TESTING TRAJECTORY OF ROAD TRAINS WITH PROGRAM COMPLEXES

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Abstract

The article provides information about using software for determination off tracking and trajectory movement of trucks. It describes experiment of determination of trajectory movement of trucks, using GPS system, to assess the compliance of similar models of the movement of road trains in computer-aided road design systems. Experimental study was conducted using truck KAMAZ 54115 and semi-trailer M 9397 in real road conditions. There are presented and compared results of the study of movement trajectories of road trains with results obtained of the Auto TURN software package application. As a conclusion the use of AutoTURN software package is validated for determining dynamic dimension of cars and for modelling trajectory of movement, not only for road trains, but also for all types of vehicles in the area of their design.

Keywords: truck, GPS system, AutoTURN, trajectory, offtracking, experiment

1. Introduction

In the study of the trajectory and offtracking of the vehicle can be used various methods of field tests [4, 5, 7]. In source [28], the experimental procedure involves the installation of two nozzles on a road train, which spray paint at pressure and, as a result of processing individual points, get a trajectory of movement.

A similar study was conducted by Russian scientist [3]. To record the trajectory in a curvilinear motion, a coloring fluid was used, which was sprayed by special nozzles onto the surface of the coating under pressure. The nozzles were installed in the middle of the front axle of the vehicle and the rear axle of the trailer. According to the author, these methods have a number of disadvantages, among which one should note the low accuracy of measurements in the absence of fixing the vehicle speed and the trajectories of its body points.

Also to study the trajectory of the movement of vehicles on the curves of different radii was applied the method of video [2, 6, 12, 27].

Nowadays, to determine the offtracking of vehicle, it has become possible to use modern research methods using GPS navigation [14-16, 19, 22].

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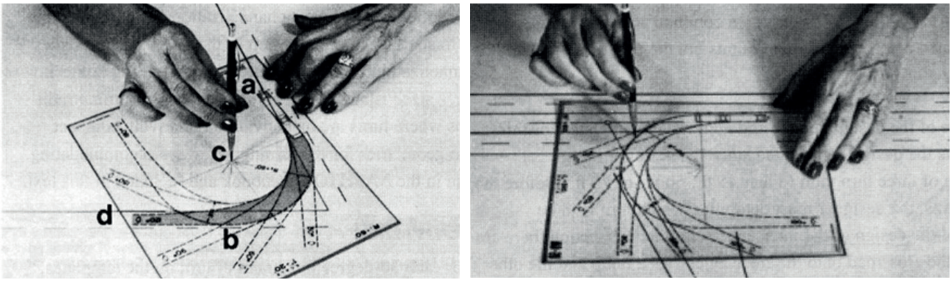

Fig. 1. Using a transparent template to determine the minimum radius of curves in the plan for specified types of cars

Prior to the use of computer-aided design systems, practically the only way to determine the minimum radius of congresses was special transparent templates depicting the dynamic dimensions of road trains at various radii of motion [26]. It is illustrated by Figure 1.

At present, such software systems as Auto TURN (Transoftsolution, Canada), IndorCAD (Russia), AutoTrack (Savoy Computing Services Ltd, United Kingdom), AutoCAD and others can simulate the movement of vehicles on curves in the plan and determine their dynamic size [10, 17, 21]. According to authors [11, 20, 23, 25], these methods are modern and more accurate to determine the off tracking of vehicles.

2. Experiment

To assess the compliance of similar models of the movement of road trains in computer-aided road design systems, we decided to conduct an experimental study to determine the dynamic dimensions of road trains in real road conditions.

For this purpose, we set the task to compare the results of study of movement trajectories of road trains in field experiments with the results obtained of the Auto TURN software package application.

AutoTURN is used to confidently analyze road and site design projects including intersections, roundabouts, bus terminals, loading bays, parking lots or any on/off-street assignments involving vehicle access checks, clearances, and swept path maneuvers. As the vehicle swept path analysis software of choice for transportation engineers, planners, drafters, and architects [8, 9, 18], AutoTURN is used every day. In fact, almost every state DOT in the US and provincial MOT in Canada use AutoTURN making it the defacto standard software of its kind for government agencies [30].

To build the trajectory of the tractor with semi-trailer, it was proposed to investigate satellite navigation equipment. It was assumed that during the experimental process of train, the coordinates of tractor and trailer would be fixed in time. Fixation of the coordinate should allow, based on the developed algorithms, to build a dynamic dimension in the process of movement [13, 24]. Accuracy of construction was achieved due to driver qualification (the requirement of minimum speed with a given intensity of steering wheel rotation), high-precision equipment, recording coordinates, technical conditions of tractor and semi-trailer.

For the experiments, the road train was selected as part of the KAMAZ 54115 tractor unit and the M9397 semi-trailer with dimensions shown in fig. 2 and tab. 1. The parameters and characteristics of the car, in particular the road train, adopted in this work as a subject of research, were determined by experimental and calculated means.

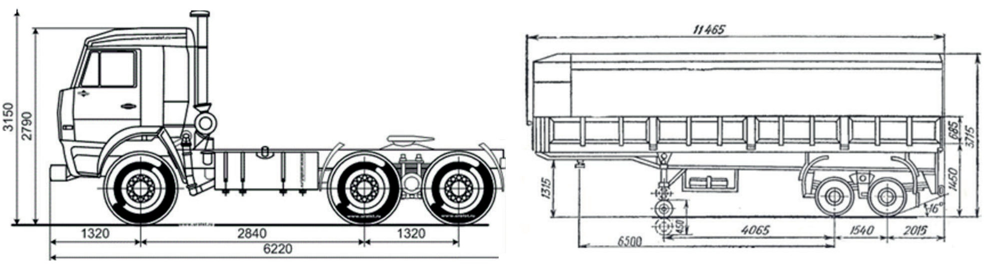

Fig. 2. KAMAZ 54115 with the semi-trailer M 9397

Tab. 1. Technical characteristics of truck KAMAZ 54115 and semi-trailer M 9397

Options	KAMAZ 54115	Semi-trailer M 9397
Length	6220 mm	11465 mm
Width	2500 mm	2500 mm
Height	3110 mm	3715 mm
Allowable travel speed	90 (km/h)	85 km/h

The following equipment was used:

- Netbook;
- GNSS NovAtel DL-V3,
- Rover – OEMV1-G in branded cases,
- Rovers – G3Ant-3AT1,
- Master – GPS-702GG,
- RG58 Cables;
- BP7-12V3 batteries.

Software:

- NovAtel Connect,
- Putty,
- AutoCAD Civil 3D.

The DL-V3 receiver provides real-time measurements and coordinates obtained from the receiver's installation site using both GPS and GPS and GLONASS together. This allows the most beneficial use of the receiver for a variety of its provisions, as well as significantly improves the accuracy of positioning [1, 29]. The DL-V3 receiver receives GPS L2C and L5 signals, and also has the ability to work with the L-band used by OmniSTAR services.

Rover - OEMV1-G is designed to process measurement results and has a full ("all-in-view") 14-channel tracking of frequencies L1 and L2. Both dual-frequency boards carry out measurements using the new L2C civil code. This ensures their full compatibility with new GPS signals.

Highly efficient, compact and lightweight GLONASS + GPS antenna G3Ant-3AT1 is designed specifically for mobile applications. Available with or without a magnetic mount.

Master - GPS-702GG is a GPS and GLONASS antenna with patented Pinwheel technology and a highly stable phase center; designed to determine the location of the coordinates of a point, in this case determine the location of the tractor.

Fig. 3. Interface of NovAtel Connect

Since the GPS-702GG was the main "master", with the help of this sensor it was determined trajectory of the train. That means determined the coordinate location of the sensor in space and time. Two sensors G3Ant-3AT1 determined the angle of the sensors. It means that, these sensors determine the angle between the GPS-702GG path and the G3Ant-3AT1 path. Subsequently, after the mathematical calculation, the length of the points of GPS B and GPS C is determined. In summary, we have a triangle, where GPS A defines the movement trajectory, GPS B and C the length between points (see Figure 4).

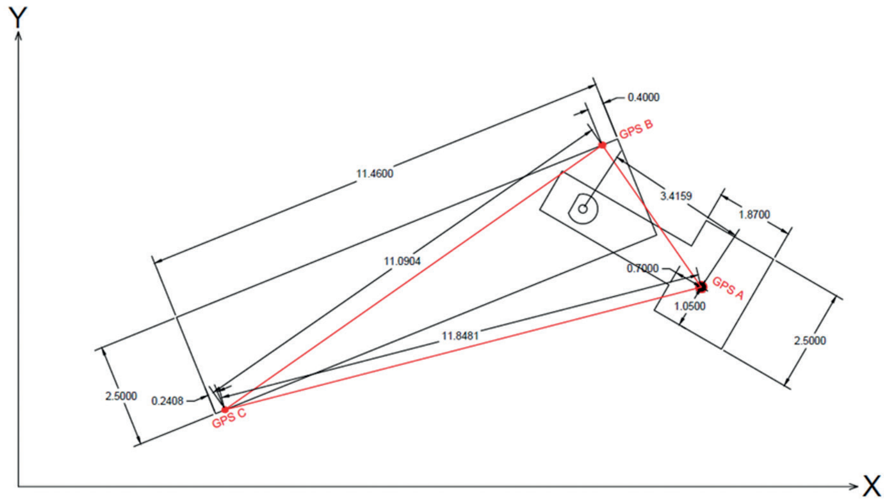

Fig. 4. Location of GPS sensors on the road train

Based on this it was determined the dynamic clearance of the train. After receiving the data on txt and log formats, the results were "materialized". Since we had more than 22,500 values, we had to automate the process. To do this, we used the "screen" .scr format, which allows you to enter data through this format on AutoCAD Civil 3D 2013 and get the location of the points along the coordinates (see Figure 6).

Fig. 5. Installation of receivers on the road train and recording equipment in the cabin

The driver that participated in our research with has 28 years of experience of work on road trains. Recording equipment was placed in the cab of train, the recording of the recorded parameters was performed using the above equipment. The movement of road train on test sites was carried out under steady-state conditions after the acceleration of the tractor to a given speed. In the process of research, calibration of the recording equipment complex was performed.

The study was conducted on a flat area with asphalt concrete pavement, specially prepared for such a maneuver.

Two special GPS navigation sensors G3Ant-3AT1 were installed on the top of the board (Fig.5b), the GPS-702GG sensor was installed in the center of the cabin (Fig.5a). Sensors were installed in a way to cover dynamic dimensions of the road train. The sensors were located as far as possible from each other for more accurate shooting of coordinates. Total number of sensors on the road train was 3 pcs. The frequency of removing the coordinates was 10 Hz. An on-board computer is installed in the driver's cabin to record the signals from the sensors. The experiment was conducted at a speed of 5 km/h, 10 km/h, 15 km/h a turn of 1800. In each speed, the process is repeated 5 times. Experimental data were recorded online. After the data processing by the software, the results were issued in *.txt and *.log formats.

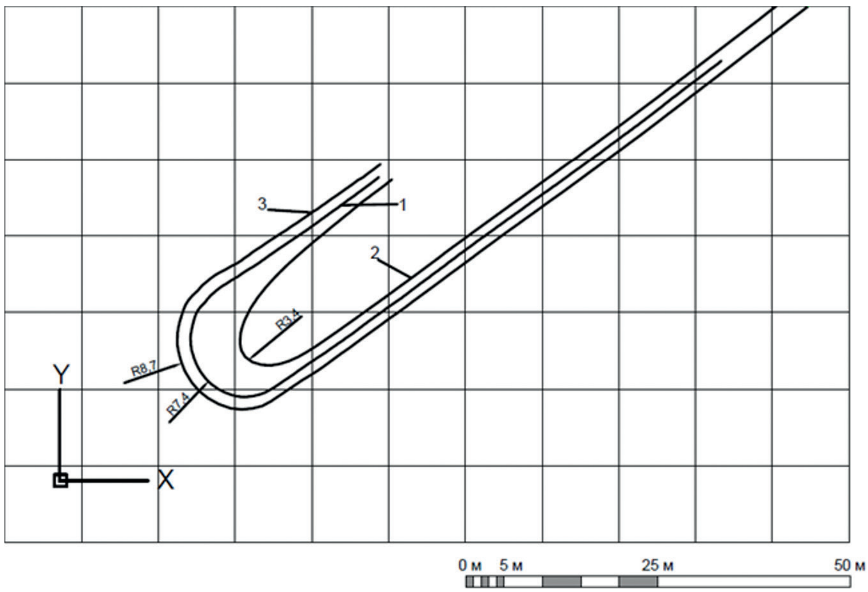

Fig. 6. Road train motion trajectory (1 – results obtained from GPS-702GG; 2 and 3 – results obtained from G3Ant-3AT1)

3. Recapitulation and conclusions

To compare the results, 20 control points were noted, in which the dynamic dimension of the road train was measured. Even with a visual comparison of the experimental and theoretical curves, it is possible to note a practically identical level of amplitude and similar character of the attenuation of processes in both plots. This similarity was confirmed by detailed analysis.

Figure 7 presents trajectories obtained in the study of movement of the train and results of the calculation

on the model. Both of these curves record the same parameter - the width of dynamic dimension of the train. The slight discrepancy between the curves is due to some discrepancy between its calculated trajectory and the actual trajectory of the trailer train, which depends largely on the driver and his reaction to the maneuver. It is different even when the speed of movement of the train when performing the maneuver is the same. This is due to the psychophysiological state of driver (work experience, the age of the driver, the reaction of the driver, the mood of the driver, condition of the driver and etc.) and the accuracy of device used for recording trajectory of the train. Real time positioning accuracy was 5 m/km.

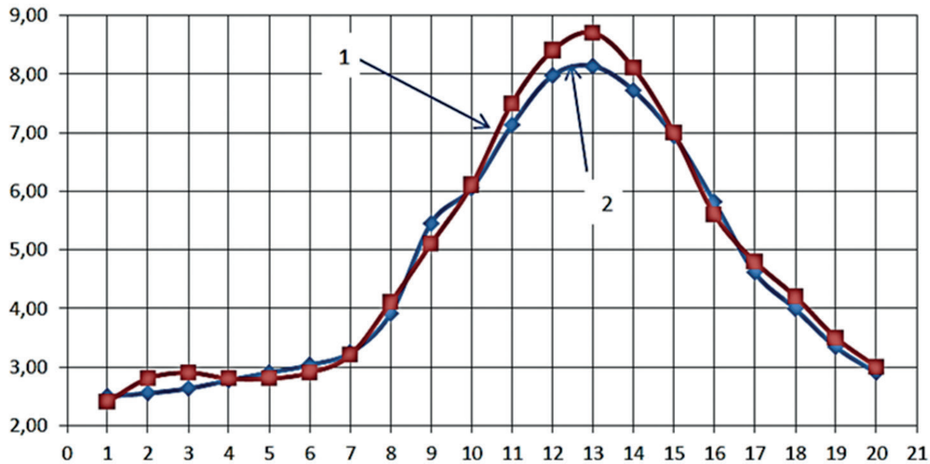

Fig. 7. Comparison of results of the study of movement trajectories
(1 - experimental studies; 2 - calculation by the program AutoTURN)

It is also necessary to note the discrepancy between the curves. The curves characterizing the change in the width of the dynamic dimension are different from each other (Fig. 7). This difference is especially noticeable at the control points 11–14, but on the whole trajectory character of experimental and theoretical curves agrees well with each other.

The difference in AutoTURN data in comparison with experimental values does not exceed 4.07 %, which, given the very similar nature of the curves, can be considered valid, and this is the basis for using the results obtained in the AutoTURN software package when determining the dynamic dimension of cars, as well as in modeling the trajectory of movement not only for road trains, but also for all types of vehicles in the area of their design.

4. Acknowledgement

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