

# Case Study: KTH Royal Institute of Technology

## Adams Demonstrates Ability to Accurately Evaluate New Logging Machine Design in a fraction of the time required by the build and test method

### Overview



Traditional Komatsu forwarder on a steep slope

The predominant forest harvesting method used in northern Europe is cut-to-length logging (CTL). CTL is based on a two machine solution – a harvester is used for felling, delimiting and bucking trees and a forwarder carries the logs from the harvesting area to a roadside loading area where they can be picked up by a truck. These are both off-road machines with a frame mounted crane that operate in areas not accessible by conventional wheeled vehicles at low speed. In order to stay competitive the Swedish logging industry needs to increase productivity by 2% to 3% per year. Increasing the speed with which forwarders can move logs is one area where logging companies are hoping to achieve productivity improvements. “A key limitation in the ability of forwarding machines to drive in the terrain is the vibrations that the driver is exposed to,” said Abbas Ismoilov, Ph.D. student at KTH. “In addition, forestry machines are heavy and the risk for rutting and soil compaction is high. Improving the productivity of forest machines will require new suspension systems that offer improved operator comfort and are gentler to the soil than current designs.”

### Challenge

Skogforsk (the Forestry Research Institute of Sweden) is the central research body for the Swedish forestry sector, and is financed jointly by the government and the members of the Institute who include most of the major manufacturers of forestry equipment. Skogforsk has funded a KTH research initiative intended to help improve the suspension of forestry machines with the goal of achieving significant productivity improvements. But improving the design of forestry machines using conventional methods is very expensive and time consuming. It can easily cost millions of dollars to build a prototype and test it in remote logging regions. KTH's mission is to streamline the design process by validating the capability to simulate the operation of forestry machines under real-world operating conditions.

Most current forwarders on the market have articulated steering and are equipped with bogie suspension systems. Bogies serve as a mechanism for averaging and smoothing the path of the center of gravity of the vehicle when it encounters obstacles in the terrain but with bogie suspensions the only damping is provided by the tires. Thus severe limitations exist on the speed with which bogie machines can be driven without generating excessive vibrations in the cabin and

causing soil damage. One alternative that is being considered is a pendulum suspended system in which each wheel is independently mounted on a link arm that is mounted on a revolute joint on the main frame. Usually a hydraulic cylinder is mounted between the arm and the frame to provide vibration damping and potentially also a leveling function.

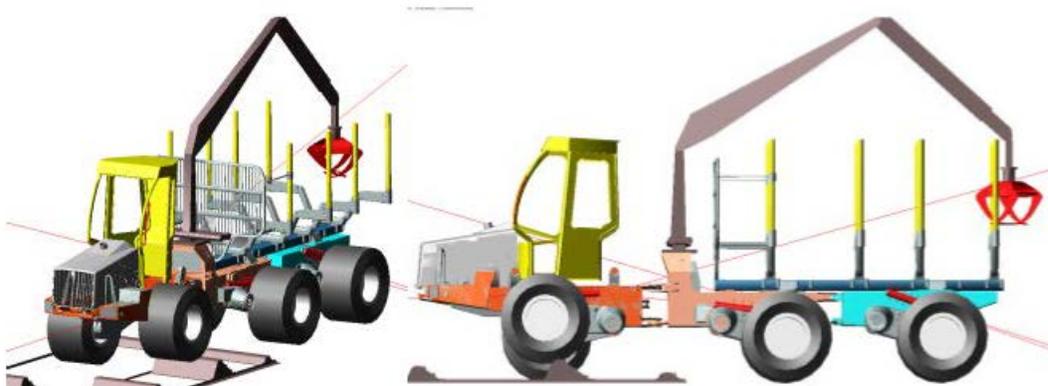
A prototype of a fully suspended six-wheel prototype was recently manufactured and assembled. This pendulum arm suspended forwarder prototype will serve as a demonstrator of suspended logging machine technology and a research tool for active control and automation. A pendulum suspension enables all wheels to adapt individually to the terrain, making it easier to pass over large obstacles with good ride comfort. In addition, a pendulum suspension can be upgraded to an active system. KTH researchers were asked to simulate the new forwarder and validate the ability of the simulation to accurately predict its performance under realistic operating conditions.

### Solution/Validation



Adams model and the physical test model of traditional forwarder

KTH researchers used MSC Software's Adams to model three different suspension concept configurations. The first is a standard Komatsu bogie forwarder with the wheels mounted on four bogies. The second configuration is a six-wheel machine with rear bogies and pendulum suspension for the two front wheels. The front and rear frames are connected with a roll joint and an articulation joint so they cannot move vertically relative to each other. A variant of the second configuration has an additional linkage between the middle joint and front frame to enable the front frame and cabin to move vertically relative to the rear frame. The third configuration is a six-wheel vehicle with all wheels individually mounted on separate pendulum arms.



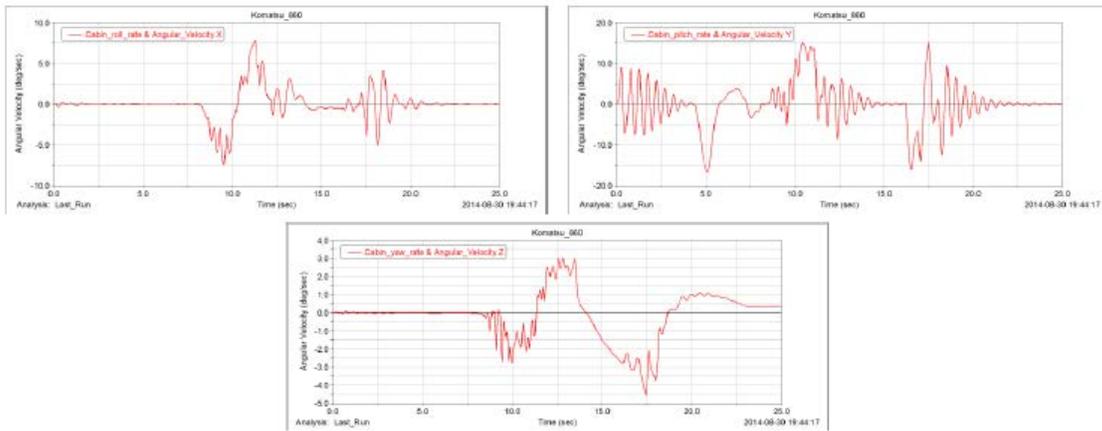
Simulation of forwarder with pendulum arm suspension going over obstacle



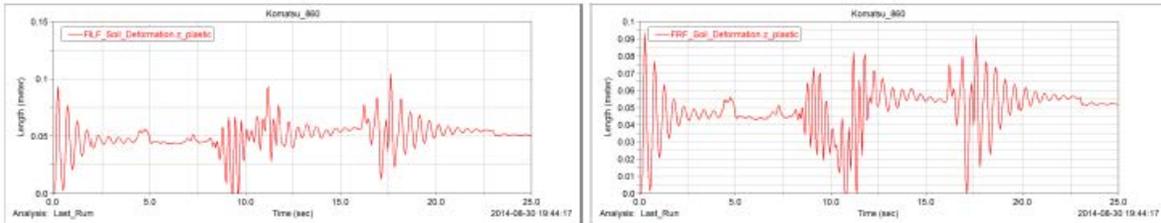
Real forwarder undergoing bump test on proving ground



Adams model simulating the same bump test

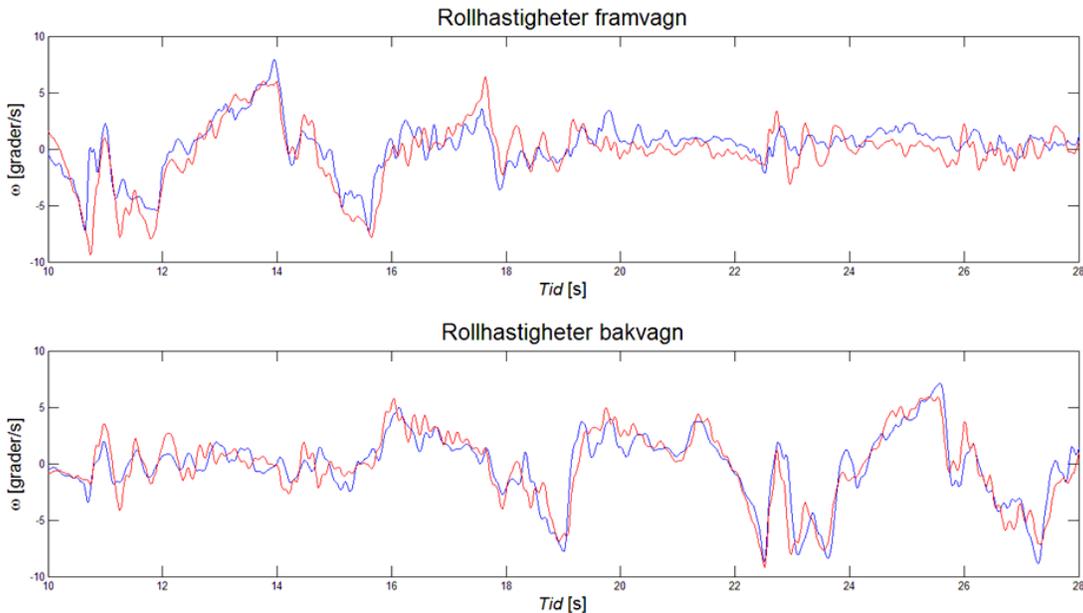


Cabin angular velocity in the roll, pitch and yaw



Plastic soil deformation at the front wheels

The CAD model with the dimension and mass parameters of a popular industry forwarder was imported into Adams. Three variants of the model were developed and simulated on a representation of the standard Skogforsk hard ground test track. FTire was used to model the tires based on regular tire properties such as diameter and inflation pressure. Adams calculated the wheel forces, joint forces, displacements, velocities and accelerations on the test track. The time history responses were imported to Matlab and transformed to the frequency domain for further analysis. The performance of each concept was analyzed and its performance in terms of operator comfort and impact on the soil were estimated relative to the performance of the traditional forwarder. The relative values were defined in such a way that higher values indicate higher performance. The vehicle with the pendulum suspension performed substantially better than all of the other configurations. The simulation results for the traditional forwarder and pendulum suspended forwarder were compared to the existing prototypes and both provided a very good match.



Comparison between roll rate predicted by simulation (red) and measured during testing (blue) for front wagon (top chart) and rear wagon (bottom chart) of forwarder

## Results

“Now that we have validated the ability of Adams to accurately simulate the performance of forwarders, we will be able to evaluate new design alternatives and optimize the performance of concept configurations in a fraction of the time required by the build and test method,” Ismoilov said.

“The ability to evaluate more designs in less time will make it possible to optimize the suspension and other components of the vehicle in order to provide higher productivity without causing discomfort to the operator or damage to the soil.”

### **About Royal Institute of Technology**

KTH Royal Institute of Technology in Stockholm is the largest and oldest technical university in Sweden. One-third of Sweden’s technical research and engineering education capacity at university level is provided by KTH. Times Higher Education (THE) ranks KTH as the 126<sup>th</sup> best university in the world, the 52<sup>nd</sup> best university in Europe, 13<sup>th</sup> among purely engineering and technology universities in the world and 6<sup>th</sup> among purely engineering and technology universities in Europe.