US Army Corps of Engineers®
Engineer Research and Development Center

Finite Element Modeling of Tires on Snow and Unsurfaced Roads

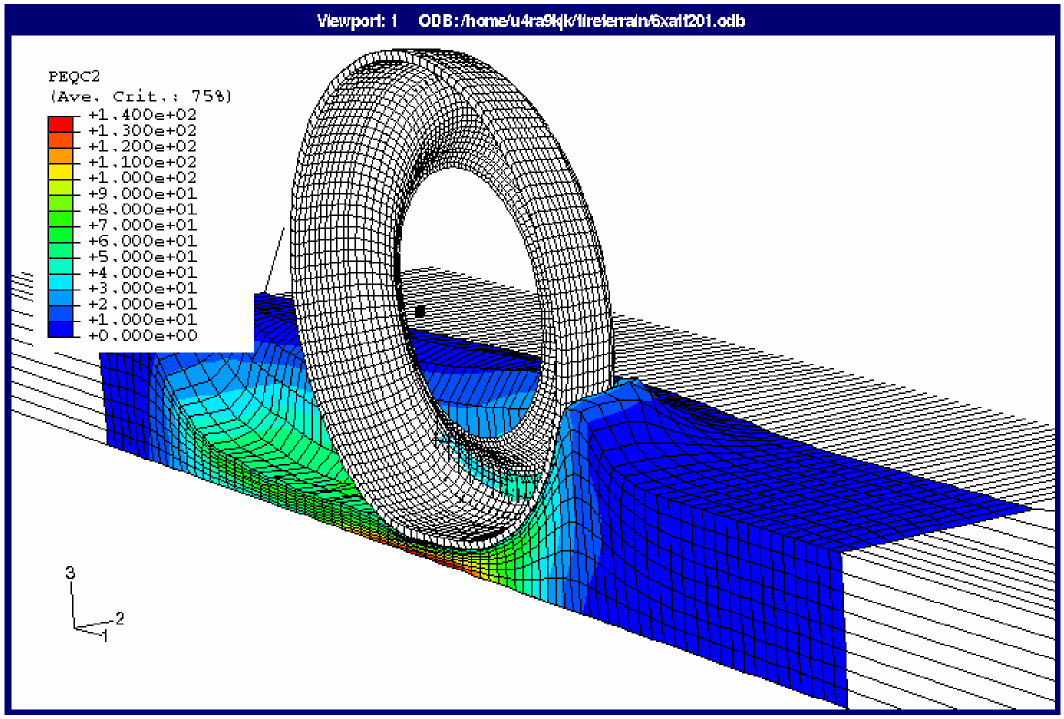
Problem

Vehicle movement on snow-covered surfaces and unsurfaced roads is important to the military, as well as to the agriculture, forestry, mining, construction, and recreation industries. Because of the complicated nature of vehicle–terrain interaction, comprehensive modeling of off-road mobility is often done using empirical algorithms. The desire to incorporate more physics into performance models has generated great interest in applying numerical modeling techniques in a full three-dimensional analysis, accounting for the deformation of both the tire and the terrain.

Military vehicles must travel on substandard roads year-round.

Description

Three-dimensional finite element models were constructed to simulate a tire rolling over snow or other deformable surfaces, such as an unpaved road. The snow was modeled as an inelastic material using critical-state constitutive modeling and plasticity theory, while two similar models were developed for unsurfaced roads: a rutting model and a washboard model. The tire models, which represent a range of sizes from passenger car and light-truck tires to large, off-road vehicle tires, were rolled on snow of various depths and on muddy roads. The combined tire–terrain models were validated using force measurements collected with instrumented vehicles and with measured snow deformation, as well as measurements from roads damaged during the spring thaw. The snow model results were also compared to vehicle mobility predictions made using the winter algorithms of the NATO Reference Mobility Model. These comparisons illustrate the agreement between the finite element models and field measurements of motion resistance forces and deformation under the tire. Current research looks at the mechanics of vehicle traction and turning maneuvers on a deformable surface.



Finite element simulation of a tire rolling through snow.

Expected Products

Ultimately, the model could be used to design or specify tires, to predict vehicle performance, and to predict terrain damage and reduce the environmental impact of off-road travel (issues of high importance to Army training). The finite element model also is adaptable to addressing problems regarding the mobility of lightweight robots on snow.

Potential Users

The Army, Department of Defense, and the Nation will benefit from this model. Cold regions constitute over 50% of Earth's landmass, and many of the world's current political hot spots fall within these regions, including the Balkans, the Korean peninsula, Afghanistan, and mountainous border areas, such as the India–Pakistan border. However, vehicle performance on snow, winter surfaces, and secondary roads is also of interest to the agriculture, forestry, mining, and construction industries, and is of particular importance to commercial and passenger vehicles traveling on roads in winter and during spring thaw.

Projected Benefits

Such a model would enable detailed analysis of the complex interactions resulting from contact friction and would further our understanding of off-road vehicle mobility by defining critical mechanisms involved in vehicle traction and motion resistance. This would benefit the military in its deployments around the world, as well as for training exercises. Spin-offs to the private sector, e.g., for tire design and vehicle performance modeling, are probable.

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