MODELS OF STATIONS WITH FUNCTIONALITY OF PROTOTYPES OF PHYSICAL AND TECHNOLOGICAL PROCESSES

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ABSTRACT

Possibilities of model reconstructions of railway stations of different complexity level with the reproduction of technology of their operation on the basis of algorithms of correct physics of processes are considered. Realistic construction of models is emphasized by a 3D interpretation of the results of computational procedures, with the help of which a visual image is formed, an ersatz structure of the station is created, and the meaningful properties of the prototyped objects are copied. At the same time, the space-time changes accompanying the modeling correlate with a set of nonlinear phenomena and a multitude of factors of a systemic and non-systemic nature.

Keywords: system, 3D station model, prototype, technology, physical processes, nonlinear phenomena, failure prediction.

Background. *The fulfillment of any technological operation is associated with the account of complex influence of various external and internal factors [1]. Therefore, for correct model interpretation of station technology, an important role is played by correct reflection of the bonds of interacting objects [2]. Objects in such a model must change their position in accordance with the laws of real-world physics. Model cars are considered [3] as pseudo-physical constructions of elements with elastic and rigid connections, possessing a certain inertia of motion and capable of moving under different forces through virtual railway tracks. Rotational movement of wheels of rolling stock, by analogy with real physical processes, is transformed into a progressive movement of a car.*

Modeling of any technological process is connected with the realization of a number of operations inheriting the content of each other [4]. The transition of the operation O_i to the technologically connected operation O_{i+1} is determined by the algorithm of the model technology that ensures the transfer of the achieved state of the object at the time of the completion of the operation O_i to the next position. Therefore, for each subsequent operation, a prediction image of its state, reached by the object at time t, is formed. The technological process that takes place during time T_k is divided into quanta so that $T_k = N_k \cdot \Delta t$, where N_k is the number of calculated points on the time scale of the process; Δt is the period of time between two adjacent quanta. It is assumed that the change in the state of the object occurs only at times that are multiples of Δt. As the number of quanta N_k increases and the distance Δt decreases between them, the visualized result of changing the position of objects on the corresponding 3D model becomes smoother and more realistic. In particularly dynamic processes (for example, the dissolution of cars from a hump), the period of time Δt can be variable and inversely proportional to the speed of the technological process.

If the technological operations are performed in a regular mode and have a cyclic character, then the change in the state of objects, defined as movement of cars along the tracks, can be associated with a fixed effect of traction forces of various types (locomotives, loading and unloading mechanisms, winches, etc.) and the inhibitory effect of the forces of resistance.

Objective. *The objective of the author is to consider models of stations with functionality of prototypes of physical and technological processes.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, mathematical apparatus, simulation.*

Results.

Model reconstruction of the physics of technical system functioning. *A model of a system with an estimate of the influence of various factors is considered as an environment prototyping real processes with appropriate credibility. The adequacy of reconstruction of the virtual world of information images to real technical structures depends on accuracy of calculations of the influence of forces of different nature. Therefore, various model analogies for reconstruction of many regular and irregular effects and their cause-effect relationships will have different accuracy in reconstruction of physical and technological effects (Table 1).*

Of particular importance is the transfer of the results of the calculated states to the 3D installations, since it becomes possible to observe the change in the state of objects on the scale of a sufficiently perfect copy of the prototype real system.

The zero-level model. *The realization of such a model implies taking into account the influence of regular internal and external factors of a different nature. In this case, technological operations, repeated at specified intervals (arrival of trains, dissolution, delivery of cars for cargo operations, etc.) are decisive, and the accompanying multi-factor impact of factors is taken into account through some correction factor. The calculation is reduced to finding the values of displacement of objects under the action of a fixed force, proceeding from the identified object.*

The main object of this model is a car with such properties as dimensions, mass, speed. When modeling the motion of the car, the action of traction and resistance forces are taken into account, which provide a certain resultant effect on the design object and facilitate the movement of rolling stock along a model railway track with variable speed.

All changes in the state of objects in the zero-level model are determined by repetitive operations, which are performed in full accordance with the regulatory technology of the railway station (reception and departure of trains, loading and unloading of cars in the warehouse of a freight terminal, etc.). The model image of a cargo operation is a simple dynamic picture of filling of a car or its unloading with piece, bulk, bulk or other cargo, depending on the duration and nature of the operation.

The initial-level model. *The model car is considered as an info-object with a number of additional properties that characterize it in the systems of interaction «car–track», «car–cargo», «car–locomotive», etc. To the minimal set of properties characteristic for the zero-level model, other significant properties of the railway track are added (parameters*

Table 1

Classification of model schemes for prototyping technological processes of the railway station

Model of the level	Appearance of objects	Functionality	Restrictions	Possible areas of application
Zero	Realistic 3D image of tracks and cars	Change in the state of objects under the influence of constant cyclic influences of the surrounding environment	Lack of consideration of the influence of factors of irregular action	Interactive learning technologies, application as animation illustrations in electronic textbooks
Initial	Forming of information 3D objects of the station	Integral assessment of the influence of multiple factors on the state of objects	No evaluation of the isolated influence of significant factors of irregular action on the state of objects	Studying dependence of the influence of significant factors of the irregular effect on the state of objects; development of methods of verification of initial-level models
Regulatory	Highly realistic in form and adequate in terms of content a model world in the dynamics of functioning processes	Application of the equilibrium regulator of the model system with elements of adaptive correction	The lack of a full-value mechanism of adaptation to sharp impacts, capable of removing the system from the region of stable equilibrium	Studying the properties of objects in the model environment, an adequate real technical system
Reproductive	Stably functioning model in autonomous mode with high reliability of prototyped processes	Behavioral functions of the model environment ensuring reconstruction of technological processes in the effective mode of a wide range of actions	Restriction of efficiency of the behavioral functions of the model medium under the major conditions	Studying the possibilities of the model reaction under normal conditions of technology reconstruction
Constructional	Appearance in the modern system of technically advanced and new objects	Self-reproducing environment of new capabilities of the prototyping system based on the use of polymorphic algorithmic structures	The impossibility of complete verification of prototyped technological processes under any conditions of functioning	Transformation of the model world into a physically tangible environment by means of technologies of three-dimensional printing of informational objects with their functioning in a self-sufficient mode

of the rail-sleeper grid, track superstructure and substructure, current condition, repair schedule, defects, etc.). The tandem bunch «car–track» allows to calculate the internal stresses and deformations of the track superstructure from shock loads transmitted by moving rolling stock.

A characteristic feature of the initial-level model is the calculation of the states of related objects that affect each other in the process of interaction. The prevailing object is a car that interacts with a railway track, a locomotive, cargo. Buildings and structures are present in this model, but as entourage objects. From the integral impact of other factors, the effects that reflect the contact of cars with track elements are identified.

The model of the regulatory level. *In the real system, other external forces of different origin (load from gusts, temperature effects, defects in wheel sets of cars and rails, deformation of the track, etc.) exert a significant influence on the processes taking place. These influences form the environment of the fluctuation effect of factors, which together with the forces of traction and resistance determine the nature of performance of technological operations. In the model of the regulatory level, the presence of the fluctuation component is demonstrated by calculations of the variational forces of irregular action. The integral picture of the external influences of the initial-level model is decomposed into components with the study of the characteristics of the environment of the key performers of the technological process, the determination of their conjugation points and the identification of individual influence. The availability of information on upcoming weather conditions, the condition of cars of arriving trains, the current state of the track allows to generate a forecasted fluctuation effects chart that corrects the specified course of technological operations.*

In a real technical system, there is a regulatory norm, a kind of formally established (institutional) stamp of the state of objects, characterized by the position on the time axis of the deployment of the technological operation. Such a technological template usually does not bring the desired effect due to a number of non-systemic factors. Therefore, the target force influence on the object, leading to a change in its state, can be considered as a kind of impulse identical to the combined multifactorial influence of the external environment.

The regulatory level model contains a feedback loop. If, with a specific combination of parameter values, some achieved mode of work of the model was considered unsatisfactory (leads to dangerous situations, accompanied by the failure of devices, etc.), then in subsequent cycles this mode will be excluded.

The model of the reproductive level *develops the feedback loops, forming fault-tolerant combinations of the values of the parameters of the functioning of objects and ensuring the growing completeness of the customized behavioral responses of the model system. In the process of work, the intellectual knowledge base accumulates, allowing to improve and optimize process modes with the formation of a model institutional stamp of the state of objects with possible deviations. The knowledge base contains multiparameter connected constructions with state-dependent values of not only* *one object (homogeneous structures), but also several objects (heterogeneous structures) – for example, car and track, car, track and cargo. Heterogeneous structures are especially important for the reproductive model. They help to form new effective modes of station operation, which are absent in the practice of real technical systems.*

The model of the constructive level *has developed information means of adaptation to external influences with the adjustment of the system of technological support to the conditions of the technological operation. At the same time, the capabilities of the model environment, aimed at neutralizing the negative influence of the environment, are activated. For example, a program analysis shows that the strength of the wind is an important factor, the effect of which leads to significant economic losses during the dissolution of cars on the hump. The constructive algorithm of the model in response projects a protective structure with its subsequent commissioning of the prototyping image of the technical system.*

In addition, the model can use measures that directly affect the causes of the occurrence of negative influences. The same wind impact on the process of the dissolution of cars from a hump can be ruled out by other means external to the railway stations. For example, with the help of climate stations, which extinguish air flows on the approaches to industrial centers and cities. Since we are talking about model measures, in the algorithm of the work of such megastructures at the level of designing processes and objects, global optimization regimes can be laid down with the release of the reconstructed environment beyond the boundaries of a separate transport point.

The model of the constructive level allows to correct the negative influence of the environment every time when repeated negative processes occur, resulting in significant costs. The introduction of new objects into the model system is only carried out when the calculations prove the possibility of reducing the overall losses of economic or other nature and ensuring more safe functioning of the entire reconstructive environment. Otherwise, the intelligent model environment seeks rational options for changing technology, minimizing any negative impact.

Thus, the constructive level model has the potential of object and process reconstruction. Object reconstruction is developing the model environment, expanding the numerical composition of objects, complements the existing variable resource in the architecture of the model environment. Process reconstruction is no less complicated, because it leads to a change in technology, being a powerful productive tool of non-local optimization. The combined use of object and process reconstructions in models of high intellectuality increases the chance to prototype developing environments, making projected and used technical systems really progressing.

Conclusions. *Models of a functioning railway station can be formed as a series of coherent sequential program modifications. The zero-level model reconstructs only significant technical and technological properties of objects, determining the overall picture of the development of processes. The following levels inherit the information images of the previous ones with the development of the interaction medium of objects in the direction of adequacy to the functional of prototyped images. Thanks to the mechanism of adaptation and use of an extensive knowledge base, the accuracy of reflecting the current technological processes is increased.*

Actualization of model technological processes is provided by means of comparing the achieved states of prototyped objects to control points of the deployment cycle of real technological operations. These points can be fixed or vary depending on the nature of the complexity of the operations performed.

The realism of model structures is emphasized by the 3D interpretation of the results of all computational procedures. The representation of the final states of objects in the form of a three-dimensional reconstruction forms a visual image, creates an ersatz structure of the real station, copying the significant properties of the objects being modeled. The presence in the models of monitor and adaptive tuning circuits brings the reconstruction closer to real technical systems that function in a cyclic mode of balanced states of objects and ranges that are allowed by physical laws and technological requirements.

Simulation of space-time changes in objects and processes at the railway station affects the need to reproduce complex nonlinear phenomena with a multitude of influencing factors of systemic and extra-systemic nature. Therefore, it is impossible to reconstruct all events occurring at a real station. It is about prototyping only significant operations. The reliability of such models should be defined as the ability of the information environment to replicate operations regulated by the technological process of the station, and correctly calculate possible positions of objects as consequences of certain factors.

Reproduction of the work of the railway station in an adequate model analog with various accuracy of the reconstructed physical processes significantly expands the scope of forecasting failures of technical means, assessing the level of safety of the technological operations performed in the event of major circumstances, and also designing better ways of organizing production.

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Article received 04.10.2017, accepted 27.10.2017.