Compressing the Time Cycle

"We only needed one physical prototype and are on track to complete the design in only one year."

Customer:
John Deere Welland Works,
Ontario, Canada
www.johndeere.com

Software:
MSC.ADAMS®, ADAMS/Durability, FE-Fatigue

Summary:
With the help of MSC.Software Professional Services and products such as ADAMS/Durability and FE-Fatigue, John Deere Welland Works completed the design and testing of their new rotary cutter system within two weeks instead of several months. Thanks to the implementation of durability analysis, John Deere could reduce the number of the required physical prototypes and was able to try out several design concepts. As a result, the total development time on one cutter was reduced from four years to two, and John Deere is on track to produce another cutter in one year.

The implementation of durability analysis at John Deere Welland Works was one of the key factors in reducing development time for their rotary cutter systems. On the last two product generations, each design and test cycle was completed in one or two weeks using a virtual prototype instead of several months as required by physical prototypes. As a result, development on a 20-foot cutter was reduced from about four years to two, and most recently, to one year.

One of the most time-consuming aspects of the cutter systems' development in the past was the lengthy process of building physical prototypes, testing them for durability, then redesigning several parts and starting all over again. In the last several years, Deere engineers have streamlined this process by building a virtual prototype of the entire cutter, including finite-element representations of the most fatigue-sensitive components.

Deere's virtual prototyping procedure mimics a physical durability test of its rotating drum. The virtual tests produce stress time-histories that are used by durability analysis software to make fatigue life predictions. These predictions have proven very accurate when compared to physical testing. "Using the new method,
we have reduced the number of physical prototypes from three or four previously, down to two, and now one on our two most recent designs," says Terry Ewanochko, product engineer for John Deere Welland Works. "These time savings made a big contribution to the dramatic reductions in the development cycle on our latest products."

The 15-foot and 20-foot Flex-Wing rotary cutters made by John Deere are used by farm operators, road side maintenance companies, and municipalities for turf and grass mowing, pasture clipping, knocking down and shredding stalks, and clearing out brush. For this heavy-duty work, the cutters must be extremely durable. The cutter assembly consists of three articulated sections, the center and two wings, as well as rotating cutting blade sets and support wheels. The sectional design floats to follow the ground contour, allowing uniform cutting height on hilly terrains while preserving the full cutting width of 15 feet or 20 feet.

For more convenient transporting, the wings can be folded to reduce the width of the cutter. A tractor that provides a mechanical power take-off together with hydraulic lines tows the cutter. The power take-off drives the rotating cutters while the hydraulic lines drive the actuator cylinders that are used to control the cutter height and wing lift. The wings and center structure are fabricated using a doubledeck steel plate construction concept. The center and wing axles and lower hitch arm, are also fabricated. Continuous-seam and stitch welding provide extra strength for greater durability and manufacturing benefits over bolts and rivets.

Traditionally, Deere has relied on a series of physical tests to ensure the survivability of these products when subjected to static and cyclic loadings. The most important is performed on a bump-test fixture, which simulates the jarring and twisting impact a cutter experiences when running over large bumps and rocks. The cutter is attached to a grounded drawbar while the wheels ride on rotating drums - one for the center section and one for each of the wings. Triangular-shaped cleats attached to the drums are used to simulate bumps. “In the past, we had to keep building new prototypes and testing them on this fixture until we were satisfied with their life,” Ewanochko says. “The problem was thatprototypes are very expensive and take a long time to build and test. When we found problems with one or more major structural components we would have to redesign and rebuild the prototype, and start the testing again several times. This build-andbreak process had to continue until the quality level was acceptable.”

Deere engineers believed the process could be improved while they were creating several small component-level virtual models. ”We hired MSC.Software consultants to use MSC.ADAMS multibody simulation software to simulate the performance of several components,” Ewanochko says. “We were impressed with the ability of the software to generate component-load profiles that can be used as input for fatigue analysis software. We decided to move to the next level by developing a prototype of the complete rotary cutter and modeling its performance on the bump-test fixture.”

Utilizing ADAMS/Durability enabled complete integration of key virtual prototyping techniques such as finite element analysis, multibody simulation, and fatigue life prediction. The initial MSC.ADAMS model of the cutter and test fixture was generated in the Pro/ENGINEER (PTC) environment using the embedded product MECHANISM/Pro. This software package is seamlessly integrated within Pro/ENGINEER, so the consultants were able to perform kinematics analysis to validate the model without leaving the CAD environment, then perform one-button transfer to MSC.ADAMS where full dynamic simulations were performed.

MSC.Software engineers finalized the model by adding high-fidelity features such as contacts, bushings, motions, couplers, and more complex joints for the bump test. The flexibility characteristics of the structural parts were modeled by generating finite element meshes of these components using Pro/MECHANICA (PTC) and exporting them in the format used by ANSYS (ANSYS, Inc.) finite element software. ANSYS was then used to generate flexible body modal neutral files that contain the modal mass, stiffness, and deflection characteristics using a modal representation of the component. The orthonormalized modes, including static correction modes, were computed within ANSYS and then transferred to MSC.ADAMS, which modeled the flexible body deformations as a linear combination of mode shapes. The dynamic bump test was simulated in the virtual prototyping environment by first reaching static equilibrium for one second, then accelerating the drum operating speed. Using the full finite element models of critical components, Deere engineers obtained local stresses with the MSC.ADAMS solution. The mode shape participation factors were used as the scalars on the stress solution of each mode shape in a linear superposition to represent the component’s instantaneous stress shape. This superposition was performed at every node in the finite element model for each time step in the simulation, making it possible to define a stress time-history at every location in the flexible component models. The modal coordinates, or scaling factor time-histories, were output from MSC.ADAMS for each component in a format that is directly readable by FE-Fatigue, a popular durability analysis software package from nCode International. Also, the stress solution for each mode shape was solved in ANSYS and exported to FE-Fatigue. FEFatigue then performed the stress superposition at every node for the purpose of life prediction. This involved automatic, multi-channel peak/valley extraction and rainflow cycle counting, followed by the damage sum.

“The results of the durability analysis showed good correlation with our physical test results on an initial prototype, giving us the confidence to predict service lives based on the virtual prototype simulation,” Ewanochko says. “As a result, we integrated the virtual prototyping process midway into the development cycle of our new 20-foot rotary cutter and from the very beginning of our latest 15-foot rotary cutter. On the 20-foot cutter, we had already produced one physical prototype when we created the virtual one. After validating the virtual prototype against the physical prototype, we finalized the design with the virtual prototype, and only one more physical prototype was required to complete the design.”

“Experimental testing of this prototype further verified the predictions that we had generated with the virtual prototype,” Ewanochko continues. “The big advantage was that we completed each design and test cycle using the virtual prototype in only one or two weeks. This is compared to several months required in the past when we had to actually build the design in order to determine whether or not it would work. As a result of these improvements, and others in different areas of the design process, we were able to reduce the development on the 20-foot cutter to about two years. This was only half as much time as we had ever been able to do previously, based on the best time-compression techniques used in the past.”

“On the 15-foot cutter, we used virtual prototyping from Day 1. As a result, we only needed one physical prototype and are on track to complete the design in only one year,” Ewanochko states. “Compressing the time cycle also meant that we were able to evaluate many more design concepts than we could in the past, including innovative approaches that we probably couldn’t have spent the time and money to test.”

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