Development and scientific justification a set of the high-speed road construction machines with hardware-percent integration and intellectual interactions algorithm of various technical systems

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Abstract. The description of complex technical systems with the implementation of hardware and software integration through the introduction of additional controls is presented. Recommendations for increasing the service life of the road surface and preventing premature repair of asphalt concrete surfaces are presented. A review of possible difficulties in implementing new technologies in road construction companies is performed. The project of modernization of new equipment is described, considering the research conducted in the field of finding alternative solutions to eliminate the "human" factor during road construction works. The interaction of the components of the complex for high-speed construction of asphalt concrete pavements is considered. The work of machines is described from the energy point of view, which is based on various interaction processes. The main components of the system structure and principles are considered. Multi-factor processes of road construction equipment operation are explained. The structure of algorithms for implementing an integrated machine management system is presented. The structure of hardware interaction through mathematical modeling to direct control of machine functionality in real time is described. Asphalt paving is represented by a multi-factor process, where one of the significant factors of the quality of the laid asphalt concrete is the road construction equipment used, which provides the required quality parameters of the road surface. The article describes a method for creating complex structural elements that allow creating artificial intelligence systems in the future.

1. Introduction

When building and repairing road surfaces, contractors are increasingly faced with the problem of introducing new technologies and machines into the road construction process [1]. A group of scientists from the Department of Road-building machines MADI jointly with the plant "BETSEMA" was designed and developed high-performance range of machines (figure 1), consisting of haul trucks with bottom discharge loader asphalt mix, paver and band sealing equipment. In the resulting full-scale samples, it is possible to configure various parameters and operating modes of each machine. After the introduction of these machines into operation, the task appeared not only to manage each machine in the complex, but also the entire complex. This task is determined by several factors that affect the choice of equipment suitable for road construction. The first factor is economic feasibility. Not every organization can afford to purchase new equipment for work, and even more so if we are not talking about one car,
but about a whole complex of cars. For small developing companies, there is a solution – to purchase such equipment on lease, but then every minute of equipment downtime will cost "a pretty penny", and to coordinate all processes so that there are no downtime is a very difficult task.

![Complex of machines for high-speed technology of laying asphalt concrete surfaces.](image)

**Figure 1.** Complex of machines for high-speed technology of laying asphalt concrete surfaces.

But even if a road construction company is ready to accept such conditions, there is a second important factor-the competence of its employees when working with new equipment using new technology. After all, even when using the old classic technology of laying asphalt concrete pavements, when considering the work of the road construction team, it is almost always possible to talk about violations of technology, and violation of technology leads to loss of quality of the roadbed [2], which in turn leads to decrease in the service life of the road surface and premature repairs. If we consider the new technology of high-speed construction of asphalt concrete pavements, then the nuances and undesirable problems associated with the "human" factor become much greater. And if we consider the fact that the equipment used in this technology is new and not familiar to ordinary employees of a contractor, then thoughts about introducing any innovations disappear by themselves.

Based on the results of a large survey of road construction organizations, the main problems and shortcomings of new equipment and technology that most concern organizations were identified [3]. And based on the received material, it was decided to create a project for the modernization of new equipment in accordance with the requests. There was a goal-to improve road construction machines used in high-speed technology for the construction of asphalt concrete pavements, so as to eliminate as much as possible the possible negative impact of humans on the process of creating a road surface. Since it is necessary to minimize human involvement to solve the task, it is possible to implement a project of such complexity without changing the processes of construction technology only using a hardware and software integration complex and an intelligent algorithm for interaction of various technical systems.

### 2. Description of hardware and software integration

To understand the implementation processes in technology, we need to understand the overall goals of integration:

- reducing the cost of equipment operation (achieved by reducing the time for synchronization processes);
- increase the speed of performing the main processes of machine operation in a joint mode;
- improving the quality of the road surface;
- increase the safety of personnel (by minimizing participation in the processes of paving).

You can get closer to achieving common goals by looking at the structure and principles of the system in detail.

For each of the machines used in the technology, there is a so-called external (technological) environment, which includes equipment, equipment and objects of work.
When considering each machine of the complex, the main components can be identified. The first component is mechanical, a device that has a working organ as the final link in the chain. The second component is electronic, which includes power converters, executive motors, and drive units. And the third component is a computer, a device that is responsible for control, or through which the device or machine is controlled.

The first component is designed to convert the movements of the component elements into the movement of the working body and may include brakes, clutches, gears, mechanical links, and so on.

The second component includes a number of microelectronic devices, converters and electronics of measuring circuits, all sensors and sensor systems responsible for collecting data on the actual state of the external and internal environment.

The third component is used to control the process of mechanical movement in real time with the ability to process information from sensors. Coordination of control of movements of working bodies depending on external conditions is carried out, the organization of data exchange with peripheral devices is carried out.

Since the operation of the machine from an energy point of view is based on various pneumatic, hydraulic, or combined processes, it is necessary to add appropriate sensors and transducers to the system. Each element of the chain must be connected not only by hardware, but also by software, in order to exchange data in real time.

3. The intelligent algorithm of the interaction of technical systems

Turning to the interaction of technical systems, I would like to note the fact that even without the introduction of an integrated control system, machines can perform work in a rational range solely by setting the appropriate parameters by the machine operator [4]. Setting any operating mode by the operator of the machine may cause the machines to be out of sync with each other, since any change in the external environment, any unpredictable factor entails a change in the operating mode parameters of each machine in the complex. Since the laying of asphalt concrete pavements is a multi-factor process, it is necessary that road construction equipment both meets the parameters of variability of external conditions, and adequately responds to such changes (figure 2), adjusting the operating modes in accordance with the established parameters of the external environment. In addition to the external environment is crucial to the interaction of complex machines because the machines move each other by performing the operation between the machines must be linked [5,6] to the first machine could send information from sensors on the next machine in the processing chain, and they, in turn, was able to set modes and parameters of work in accordance with the incoming information.

![Figure 2. Influence of external factors on the cooling of the asphalt mix in the roller.](image-url)
It is advisable to create the implementation of such algorithms based on several integration points (figure 3), thus forming an intelligent network of interactions between the machines of the complex [8]. At the same time, the essence of the created automatic systems is the ability to make a choice from a variety of variations and make optimal decisions based on previously obtained experience and rational analysis of external and internal environmental influences without the direct participation of the operator.

4. Theoretical background to the creation of the "smart machine" system

Any software component strives to become an element of artificial intelligence in the future. When creating complex structural elements, various approaches to the possibility of creating artificial intelligence systems may arise:

1. Logical.
   This approach is based on Boolean algebra. The most interesting technique in this approach is the concept of fuzzy logic. A distinctive feature of the method is additional conditions, for example, veracity can take alternative intermediate values in addition to "Yes/no" (1/0) - the values "I don't know" (0.5), "rather Yes than no" (0.75), "rather no than Yes" (0.25).

2. Structural.
   A special feature of this method is attempts to create artificial intelligence by modeling the structure and operation of the human brain.

3. Evolutionary.
   Attempts to create artificial intelligence systems by creating a basic model and setting parameters and rules for changes in development (evolution).

4. Simulation.
   This system uses the concept of "black box". This is a device that is a software module or random data set, where any information about the internal content is missing, but the input and output data are known. For example, an object whose behavioral characteristics are simulated is essentially a "black box", and it doesn't matter what processes take place inside, the main thing is that the model behaves exactly the same in similar simulated situations.
   The most common and promising system is Logical, which involves creating algorithms for artificial neural networks and fuzzy logic.

5. Conclusion

In modern conditions of development of computer technologies, it is important to maintain a balance between the interaction of equipment and computer technologies that allow you to create complexes that provide an unprecedented quality of road construction work to repair and create new, durable asphalt concrete surfaces. Software packages allow for optimal interaction between machines within the same complex for high-speed construction of asphalt concrete surfaces, as well as between machines and the external environment, which has a significant impact on the operation modes of equipment. This allows you to increase the productivity and overall efficiency of the entire complex, which in turn will lead to an improvement in the quality of the resulting road surface, reduce the time to create such a section of road and improve performance.
The input parameters of the plot
L - length
B – width of the section coverage
H – the thickness of the layer

The input parameters of the paver
v – the speed of the machine
V – Volume of hopper
Ψ – e Frequency of rotation of the screw
vck-conveyor Speed

Calculation of the performance of the paver
\( \Pi_{p} = \Pi_{i} \cdot h_{i} \cdot b_{i} \cdot \rho \)

Traction calculation
\( \sum W_{i} = W_{1} + W_{2} + W_{3} + W_{4} + W_{5} \)

The input stage loader
D – width of the receiving hole
HP – height of the receiving hole
NP – the height of the loading
LP – loading length

Determination of the cross section of the asphalt concrete mix roller
\( S = 0.5 \cdot (a + b) \cdot h \)

Determining the speed of the loader conveyor
\( v_{c} = v_{0} / v_{p} \)

yes

yes

Data entry dump truck
Vc – the volume of the dump
vp – operating speed
VT-transport speed

The opening angle of the flap \( \Psi = 20° - 44° \)

yes

yes

The performance of the paver
\( \Pi_{p} = V_{p} \cdot h_{c} \cdot b_{c} \cdot \rho \)

The opening angle of the flap
\( \phi = 20° - 44° \)

F_{w} = \Pi_{w} \cdot F_{w}

The performance of the dump truck
\( \Pi_{w} = G \cdot \Pi_{w} \)



Figure 3. Algorithm for calculating the main parameters of the complex for high-speed construction of asphalt pavements
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