

# Implementation Features of Continuous Control of Asphalt Mix Compaction

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**Abstract**— Problematic tasks of Scientific-Practical direction of development of control and management systems for the main processes of road-building machines are considered. The stage "paving - compacting of asphalt mix" is separated. Effective management of this stage leads to a significant improvement in the quality of asphalt concrete pavements, increasing longevity and reducing coating imperfection. The prerequisites for the development of intelligent control systems by the working processes of road-building machines are grounded. Variants of complex automation of the technological process of road surfaces construction are offered.

**Keywords**— road building machines; asphalt paver; road roller; automation; intellectual compaction; continuous compaction control; control system

## I. INTRODUCTION

Asphalt pavements are the most common road pavements in the world. All stages of the road construction technological process have a significant impact on the quality of road coverage.

There are examples [1] of the existence of competition between road builders of cement-concrete and asphalt-concrete pavements in the USA. Supporters of flexible pavement with layers of asphalt concrete summarized the positive experience and proposed designs with a design life of the same as for cement concrete pavements – about 50 years. The service life of layers is from 3 to 15 years, depending on their quality and operating conditions. The accumulating internal stresses and irreversible deformations give rise to various defects and damage to the asphalt pavement [2].

The structure of asphalt concrete, which determines its strength and longevity, is largely formed as a result of compaction by road-building machines – the working attachment of the stacker and vibrating road rollers [3].

Deformations and road damage are divided [4] into defects and damage to the pavement and road surfacing in general. According to the authors' study [5], asphalt pavement of automobile road comes into operation already with a set of defects acquired at the previous stages of the life cycle.

According to the data of the world road statistics, there are three main reasons for the appearance of all (100%) defects in asphalt concrete coverings [6, 7]:

- 50% – low quality of asphalt mix compaction;

- 30% – poor selection of the grain size composition of the asphalt mix or deviation from the standards;
- 20% – low quality of materials in the mixture, especially bitumen, poor coating of particles by bitumen with stirring on bitumen concrete plant, low adhesion of bitumen to the particles of the mixture.

There are known scientific works [8–16] devoted to improving the quality of asphalt mix and road surfaces due to the complex automation of technological processes.

Taking into account all the above, it can be argued that a significant improvement in the quality of construction of asphalt concrete pavements, with a reduction of up to 50% of all defects and damages [6, 7], can be achieved through the technological stage – compaction of the mixture. It is based on modern technology of automated process control, realizable set of road-building machines (SRBM) for laying and compacting the mixture, which includes an asphalt paver and a link of rollers.

From the practice of road construction is known – the higher the density of asphalt after the stacker, the smoother and more durable the finished pavement [17]. Sealing capacity of asphalt pavers, as well as machines with similar sealing bodies, implementing the technologies "reshope", "regrip", "repave", "remix", "remix +", according to research of foreign and Russian scientists allows to achieve the specified coefficient of compaction, but manual control of this process is inefficient [18].

Leading foreign manufacturers of vibrating rollers offer sealing control systems (Asphalt Manager фирмы Bomag), control and measuring systems (ACE – Ammann Compaction Expert компании AMMANN) and others, adapted to their types of vibrating rollers. These and other systems allow accomplish continuous monitoring of the compaction degree, adjusting the amplitude and frequency of the roller vibration [19]. Road rollers do not guarantee obtaining of asphalt pavement of high quality: flaw is up to 65 % [20].

Road rollers in the Russian Federation are manufactured by enterprises without systems for automatic control and control of the compaction process that reduces their competitiveness in comparison with foreign ones, with a similar design and drive mechanisms.

Automation of road construction processes due to the development of the Internet network, global navigation systems (GPS, GLONASS), the use of microprocessor control systems, allows considering the tasks of road construction management efficiently and comprehensively, implementing the concept of BIM-technology - regulating the operating modes of machines using the information model of project road, current quality control and documentation of construction results.

Highlighting the technological process of asphalt mix compaction from the stages of road construction, in order to ensure compliance with the level of scientific and technological progress, a modern road roller, in addition to control systems for the vibration generator and quality control of the compacted material, must contain an adaptive engine control system and a state monitoring system, self-diagnostics, collection, storage and transmission of data of parameters set of the machine, its nodes and systems. It can be achieved by increasing the level of automation to the intellectual level.

Thus, the "intellectualization" of the roller makes it possible to improve significantly its most important technological indicators. The quality of compaction was improved by the use of systems for operational control of compaction; performance – by application of a vibration generator control system; reliability - using a system for monitoring the parameters of the units and systems of the roller; fuel consumption and emission toxicity - using the engine optimization system. Unfortunately, road construction machines manufacturers of the Russian Federation do not yet produce such products.

## II. IMPLEMENTATION PROBLEMS OF AUTOMATIC CONTROL SYSTEMS

The main obstacles that hinder the development and implementation of automatic control systems for vibrating road rollers are [21]:

- absence of Russian multimode vibration generators;
- lack of reliable and informative systems of the operational control of the road-building material state in the process of its compaction.

Among the shortcomings can be noted the significant cost of automated systems of foreign manufacturers, which does not allow to consider them for implementation to Russian models of road rollers.

Based on the analysis of the current state in the field of automation of road building materials compaction in the United States, the following conclusions can be drawn:

- to organize the promotion of intelligent compaction (IC) technology for grounds and pavements in the United States, the Task Working Group was formed, which included representatives of federal agencies (FHWA – Federal Highway Administration), representatives of IC developers of leading research centers;
- the main road-roller manufacturers – Caterpillar, Dynapac, Sakai, Ammann, Bomag, Volvo offer rolling equipment with IC, GPS and radio equipment;

- over the past few years, theoretical and experimental research on IC technology and, continuously spreading in Europe and China, continuous compaction control have been and continue to be carried out in leading research centers with the financial support of the Federal Highway Administration.
- in different states of the USA, practical seminars are organized to train specialists in theoretical and practical IC basics and methods for controlling vibratory rollers, standardizing road construction works;
- demonstration tests of vibrating rollers of different manufacturers equipped with IC automation are conducted during the year;
- the technology of intelligent compaction is brought to the level of standardization of road construction works;
- all activities conducted in the US based on the system approach, contributes to a significant improvement in the quality and productivity of road construction.

In the Russian Federation, none of the above activities are available, with the exception of the initiative research works carried out by scientists in educational institutions: MFCU, MADI, Peter the Great St. Petersburg Polytechnic University, Yaroslavl State Technical University, the Siberian State Automobile and Highway University (SIBADI), Pacific National University, Siberian Federal University, etc.

Taking into the account current level of theoretical knowledge about road building materials compaction, scientific and technical achievements in the development of automatic control systems for road rollers, it is possible to formulate a scientific task on the necessity to develop a concept of integrated automation and intellectualization of the paving processes and asphalt mix compaction s in order to improve the quality road surfaces.

## III. DESIGNATION AND GOALS OF THE SYSTEM CREATION

The complex system of automated control of the working processes of the "asphalt paver – road rollers" kit (hereinafter referred to as SYSTEM), providing the paving and mixture compaction, is designed to control the operating parameters of the PRBM, which, without the direct involvement of the human operator, are adapted to the changing conditions of technological processes, taking into account the characteristics of the road building materials, other disturbing factors to ensure a given degree of compaction of the asphalt pavement.

The objectives of creating a SYSTEM are:

- improvement of working conditions of machine operators due to automation of process control;
- improvement of performance indicators for PRBM;
- increasing of asphalt pavement longevity.

SYSTEM management criteria.

Evaluation criterion of achievement system creation objectives are:

- increasing the productivity of the PRBM and reducing the "human factor" in the management of machine operation modes;
- maintaining the specified level of compaction degree.

The actual direction in the improvement of machines for the asphalt mixture construction is the development of new technical solutions, theoretical and experimental studies, and preparation of techniques for designing new structures.

Using the system approach in the scientific and applied area of the implementation of the concept of integrated automation of the SYSTEM, the authors developed new technical solutions for automatic control systems for the processes of paving and asphalt mix compaction [22-27]. Also known [28, 29] modern solutions for the integrated automation of the "asphalt paver - roller" set based on the temperature control of the asphalt mix, which allows the machinists to take prompt and correct actions to control the operating modes of the machines. However, it is necessary to have a high qualification of the driver for this process management variant.

Taking into account the complexity of the asphalt paver construction, due to the presence of several technological units with hydraulic gears (running gear, feeder, left and right screws, left and right, electrohydraulic height control of the working device, sidewalls of the bunker, lifting mechanism the working element into a position for transportation, tamper bar and a vibration plate), it is recommended to use a decentralized automated control system combining information flows in the on-board computer of the machine. Control systems regulators of stacker aggregates, taking into account the features of the working process, significant influence of external disturbing factors, can be created using intellectual (fuzzy, neural, hybrid) technology. This kind of machines automation can be referred to the intellectual.

It is proposed to supplement the already existing control systems for the asphalt paver with the control system of the sealing process by the working body on the basis of fuzzy logic, an artificial neural network. The input data on the efficiency of mixture compaction by an asphalt paver the subsystem of compaction control can obtain by using a radio signal from the vibrating roller following it, taking into account the current level of development of automated vibrating rollers, which makes it possible to obtain information about the compaction factor with a sufficiently high degree of reliability.

The second variant of the subsystem of stacking control by the stacker is proposed as a set of elements. These elements form a control signal for changing the rotational speed of the eccentric shaft of the ramming bar by comparing the reference control signal and the output converted signal of the strain gauge corresponding to the force in the tamper bar structure.

Automatic control systems for asphalt vibratory rollers are developing in the direction of intellectualization of the compaction process with centralized control. The fuzzy and neuro-fuzzy regulators are proposed to be used in ACS for vibrating rollers [27].

#### IV. CONCLUSION

Taking into account the strategic plans for road construction in the Russian Federation, in order to ensure the high quality of the finished asphalt pavement, it is necessary to introduce intelligent automated control and control over compaction processes at critical stages of road-building works of paving and compacting of the asphalt mix.

Implementation of the BIM-technology concept in road construction works involves the use of vibrating rollers with devices for intelligent compaction (or continuous compaction control), with a set of global navigation and radio communication equipment, which significantly increases the efficiency of work. In the United States, these systems are gradually becoming a standard in the road industry, and specialists are training actively to use these systems. In the Russian Federation, such work does not have the necessary level of state support. There are both objective and subjective factors that inhibit the implementation of similar technologies and methods in the industry. The variants of implementation of the intellectualization concept of technological processes control systems for the road construction of road asphalt concrete pavements are proposed.

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