



Laboratory of Computational Mechanics  
Bryansk State Technical University, Russia  
Phone, fax: +7-4832-568637  
E-mail: [um@umlab.ru](mailto:um@umlab.ru)  
Web: [www.umlab.ru](http://www.umlab.ru)

## **Simulation of dynamics of railway vehicles in Universal Mechanism software**

This document is an overview of accumulated experience of using Universal Mechanism (UM) software in railway industry. The list of UM users, applied researches and the comparison with other software are considered.

### **List of users**

Below you can find the list of users of Universal Mechanism software from railway industry:

- Russian Railways – the biggest Russian railway operator  
(<http://www.eng.rzd.ru/>);

The meeting that was devoted to “Using Universal Mechanism Software for simulation of derailment cases” took place in headquarters of JSC Russian Railways in Moscow under the chairmanship of the vice-president of Russian Railways on 29th of November, 2007. Representatives of several departments of Russian Railways, VNNIZHT, VNIKTI and other institutes and enterprises took part in the meeting. As a result the decision to recommend Universal Mechanism software as a basic tool for simulation of railway vehicle dynamics and derailment cases was approved.

- All-Russian Railway Design Institute, Moscow, Russia, uses UM for complex problems of safety of railway vehicles, choosing optimal railway wheel profiles, optimal gauge etc.

- All-Russian Locomotive Design Institute, Kolomna, Russia, uses UM during designing of new diesel and electric locomotives;
- State Unitary Enterprise "Production Association "URALVAGONZAVOD", Nizhniy Tagil, Russia - the biggest Russian producer of freight bogies and wagons (<http://www.uvz.ru/eng/>);
- JSC "Metrowagonmash", Moscow, Russia – a big producer of the metro cars and armored trucked vehicles (<http://www.metrowagonmash.ru/english/index.htm>);
- JSC VELNII (All-Russian Scientific Research and Design Institute for electric locomotive building), Novocheerkassk, Russia – the Russian leading design institute of electric locomotives (<http://velnii.ru/velniiAng2.html>);
- Central research institute "TransElektroPribor", St.-Petersburg, Russia – R&D institute, that is concentrated on suburban electric trains and locomotives;
- Central design office of transport engineering, Tver, Russia – the Russian leading design institute for military railway transport, rocket transportation and so on;
- JSC «Kolomna Locomotive Works», Kolomna, Russia;
- JSC "Bryansk Machine Building Works", Bryansk, Russia;
- State R&D Center of Railway Transport, Kiev, Ukraine;
- "INKA - Indonesian Railway Industry", Indonesia – the Indonesian biggest producer of electric locomotives, passenger coaches and freight wagons (<http://www.inka.web.id/>);
- Vossloh Spain, Spain - as Europe's leading manufacturer, "Vossloh Spain" company designs and builds locomotives as well as passenger trains (<http://www.vossloh-espana.com/>);
- Moscow State University of Railway Engineering ("Locomotives" and "Cars" departments), Moscow, Russia;
- Bryansk State Technical University, Bryansk, Russia;
- Far-Eastern State University of Railway Transport, Khabarovsk, Russia;
- Irkutsk State University of Railway Transport, Irkutsk, Russia;

- Russian State Open University of Railway Transport, Moscow, Russia;
- Ural State University of Railway Transport, Ekaterinburg, Russia;
- Samara State Academy of Railway Transport, Samara, Russia;
- Rostov State University of Railway Transport, Rostov-on-Don, Russia,
- Silesian Technical University, Katowice, Poland,
- Seoul National University, Seoul, Korea,
- The University of Tusla, Tusla, USA.

Laboratory of Computational Mechanics carried out the following researches with the help of Universal Mechanism software.

- Specialists of All-Russian Research and Design Railway Institute and Laboratory of Computational Mechanics developed a library of UM-models of locomotives. The library includes models of 17 locomotives and is aimed for carrying out complex researches of its dynamics and especially safety analysis. Only two months were required to develop the models due to new advances technologies implemented in Universal Mechanism.
- Parametrical optimization and dynamical analysis of automobile carrier car for JSC “VKM-Engineering”, 2006.
- Series of applied researches of three-piece bogies (23.5, 25, 27 ton per axle) for Russian biggest producer of freight cars, 1999-2008.
- Dynamical analysis and optimization of parameters of newly designed locomotives TA25, TA35 for "Bryansk Machine Building Works", Bryansk, Russia, 2001-2004.
- Dynamical analysis of alternative freight three-piece bogie for All-Russian Locomotive Design Institute, Kolomna, Russia, 2001.
- Series of researches which is devoted to derailment cases due to wheel climbing and its reasons for All-Russian Railway Design Institute, 2001-2007.
- Dynamical analysis and choice of optimal parameters of electric locomotives EP2 for JSC «Kolomna Locomotive Works», Kolomna, Russia, 2004.

- Applied research for obtaining optimal wheel profile for freight cars from point of view its stability and wear factor for All-Russian Railway Design Institute, 2003.
- Research of dynamical behavior of running gears and optimization of electric locomotive 2EC4K for All-Russian Locomotive Design Institute, Kolomna, Russia, 2004.
- Development of tribology models for rail and wheel wear prediction for All-Russian Railway Design Institute, 2005.
- Stress load and durability analysis of long-wheelbase flat cars for Russian Railways, 2006.
- Optimal repair rail profiles for preventive rail grinding and its life time prediction for All-Russian Locomotive Design Institute, 2001-2008.
- Number of examinations of derailment cases, 2003-2008.
- Development of refined mathematical model of safety factor for All-Russian Railway Design Institute, 2004-2006.

Totally more than 40 models of railway vehicles were developed. You can find some of them in the list below: TEP70, TEP80 locomotive for Kolomna Locomotive Works, 1993, 2004; AC4 railcar, 1993; 120-ton eight-axle tank car for Kolomna Locomotive Works, 1995; TE116 diesel locomotive, 1995; freight car with three-piece bogie, 2001; TEM21 yard locomotive for Bryansk Machine Building Works, 2002; diesel suburban train DR1 by “Railway cars” department of Bryansk State Technical University, 2003; metro car of 81-717 model and tram of 71-608 model, 2003; electric locomotive VL80, 2003; Polish sleeping car 152A, 2004; ChS2, ChS4, ChS6, ChS7, ChS8, ChS200 electric locomotives, 2006; ChME3 yard locomotive, 2006; VL10u, VL15, VL60, VL65, VL80, VL85, EP10 electric locomotives, 2006; freight car with Y25 bogie, 2007 etc.

Several electro-dynamical models that incorporate accurate dynamical and electrical parts of electric locomotives were created in cooperation with South-Russian State Technical University, Novocherkassk, Russia.

UM model of three-piece bogie is quite popular among researchers in the field of freight car dynamics. The full parameterized model allows obtaining any specific bogie by simply changing parameters of the model.

### **Scientific potential**

The following post-doctoral and doctoral thesis were implemented in or prepared with the help of results obtained in Universal Mechanism software: Pogorelov [10], Kossov [6], Pavlukov [9]; Dmitrochenko [1], Yazykov [13], Zagorsky [4], Selensky, Galichev [3], Kovalev [5], Mikheev [8] and others.

Scientific researches of Laboratory of Computational Mechanics have been supported by Russian Foundation for Basic Researches for already 10 years. For last 5 years more than 50 papers were published by researches of members of the Laboratory.

### **Software verification**

A number of field and test bench experiments were fulfilled by independent researchers. Sakalo and Kossov in [6, 12] considered dynamics of a TE116 locomotive and drew a conclusion that "... satisfactory convergence of theoretical and experimental values of all considered features are achieved. The divergence between results of computer simulation in UM and field experiments does not exceed 15 %."

Pavlukov and others ran test bench experiments with a freight three-piece bogie. The convergence between results of numerical simulation and test bench experiments within 10% bounds is obtained, [11].

So called Manchester Benchmarks were published in 1998 and include prototypes of passenger and freight cars. Results of simulation of test cars from Manchester Benchmarks are now available for most of commercial software (ADAMS/Rail, MEDYNA, GENSY, NUCARS, SIMPACK и VAMPIRE) and published in [14]. Results of Manchester Benchmarks for Universal Mechanism software are available in [7].

## **Key features of Universal Mechanism software**

Let us consider the contrastive analysis of Universal Mechanism software and other software for simulation of railway vehicle dynamics. Universal Mechanism has the following key features.

- Effectiveness of numerical simulation. UM software is extremely fast one, according to Manchester Benchmarks it is up to 10 times as faster than analogues.
- UM allows full parameterization of its models. It helps an engineer to significantly increase effectiveness and reliability during model analyzing.
- Generation of equations of motion in symbolic form. For complex models with many degrees of freedom it helps to accelerate numerical simulation up to 30-50% in comparison with numerical generation.
- Animation of motion during numerical simulation. In other programs numerical simulation goes first and only after that a user can have a look at plots and animations. That is quite inconveniently especially on the stage of model testing and checkout.
- UM has unique modules that are oriented to railway industry: modules for longitudinal train dynamics UM Train / UM Train 3D, module for railway wheel and rail wear prediction.
- Accurate model of three-piece bogie has frictional wedges introduced as separate bodies that significantly increases precision of results of numerical simulation.
- UM has a direct interface with the most of popular CAD-programs that accelerates the creation of model.

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