SIMULATION OF TRANSPORT OPERATION IN URBAN CONDITIONS WITH VARIABLE VIRTUAL TIME INCREMENTS IN THE PROGRAM STAMM 4.1

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ABSTRACT
When studying the operating modes of a vehicle in urban conditions, it is necessary to take into account the peculiarities of changing some of its parameters over time, such as the speed or speed of rotation of the drive shaft of the power plant. There is a cyclical change in these indicators, and the type of cycles depends on the duration of the period of operation. You can identify typical cycles of changes in the above parameters that are typical for a work shift, calendar week, month, and so on. Within all the considered cycles, the periods of "fading" of parameter values are repeated. These features must be taken into account when reproducing the performance indicators of rolling stock in simulation models. The purpose of this work is to take into account the peculiarities of transport operating cycles when simulating its performance indicators. The Stamm program developed by the author uses two approaches for simulation of dynamic processes or systems. The first is using spreadsheets like Microsoft Excel that allows cross-referencing between cells, and the second is using visual object models. Both of these approaches allow us to take into account the features of operational cycles of transport by dynamically changing the value of the modelling step during the simulation experiment. When using a table model, this is a special cell for synchronizing the model time step. In the second case, the algorithm for changing the step of virtual model time is implemented using logical expressions in special components of system dynamics models – "Formula" The proposed approach significantly reduces the time of experimental research without losing the accuracy of the simulation model.
Keywords: operating cycle of a vehicle, urban traffic conditions, simulation modelling.

1 INTRODUCTION

Modelling processes and systems of the vehicle is a non-trivial task, since it is a complex dynamic system. In modern conditions, the simulation modelling method is widely used for this purpose. At the same time, it should be taken into account that some parameters of the car during the movement change randomly, under the influence of a large number of external factors. For example, the speed of a car and its associated parameters depend on the road situation, road surface condition, weather conditions, driving style, and other factors [1]. At the same time, if the vehicle is idle, most processes are stationary, and their parameters change quite slowly. Computer simulation provides a discrete change in model variables, the simulations used for this modelling step, which is measured in units of model time. At the same time, the accuracy of reproducing real processes largely depends on the numerical value of this value. The optimal value of the simulation time increment (step) depends on the maximum frequency of changes in reproducible in the model variables. Taking into account the above-mentioned features of speed change, it can be assumed that the optimal value of the step, when modelling the operating modes of the vehicle, will depend on the nature of the change in speed or speed of rotation of the engine crankshaft, associated with the features of operation [2]. Increasing the increment step of the model time reduces the simulation time. Popular simulation systems involve changing the step in the model settings, for example, Northwestern University [3]. There are usually two approaches: fixed time increment and variable time increment [4].

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2 THEORETICAL REPRESENTATION OF VEHICLE OPERATION MODES

To describe the mode of operation of the car, driving or load cycles are most often used. As a rule, this is the velocity dependence on the current time or distance. However, at research some processes or phenomena that accompany the operation process, one driving cycle may not be enough. This is especially true when the object of research is considered for a fairly long time period.

Regardless of the length of the time period in which the process of vehicle operation is considered, it always contains cyclically repeated sections with identical characteristics, that is, it is a cycle. Depending on the tasks to be solved, you can allocate daily, weekly, monthly and annual operating cycles.

2.1 Daily operating cycle

Its use can be justified if, for example, the thermal state of the engine or the level of charge of the battery is being investigated. Below are graphical dependencies of speed changes during a calendar day for various vehicles (Figs 1 and 2). As can be seen from Figs 1 and 2, the daily operating cycle consists of two basic phases – the “Working phase” (part 2 in Figs 1 and 2) structure, which depends on the purpose of the car and the “Idle phase” (part 1 in Figs 1 and 2) when the car is stored in a garage or in an open Parking lot. The relative duration of each phase may vary significantly depending on the nature of the vehicle’s use. If it is used around the clock, such as an ambulance, there may be no “Idle phase” at all. In contrast, for a fire truck, this phase may take up the entire daily cycle.

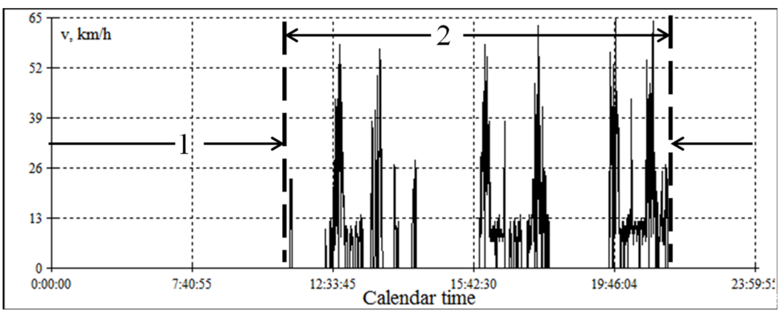

Figure 1: The daily operating cycle of a universal car. (1) Idle phase; (2) Working phase.

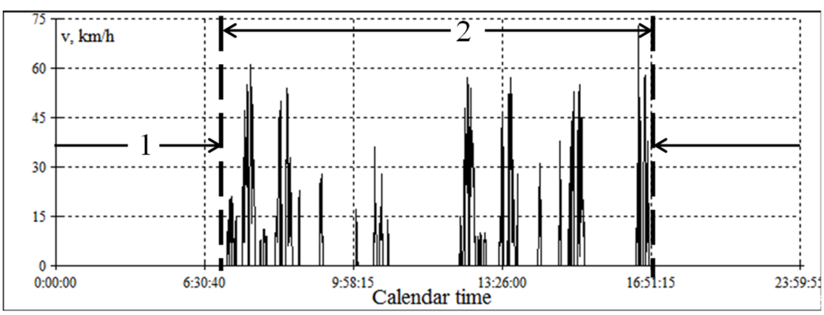

Figure 2: Daily operating cycle of a specialized vehicle (mixer). (1) Idle phase; (2) Working phase.

In turn, the working phase is also a cycle, since it periodically alternates sections of speed change corresponding to acceleration, steady movement and technological stop. In fact, the "Working phase" is the driving cycle, if we consider the car only as a means of moving cargo or passengers in space. However, in practice, there are a significant number of specialized vehicles that perform additional work operations in addition to driving or during it. This should be taken into account when studying the performance properties of such vehicles, so the operating phase of the operating cycle will look like this, as shown in Fig. 3. In the case of a general-purpose vehicle, a technological stop is an idle time associated with traffic conditions. if a special vehicle is considered, it may be the performance of a work operation while parked.

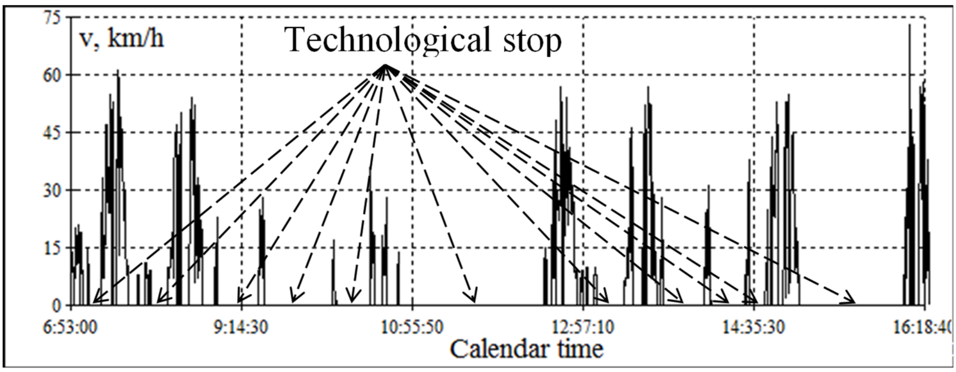

Figure 3: Working phase of the vehicle's operating cycle.

If the object of research is a special car that performs working operations during Parking, the technological stops associated with these operations require additional description by means of engine load cycles. Whereas for a normal car, it's just the engine idling. For a special car that performs additional operations while driving, such as a mixer car, it is also necessary to load the engine cycle, since in the case of using standard driving cycles, since the load of the internal combustion engine depends significantly on the duration and "severity" of these operations.

The ratio of phases of the daily operating cycle for various vehicles is constant and can be easily transferred to the virtual model time. The greatest difficulties are presented in the simulation model of the working phase in terms of moving the car or driving cycle. Almost every country uses national standards for driving cycles. However, creating a universal average driving cycle is a big problem, since the velocity profiles of vehicles, even in a single city, differ significantly depending on the selected route, time of day, day of the week, etc. The following approaches are usually used when creating a typical driving cycle [5], [6]: collecting data about speed profiles in typical conditions; selecting the basic elements of a profile or micro-trips; cluster analysis of data; adding the clusters in the cycle.

2.2 Features of processes in different phases of operational cycles

The figure below (Fig. 4) shows the process of changing the engine coolant temperature in the operating phase of the vehicle's operating cycle. Curve 1 corresponds to a technological stop, and curve 2 corresponds to a movement.

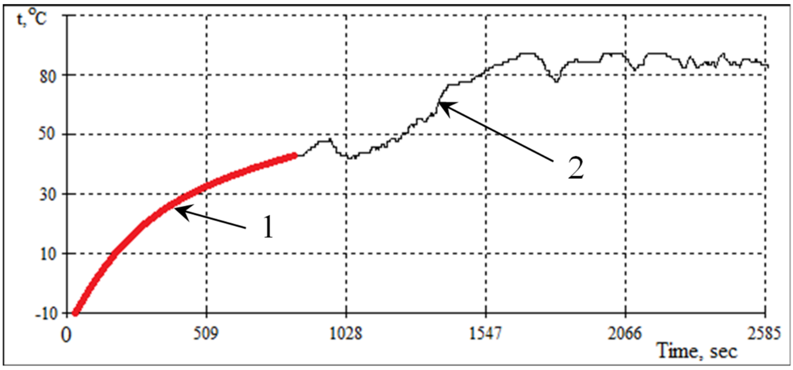

Figure 4: Changes in engine coolant temperature during the operating cycle (start of the Working phase). (1) Stationary process; (2) Non-stationary process.

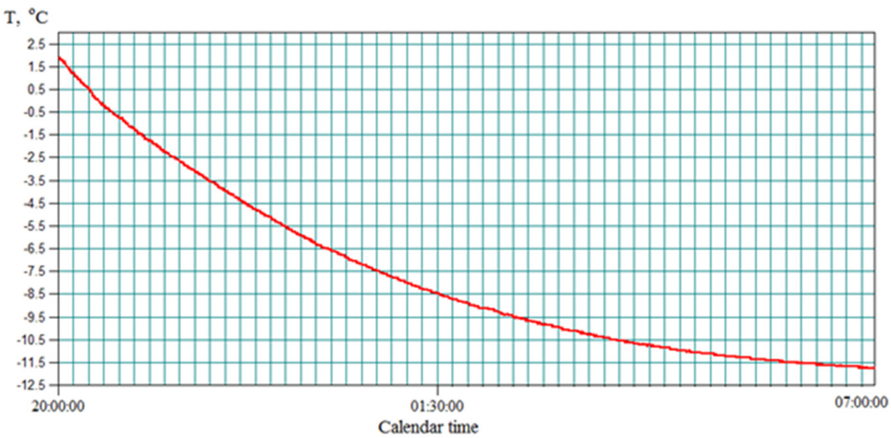

Figure 5: Changes in engine coolant temperature during the Idle phase of the service cycle.

Fig. 5 shows the dependence of the engine coolant temperature on the time in the Idle phase of the daily operating cycle.

Change the temperature in stationary mode during the “Idle phase” or during technological stops of the “Working phase” can be represented in models using known mathematical dependencies. a constant is used – the rate of heating or cooling. In non-stationary mode, the heating rate at each step of the simulation is formed dynamically under the influence of related variables – car speed, engine crankshaft speed, load (degree of throttle opening), etc. It is difficult to describe these variables analytically in the “Working phase” of the daily operating cycle. Therefore, it is convenient to use table functions depending on the dynamically changing parameters of the car from time to time.

3 MODELING OF OPERATIONAL CYCLES IN THE SYSTEM “STAMM”

The author developed the program “Stamm” [7], [8], which is designed for processing and interpreting experimental data (Fig. 6). one of the important functions of the program is

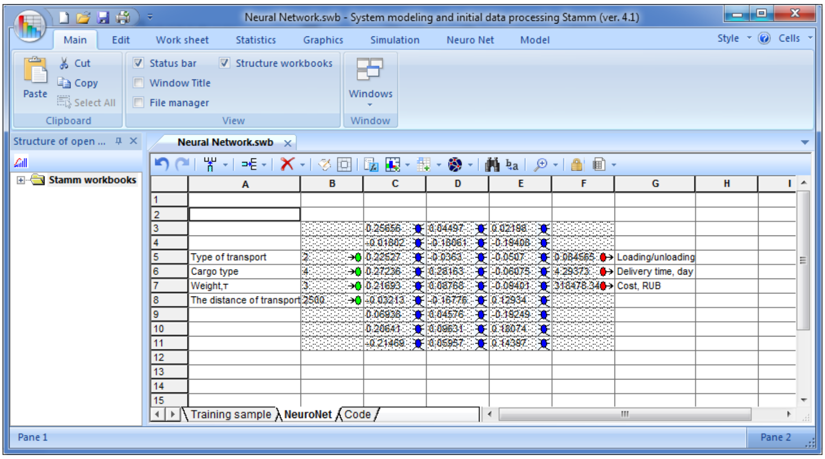

Figure 6: Program "Stamm" version 4.1.

simulation. There are two types of simulation models-in the form of a special table and object visual models. Both types support dynamic change of the simulation step during the simulation experiment. This approach significantly reduces the time spent on research.

3.1 Using variable step in table-type simulation models

When using table-type models (Fig. 7), the program "Stamm" uses a special internal variable "Step", which stores the numerical value of the modelling step. In system dynamics models presented as tables, this variable is used when transferring table function data to cells or when calculating time-dependent data. For example, the values of the simulation step can be changed depending on the current calendar time of day reproduced in the model. In this case, you can simulate the phases of the daily operating cycle of land vehicles with different increments of time. Fig. 8 shows a panel for configuring the management of tabular simulations. If the "Synchronize by" field contains the cell address, the simulation time step changes dynamically, depending on the value of the variable in this cell.

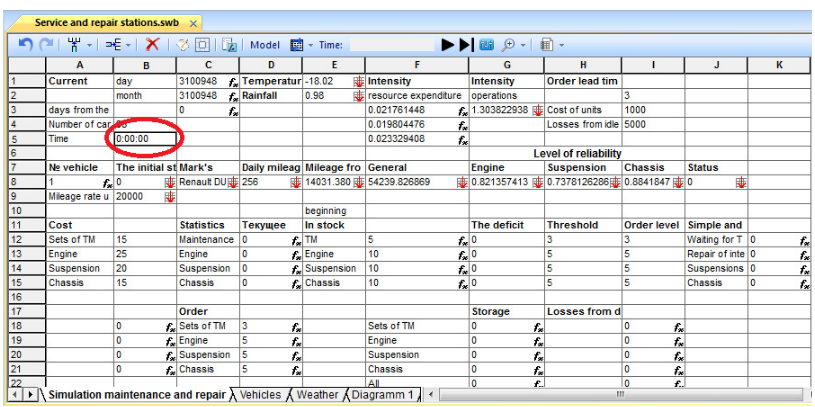

Figure 7: Table-type Stamm simulation model.

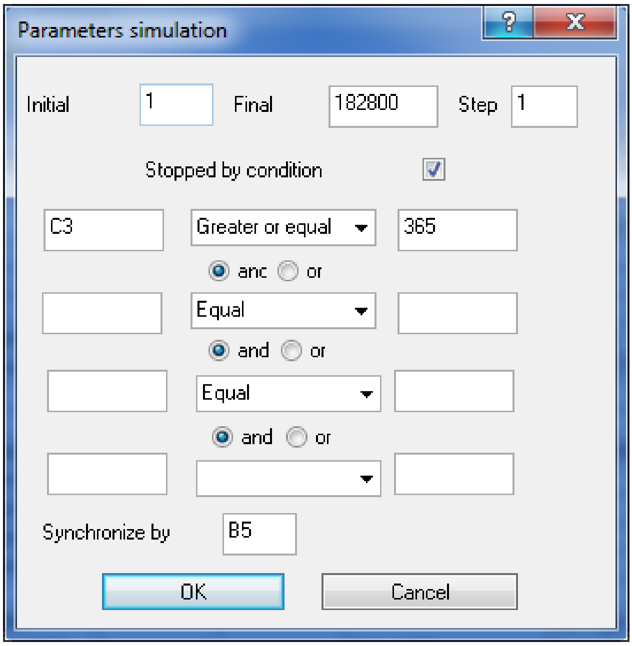

Figure 8: Panel for configuring table-type model parameters.

3.2 Variable step of modelling in object models

When an object visual simulation model is used, the dynamic change in the step of the model time occurs in special visual components – the “Formula” (Fig. 9).

To dynamically change the model time increment, put a logical expression containing this variable in the component (Fig. 10).

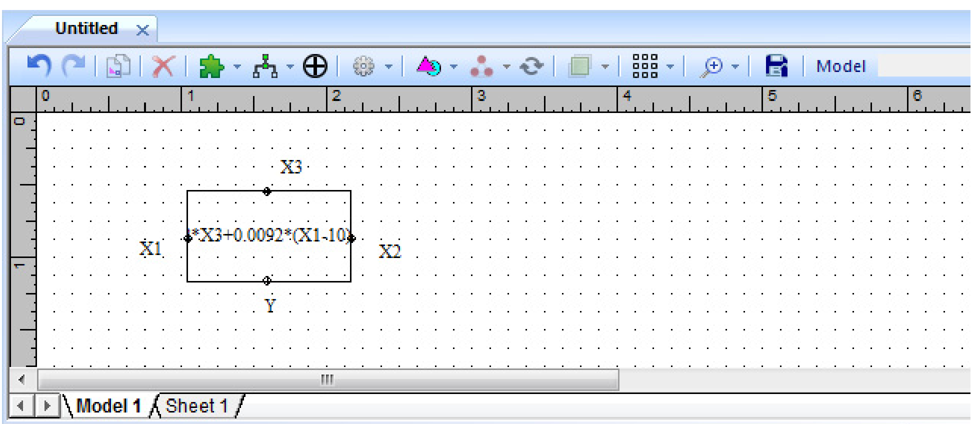

Figure 9: Object model. The component “Formula”.

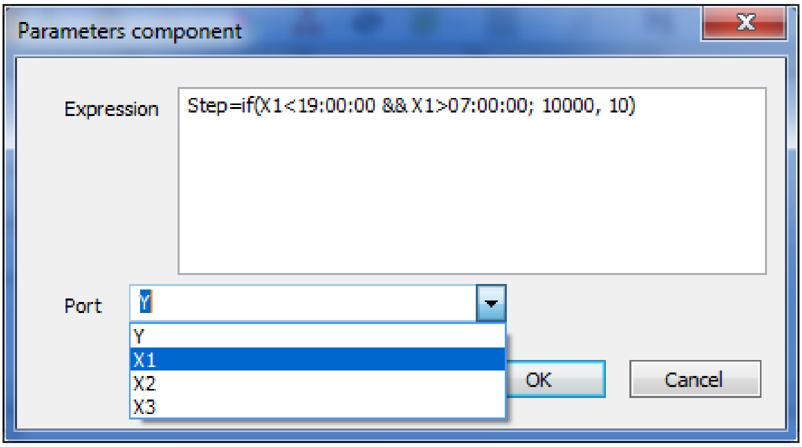

Figure 10: Setting the model time step in the parameters of the component “Formula”.

4 CONCLUSIONS

Thus, when simulating the processes that accompany the operation of cars, it is necessary to take into account the following conditions.

- The step of modelling in discrete simulation models is determined by the intensity of occurrence of events in the simulated system. In continuous models of adequate reproduction of changes in parameters of complex dynamic processes, it is necessary to use a sufficiently small step in the increment of modelling time or its change in the course of a simulation experiment.
- Variable increment of simulation time is implemented, for example, in Simulink [3] and Transient [9]. Sometimes a hybrid approach is used [10], [11], [12]. Most methods for determining the step value are based on the Runge-Kutta method and the value of the variable found in the previous step of the simulation. This, in turn, involves the cost of processor resources, the amount of which depends on the required order of accuracy. In the Stamm program, the optimal step value for different model time periods is calculated before the simulation starts, taking into account the Nyquist–Shannon theorem, and its change is made using conditional synchronization, as shown above.
- Vehicle operating cycles contain two phases that differ sharply in the dynamics of processes – the “Working phase” and the “Idle phase”. Moreover, the working phase itself contains cyclically repeating sections. A significant part of the working phase cycles in urban conditions are technological stops. The profile of changes in the load on the power plant during the process stop is determined by the purpose of the car.
- To optimize the model experiment, it is advisable to dynamically change the step of the model time taking into account the dynamics of the simulated processes. For example, in the process of modelling the operating cycles of cars, it is advisable to use different numerical values of the increment of the model time in the working phase and in the idle phase. In addition, it is advisable to apply the change in model time when modelling technological stops of vehicles.
- As a simulation program for vehicle operating modes, you can use the Stamm program, which supports changing the increment of virtual time during simulation.

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