INTEGRATED MODEL OF STATIONS WITH ADEQUATE 3D VISUALIZATION OF OBJECTS

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ABSTRACT

The author suggests a 3D model of a railway station, which is the closest to reality in terms of external perception and the essence of the processes. It is shown that an attempt to simplify model operations, not to take into account the technological links of individual processes, basing only on physical analogies, leads to development of non-functional reconstructions. This is a claimed system of model images that only can reproduce the dynamics of movement of cars along the station tracks, as well as can visualize the successive states of objects in their interaction.

Keywords: 3D model, railway station, system of model images, physical processes, synergetic properties, empirical characteristics.

Background. *Railway stations perform the operations regarding train, car, cargo and passenger traffic in regulated zones of safe technological processes. Differences in conditions of operations depend on many factors. Despite the cyclical operation of the station and a relatively small set of basic technological operations (receiving and dispatching, disbanding-formation of trains, supply-removal of cars, loading and unloading of cargo, embarkation and disembarkation of passengers), a model reconstruction of technology is a rather complex problem from position of assessment of reliability of its prototyping. In this case, it is important to consider the technological limitations that prevent operations from being executed in a more intensive mode than allowed by the physics of the processes. Such restrictions lead to a decrease in the speed of movement when receiving trains to the station, in the speed of thrust and disbanding on the hump, in the height of loading of goods in cars, etc. Therefore, the existing connections of the physics of processes and the technology of operating trains at the station must be appropriately recreated in model interpretations.*

Objective. *The objective of the author is to consider integrated model of stations with adequate 3D visualization of objects.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, evaluation approach, mathematical apparatus, computer simulation, 3D modeling.*

Results.

Model environment of physical and technological reconstruction. *3D reconstruction of objects that functions in accordance with the laws of physics and technology requirements is the most adequate and obvious way of presenting the results of modeling of the station operations [1–3].*

The reproduction of the dynamics of real movement of the information analogues of cars, as well as reproduction of the changing position of the model rolling stock with mutual action of traction forces and resistances, both make it possible to get a 3D installation with high correspondence to the on-site objects both in form of display and contents (for example, movement of reconstructed images of cars is observed along the model tracks of the descent part of the sorting hump with slowing of speed of uncouplings when approaching the calculated points in the sorting fleet). The high accuracy of reconstruction of the physics of movement of model cars, complemented by the requirements of technology for operating trains and cars, will provide an effective information environment corresponding to a really functioning transport system.

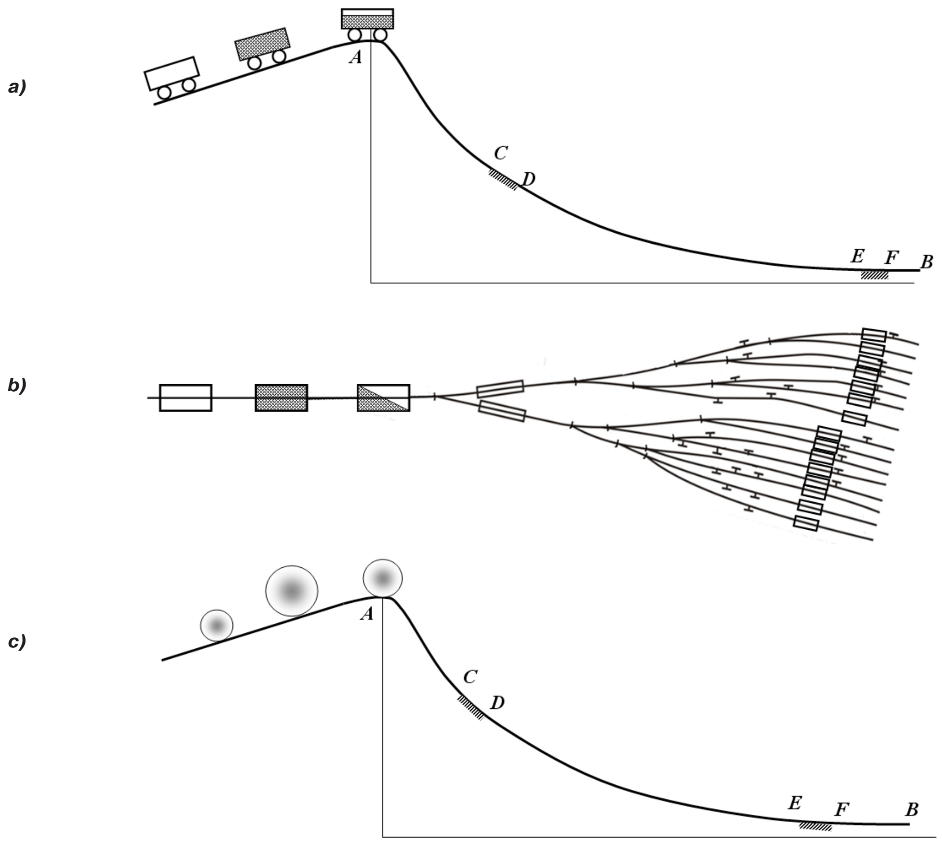
Thus, the adequacy of the model image of the station to its prototype can be regarded as compliance of information objects with physical laws (gravitation, inertia, conservation of energy, etc.) and current technology standards (security, safety, flow of operations, etc.).

A special problem is the search for an acceptable algorithm for reproducing the effects of the laws of physics on model objects, leading to observable and recorded results of the real world. The incompleteness of fundamental knowledge about the nature of physical laws, the cause-effect dependencies of their influence, the complexity and multidimensionality of the impact on real objects determine the fuzziness of the initial data, which can lead to incorrect prototyping. Therefore, model physics is considered as a medium that reconstructs the new state of objects by the multiple integral influence of other objects and environment on them [4].

Model technology can correct the direction of physical transformations of a reconstructive image. For example, according to the results of calculations, information reconstructions of cars can roll down from the hump to any sorting tracks, and technological requirements determine for each uncoupling a fixed track in accordance with the established plan of formation; the cars sent for loading are fixed to a certain cargo place for a given cargo, etc. Therefore, the rules of technology can act as limitations that significantly reduce the dimensionality of the set of states of objects that are allowed by physical processes. In this respect, the technology acts as a certain target norm, correcting and regulating the ranges of parametric data of objects when performing operations (thrust speed – from $V_{\text{thrust}}^{\min}$ *up to* $V_{\text{thrust}}^{\max}$, *loading of a car – from* $m_{\text{car}}^{\min}$ *up to* $m_{\text{car}}^{\max}$, *distance between uncouplings on the hump – from* L_{min} *to* L_{max} *etc.). Unconditional adherence to the norms of technology meets the existing requirements for safety of transportation, safety of goods, obtaining of a significant economic or social effect.*

The model technology should algorithmically reproduce the control stimuli, which in real conditions come from the duty officer on the hump, the station duty officer, from the dispatcher, the speed regulator of uncouplings. Since the results of modeling of station operations lie in the plane of compulsory fulfillment of technological requirements, the latter have the same binding force for model simulation as the canons of physics.

A certain difference between technological requirements and physical laws lies in the greater variability of the former and the need to adjust their



Pic. 1. Model schemes for the work of the shunting hump with calculation of physical and technological effects: a – when the balls roll down the surface; b – during breaking-up of cars from the hump; c – the plan of the hump neck.

positions to the current conditions for processing trains at the station, the condition of the track, climatic and other factors. Therefore, the range Ω of the norms of the fixed technological rule $Tech_i$ is wider than the analogous interval I of the variant action of some physical canon $Phys_j$. The proportionality of Ω and I makes it possible to compare $\Omega(Tech_i)$ and $I(Phys_j)$, despite the fact that $Phys_j$ has a fundamental, natural, absolute character, and these forces are perceived as fundamental, being the causes of changes in the state of objects under the influence of unshakable natural canons. In its turn, $Tech_i$ is conditioned by a number of relative, postulated positions dictated by practical considerations and depending on the current state of technology and equipment.

Interpretation of images of the shunting hump

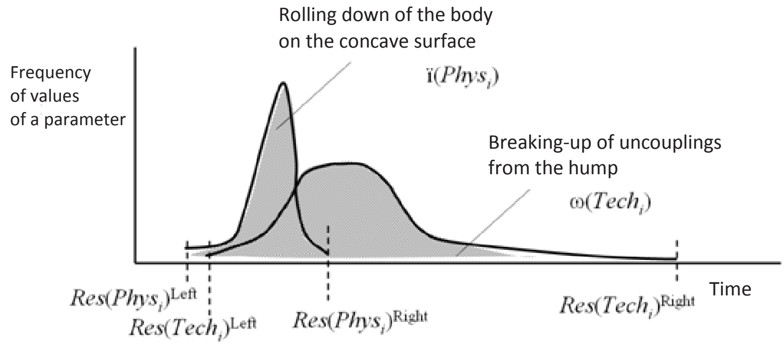
The division of requirements within the model of the technical system's operation into physical and technological ones leads to the possibility of reproducing the dynamics of rolling of objects along the surface in two different modifications. Let's consider I- and Ω-reconstruction of the shunting hump (Pic. 1).

The physical interpretation of the processes (see Pic. 1a) assumes the realization of the model irrespective of the technological aspect of the dissolution of cars from the shunting hump. In this formulation, attention is focused on calculation of physical effects when moving on a concave rigid surface of metal balls with different masses uniformly distributed throughout the volume, which roll down from some initial point A to point B. Additional conditions of the physical task are:

- *speed of the ball rolling is not exceeded by the maximum permissible $V_{max.perm}$ at any point of the route of movement;*
- *maintaining the interval on the route of rolling between adjacent balls is not less than I_{min};*
- *the presence of resistance to overcome the movement of metal balls along the entire rolling route;*
- *beginning of the ball's movement with the speed in the interval $[V_{min}, V_{roll}]$.*

Observance of the required intervals between the balls and non-speeding are achieved by including a viscous medium in the model – simulating the brake moderators in the sections CD and EF. It is assumed that on the surface elements it is possible to quickly replace a solid substrate with a rubber one and vice versa. Replacement occurs during the waiting time for the ball to enter this area, when the previous ball has already passed the relevant section, and the next ball has not yet entered the surface of increased resistance. The possibilities of controlling the process of rolling balls of variable mass over a fixed surface are minimal and are associated with a change in the initial speed of rolling down V_{roll} and the inclusion (or cutoff) of additional resistance to movement in the sections CD and EF.

The second model analogy (see Pic. 1b) reconstructs the work of the shunting hump with fulfillment of the main series of technological requirements. The physical processes in this installation are represented by some «black box» with



Pic. 2. Distribution of the areas of variation of parameters in different models.

empirically calculated effects of motion, braking, collision, etc. Technological simulation reproduces the work of the hump taking into account all the features of rolling stock and the state of the hump track. The model breaking-up of the train is made in full accordance with the hump layout plan (see Pic. 1c) for prototyped thrust and breaking-up tracks, broken into uncouplings according to the formation plan. The change in the speed of movement of uncouplings is ensured at the braking positions. Additional physical conditions for the technological statement of the model problem are:

- *analytic-empirical calculation of the values of resistance of movement and the speeds of rolling down;*
- *integral corrections to the parameters of uncouplings, which determine their physical features and the nature of breaking-up.*

In the calculations of the technological model of the hump, the plan and profile of downway tracks of the hump neck are taken into account; position of retarders and other braking devices; the plan of formation, which determines securing of the track of the sorting park for the appropriate assignments. Assessment of changes in the state of objects of breaking-up is made by the cumulative effect of the influence of interacting bodies on each other. This means that a deep model study of the arising friction in individual nodes and details of cars, as well as wheels and rails, which are very complex in the calculations, is excluded [5, 6].

Comparison of prototyping models

For each of the models under consideration, we distinguish ï($Phys_j$) and ω($Tech_j$) as elements of many physical laws and technological rules reproduced in the corresponding installations of the shunting hump. According to the hypothesis that provides for the equivalence of physical and technological processes from the point of view of their reproduction algorithms, the result of action on the model object of some k-th law of nature is characterized by the lower limit of the possible influencing conditions $Res(Phys_k)^{Left}$ and the upper boundary $Res(Phys_k)^{Right}$ ($\Delta Res(Phys_k) = Res(Phys_k)^{Left} - Res(Phys_k)^{Right}$), and the action of the s-th technological requirement on the same object will result in a multifactor effect on the result $\Delta Res(Tech_s) = Res(Tech_s)^{Left} - Res(Tech_s)^{Right}$.

Then for any k and s: $\Delta Res(Tech_s) >> \Delta Res(Phys_k)$.

A graphic illustration of this case is shown in Pic. 2.

As a parameter of comparison of physical and technological processes, we choose the duration of breaking-up of cars at the shunting hump. The frequency curves of the parameter values show that the «pure» physical processes of $Phys_i$ set provide a shorter time for the bodies to roll over the concave surface due to a higher speed of movement. The technological requirements for movement of cars along the slope of the hump are more stringent, limiting the speed of rolling down because of the need to take into account the intervals between runners, the characteristics of the passage of car retarders, etc. Such regulations lead to an increase in the breaking-up time, and the corresponding distribution curve ω($Tech_i$) according to the frequency of the compared parameter is lower, wider and shifted to the right.

In the physical reconstruction, technological components are implicitly present (the weight of the balls can be different, which simulates the masses of rolling uncouplings, the areas of the rubber surface on the rolling track of the balls reproduce the action of the car retarders), they approximate the model to the actual construction of the hump. That is, the model physical structures are adjusted to the technological features of the system, which leads to a change in the distribution region ï($Phys_i$), shifts it to the right and brings it closer to Ω($Tech_i$). On the other hand, technological interpretation with the use of more accurate corrections, passing into the analysis of the calculation of physical effects, provides a displacement of ω($Tech_i$) to region I($Phys_i$).

Thus, the initial models are enriched by the inclusion of conjugate factors (the achieved rate of breaking-up of the physical body moving due to the reserve of potential energy from the top of the hump along the slope curve varies depending not only on the external conditions of the physical medium, but also on the current technological regimes of the shunting hump). As a result, it turns out that it is rather difficult to separate station processes strictly into physical and technological processes in model images that claim to be subsequently effective.

Railway stations operate, as a rule, in the regular modes of operating trains and cars. These modes are most often resistant to various changes of a major character. Technology requires the use of physical processes that facilitate the quality of the stated operations. However, the repetition of the same technological operation in the next workstation cycle causes some change in the result, due to the complementary action of $Res(Tech_s)$ and $Res(Phys_k)$. The possibility of registering individual results of physical and technological model components is difficult because a certain symbiotic, correlated result Cor{$Res(Tech_s)$ and $Res(Phys_k)$} is formed at the output, consolidating the individual effects of a physical and technological nature and leading to recombination of joint influence of Ω($Tech_i$) and I($Phys_j$).

An analysis of the reasons for changing the requirements of Ω($Tech_i$) and I($Phys_j$) shows that there are general conditions and factors that simultaneously *have an effect on the physics and technology of the station processes being studied. Physical processes at the railway station occur in the field of action of the laws of nature, technological processes are a specific consequence of the physical and are performed in accordance with the requirements of the established regulations. Therefore, station-based technological processes cannot be performed outside physical causality. The operations of receiving trains, disbanding, accumulating, dispatching would take place differently with other manifestations of the laws of nature.*

The zone of variations I of some result of the action of the physical law turns out to be more certain, predictable in comparison with the dimensions of the deviations of the technological operation. It turns out to be difficult to separate the interdependent state of model objects of the track and rolling stock. The separation of the groups $\Omega(Tech_i)$ and $I(Phys_j)$ in individual model interpretations leads to the loss of synergistic relationships that distinguish the functioning of real transport systems from their model counterparts. Multiplicativity of general action, perhaps, is that key feature that fundamentally distinguishes the low quality of prototyping of reconstructive systems with isolation of individual effects.

The functioning of existing railway stations occurs in the continuous connection with the dynamically changing states of the modeled infrastructural objects. In fact, all direct and indirect factors and conditions affecting the processes are intertwined in some way in time, duration, periodicity and strength of their action. Undoubtedly, the decomposition scheme of the model definitely leads to a simpler, easily reproducible structure. But without taking into account the technology, the physical process of the model technical system is abstract and has no practical application. The functioning of an ideal system only in the field of physical phenomena essentially transforms the real environment into some formal construction. Such an algorithmic conversion of the contents of the processes of the transport system leads to a problem that is solvable from the position of formalization, but excludes fundamentally important interobject connections.

The multiplicative action of connections can be described by some numerical corrections in the form of a group of empirical coefficients designed to cover the unaccounted influence of the system's synergies. However, in this case, there are cases when due to a certain mutual effect of a number of factors there is a repayment or a significant reduction in the resultant force on the model structure. This means that the multiple influence of a number of factors leads to a peculiar dispersion of their cumulative effect on the station object. For example, deceleration of speed of movement of the car on the track is not only due to the forces of resistance of the wheel and rail, but also to possible additional friction in the structural elements of the car, which has been in operation for dozens of years. Losses of kinetic energy occur at the joints of rails, including defective sections of tracks, from accidental impacts of gusts of wind, changes in the position of the center of gravity of the «car–cargo» system due to displacement of the latter as a result of collisions during breaking-up from the hump.

Similar processes occur in the technological field of the action of $\Omega(Tech_i)$. Disbanding a train on a shunting hump does not always lead to strict compliance with the plan of formation with movement of individual couplings to the corresponding track of the sorting park because of the non-couplings at the top of the hump; uncoupling of cars of different assignments on the down part of the hump with a high rolling speed; the presence of re-sorting due to the lack of a sufficient number of sorting tracks, corresponding to the number of assignments under the train formation plan, etc. In addition, the canons of technological requirements do not remain unshakable.

Conclusions. *As follows from the context of research, one model of a functioning technical system should ultimately be formed, in which physical and technological interpretations are considered as stages in the development of a prototyping model environment that successively approximates the reproduced structure to an adequate, practically meaningful information alternative to a real railway station.*

Multiple effects of interaction of objects in the process of rolling down from the surface of balls (physical interpretation) and uncouplings during breaking-up from the hump (technological interpretation) are integrated by some general algorithm with a number of empirical parameters. As a result, a unified reproductive model of the dynamic train breaking-up system appears, capable of reproducing the observed and parameters of the shunting hump under comparable initial conditions. Integral components of the model in a certain way multiply multiple effects, providing information reconstruction with corrections, «leveling» model inaccuracies in the field of real processes.

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