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LINKAGE OPTIMIZATION

DJH ENGINEERING (DJHEC) Technical Newsletter

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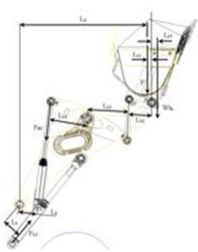
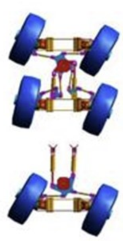
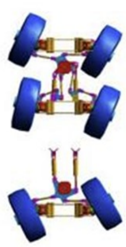
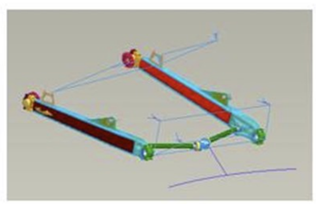
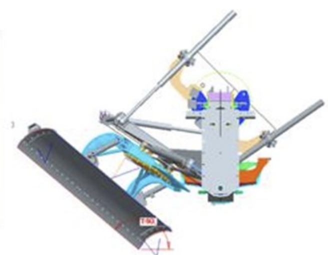
In this issue:

- Linkage design challenges
- Introduction to optimization tools used at DJHEC.
- Hood linkage optimization case study
- Benefits realized

Linkage Design Challenges

Approaching linkage design can be a daunting task. Often all that is known is what the end result should be and locations that joints and links are not permitted due to interference with surrounding components. Questions of joint sizing, joint location, link motion, forces in links and joints, and what materials should be used are just some of the many questions surrounding a linkage design. It is often beneficial to use pre-designed joints, off-the-shelf components, or common hardware, but implementing these can be a challenge and can lead to undesired linkage motion or not meeting the requirements if not implemented correctly.

Another challenge in linkage design is knowing what happens to the linkage when a joint location is either forced to move due to surrounding components or slightly different motion is desired. What happens to the linkage motion? Are the links still clearing surrounding components? Did your forces just exponentially increase? Rather than costly prototypes and hours of engineering time solving complex equations, DJHEC has 30+ years in the industry and experience optimizing a variety of linkages including vehicle suspensions, loader booms, skid-steer booms, excavator booms, cab suspensions, engine enclosures, dozer blades and grader blades, just to name a few. In this issue we will explorer a smaller optimization that was done on a tractor hood linkage.


Optimization Tools

DJHEC has many years experience designing linkages based on key requirements from customers. Whether the desire is for optimal performance, manufacturability, user input forces, life of joints, serviceability, or any combination of these metrics, DJHEC is able to efficiently provide the desired results. DJHEC has access to multiple software packages. Based on the project, the most efficient method and software is chosen. Altair® has 3 software packages that DJHEC uses for linkage design and optimization. Altair Inspire™, Altair MotionView™, and Altair MotionSolve™. Another useful tool is PTC's Mechanism feature inside CREO™. DJHEC used PTC Mechanism to smoothly implement 3D model changes for a vehicle suspension based on output from the mechanism in the form of performance characteristics. Whatever the requirements, DJHEC has knowledge to select the right software package for a customer's particular requirements.

Hood Linkage Optimization

In this example, the requested deliverable from the customer was to provide a linkage that would raise an engine enclosure. Challenges were the design space to package the linkage in due to tight clearances to the engine and cooling package as well as the large weight of the hood (300kg/660bs). Using MotionView™ we were able to show that the original desire of simple gas struts or torsional springs was not feasible due the inability to balance the opening and closing forces to be within an operator limit (~20-40 lbs.). The final solution was a linear actuator which proved to work very well for the customer.

Key Parameters

- 660lb. Hood
- Operator must be able to close it and open it with minimal force (~20lbs).
- Three concepts considered for lift assist.
  - Gas Struts (eventually ruled out due to the high input force required)
  - Torsional Springs (eventually ruled out do to the required force and packaging constraints)
  - Linear Actuators

The initial concept was to use torsion springs that have previously been used for similar applications and enclosures. The benefits are the existing knowledge and design of the springs as well as off-the-shelf components. The desire was to re-use these but add additional as needed for the specific requirements of the application. Through MotionView™, it was easy to observe that it was not going to be very feasible to package the springs that would be required. Figure 1 shows 6 different scenarios quickly run in MotionView™ of the torsion spring concept where the weight of the hood was explored for possible mass reduction and the linkage arms were adjusted within a given range. With 13 springs being the maximum that would fit in the space it was easy to eliminate this concept with little design time spent.

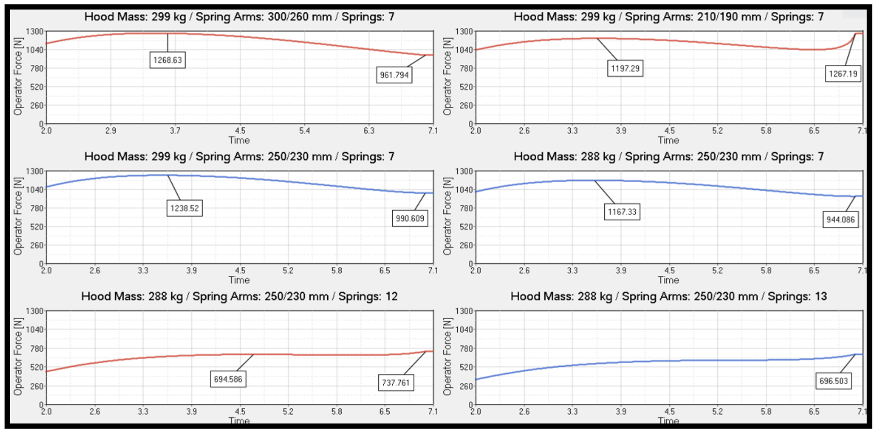


FIGURE 1: Output from MotionView™ for torsional spring hood linkage.

The next concept was to implement gas struts into the linkage similar to what is shown in Figure 2. Gas struts are readily available and used in similar applications in the automotive industry. Minimal time was spent adding this link to the system where it would be feasible to package. A range of positions were set where the link end points could be without interferences with surrounding components. It was again quick to observe that the forces from gas struts were not going to work with this application. The large weight of the hood and limited ability to move the linkage points around due to the tight clearances with the engine made it unfeasible to use. The force to initially raise the hood and close the hood were too great. As shown in Figure 3, three quick iterations were run in MotionView™ but a solution with required operator force was not found.

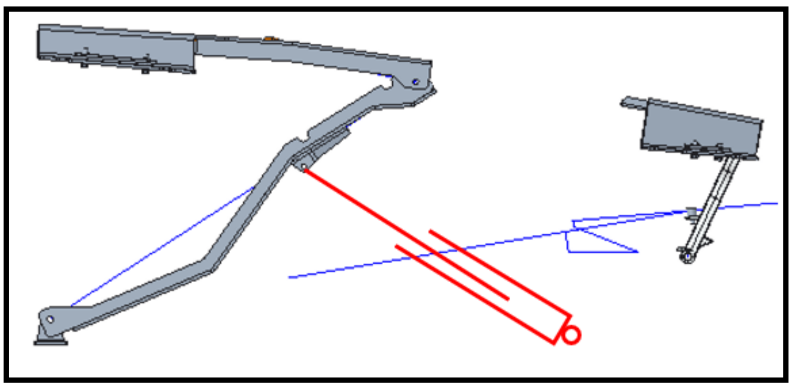


FIGURE 2: Hood Linkage image from MotionView™

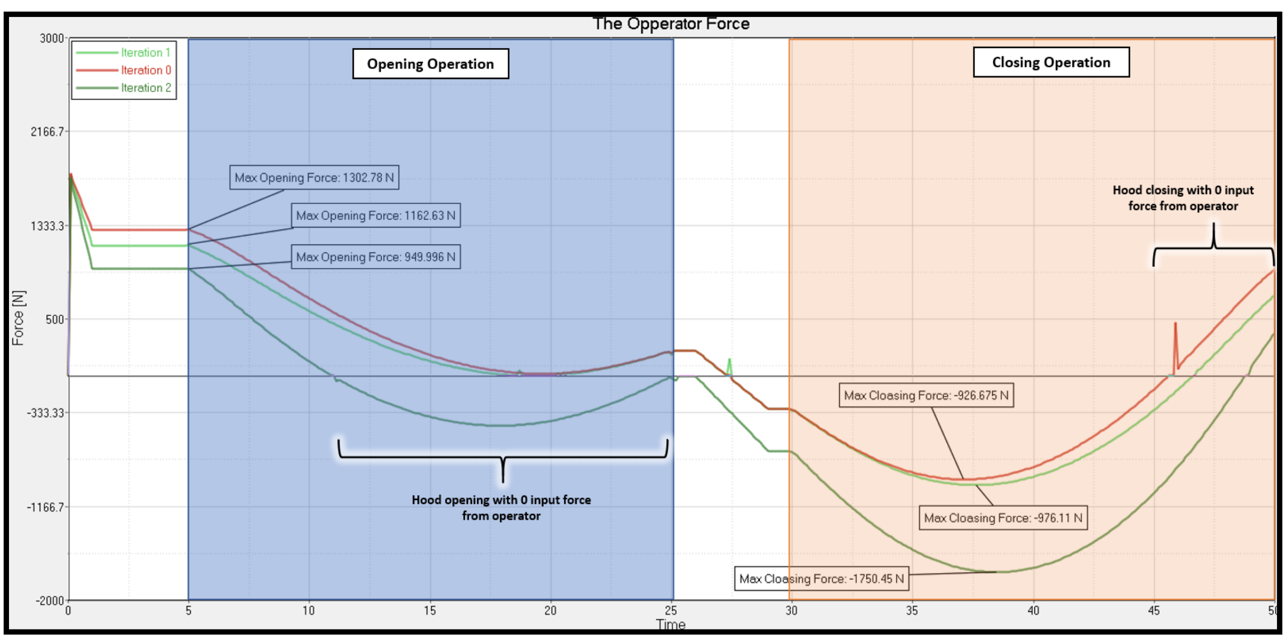


FIGURE 3: Output from MotionView™ for gas strut hood linkage.

The final solution was found in linear actuators (Figure 4). The actuators were able to package in a very similar location as the gas struts and offered the forces required to easily open and close the hood by the push of a button. MotionView™ was used to optimize the location of the linkages points. Through the optimization software, the required travel, forces, and size of the actuator was matched to an off-the-shelf component readily available. Figure 5 below shows the force and length requirements of the actuator through the full range of motion. This was shared with a supplier and an actuator was chosen. The forces were then transferred seamlessly over to the FE model to verify stress and displacement in the mounting brackets (Figure 6). The customer was extremely happy with the results for the vehicle to showcase the new engine and other features under the enclosure through several displays to internal leadership.

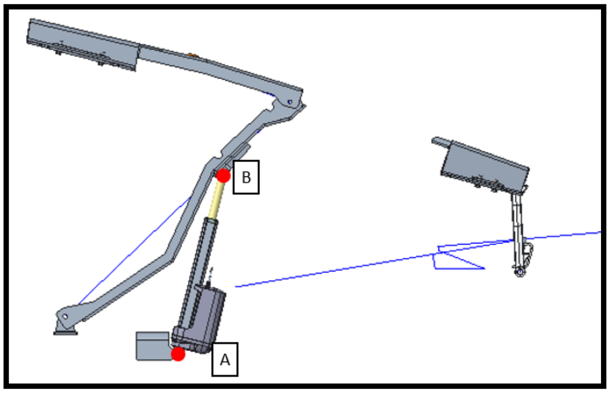


FIGURE 4: Final CREO™ of linkage with actuator.

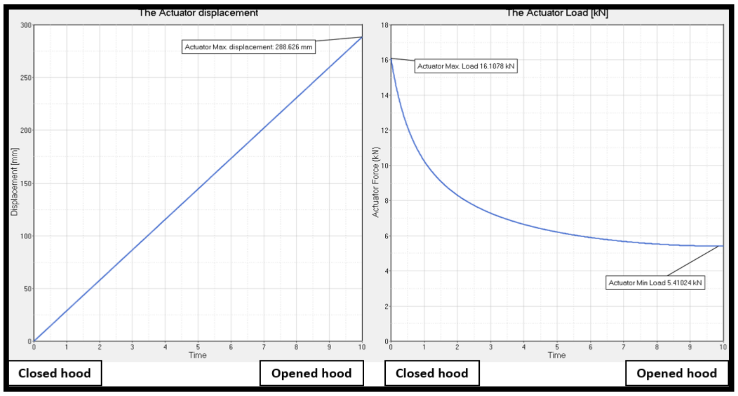


FIGURE 5: Output from MotionView™ Actuator Length and Force

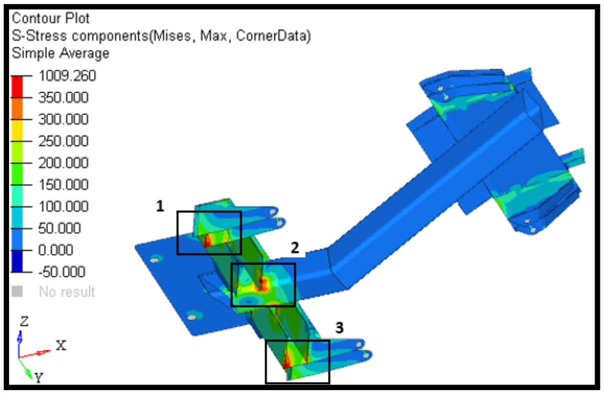


FIGURE 6: FE Model of actuator brackets under load

Benefits Realized

Through the years, the available tools have of course improved the time to a solution as well as the opportunity for co-simulation. For example, linkage motion and forces are readily available in a single analysis. Shape optimization of the links can be shown based on the forces with minimal additional time/resources as shown in Figure 7.

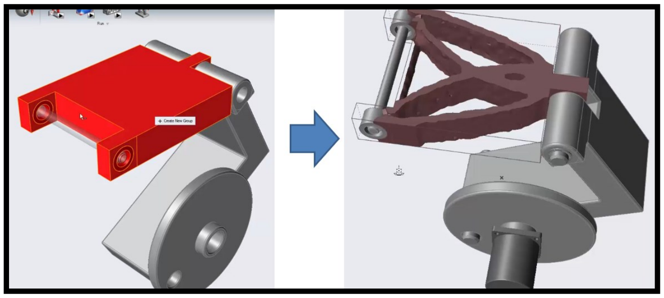


FIGURE 7. Linkage with shape optimization solution in Altair Inspire™.

Reduce Cost: DJHEC has been able to drastically reduce the time spent on designs through the use of linkage optimization software. Cost savings can be found in many avenues when optimization software is used, for example—optimize around common joints to keep unique part count down, optimize shape to reduce material used, optimize around forces to reduce joint sizes, or optimize around joint location to keep mounting supports minimal.

Improve Quality: Robust and efficient designs are the results of linkage optimization. When a linkage has been optimized, longer life, better user experience, and clean packaging can be expected.

Improve Time-To-Market: Through the use of a variety of optimization tools, DJHEC has been able to smoothly transition from an optimized linkage into shape optimization, updated CAD geometry, and through final verification using Finite Element Analysis. This method has been successful for DJHEC to move concepts from ideas to satisfied end user hands for a variety of projects.