

USING INTEGRATED SIMULATION TO OPTIMIZE HEAVY EQUIPMENT DESIGN

Heavy equipment manufacturers want to design products that are durable and perform at their peak under a variety of conditions. To accomplish this, Altair provides an integrated multi-disciplinary simulation environment to virtually test and optimize equipment performance and therefore, help reduce design and development costs. Using simulation-driven design, studying the full dynamics of a product or system is possible, from motion analysis to complete lifecycle durability testing.



Overview

Construction equipment like excavators, for example, operate in diverse, harsh work environments and constantly undergo extreme loads during a typical workday. These machines cater to multiple applications with use cases such as digging, trenching, loading, lifting, breaking, and ripping.

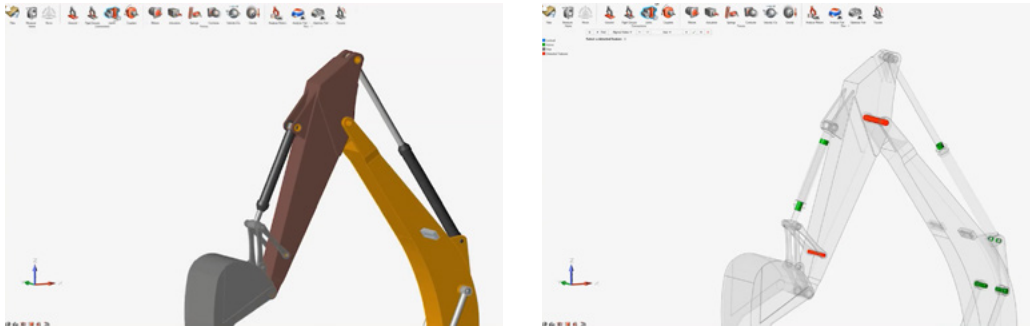
With heavy equipment often being subjected to unplanned forces and loads, it's a challenge for designers to create them with all possible load conditions in mind using only physical test data. With integrated simulation technology, designers and analysts can work together to produce more reliable designs and move away from the traditional 'trial-and-error' design approach, reducing development iterations by embedding known certification requirements upfront in the analysis or optimization loop.

This document will demonstrate a full user-level workflow on a mid-sized hydraulic excavator. [Advanced simulation features](#) allow heavy equipment manufacturers to extract realistic loading conditions to perform accurate structural analysis, durability and fatigue life prediction, and kinematic and structural optimization on machines of any size that endure various load and environmental conditions.

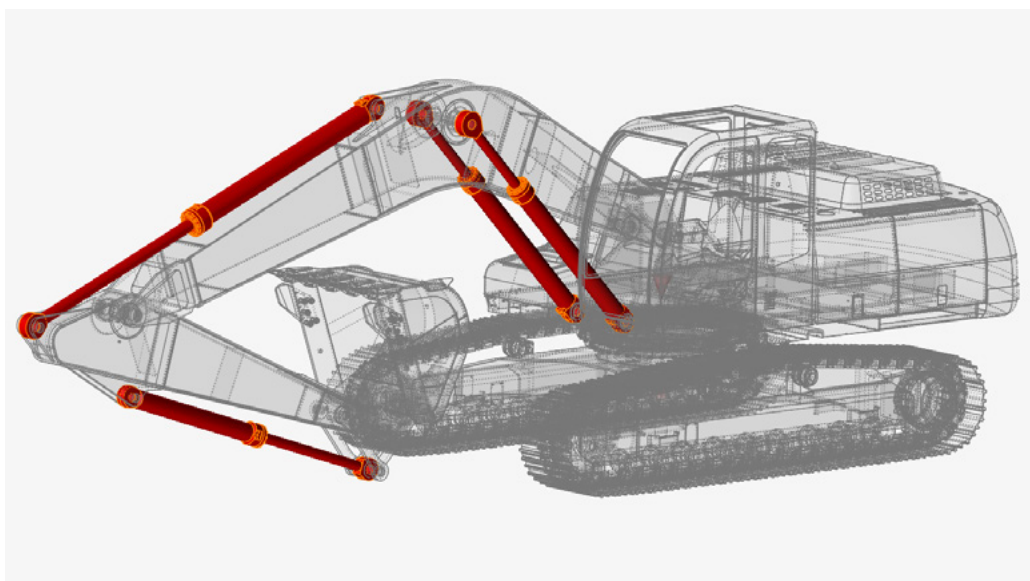
Extracting Realistic Loads to Perform Detailed Analysis

Whether it is a structural analysis, durability, fatigue, or light weighting analysis being performed, accurate loads are the key to receiving the most realistic simulation results. [Altair® Inspire™](#) enables intuitive multi-body set-ups so that complete multiphysics and analysis workflows can be completed to predict model loads. In the tool, users can define key points, such as joints and actuators, on virtual models to prepare for different types of analysis that are required for extracting realistic load results. In this step, basic motion assignments were made to validate the initial set-up and kinematics of the excavator arm.

Once a model is created in Inspire and all necessary connections are defined, kinematic models can be created to study motion profiles using Altair's reliable solver power. As a way of significantly reducing expensive prototype-builds and physical testing, [Altair® MotionSolve®](#) is cost-effective and an essential part of Altair's suite of multiphysics CAE tools available via Altair's patented units-based licensing.



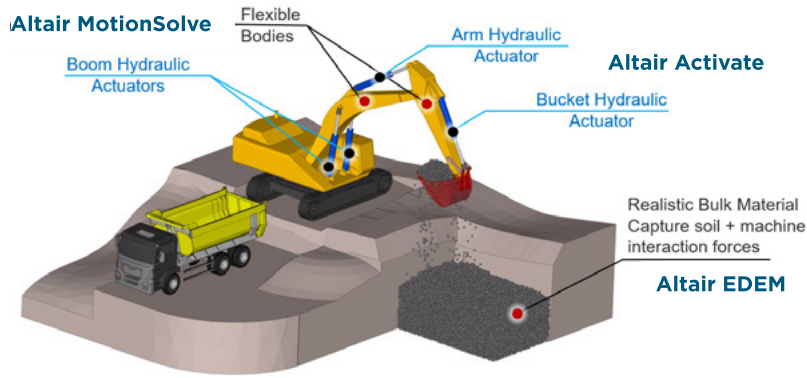
Setting up the design space and motion profiles in Inspire for complete motion simulation.



In Inspire Motion, actuators were added at each piston/cylinder pair on the arm.

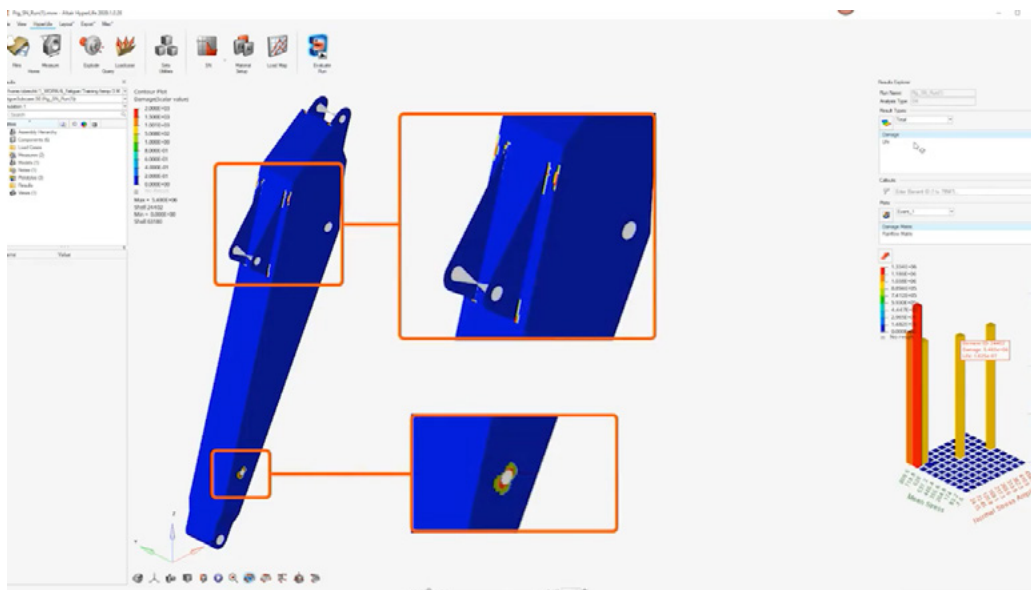
In combination with the previous motion and load results, [Altair® Activate®](#) is an open integration platform that allows users to simulate all of these 1D and 3D analyses (motion, structural, hydraulics, soil/terrain) together in one unified platform. The excavator model was actuated with motion constraints applied on each of the boom, arm, and bucket cylinders, as well as swing of the hood-cab. These motion constraints served as a baseline to verify the actuation of the hydraulics model. Once the Activate model was built, the excavator's hydraulic performance was tested and verified against pre-determined performance parameters. Activate offers the ability to connect to other tools within Altair's simulation platform, making it simple to tune system motion and parameters to reach desired full system performance.

Coupled with [Altair® EDEM™](#), Altair's discrete element method software, 3D representations of machine-material interactions can be closely observed for bulk and granular material. EDEM provides engineers with crucial insight into how soils, rocks, and ores will interact with equipment during a range of operation and process conditions. It enables engineers to get realistic material loads in finite element analysis and multi-body dynamics simulations for optimal designs.



Predicting Durability and Fatigue Life of Heavy Equipment

After importing CAD geometry into Inspire and determining realistic loads for the model, real life durability and fatigue predictions can be made to understand the potential lifecycle of your product or equipment.



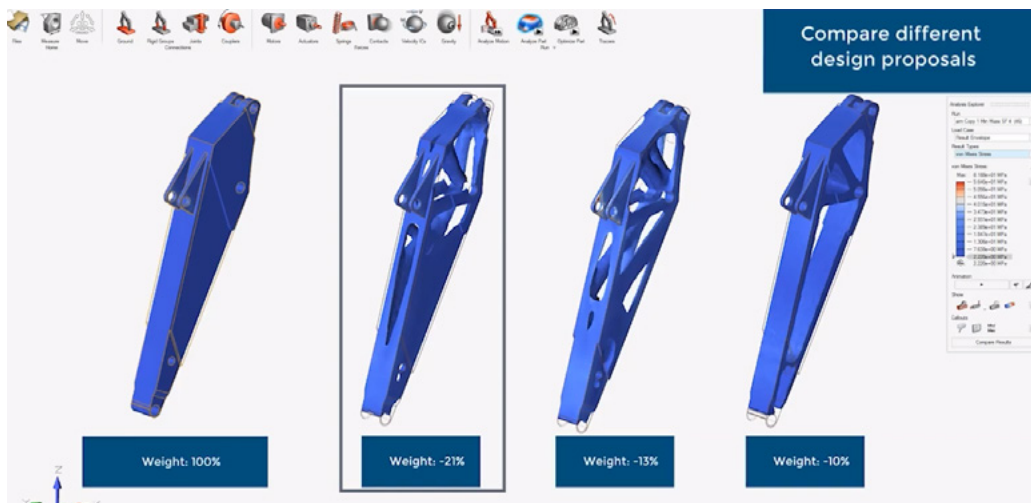
Main stresses found in excavator arm.

For this example, the hydraulics of the excavator arm, the impact of loads, and the interaction between the equipment and soil had to be observed together to fully understand the durability of the excavator. In a truck loading scenario, the excavator performed a motion of extending its arm to scoop sand from an EDEM-generated soil bed, and then turn to load material into a truck trailer. This co-simulation yielded important results about which areas of the excavator were experiencing the most stress during the truck loading motion. Using [Altair HyperLife™](#), fatigue life and durability of equipment can be predicted under a number of repetitive loadings experienced in the heavy equipment industry. Rather than relying on physical test data alone, analysts can compare baseline physical test data found during a typical truck loading operation against the virtual results found in simulation. Based on co-simulation results, fatigue-damaged locations on the excavator arm were found, mostly at weld lines and bolt holes.

Using Structural Optimization to Ensure Performance Using Less Material

With accurate loads, users can also perform structural optimization to ensure peak performance while using less material. With modern material optimization techniques, it's possible to create heavy equipment designs that may not mimic the traditional look of equipment normally seen in the construction and heavy equipment sector, although all typical manufacturing constraints can be used to limit proposals to achievable designs. With topology optimization, producing

natural, organic shapes that meet strength and stiffness objectives while using minimal material is possible. In this simulation, Inspire was used to compare different shapes and optimization design proposals with varying weight objectives for the excavator arm.



Compare different optimization design proposals with Inspire.



Explore organic shapes using topology optimization techniques.

[Watch this presentation for more information.](#)

Working with Altair

Dynamic heavy equipment requires a greater project scale due to the heavy loads and extreme environments the machines endure. Altair's simulation-driven design tools enable off-highway equipment manufacturers to make informed, reliable product design decisions faster and within project timelines while keeping overall development costs at a minimum. Simulation tools allow for rapid investigation and analysis of product performance, factoring in fatigue and impact loads, and offering countermeasures for product improvement.

Using a complete multiphysics approach, coupled with non-linear and motion analysis makes it easier to confidently reject low-potential designs earlier in development cycles. Designers can rapidly create 1D models through the [Altair® Activate®](#) tool to study overall product behavior before performing more detailed analysis on the model. Then using [Altair® MotionSolve®](#), multi-body simulation enables modeling the dynamic response of mechanisms including the integration of its control system. Adding the insights of [Altair® EDEM™](#) means engineers can increase the accuracy of their system-level simulations by having access to high-fidelity representations of bulk material loads and forces acting on equipment. These insights are key to optimizing equipment performance and durability.

Interested in learning more? Visit altair.com/agriculture-construction