TECHNICAL DOCUMENT

AUTOMOTIVE SEAT DESIGN EXPLORATION IN THE CLOUD

The benefit of design exploration and optimization is understood and accepted by engineers, but the necessary computational resources and software licenses and the tremendous amount of data created by a design exploration/optimization process has always been a challenge. The Altair Unlimited™ cloud appliance addresses some of these challenges. The aim of this study is to showcase the benefits of Altair Unlimited for optimization-driven design of a complex system and how the associated simulation process and data management challenges are addressed. For this purpose, an automotive seat design for crash load cases has been selected.

Challenges in Seat Design for Crash

Automotive seat manufacturers are required to verify that their seat designs meet crash and safety regulations for their specific market. They need to consider many different loading conditions, two of which are cargo retention and rear impact scenarios. In the cargo retention case, the seatback is impacted by a moving cargo block during a crash event and the seat must protect the occupant from the cargo. The requirement in this case is that the seatback frame does not displace beyond a particular reference plane. In the rear impact case, the occupant loads the seatback frame and seatback frame displacement must be limited in order to retain the occupant.

Automotive seats are typically made of many metallic parts, all of which need to be sized appropriately to meet regulations while not exceeding weight targets. The interactions between these parts for weight and structural performance during a crash form a complex system, so it is challenging to find an optimal design with a traditional trial-and-error process, either analytically or using physical prototypes.

In this paper, we are proposing an optimization-driven design process using FEM. The models are created using Altair HyperMesh™, a high-performance finite element pre-processor. They are then simulated with Altair Radioss™, a structural analysis solver for highly non-linear problems under dynamic loadings. The optimization-driven design process is conducted using Altair HyperStudy™, a multidisciplinary design exploration, study, and optimization solution. An optimization-driven design process allows the engineer to automate the simulation process and easily create intelligent variations of the design. This enables fast discovery of the physics of the application, but the process is not free of challenges, including intense requirements for computational resources to run the simulations, integration with high-performance computing (HPC) components, and associated data management challenges.

In this optimization-driven design process, a large number of simulations will be created. Since crash problems are non-linear and time-dependent simulations, they require long run times and create a large amount of data. As a result, it is impractical to run these on one's personal computer (PC) and hence they are often run on a compute cluster with sufficient computational resources. However, when running on a compute cluster, the setup of a study can be difficult and time-consuming. In addition, job submission and management through a queuing system, file transfer, and viewing results can be cumbersome to manage.

ALTAIR

To overcome these computational and data management challenges, we conducted the seat design studies using Altair Unlimited, a private cloud solution for computer-aided engineering (CAE), with fully configured (HPC hardware and software, offering unlimited use of all Altair HyperWorks™ engineering applications. In the Altair Unlimited cloud appliance, the web-based Altair Display Manager portal is used for remote visualization running the HyperStudy design exploration tool with strong workload manager (Compute Manager and Altair® PBS Professional®) integration for HPC job submission. Key performance data required for optimization and design exploration is extracted by HyperStudy running remotely, and non-essential data is deleted. Key performance indices to provide traceability of simulations to data sources and compare simulation results via dashboards is managed by an SDM web application (Simulation Manager). All the necessary tools are brought together in a single package with Altair Unlimited, and using this process the entire study is set up and run remotely, leaving the user to free up their local PC for other tasks without interrupting the optimization study running remotely on a private cloud.

Model Definition

The seat model was created using HyperMesh. Two models are created, one for each load case. The FEM model size is approximately 100K nodes for the seat structure and associated components. The cargo retention load case includes an 18kg cargo block, which is a cube with 300mm sides. The cargo block is positioned 200mm from the seatback and a rearward sled pulse is applied to the floor. The resulting motion causes the cargo block to impact the seat. The rear impact load case includes a finite element model of the Hybrid III 50th percentile dummy. The dummy is positioned at the seat H-point, the seatbelt is wrapped, and the seatback and cushion foam are deformed to match the dummy profile. A forward sled pulse is applied to the floor, which causes the dummy to load the seatback.

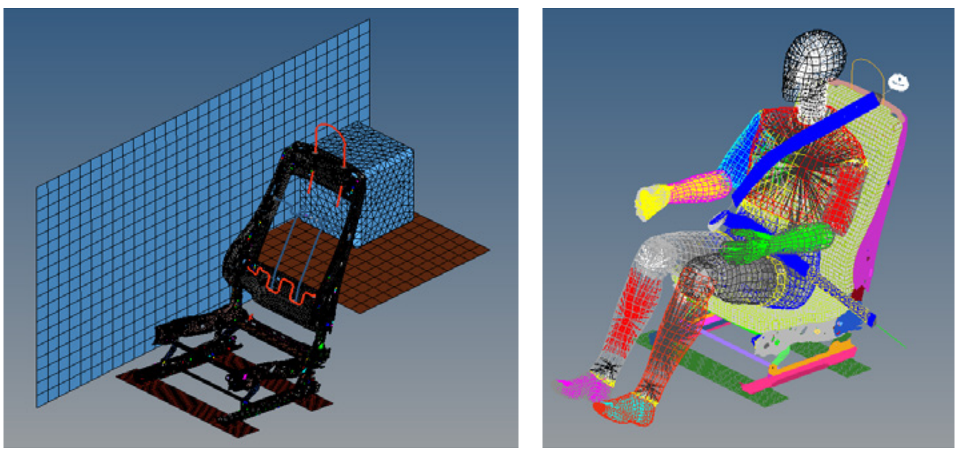
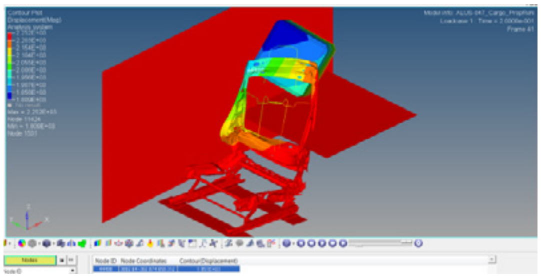


Figure 1: Seat Finite Element Models for Cargo Retention and Rear Impact Loadcases.

Radioss version 13.0 is used for the simulations. Each simulation takes approximately one hour on the Altair Unlimited machine using 48 compute cores. Each simulation run produces 1GB of data.

Problem Formulation

Out of several shell parts that make up the model, those that are potentially critical for mass and crash performance for both load cases are identified. Thicknesses of these 17 components are used as design variables. Lower and upper bounds of the variables are assumed to be ±5% of the initial design values. Two load cases are considered in this study: cargo retention and rear impact. In the cargo retention case, the seatback is impacted by a moving cargo block during a crash event and the seat must protect the occupant from the cargo. The requirement in this case is that the seatback frame does not displace beyond a particular reference plane. A response is defined for this measurement with an initial value of 322.40 mm.



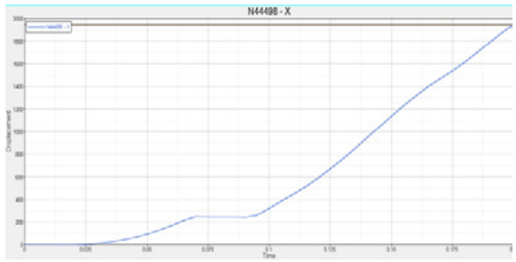


Figure 2: Cargo Retention Loadcase Response

In the rear impact case, the occupant loads the seatback frame and seatback frame displacement is required to be limited in order to retain the occupant. A response is defined for this measurement with an initial value of 186.97 mm. Finally, the mass of the 17 components that are hanging is defined as a response. The initial value of this response is 0.006 ton.

Study Setup in Altair Unlimited

There are several ways of conducting optimization studies for computationally demanding simulations. Admittedly, none are easy and they all come with their own drawbacks. Traditionally, users would set up the study session on their PC and submit jobs to the compute cluster. This requires special scripts for file transfer and job submission. These scripts depend on the compute cluster operating system, company regulations, and any job submission program, and they will often generate large amounts of data going back and forth between the user's PC and the compute cluster. The setup usually takes several iterations to get everything running correctly. Once setup is complete, the user's PC will be busy with the study for several days. If it is a laptop, the user cannot simply close and transport it freely. In some cases, the input and output file transfer between the compute cluster and the PC may add significant overhead to the study. In addition, the user's PC will be storing several gigabytes of data, which is not practical. Finally, capturing and embedding the relevant information from these studies to be used in the design process is cumbersome. A large amount of data is created during design exploration, but only a small part of it is relevant for the entire design process as only a few scalar metrics are required from the huge simulation results. Data from design exploration is typically not in a format that design engineers can easily use, so it needs to be converted to useful formats for visualization (e.g., which parts have changed and by how much).

Another option is to set up these studies in the compute cluster itself. However, most compute clusters do not have a graphic node, so interactive applications like HyperStudy cannot be run remotely. The drawback of this is that the user cannot review the process as it is running and it is often hard to debug batch processes that in turn call other batch solvers running via an HPC queuing system.

Altair Unlimited includes not only unlimited HyperWorks licenses but also a platform that enables engineers to easily set up design exploration and optimization studies in the cloud. This platform includes Display Manager, where the studies are set up and reviewed, Compute Manager, where the jobs are monitored, PBS Professional for HPC workload management, and Simulation Manager for automatic capturing and embedding of design exploration results for effective usage and sharing in the design process.

In this process, the user simply logs in to Display Manager via a web browser. Here one can use HyperStudy just like they would use it in their local PC environment. For the simulations, the user needs to submit the jobs to Compute Manager so they can be orchestrated by an HPC workload manager that ensures compliance with company regulations. Once the study is complete, an archive file is created by HyperStudy. The archive is a small zipped file that includes only the essential elements of a study without large data files. Due to its small size, the archive is easy to transport and store. Simulation Manager then imports this archive file and develops charts and graphs to convey the essence of the study via dashboards for future traceability and knowledge capture.

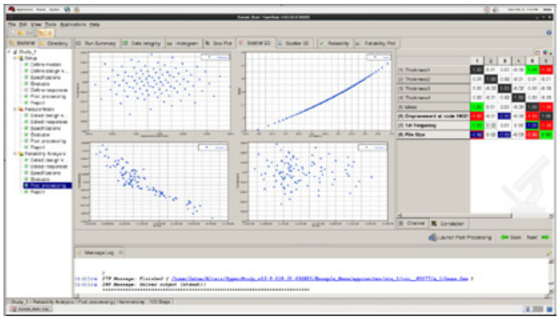


Figure 3a: Process Automation and Design Exploration Data in HyperStudy

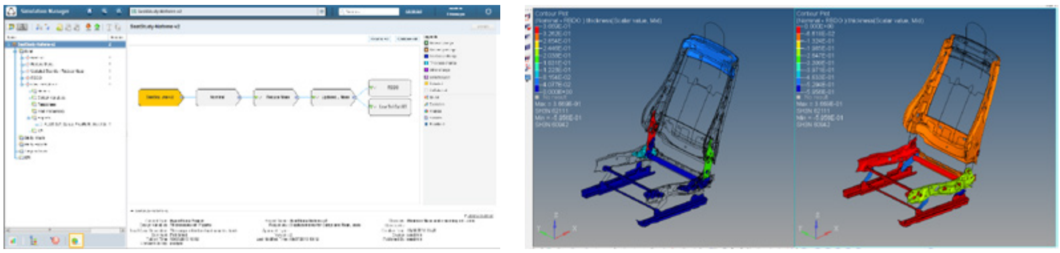


Figure 3b: Process and Data Management in Simulation Manager

Design Exploration and Optimization Studies

Reducing Mass while maintaining performance

The objective of this optimization study is to reduce seat mass while maintaining structural performance. To meet this objective the problem is formulated as:

- Minimize seat mass
- Such that: cargo response < 392.42 mm
- Rear impact response < 186.97 mm

HyperStudy's Global Response Surface Method (GRSM) is used for this study. GRSM is an efficient and effective global search method that requires minimal user settings. Using the multi-execute option in HyperStudy, both the load cases can be run concurrently, which reduces the runtime of a design simulation to one hour.

The optimal design response values for the 50-run optimization study are:

- Mass = 0.0056 (6.7% reduction),
- Cargo Displacement = 394.25 (feasible),
- Rear Impact Displacement =173.81(feasible)

It is concluded that the optimization study has converged within the time allowed. Note that the initial design was a mature seat design and any further mass reduction was satisfactory.

Increasing Reliability while Minimizing Weight

Reliability analysis investigates the probability of a design meeting requirements, given design variations due to many factors such as manufacturing, operating environments, and modeling assumptions. In this study, we are only concerned with manufacturing variations in part thicknesses.

For this study, a ±0.05 mm manufacturing variation for thicknesses is assumed. It is also assumed that these variations follow a normal distribution. Using these probabilistic properties for the 17 design variables, a sampling-based reliability analysis is run. In sampling-based reliability analysis, a number of runs are executed and the reliability is calculated as the percent of success among these runs. The Hammersley sampling method is used for this purpose and the number of runs is set to 200.

From this study, the reliability of cargo performance is most critical, as it was only 15.50%. Based on the low reliability, reliability-based design optimization to find the minimum-mass design that has at least 90% design reliability is run. Sequential optimization and reliability analysis (SORA) is used for this purpose. This approach took 404 simulations to converge to 90% reliability. Mass increase was negligible.

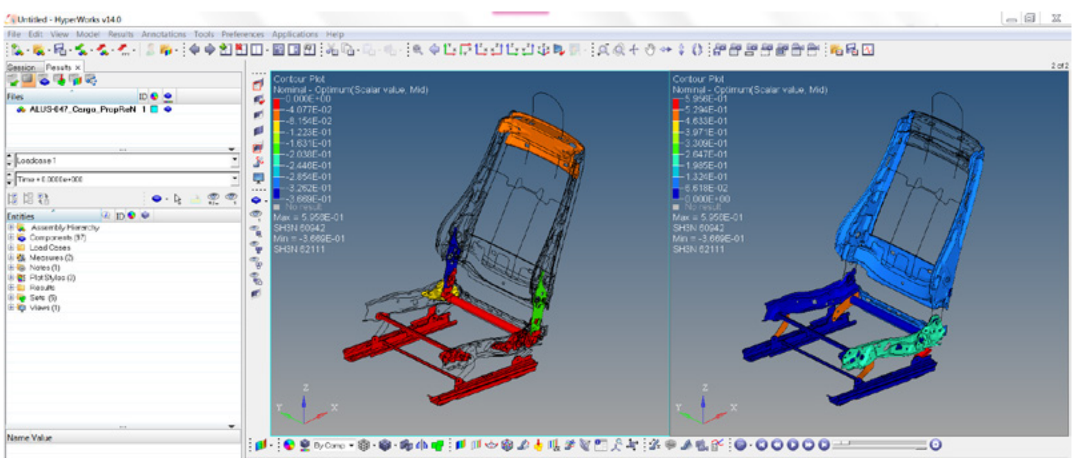
Simulation and Data Management

Simulation and data management take place in two levels in this study. The first takes place on the user level and the next on the project level. The user in this case is an engineer who does design exploration.

The first step in design exploration is process automation, which involves three main steps: design parametrization, solver execution, and result extraction. HyperStudy helps the user perform these three steps. Once they are complete, users can proceed to design exploration and optimization. During design exploration a large amount of data is generated but only a very small portion of it is used. This small portion is what gets extracted by HyperStudy. As a result, the user avoids dealing with large numbers of files. Once design exploration is complete, an archive file that captures the essentials of the study is created. This file is small compared to the entire design exploration runs and hence easy to transport and store. Once imported back to HyperStudy, this data displays everything that was studied and has all the necessary inputs for conducting future studies.

On the project level, Simulation Manager has the HyperStudy archive embedded in the design exploration step of a much larger design process. This is implemented such that none of the raw data from HyperStudy is visible unless required. Instead users can choose designs that are proposed by HyperStudy and see only what parts changed and by how much. Simulation Manager has metadata search, access control, and file tagging capabilities that allow easy management of these files for future reuse and sharing among multiple stakeholders who might not be experts in design exploration and optimization.

Figure 4: Automatically created visualization of optimal parts



that are thinner and thicker than the baseline design

Conclusions

In this paper, an optimization-driven design process is applied to an automotive seat to reduce seat mass while maintaining current performance for the cargo retention and rear impact load cases. A finite element model for the seat is created using HyperMesh and simulated using Radioss. Optimization and reliability studies are conducted using HyperStudy. The entire study is performed in a private cloud via Altair Unlimited. In Altair Unlimited, Display Manager for remote visualization, Compute Manager for job submission, and Simulation Manager for data and process management is used.

The mass of the seat is reduced by 6.7%. This reduction leads to significant savings in an already mature design. The driving load case in this redesign work is the cargo load case. Following this, a reliability-based design optimization is run to increase reliability levels to the required 90%.

Optimization-driven design and stochastic studies are not new to the automotive industry. Their importance is well understood but they can be challenging to implement due to intensive computational requirements and the difficulty of setting up large design exploration studies on a compute cluster, plus challenges associated with large data movement. Altair Unlimited brings all the necessary tools together in the cloud and allows users to perform such studies efficiently and manage the complete simulation lifecycle as part of the process for future traceability and archiving.

Working with Altair

Altair's broad portfolio of solutions and flexible licensing system provide multidisciplinary engineering teams with a suite of complementary software for efficient simulation-driven design exploration and optimization. The comprehensive suite includes robust solvers plus pre- and post-processing tools for efficient project development and smart data management during the global exploration process. Users gain access to the scalable computational resources required by complex, optimization-driven design processes.

Altair is a global technology company that provides software and cloud solutions in the areas of simulation, HPC, and artificial intelligence. Altair enables organizations across broad industry segments to compete more effectively in a connected world while creating a more sustainable future.

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