

# Tracked mechanism simulation of mobile machine in MSC.ADAMS/View

J. MATEJ

*Department of Forest and Mobile Technology, Faculty of Environmental and Manufacturing Technology, Technical University in Zvolen, Zvolen, Slovak Republic*

## Abstract

MATEJ J., 2010. **Tracked mechanism simulation of mobile machine in MSC.ADAMS/View.** Res. Agr. Eng., 56: 1–7.

Tracked travel mechanism is, in some cases, a significant alternative of wheeled travel mechanism. A suitability of application depends on particular work conditions, which opens the space for computer simulation. This paper is focused on possibilities of tracked vehicle simulation in MSC.ADAMS; mainly in the universal module MSC.ADAMS/View, which is not especially customized for tracked vehicle simulations. The study presents a concrete example of tracked vehicle simulation and a method of its successful realization during travel through terrain obstacle as a basic manoeuvre for evaluating of chassis properties and work ergonomomy.

**Keywords:** tracked mechanism; tracked vehicle; MSC.ADAMS/View; dynamics of movement; simulation; chassis; work ergonomomy

MSC.ADAMS software package is focused on dynamical simulation of mechanical systems. It consists of core packages and extending packages. ADAMS/View package is the core package for visual modeling of general mechanical systems. Other packages are more closely focused on specific area of mechanical systems, e.g. rail vehicles, airplanes, cars, etc. There is no present package for modeling the tracked vehicles, but there is possibility to buy ADAMS Tracked Vehicle (ATV) Toolkit, which can solve almost all the problems with tracked vehicle simulations. However, it is a commercial product without education license option so its purchase should be profitable. If there is a need to perform only a few simulations, or the purchase of ATV is not profitable, the only solution is to use the basic ADAMS/View environment. This study describes some used methods of simulation and also describes in short ATV Toolkit for comparison.

Other published papers describe the use of MSC. ADAMS for tracked vehicles but without description of tracks (KÁRNIK 2006). The paper mentions a possibility of simulation of the whole robot with tracks and terrain and possibility to investigate a stability of the robot. Many papers employ ATV for tracked vehicle investigation; yet there are only several papers which use ADAMS/View (MADSEN 2009), but without a particular description of the method to use ADAMS/View for successful tracked mechanism simulation.

## MATERIAL AND METHODS

ATV Toolkit (Fig. 1) is a product of Swedish MSC Software group (MSC Software, Västra Frölunda, Sweden), developed by Mechanical Dynamic Sweden AB, Malmo. It allows creating, modifying and

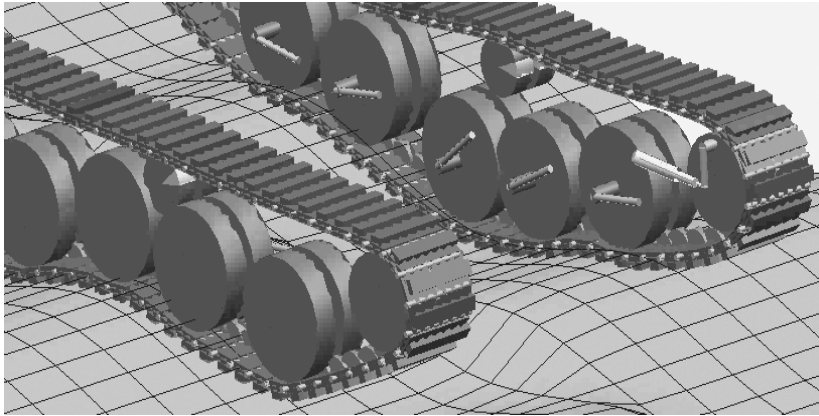


Fig. 1. Tracked vehicle model in ATV Toolkit

simulating realistic spatial models of tracked vehicles in the ADAMS environment. It is usable for a wide range of applications. ATV environment allows creation of tracked vehicle models in graphical user interface, it uses an assembly routine that automatically wraps the track segments around the wheels, free-form design of sprocket teeth, and a lot of other functions and algorithms. The key feature, from the author's point of view, is that a model of tracked vehicle is created through a user database, which contains all necessary input information to create and modify the model.

MSC.ADAMS/View is the core, general tool for modeling the common mechanisms and it has not special tools for tracked mechanisms, as mentioned above; general tools therefore have to be used for model creation and evaluation of results.

A basic model must contain at least wheels, track segments and terrain. A terrain can be created with polyline tool, extruded to a third dimension and locked to ground. Within a non-optimized case (from point of view of time needed to perform simulation), the simplest solution is to use solid-to-solid contacts, which must be defined between

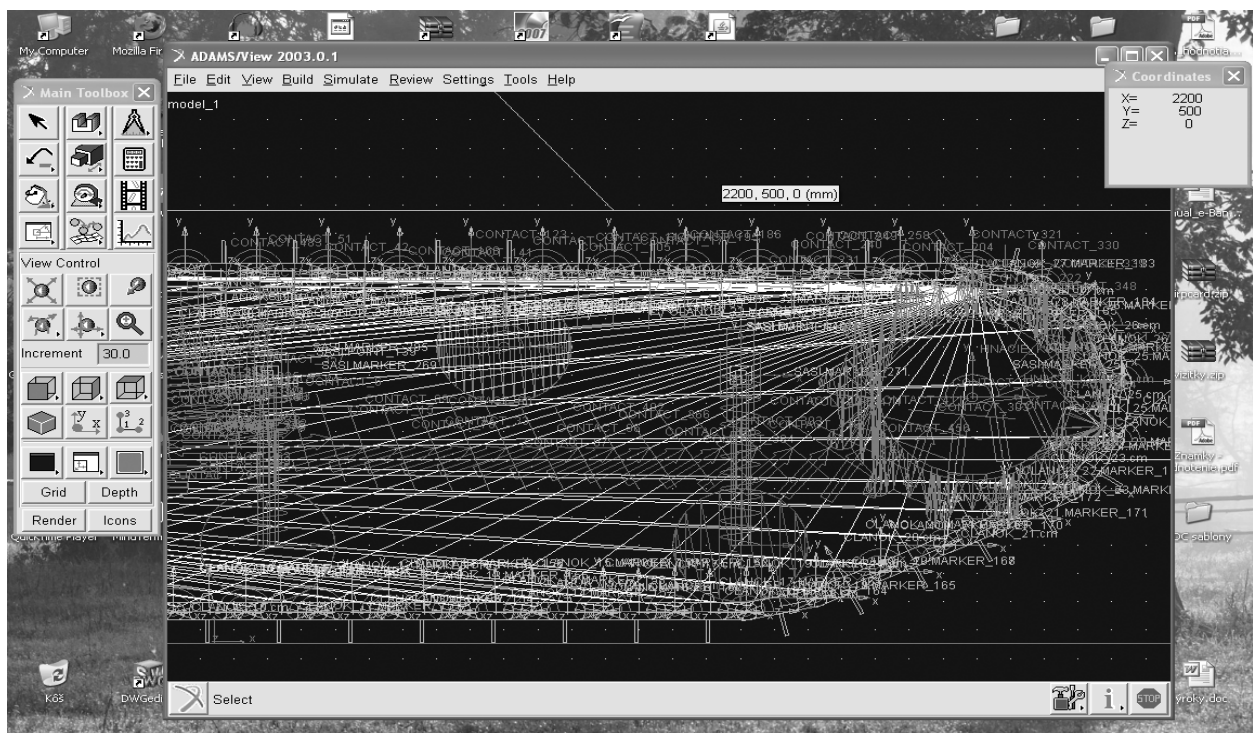


Fig. 2. Hundreds of contacts in MSC.ADAMS/View. Each track segment has defined contact with each wheel and terrain (web of lines)

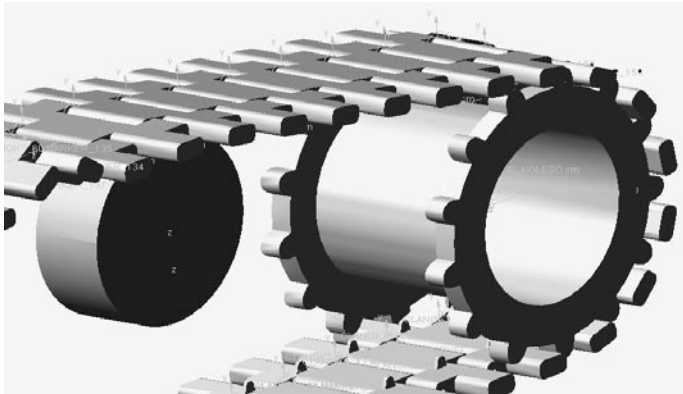


Fig. 3. Tracked mechanisms in ADAMS/View environment. Sprocket wheel and track segments are created in SolidWorks. The track at figure freely wraps around wheels

track segment and all wheels and terrain, for all track segments. That gives us approximately some hundreds of contacts (Fig. 2).

Track segments and wheels can be created with ADAMS/View modeling tools or they can be imported from CAD system, e.g. SolidWorks. The use of View tools seems to be better solution from point of view of time needed to perform simulation, while the import provides more possibilities (in comparison with ADAMS v.2003 Full Simulation Package). All of the elements of a model must be placed manually on their position, especially track segments must be wrapped regularly around the wheels. Within simulations described below we used planar joints to restrict motion of track elements and whole vehicle, too. From the point of view of vehicle's drive there are at least two possibilities. As it can be seen at Fig. 3, the first option is to create all parts of model within CAD software, e.g. SolidWorks. Especially a sprocket wheel and track segments must be designed carefully, because it has

a direct influence on the success of simulation. A power drive is realized through motion of sprocket wheel. As mentioned above, the contacts have to be defined for each track segment and terrain and for each track segment and all wheels. We created contacts between track segments and wheels as frictionless and all wheels except sprocket wheel were fixed to frame directly or via spring-dumper, and the contacts between track segments and terrain were created to employ coulomb friction force. A second option is a simplification of the first one. There is no sprocket wheel and all wheels are fixed to frame directly or via spring-dumper (Fig. 4). This approach is suitable for dynamic analysis mainly, e.g. accelerations of a machine at driver's place, design of spring-dumper elements and kinematics of tracked mechanism from the point of view of travel properties. The movement of vehicle is realized by single force with Step function, as it can be seen below. This approach is better for simpler solution by solver.

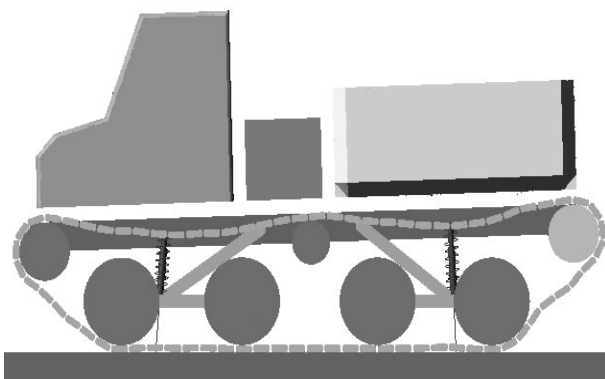


Fig. 4. Tracked mechanism of forest machine in ADAMS/View environment. There is no sprocket wheel and track segments are created in View environment only

## RESULTS AND DISCUSSION

For simulation, only general tools are available, mainly those involved in ADAMS/Postprocessor. The author of this contribution has no experience with the ATV Toolkit. In this scope, the modeling of tracked mechanisms seems to be a little problematic, mainly from the point of view of solver settings. When Pentium 4 system (3 GHz, 1.5 GB RAM) was used, the time spent for computation by solver varied from one hour up to twenty hours. In the case of forest machine model (Figs. 4 and 6) average computation time was fifty min; however, there was no sprocket wheel, which significantly increases computation time.

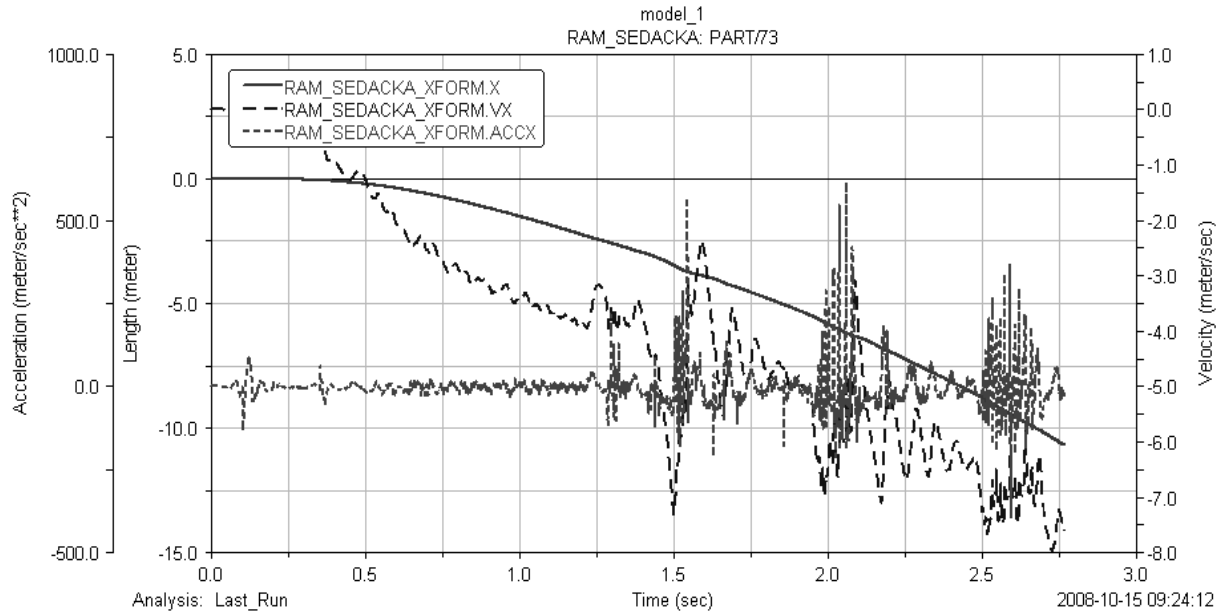


Fig. 5. Investigation of tracked vehicle dynamics. Line charts for point at driver’s seat in horizontal direction. Charts in order of appearance in legend: position, velocity, acceleration

A valued possibility is that we can successfully import geometry of a model from CAD software. We encountered no problems when the Parasolid was

used as file format for export of the models from SolidWorks, but it seems probable that it might increase computation time a little. A detailed method

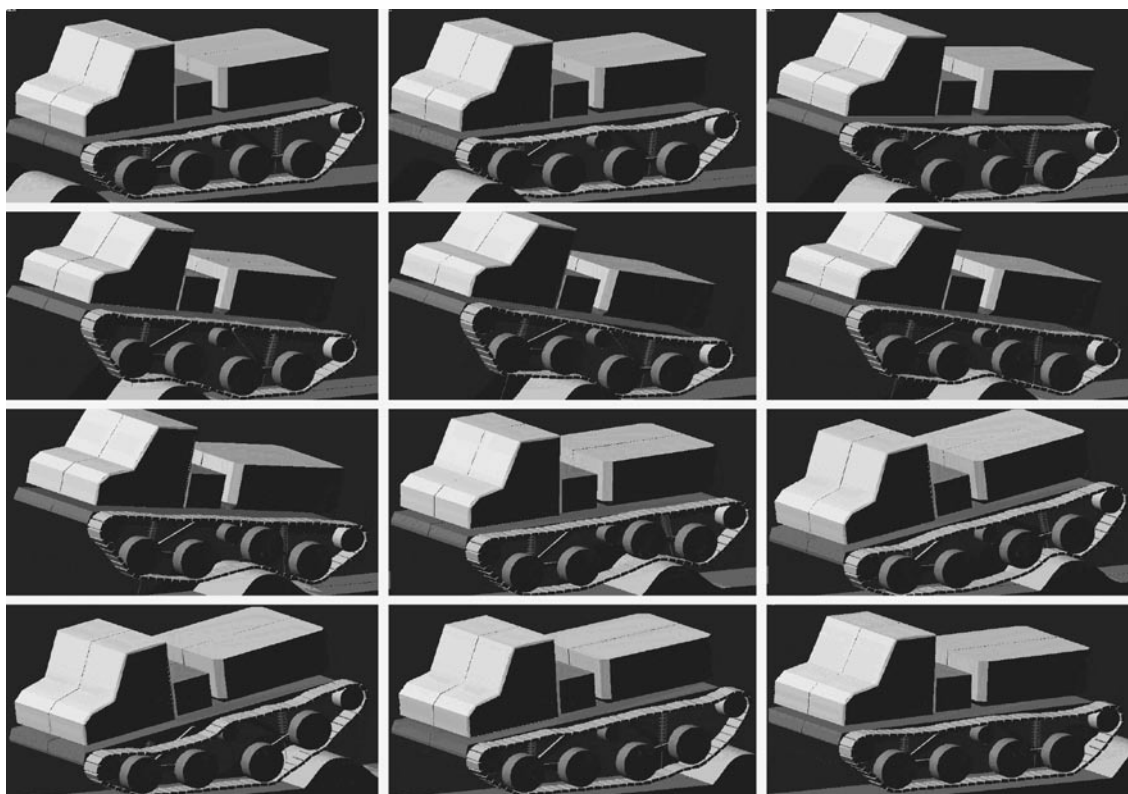


Fig. 6. Tracked vehicle during travel through obstacle

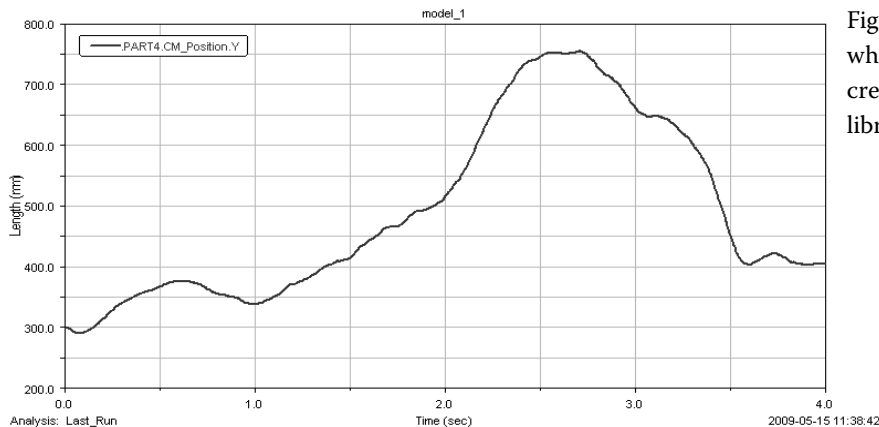


Fig. 7. Tracked vehicle with sprocket wheel drive and tube frame. Model created in SolidWorks, with imported library parts

of import is described in multimedia texts of Technical University of Ostrava (VŠB), Czech Republic (KÁRNÍK L.).

An evaluation of the results can be done with ADAMS/Postprocessor (Figs. 5 and 9), which displays the results and parameters of a model. All possibilities are the same for any type of model. Except of Postprocessor, a visual evaluation can be used for vehicle motion evaluation, of course. The Figs. 6 and 8 show results as video frames captured from AVI video created by Postprocessor.

Very important is also the fact that a simulation of tracked vehicle in ADAMS/View is possible at all and tracked vehicle model can be analyzed like any other dynamical model, as shown at Figs. 5, 6, 8 and 9.

In consideration of ATV purpose, we must state that the use of ADAMS/View for tracked vehicle investigation is limited, yet it may be only a subjective view. On the other side, this way of solution gives us a full control over the simulation. As described above, we have to create all parts of the mechanism, add all joints and contacts, step-by-step. A main weakness of modeling in ADAMS/View are thus contacts, especially their number. The main result is that ADAMS/View can be fully used for solution of tracked vehicle problems, focused mainly on vehicle dynamics, e.g. travel through obstacles. As for the possibility to import models created with CAD software packages, it enables to create very realistic models of tracked vehicles. One example of a more detailed vehicle is shown at Figs. 7, 8 and 10, created in SolidWorks, where frame and seat are created without significant simplifications. The model was created in order to test the use of sprocket wheel for drive of the model. We created many models with sprocket wheel drive and based on the results we can say that proper geometry is essential. We do not need to design the whole shape, but at least a right

diameter of sprocket wheel must be set up with respect to integer count of teeth, axial pitch of track segments and possible lock or leap of mechanism.

The method and results in this paper are based on a natural approach of modeling. We tried to realize simulation without simplification as truly as it was possible in the View environment. Other authors, e.g. SOLIS and LONGORIA (2008) modeled tracks by a set of longitudinally cascaded and closely spaced wheels that are all connected to the main body via revolute joints, with drive on the end wheel and other wheels propelled via coupler joint, without real track segments. On the other side the studies were published that employ ATV Toolkit and contain many details. Tracked vehicle model created by LI and ZHONG (2005) contains full-detailed tracks, with sprocket, road-wheels, spuds and virtual seabed terrains of flat topography, an obstacle, a trench and a slope. PINHAS et al. (2007) describes simulation of a tracked hybrid mobile robot. He used Parasolid file format for import of parts from

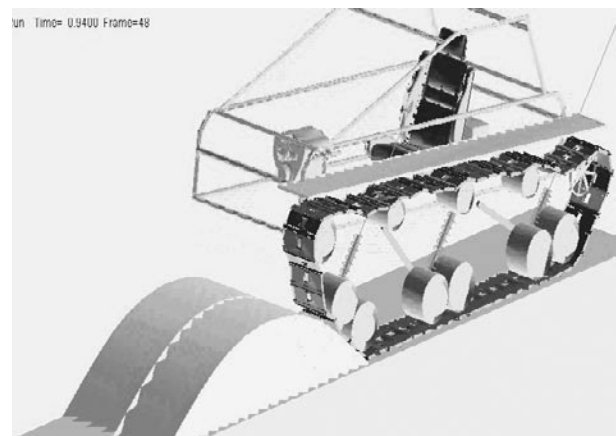


Fig. 8. Tracked vehicle with sprocket wheel during travel through obstacle

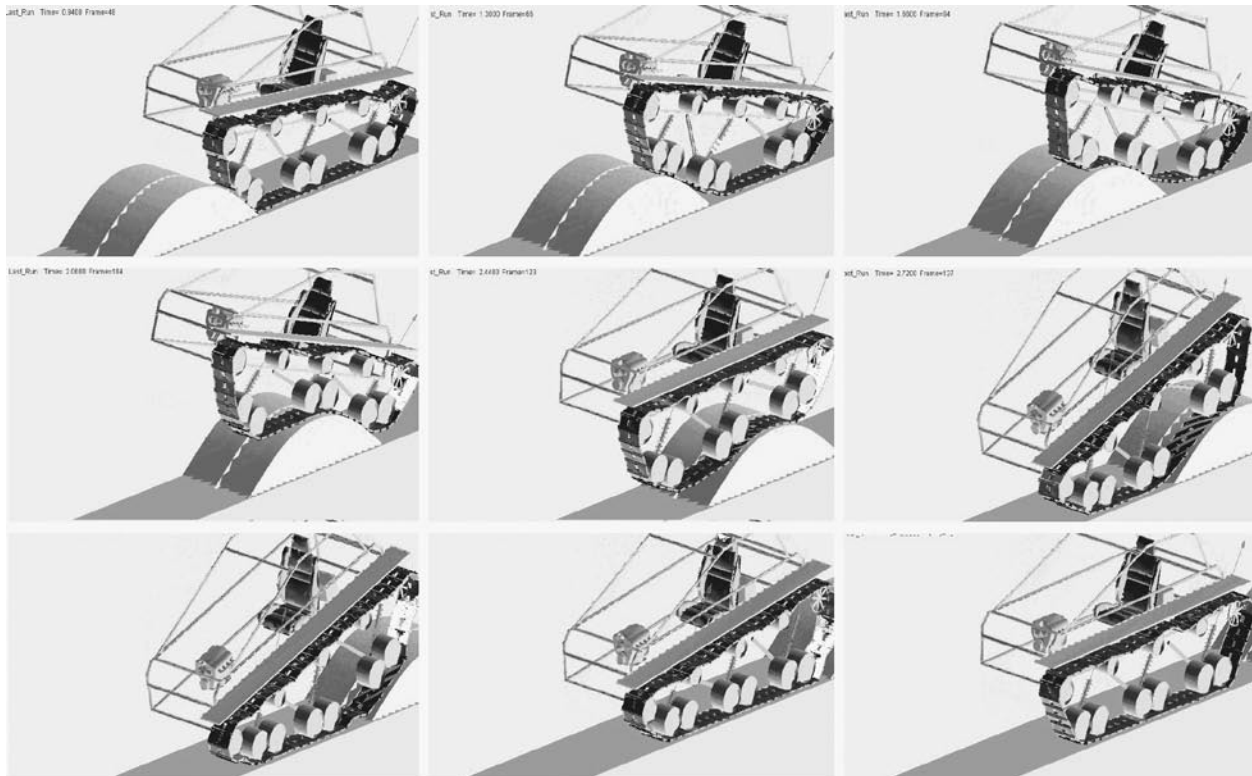


Fig. 9. Results of tube frame-tracked vehicle model simulation in the form of vertical position of driver's seat during travel through obstacle

CAD software and he fully employed ATV Toolkit for creation of model with 178 parts, 888 degrees of freedom, 41 joints and 1,579 force and contact elements. He emphasized that in this way, the design variations and changes were analyzed faster and at a much lower cost than physical prototype testing.

However, ATV is only an extended and specialized View environment. Within the pure View environment, useable studies can be performed, too; in scope of this paper it was focused on travel through an obstacle (Fig. 10), which shows effect of higher speed (Fig. 10a), and effect of too big axial pitch of track segments that resulted in visually rattled motion of vehicle (Fig. 10b). A study principally the most similar to this work was published by MADSEN (2007), and it is focused on modeling of a tracked hydraulic excavator simulation within MSC.ADAMS/View. The model consists of five road wheels, one main idler, three support rollers, a drive sprocket, and 45 tracks. The suspension system only consists of a tensioning spring on the idler. The road wheels, support rollers and drive sprocket are all rigidly attached to the undercarriage. Each track is connected to the next one by a single pin rubber bushing, which is a little more faithful solu-

tion than that presented in this paper. There is also a center block that represents a rigid connection to the chassis of the excavator, which is not modeled.

## CONCLUSION

The paper described a use of MSC.ADAMS/View in tracked vehicle simulation, and revealed steps which led to the successful simulation. The basic assumption was that the terrain is rigid. The main benefit of computer simulation of dynamical systems is generally known. Yet, the possibility to run and evaluate dynamical tests of tracked vehicle which does not exist in the real world is imposing. With present-day CAD software it is possible to create very detailed real-like models; after import into ADAMS, they are able to contribute to real and valued results. A utilization of results is given by target of virtual simulation. Within the above described method of simulation, the main contribution for agriculture and forest mobile tracked machines is in the field of investigating chassis properties and setting its optimal parameters, which has a direct influence on travel comfort.

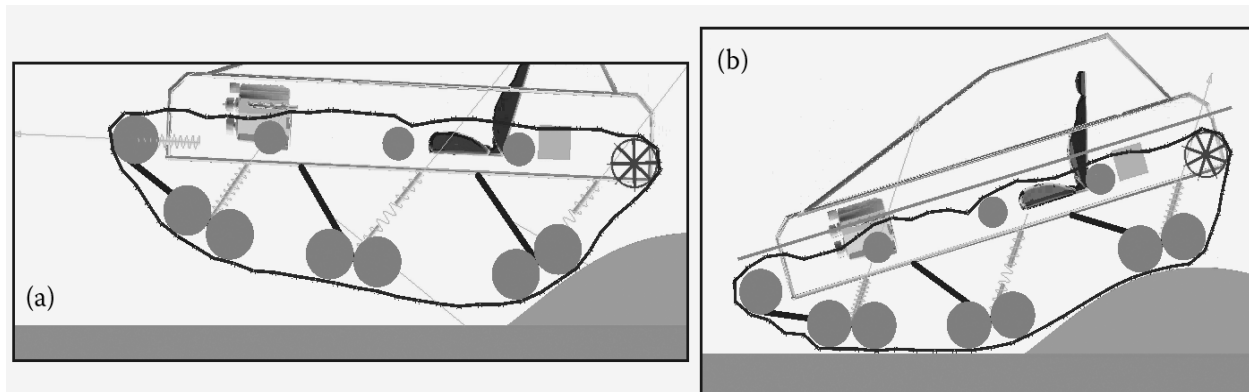


Fig. 10. Tracked vehicle simulation. Jump over an obstacle (a) and visible influence of track segment size (b)

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Received for publication March 19, 2009

Accepted after corrections September 10, 2009

### Corresponding author:

Ing. JAROSLAV MATEJ, Ph.D., Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Forest and Mobile Technology, T.G. Masaryka 24, 960 53 Zvolen, Slovak Republic  
phone: + 421 455 206 555, fax: + 421 455 320 015, e-mail: [matej@vsld.tuzvo.sk](mailto:matej@vsld.tuzvo.sk)