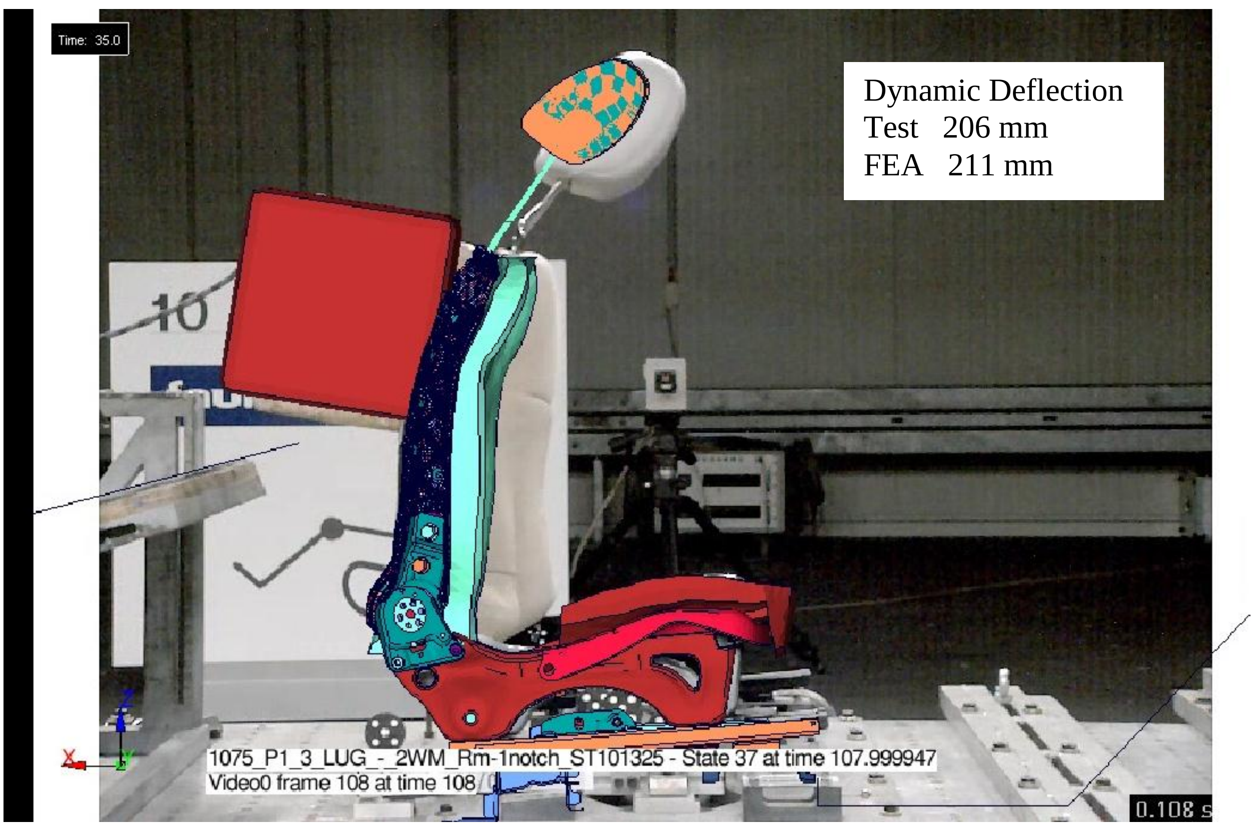


Figure 15 Overlay of CAE and Test, Luggage Retention

Conclusions

Two example seatback frames of over molded SFRT on CFRT inserts were designed and developed using FEA tools specifically developed for modeling such parts. The high degree of correlation between the test and FEA data highlights the value of the CAE tools for composite seatback development.

References

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[9] Department of Transportation, National Highway Traffic Safety Administration, "Federal Motor Vehicle Safety Standards; 571.301 Standard No. 301; Fuel System Integrity", 49 CFR 571.301

[10] ECE-R17 UNECE Agreement Concerning Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Uniform Provisions Concerning the Approval of Vehicles with regard to the Seats, their Anchorages and any Head Restraints