GOING GREAT GUNS

Finite element analysis helps to improve design of a maintenance trainer for a tracked combat vehicle.

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Building full-scale maintenance training systems for military applications is a relatively low-margin business. It requires paying strict attention to costs to meet specifications requirements while remaining profitable.

One of Kratos Defense & Security Solutions' many defense products is a hands-on trainer used to teach students how to maintain the turret and main components of a combat vehicle that uses continuous tracks for propulsion. The trainer is designed to support up to 17 students, so it must be validated to support their weight with a minimum safety factor for noncritical components of 2.0. Other companies in this industry validate trainer design by building a physical prototype; they often have to make changes after testing the prototype, which adds cost and time to the product design and development process.

Instead, Kratos utilized structural mechanics software in the ANSYS Workbench environment to simulate the initial concept design of the trainer and to develop a virtual prototype. Engineers found several problems with their initial structural design concept; by correcting these prior to cutting any metal, they minimized physical prototyping. The result was that the first trainer the company built met all of the customer's safety and functionality design requirements, saving approximately several hundred thousand dollars in development cost and time, compared to the traditional engineering design approach.

The Technology & Training group at Kratos helps military organizations to optimize performance by improving training outcomes while reducing training time and costs — empowering a workforce that is fully equipped to maintain critical systems availability. Kratos' areas of expertise include command, control, communications, computing, combat systems, intelligence, surveillance and reconnaissance (C5ISR), as well as unmanned systems, cyber warfare, cyber security, information assurance, critical infrastructure security and weapons systems lifecycle support.

DESIGNING TRAINING SYSTEMS

Kratos received a contract to build a number of U.S. Army tracked combat vehicle full-scale maintenance training systems (MTSs). The MTS provides training in critical field-level repair and maintenance tasks at the Army's Armor School Center. Each combat vehicle MTS has more than 15,000 components, weighs about 24,000 pounds, and is designed to carry an additional 3,500 pounds, including students and training equipment.

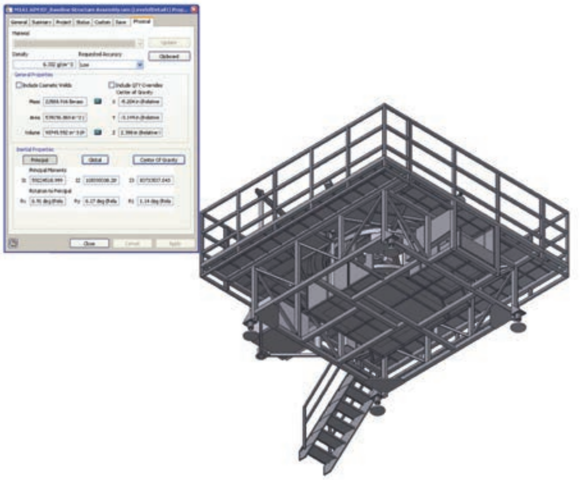
In the early stages of the project, Kratos engineers created a detailed 3-D model concept design of the combat vehicle MTS using Autodesk® Inventor® CAD software. The structure incorporates a replica of the combat vehicle turret, which is surrounded by a turret stand along with a platform that holds the class of students and instructor operator station. This station includes a computer that controls the training systems and provides feedback information to instructor and class. The traditional design process (used at a number of Kratos' competitors) involves building a physical prototype and performing physical proof-of-concept development testing to verify that the structure supports the required load with the necessary margin-of-safety factor.

BEST PRACTICES

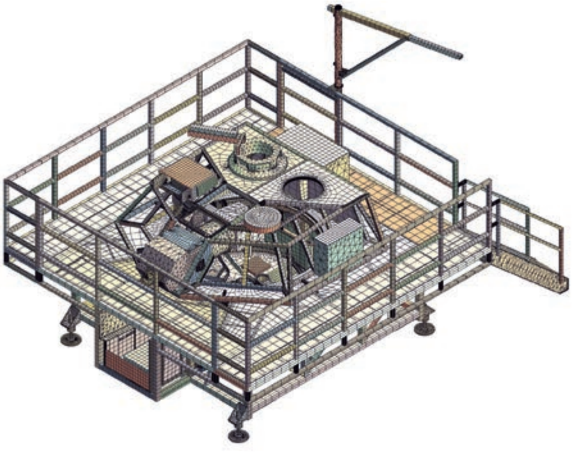
Kratos, however, has implemented an optimized design process that utilizes structural engineering simulation in the initial design process to identify problems with the concept design before building a physical assembly. This method ensures robustness of the design despite manufacturing variability, reduces the cost of product design and development, increases development team productivity, and delivers a better product in less time.

Kratos looked at a number of different simulation solutions and selected ANSYS structural mechanics technology for several reasons. The ANSYS portfolio provides the highest existing level of reliable product design and simulation technology, and it continues to steadily improve for existing and new applications. ANSYS supports an extremely broad range of engineering applications at a fair price and provides excellent technical support to users.

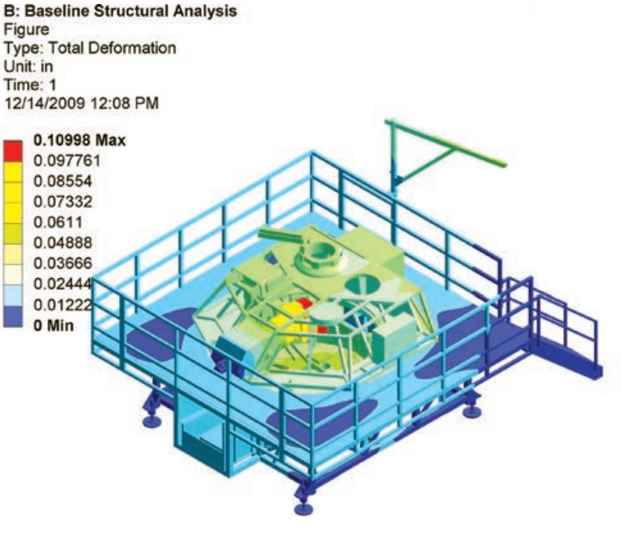
During the design process, engineers followed simulation best practices developed by Kratos. The team created detailed 3-D model geometry to ensure high-fidelity mass and inertial properties and assigned correct materials and physical properties for each component during the virtual prototype design process. They optimized the design by fully constraining the 3-D CAD geometry assembly and component models with the mating contact surfaces to ensure that they remain in full contact. Engineers cleaned up the large 3-D CAD geometry assembly model that contained more than 15,000 components to eliminate gaps and protruding surfaces between components.



Detailed 3-D model geometry design of maintenance and training system, created in Autodesk Inventor



FEA mesh with over 10 million degrees of freedom



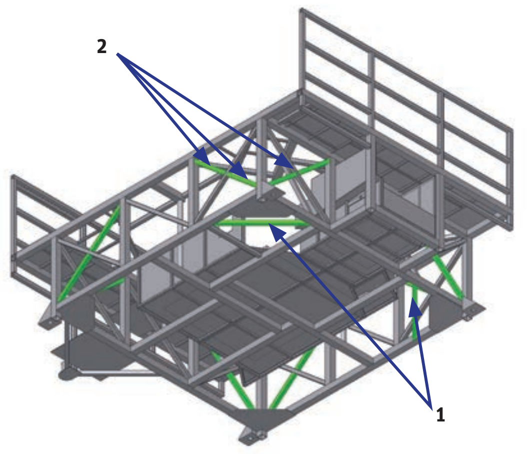
Static structural analysis results on initial design showed excessive deformation in several areas.

Kratos engineers optimized the 3-D models by eliminating small holes and threaded surfaces with little effect on the overall structure design; this decreased the number of nodes, subsequently reducing meshing and solution times. They also eliminated small fillet radii in the 3-D CAD models to avoid the stress riser effect when the model is solved. Each 3-D CAD model was grounded to adjacent components to avoid the potential for movement of floating components, which could create connection and meshing errors. When the CAD model geometry initial design was complete, Kratos engineers imported it into the ANSYS Workbench environment.

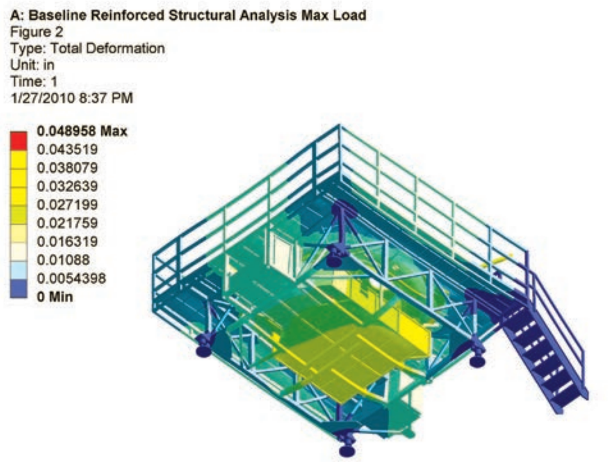
An FEA mesh was successfully generated using shell and beam modeling for the tracked combat vehicle trainer structure with more than 1.7 million total nodes, 404,000 elements, and over 10.6 million degrees of freedom. For structural analysis settings, the load of 3,550 pounds was applied in the form of 18 separate forces. These included 17 students at 200 pounds each and an instructor operator station at 150 pounds. Five supports were set with four jack-screw pads and the rear stairs. A static structural analysis was then run on the model. The initial analysis results showed that a minimum safety factor was below the required 2.0 in the cross-beam side-tube supports and bottom 45-degree tube supports located in the turret stand structural assembly. The minimum safety factor was also below 2.0 in the base-forward support posts located in the turret's structural assembly.

Kratos engineers made a number of structural reinforcement design changes to address these concerns in the virtual prototype 3-D model geometry. They inserted two horizontal steel structural tubes on the bottom frame front corners. They added eight upper-lateral steel cross beams and eight lower-lateral steel cross beams on each vertical post corner. Engineers changed the material from aluminum to steel on the turret base-forward support posts. They added a tactical-base basket-steel material component to the turret basket support assembly. These changes added 193.27 pounds to the turret stand structural assembly and 68.27 pounds to the turret structural assembly.

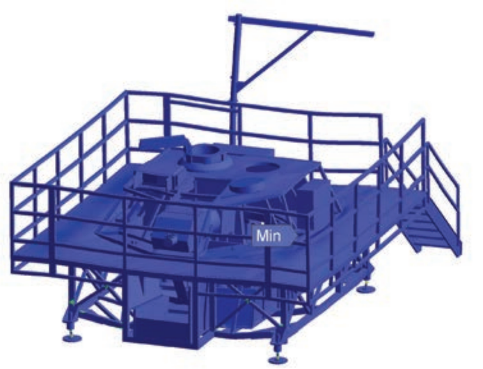
Kratos engineers then reran the static structural analysis for the



Kratos added horizontal steel structural tubes on the bottom-frame front corners (1) as well as upper- and lower-lateral steel cross beams on each vertical post corner (2).



Static structural analysis results of new reinforced design showed a substantial reduction in deformation.



Minimum safety factor for noncritical components in the reinforced design was 2.312, above the 2.0 design requirement.

Engineers optimized and validated design of a maintenance training system for a tracked combat vehicle without building a physical prototype.

reinforced structure to evaluate the effect of design changes. They applied the same loads to the structure and concluded that all critical-area safety factors were above 5.0. The final results showed a minimum safety factor of 2.312, which occurred only in a noncritical component located on the turret structure upper section. When the combat vehicle simulators were physically built and tested, the final results matched the virtual prototype simulation predictions — so no changes were required to the final design. Without engineering simulation, the system as initially designed and developed would have failed testing; it would have required revisions at considerable expense and additional development time.

Using ANSYS structural mechanics software and Workbench to perform simulation helped to substantially improve Kratos' product design process. Engineers optimized and validated the product design based on the 3-D virtual prototype without having to build a physical prototype. In addition to reducing the cost involved in product design and manufacturing, simulation shortened time to market and deployment to the customer's military bases. The combat vehicle maintenance training systems were developed on time and on budget, ready to be shipped to the customer by the end of the year. The excellent results in getting the product design right the first time helped to validate the effectiveness of Kratos' simulation and design optimization methodology.

Partially due to the success of this program, Kratos was awarded a contract extension to upgrade tracked combat vehicle maintenance simulators for an army training center. The company has also received industry recognition for its efforts, most recently by being named top simulator and training company for 2011 by *Military Training Technology* magazine.