OFF-ROAD CASE STUDY

Pratt & Miller Engineering predict mobility of military ground vehicles over soft soil terrains using EDEM and Adams

Pratt & Miller are a world-class engineering company and industry leader in automotive, commercial, military, and aerospace industries.

Using EDEM and Adams enables Pratt & Miller to perform virtual testing of their tracked and wheeled vehicles to efficiently analyze and predict vehicle dynamics on soft soils.

CHALLENGE

MultiBody Dynamics (MBD) models of wheeled and tracked vehicles can be validated and used to predict behavior on hard surfaces; however, when the vehicle is simulated over a deformable terrain, traditional approaches cannot fully represent the dynamic interactions of the vehicle and the soft soil.

Realistic modelling of terramechanic behavior is key to understanding the mobility characteristics of off-road vehicles and understanding how changes to the vehicle and terrain will impact the dynamic behavior.

Without realistic vehicle-ground modeling, vehicle design engineers will often resort to using their past experience with physical testing to predict how the vehicle will behave once it leaves the hard road surface.

Only when the vehicle is built and tested, can they obtain the actual data for how the vehicle performs over soft soils. This is a risky approach and limits opportunities to innovate and optimize a design.

EDEM's ROLE

Simulating the behavior of off-road vehicles on soft soil terrains requires modeling the behavior of both the vehicle and the soil, as well as the dynamic interaction between the vehicle and the terrain.

EDEM software simulates the behavior of granular materials and enables engineers to realistically model a range of soils. To help users, EDEM provides a 'Soils Starter Pack' including eight sample out-of-the-box material models with different ranges of compressibility and stickiness – ready to be used in simulations.

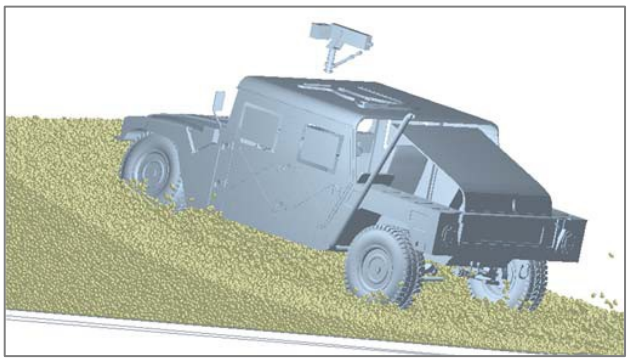
Pratt & Miller used EDEM coupled with Adams to simulate wheeled and tracked vehicles for various vehicle mobility events and a variety of different maneuvers. These included straight-line on flat terrain; single and double hill climbs; grade climbs; traversing a side slope; pivot steer; drawbar pull; and multi-pass runs. Each EDEM model was selected to ensure the behavior met the desired specifications and reflects physical testing.

RESULTS

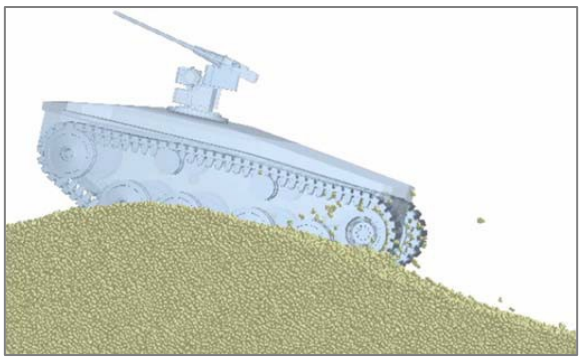
Integrating EDEM with Adams delivers improved realism in vehicle mobility simulations. Pratt & Miller is able to predict the performance of their tracked and wheeled vehicles in a variety of off-road environments and to study complex maneuvers such as hill climbs, turning and obstacle traverse.

This enables them to perform "what-if" design analysis early in the design cycle and reduce risk of late-stage design changes. By modelling with EDEM they are able to consider the damage done to the ground material and consider the effect of vehicle convoys and ground clearance of vehicle designs.

This solution means Pratt & Miller engineers can reduce the reliance on limited analytics approaches and are able to better understand performance in challenging environments without the need for physical prototyping.



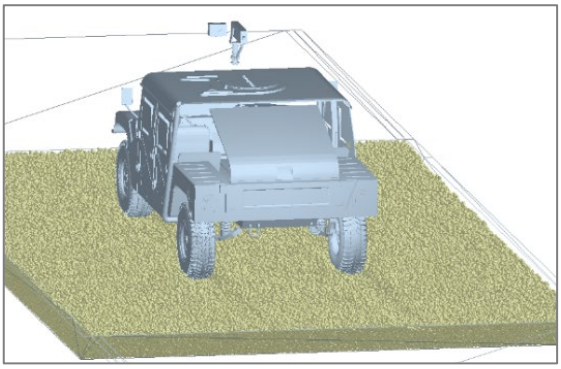
EDEM-Adams simulation of High Mobility Multipurpose Wheeled Vehicle (HMMWV)



EDEM-Adams simulation of a tracked vehicle (tank)

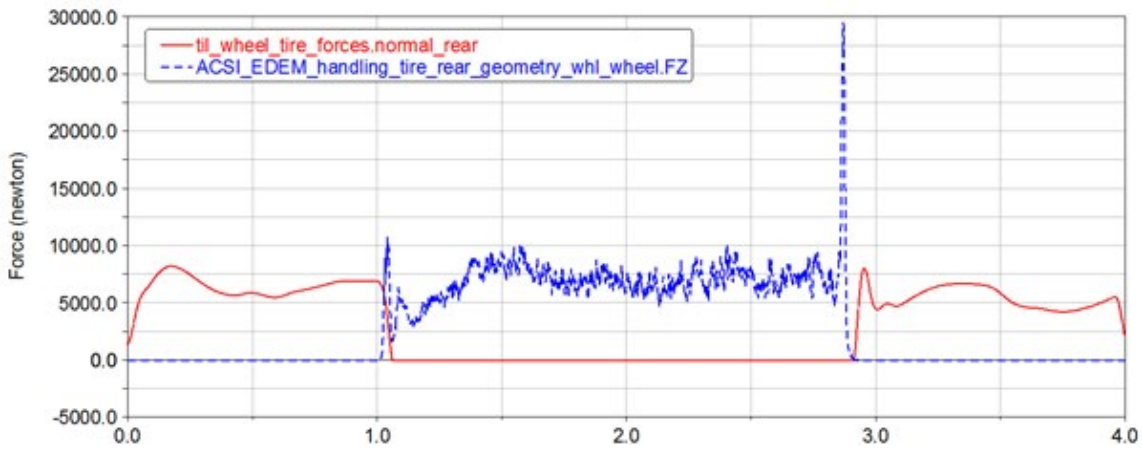
EDEM-ADAMS WHEELED VEHICLE SIMULATIONS RESULTS

The Adams model of the High Mobility Multipurpose Wheeled Vehicle (HMMWV) model was simulated performing a range of maneuvers, over a variety of soft-soil terrains.



FLAT SURFACE – EDEM VALIDATION

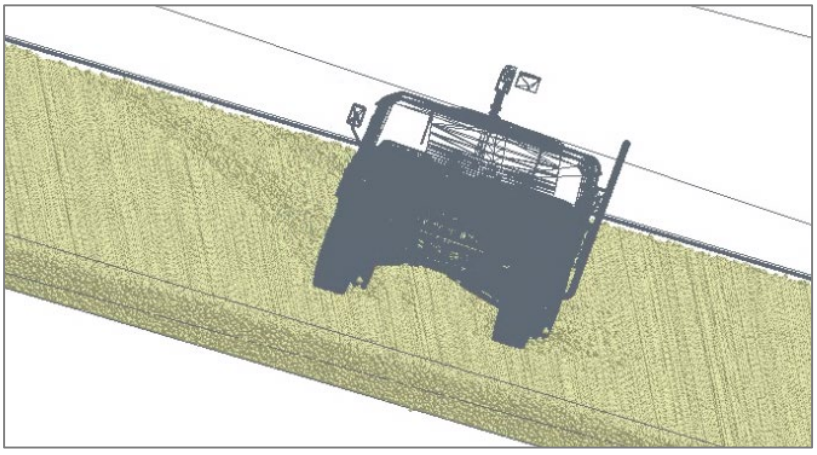
The first maneuver was the HMMWV traversing a flat particle bed. Here, the aim was to validate the response of the EDEM soft-soil model by comparing the tire forces when the vehicle is on the hard surface, against the forces when it is crossing the soft soil. The results of this validation are shown below.



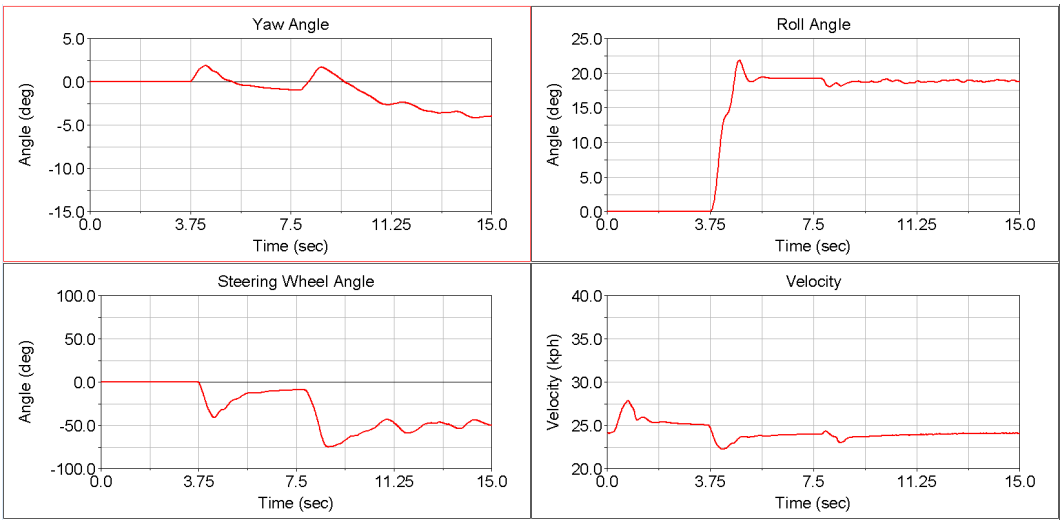
For the first 1 second, the HMMWV is on the hard surface and tire forces are calculated through standard Adams Tire routines (shown in red). As the vehicle transitions onto the soft soil, the Adams Tire forces go to zero and the EDEM particle forces (shown in blue) begin to carry the vehicle load. After an initial transient phase, the vehicle stabilizes and the contact forces calculated by the EDEM particles are equivalent to the tire forces on the hard surface. Once the vehicle returns to the hard surface, the tire forces again are calculated by the Adams Tire method.

SIDE SLOPE TRAVERSE

The second maneuver shows the HMMWV being run on a side-slope. Here the intent is to identify how the vehicle will slip and recover from traveling across the angle surface profile. The steering controller in Adams was set to try and maintain a straight-line while on the side-slope. The vehicle initially slides down the slope as the steering reacts to the lessened traction available and compensates until the vehicle begins to recover towards the desired straight-line path.

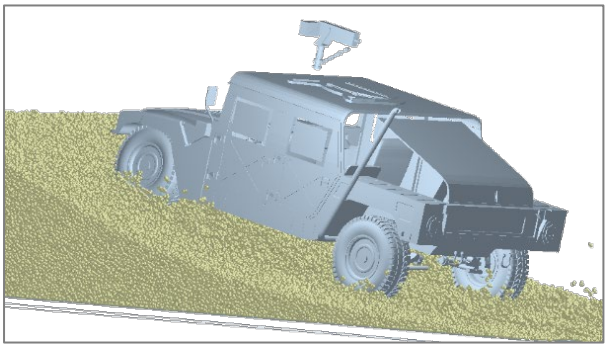


The simulation begins with the HMMWV on a flat, hard road surface that begins to gradually roll to match the EDEM slope which the vehicle enters at around time 7.6 seconds. As the HMMWV enters the soft-soil, the vehicle initially yaws to the left while the rear wheels are still on the hard surface. Once the entire vehicle is on the soft soil, it begins to drift down the slope, and the steering controller increases the angle to return to a straight-line course, causing the vehicle to yaw in the opposite direction. At the end of the simulation, the yaw has stabilized, and the steering angle is maintained to travel in a straight direction.

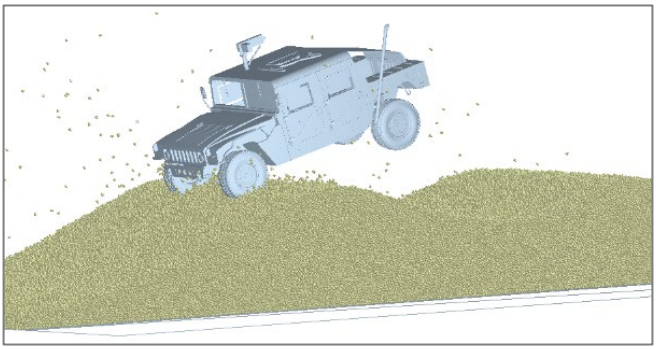


SINGLE & DOUBLE HILLS

Here, the HMMWV was run over single and double hills at various speeds to investigate the ability to traverse the obstacle as well as the power required during the event. The image on the left below shows the HMMWV at 20kph trying to climb a single hill and getting the front wheels stuck in the soft soil. At a higher speed, the HMMWV becomes airborne as it crests the hill. The example on the right shows the HMMWV taking on a double hill at 60kph. Here, the HMMWV leaves contact with the ground and impacts just before the crest of the second hill causing an impact “splash” with the soil particles.



HMMWV on single hill at 20kph



HMMWV on double hill at 60kph

Pratt & Miller has extensive expertise in modeling wheeled and tracked vehicles on hard road surfaces. However, for vehicle behavior on soft soils we have predominantly relied on spreadsheet calculations and historical knowledge, along with limited Bekker-Wong soil modeling. The EDEM-Adams integration of our MBD vehicle models is a tremendous step forward in being able to predict mobility and performance on deformable terrains. This is a cutting-edge capability that enables Pratt & Miller to deliver increased value to our customers, and positions us as a leader in ground vehicle terramechanics.

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