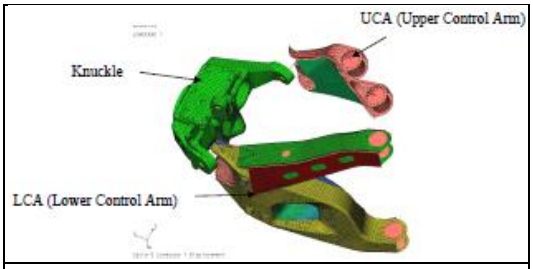
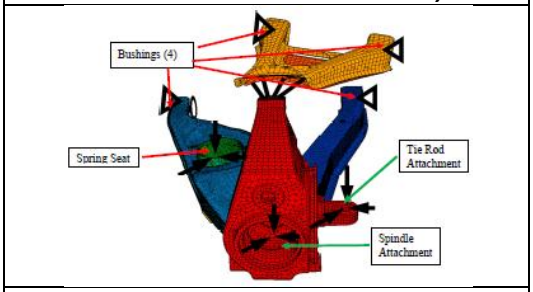
Chassis Weight Reduction In Military Vehicles and the Advantages of Utilizing High Performance Computing

Challenge

Changes in battlefield and theater of operation have unexpectedly exposed military vehicles, including the HMMWV, to Improvised Explosive Devices (IEDs) and other ballistics. Up-armoring is the practice of adding antiballistic armor to these vehicles to shield against a new threat. Since the added weight is not part of original design specifications, many vehicles have experienced fatiguing of critical components and frequent break downs in the field. To address the weight increase, engineers must redesign and optimize the suspension sub-assembly of the HMMWV, without sacrificing strength, stiffness and durability.



Double-A Arm Sub-assembly



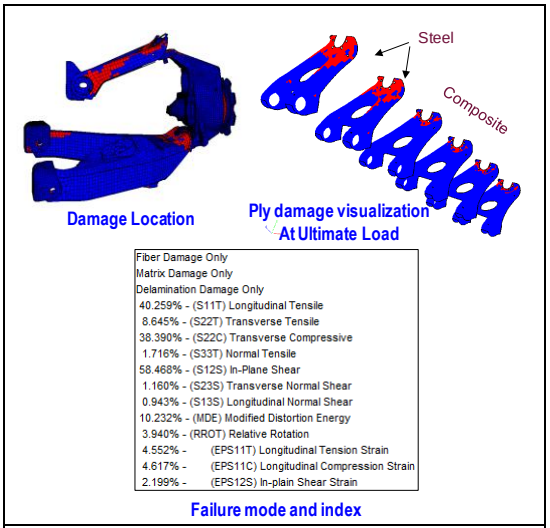
Load and Boundary Conditions

Solution

GENOA multi-scale progressive failure analysis software was used to optimize the design and performance of a HMMWV Double-A Arm suspension subassembly consisting of an Upper Control Arm (UCA), Lower Control Arm (LCA) and a cast iron knuckle. Load cases were derived from 30 mph road test data. The maximum deflection of the original design was 1.7 mm. The proposed hybrid redesign consisted of a skeletal steel structure overwrapped with graphite composite in an 8 ply quasi-isotropic layup. The design objective was to minimize mass while limiting deflection to 1.7 mm and Composite Failure Index to 0.9. The first redesign resulted in a deflection of 1.92 mm and the final redesign resulted in a maximum deflection of 1.29 mm. The weight of the original component was 35.4 kg. The weight of the optimized design was 24.9 kg, which corresponded to a mass savings of over 30%.

With regard to durability and damage tolerance, the original metal design fractured at 4.05x the initial load for given terrain conditions. Damage occurred in joint areas for both control arms and fracture modes were caused by tensile and shear strains. In the case of hybrid

construction, a 20% increase in strength was achieved over the original design. Once again, dominant failure modes for steel layers were caused by tensile and shear strains, however contributing failure modes for the composite portion were found to be fiber tensile and compressive failure; matrix damage in tension, compression, and shear; and out of plane delamination. As load increased to ultimate, damage propagated from the steel skeleton to the composite layers. Fatigue life of the hybrid was 75% greater than original metal design.



Damage Evolution

To determine the benefits of using HPC, a static durability analysis was undertaken with GENOA on a traditional workstation and an HPC platform. Comparisons were made among a lower control arm model containing 54k elements; the double A-arm suspension assembly containing 92k elements, and, a representative box beam containing 272k elements. Analysis was undertaken with 1, 2, 4, and 8 CPU cores. For the suspension unit, very little reduction in run time was observed with HPC. For model sizes exceeding 100,000 elements, a significant run time reduction was obtained. The PFA run time for the box beam model with over 270,000 elements and 8 CPU cores was reduced by 38% when compared to analysis with 1 CPU core.

Results & Conclusion

- The optimized composite/metal hybrid Double-A arm suspension generated a 30% savings in mass, a 20% increase in strength, and a 75% increase in fatigue life.
- For small finite element models, no discernible benefit was observed between workstation and multi-core HPC platform.
- For large models, such as in an entire vehicle suspension, the benefit associated with the utilization of HPC was substantial.
- For large models, run time reductions over 50% were obtained when using 8 CPU cores for models larger than 100k elements.

Key Highlights & Benefits
Product: MCQ, GENOA
Industry: Aerospace, Automotive, Manufacturing
Application: MS-PFA, Optimization, D&DT
Benefits: Mass Reduction; Increase Durability; HPC benefit over 100K element

Related Publication

Chassis Weight Reduction in Military Vehicles and the Advantages of Utilizing High Performance Computing. SAMPE Baltimore Conference Paper, May 18-2012.