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Software and Hardware Simulators for Train Drivers Training: Overview of Possibilities and Effects of Application

***Abstract**. The task of mastering and improving practical skills is one of the most difficult tasks in the process of education and training of specialists in any brunch of industry. Thanks to the rapid development of computer and information technologies, this problem could be solved through the use of multimedia simulators realised using software simulators or by application of hybrid simulators using the equipment of a real train. The paper describes the possibilities of training drivers and students to effective driving modes of train using the developments of universities.*

Streszczenie.** Zadanie opanowania i doskonalenia umiejętności praktycznych jest jednym z najtrudniejszych zadań w procesie edukacji i szkolenia specjalistów w dowolnej branży. Dzięki szybkiemu rozwojowi technologii komputerowych i informatycznych, problem ten można rozwiązać poprzez zastosowanie symulatorów multimedialnych realizowanych za pomocą symulatorów programowych lub przez zastosowanie symulatorów hybrydowych z wykorzystaniem wyposażenia prawdziwego pociągu. W pracy opisano możliwości szkolenia maszynistów i studentów w zakresie efektywnych trybów jazdy pociągów z wykorzystaniem opracowań uniwersytetów. (**Komputerowe i sprzętowe trenażery do szkolenia maszynistów pociągów: przegląd możliwości i efektów wdrożenia)

Keywords: train drivers training, train simulator, hardware system, effectiveness
Słowa kluczowe: szkolenie maszynistów pociągów, symulator pociągu, system sprzętowy, skuteczność

Introduction

The success of railway transport operation depends on the professionalism and specific contribution of each employee and their attitude towards the work, so teaching and advanced training are a key to the success and development of the industry to meet the needs for safe and high-quality rail transport, ensure effective functioning, create conditions for increasing competitiveness [1, 2]. The main goal of modern professional education is to train a qualified specialist who is competitive in the labour market, capable of effective work in specialty at the level of world standards, ready for continuous professional growth, social and professional mobility, who has the necessary level of professional competence. Therefore, there is a need to modernise vocational and technical education, introduce new technologies and tools into the educational process. The use of information technologies in the field of education makes it possible to increase the efficiency and intensity of training, reduce the time and cost of training specialists, and qualitatively test the quality of the knowledge and acquired skills [1-5]. This could be achieved by conducting training in a virtual environment as close as possible to the process of real operation.

At the same time, today a lot of educational institutions are faced with the problems that reduce the effectiveness of students' acquisition of practical skills:

• universities are often limited in their ability to provide students with equipment, materials and other means by which a student would acquire practical skills, while assimilating previously obtained theoretical knowledge;

• the volume of practical lessons devoted to master the disciplines becomes very limited, as a result of which the transience of laboratory work does not allow students to have time to comprehend the research;

• carrying out laboratory work on full-scale installations is accompanied by corresponding operating costs, the main item of which is usually the cost of electricity.

Due to this, the main goal of the paper is to overview main software and hardware simulators used in the universities and effects of their application on the mastering of practical skills in the process of education and training of specialists.

Types of training simulators

Currently, the simulator complexes are widely used in education and industry. Traditionally, they are supplied by manufacturers of traction rolling stock, but also are produced by different educational organisations.

Generally, the train driver simulators could be divided by their purpose and design into three following groups [5]:

• narrowly functional (procedural),
• specialised,
• complex,

or by the type of construction [6] the next simulators exist:

• cabin simulators with a motion mechanism (full-range),
• cabin simulators without a motion mechanism,
• desktop simulators,
• compact simulators,
• software simulators (games).

The *procedural simulators* work out the issues of studying the basic theoretical principles of electric traction (train forces, resistances to train motion, train characteristics, profiles of the route, energy consumption etc.), but also design of the locomotive and its units, study the location of instruments and devices, troubleshooting the locomotive, actions when accepting the locomotive and other issues of initial training. This group includes the simulators described in [7-11]. The *specialised simulators* are used to teach and train the fulfilment of individual tasks of professional activity (rational train management, energy efficient traction modes [12-15], brake control, actions in the event of emergency situations). And finally, the *complex simulators* provide individual or group training of locomotive crews in full scope of job duties in conditions as close as possible to real ones. The last two groups include the simulators described in detail in [16-20].

[4] describes the possibilities of developing of different skills and tasks in case of modern and traditional train driving, developing of tracking skills on railways basing on simulators which allow to perform systematic analysis of the issues of rail human factor.

[6, 18] present the conception of a modern simulator for drivers of rail vehicles and describe training program, examine sceneries, dictionary and concepts. They also define the formal scope of the methodology exercise, modelling of rolling stock movement in the simulator for trains with different types of locomotives and different routes. Another project described in [16, 17] is concentrated on designing of train driver desk simulator for university and, accept of mentioned above functions, the simulator

includes the tools for implementation of various modifications in the equipment of the train, study principles of microcontrollers' programming which makes wider possibilities for educational organisations in training of the future specialists.

The authors of [19] describe the user-centered development scheme for creation of high-standard train simulators based on 12 principles.

Let us describe in detail chosen simulators development in our universities for training students and train crew.

Software simulator for students

The *Train Vehicle Simulator* (the name in Polish version is "Symulator przejazdu teoretycznego"), shown in Fig. 1, and the *Train Simulation Program* (the name in Polish version is "Program symulacyjny pociągów"), created by *Prof. Adam Szeląg* in Electric Traction Division of Warsaw University of Technology. These simulators are mainly used by the students learning the courses in Electric Traction, Power Supply, Automatics and Control of Transport Systems.

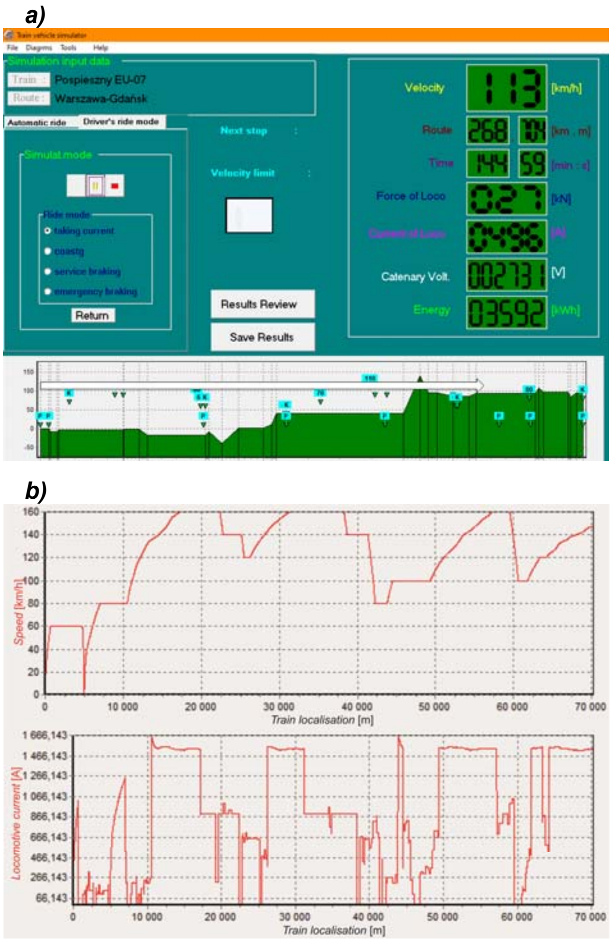

Fig. 1. Train Vehicle Simulator: a) main window, b) diagrams of speed and locomotive current in function of localisation.

The simulators are based on main canonical equations which describe the train motion and allow to chose trains, route parameters (timetable, track profiles) from existing list or input new basing on own data. After inputting the data, the simulation of train driving could be realised in a few ways and the first one is the automatic ride, which can be forced or energy efficient. The second way is the driver's mode (Fig. 1a) in which the student drives the train by himself/herself using the traction, coasting and braking modes. The route parameters include stops, speed limitations etc. which have to be managed in the process of train driving. Results are presented in a graphical way (Fig. 1b) as well as in the table showing all basic parameters allowing to compare the time, speeds, voltages, currents, powers, energies spend for traction and non-traction needs, energy consumption, unitary energy consumption. The second simulator form mentioned above allows to simulate motion of four metro trains. Of course, all mentioned simulators do not show main operations of drivers in the process of real train motion, but at the same time they are enough to understand basic parameters influencing on energy consumption and give basic imagination about principles of train motion for students.

Driver's Training Simulator – software & hardware complex for vocational and technical education

More complex simulator (Fig. 2-4) including software and hardware devices was created by the team of *K. Zhelieznov, O. Zabolotnyi, L. Ursulyak, Y. Chabanuk, A. Shvets, A. Akulov* at Engineering and Design Specialised Department «Microprocessor-Based Control Systems and Safety in the Railway Transport» (EDSD MBCSS) of Dnipro National University of Railway Transport. Main purpose was to create the simulator allowing to train locomotive drivers in the conditions close to real [5, 13]. The simulator consists of two workbenches – for driver with locomotive control panel and for instructor. As it is known, various series of locomotives have different control panels, their controls are functionally similar, but structurally different from each other, thus, for simulators designed for various types and series of locomotives, reuse of the hardware is almost impossible. As for the software part, which includes a train model, a traffic segment model, a train situation management model, a locomotive system operation model, etc., here a lot of models can be reused with minor changes or without them at all.

Fig. 2. Train driver's workbench.

The simulator allows to realise the following:

• to calculate the optimal, in terms of energy consumption, modes of running a train, taking into account the parameters of the train, the section of the track, characteristics of electric rolling stock, speed limits and adherence to the schedule;

• to manage the train situation: the signalling system, the ways of receiving the train at the station, establish obstacles, change weather conditions;

• to simulate the occurrence of the most typical malfunctions in the subsystems of a locomotive, train and signalling system;

• to simulate the operation of the traction, braking and control systems. The operation of these systems is monitored by the driver according to the readings of the instruments and the state of the indication and signalling means;

• to simulate the operation of pneumatic braking systems under various operating modes of the air distributors, including auto and high-speed modes;

• to simulate the longitudinal dynamics of trains and determine the maximum values of longitudinal dynamic forces in a train with accuracy of 10-20 kN and longitudinal accelerations with accuracy of 0.016;

• to determine the train speed with accuracy of 2-3 km/h;

• to determine the braking distance with accuracy of 10-20 m;

• to simulate the movement of a train formed from cars of different types, various workload and several locomotives with the possibility of dispersing them along the length of the train.

In addition, instructor could simulate various inconvenient or dangerous situations on the route, such as train malfunctions, voltage disappearing, interruption in the track circuit of the signalling system, driving the wrong track, obstacle or car accident at the level crossing etc. All mentioned above allow to train drivers in various situations and schedules which are close to real.

a)

b)

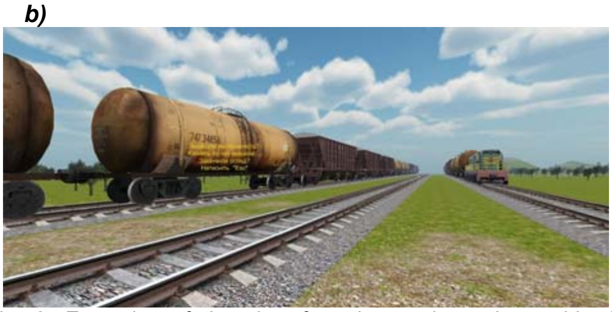

Fig. 3. Examples of the view from locomotive cab on driver's workbench: a) passing of train station, b) inspection of whole train and its elements using the function of outside view with the simulation of broken parts.

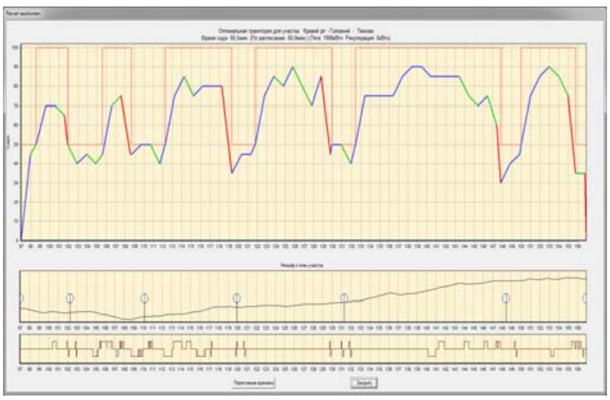

Fig.4. Example view on instructor's work bench with calculation of energy effectiveness of driver operations (upper part), profile and states of light signals (down part) where the blue, green and red lines mean traction, free running and regenerative braking driving modes respectively [5].

Effects and benefits of implementation

When working on the simulator, a student or a driver, applying the existing knowledge, gets an experience very close to work in real conditions, and at the same time there is a process of clarifying and consolidating their theoretical knowledge. It is important that at the same time, students have to be creative in solving the tasks. As a result, not only the skills of working with equipment are developed or the skill of acting according to the required algorithm is formed, but also logical and imaginative thinking, the ability to solve non-trivial problems based on the acquired amount of theoretical information. Thus, in the work on simulators, the processes of obtaining and consolidating knowledge are as close as possible. The following can be noted as the advantages of using simulators (even compared with working on real laboratory stands):

• intensification of learning without losing the quality of mastering the material;

• the possibility of conducting laboratory work by the frontal method (all students simultaneously perform one work), which significantly increases the effectiveness of this type of training;

• the possibility of wide variation of the experimental conditions;

• possibility of modelling and safe research of extreme and emergency operation modes of equipment;

• the possibility of relatively easy and quick modification of elements of the studied equipment to the latest industrial designs;

• significant energy savings are provided in comparison with the use of real laboratory stands, savings in training space, reduction in capital, operating and other costs.

At the same time, the use of train drivers simulators in universities and depots allow:

• to give the basic knowledge about train motion, its construction, operation, main electrical parameters, energy indices etc.;

• to significantly reduce the period of training and retraining of drivers;

• to assess the readiness for independent work as a driver;

• to develop skills for safe and energy-saving modes of driving trains;

• to teach actions in non-standard and emergency situations;

• to develop the skills of operative search and elimination of locomotive malfunctions during the trip;

• to assess the qualifications objectively;

• to certify members of locomotive crews;

• to carry out retraining of drivers to work with locomotives of other series.

Results of students' opinion gathered in form of quizzes, the simulators simplified understanding general theory of electric traction by 20-30% and reduce time spent for self-study approximately twice. Furthermore, in case of professional train drivers the software simulators allowed to increase understanding the dependence of energy parameters, such as energy consumption, from profile, train parameters and driving modes; moreover the hardware simulators gives higher understanding and better numerical results by 40% in comparison with pure software simulators. In addition, hardware simulators allowed to reduce the time speeded for commands and actions (including speed of reaction) with train and its auxiliary equipment twice and all operations stayed to be more clear and correct, especially in emergency situations; at the same time, the number of errors reduced by 8-12%. In case of vocational education of drivers, it was established that depending on individual professional skills, the duration of study could be reduced by 15-25% for training, up to 50-60% in case of retraining or periodic practice of train drivers and their assistants.

As it is known, the significant part of electricity used in industry is spent for railway electric traction. The trains working in different modes and under various loads represent the significant dynamical element in traction power supply system which performs a cyclical transfer and exchange of huge value of kinetic energy, which could be recovered back into traction system or inverted in AC grid. In addition, the correctness and consistency in switching between different moving modes and their regulation significantly influence on energy consumption and, as a result, on total energy efficiency. If in case of traction modes, all of this depend on understanding of the operation and skills; but in case of regenerative baking modes – the drivers frequently try to avoid switching into this mode because of instability, risks and, of course, necessity to perform additional operation.

Described above says about significant potential in training of drivers to correct and energy effective traction and regenerative driving modes. As it is known, the regenerative braking allows to give back in average form 10 to 30% of energy spent for traction and even up to 40-50% depending on type of electric rolling stock. At the same time, the correct train driving in traction mode could reduce the value of spent energy by 10-20%. According to [1], the training of train drivers allow to reduce the total energy consumption from 4 up to 15%, that is 10% in average. In practice, the complex training of drivers allowed to reduce the energy consumption by 1.4-4.7% in a few years.

Conclusions

A modern simulator is a tool for the professional training of students and locomotive crews, which allows to simulate the driver's workplace, the operation of a locomotive and the dynamics of train and locomotive control processes in usual and emergency situations. In comparison with traditional training on operating locomotive, the simulator makes it possible to set and analyse the modes of running a train on a specific serviced section, create abnormal situations in train operation, and also obtain numerous skills that can only be developed on simulators. In addition, the simulators have the ability to ask the driver about abnormal train situations or locomotive malfunctions. The correct and operational skills are developed to eliminate the problems that have arisen.

Simulators for locomotive crews provide high-quality practical training of drivers in rational train driving, they allow not only to simulate situation on the road, but also to conduct a conversation with the driver by showing results extended dynamical and electrical analysis in the process of trip simulation. Such training allows to reduce significantly the energy consumption up to 4.7%.

Simulator training combined with theoretical training in depots and road centres, as well as practical trips to serviced areas, improves the quality of training for drivers and their assistants. All this allows us to make a conclusion about the readiness of a driver for independent work.

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