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ИЗВЕСТИЯ
НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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IMPROVING THE METHODS OF MILLING GAUGE ON HIGHWAYS

Abstract. Machines for milling asphalt concrete surfaces appeared on the highways of the Republic of Kazakhstan about ten years ago. Before that, the replacement of the old asphalt pavement took place under the deafening crack of jackhammers. Road cutters made it possible to replace this outdated technology with profiling of asphalt concrete surface.

This type of work consists in removing the asphalt coating layer by cold milling. Typical characteristics of the road milling cutter: working speed of 5-7 m /min, sufficient power, traction and stability to ensure accurate maintenance of the working depth from 3.5 mm to 5 cm; automatic leveling system using a leveling beam or string; automatic control of the milling depth using guide slides; the ability to maintain a given transverse slope; auxiliary equipment for the selection of crushed material (asphalt granulate) at a given processing speed; the width of the working area of the milling strip is 2-4 m.

Profiling of old asphalt pavement is an automatically controlled process of cold milling it to restore a given transverse and longitudinal profile, remove bumps, potholes, wear zones, as well as other coating defects, and as a result, obtain a surface that allows for the immediate start of movement or the laying of a fresh coating. Modern road cutters allow you to plan the old coating, texture its surface, giving it the lost coupling and noise protection properties, remove the old coating layer by layer (with an accuracy of up to mm) or immediately to the full depth, carefully open the places of laying underground pipelines and communication lines, release the old coating manholes and even level concrete floors in industrial premises.

In this paper, this problem is supposed to be solved by presenting the road cutter as an automated road transport and technological manipulator operating in generalized technological coordinates for the repair of road surfaces with variable track age and due to the transition from elastic (power) to rigid (coordinate) closure of the technological scheme for milling track gauges.

Key words: Road milling cutter, Road machinery, Gauge, Cutting element, Cutting ring.

Introduction. Rutting on highways is one of the main reasons leading to an increase in the risk of road accidents, reduces the comfort and economic efficiency of using motor roads. For example, the variation of the track reaches up to 17 cm in height and up to 35 cm in width. Track formation is classified mainly into wear, deformation, and combined. After rain, the track is filled with water, which creates a dangerous effect of aquaplaning the wheels of vehicles. All this causes the need for milling the road surface during repairs and reconstruction /1,2,7,8/.

Over the past more than twenty years, the road technology has been modified. Accordingly, the requirements for the technology of road surface profiling, including milling, should be revised, justified and supplemented. The creation of automated road milling cutters (ARC) made it possible to implement track milling operations much easier and more efficiently as part of road repair and road safety measures.

Therefore, the topic of improving the methods of track milling is relevant, and therefore the problem of improving the efficiency of repair of road surfaces based on the use of ARC is relevant /3,4,5/.

Methods. Industry-specific road guidelines for identifying and eliminating ruts of non-rigid road clothing are considered. The document is devoted to the calculation and forecasting of track formation on non-rigid road clothing. The method of calculation and prediction of coleoptere involves collecting and processing data; by-layer calculation of the residual (plastic) deformation; component of the calculation of depth gauge with the accumulation of permanent deformation; the calculation of the component of depth to-Lea due to the accumulation of residual deformation and structural damage; calculation of the relative depth of the track due to the accumulation of residual deformations in the bitumen-containing layers.

This technique makes it possible to assess the uniformity of the coating.

In the world practice, various equipment for measuring the evenness of the road surface has been developed, depending on the principle of operation and design. In Kazakhstan, the most widespread are labor-intensive manual measurement methods using portable slats of various lengths.

Two approaches to measuring gauge parameters, developed by scientists of the Moscow Automobile and Road State Technical University using a three-meter rack and a status assessment scale, road to horn in terms of gauge parameters, were considered.

The paper deals with the formation of criteria for generalized forces, coordinates and work for the working bodies of automated road cutters. This creates a multi-connectivity and multi-contour interaction of the control vector with the vector of the driving influences and perturbations.

Two control modes are offered for the ARC control system: operator and non-operator. For implementation without operator mode, two software methods can be used: positional and power. The main types of ARC control (taking into account the similar practice of using technological robots) are divided into - cycle, positional and contour.

On the basis of the idea underlying the device for measuring the longitudinal micro-profile of roads, the concept of improving the quality of milling was put forward by eliminating from the resulting micro profile irregularities in the wavelength of which affect the vibration load of a person, this effect in milling is obtained due to a long-base chassis. The promise of this idea is confirmed by numerical experiments of modeling the use of the device.

The efficiency of laser technologies application in installation of laser scanners on road cutters was analyzed.

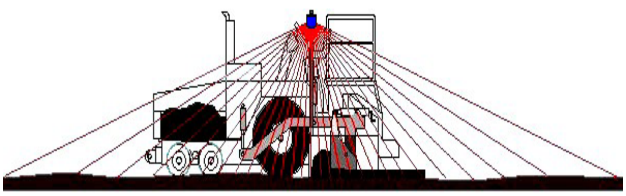


Figure 1 - RSS scanning system installed on asphalt laying

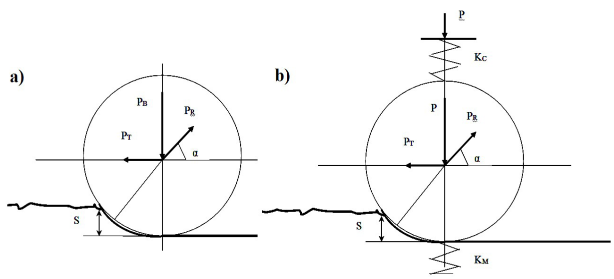
The traditional software and hardware of road cutters and the principle of their operation with these positioning and basing systems are considered. The modern RSS system (Road Scanning System), based on ultrasonic sensors and first introduced on asphalt liners, is described in detail. The concept of positioning road cutters using stationary laser posts is considered. Features of laser scanning systems arrangement on mobile units are presented. Laser scanning rangefinders operate on the principle of measuring the range to the spot on the surface based on either measuring the time interval between the sent and reflected signal, or measuring the phase shift.

Figure 2 - The result of milling the protrusions during the power circuit control

The necessity of switching from a power closure to a coordinate closure is justified, based on the general picture of the forces acting on the milling drum. An example of the result of milling a bulge by the method of elastic (power) closure of the technological scheme for milling a track and its bulges is shown in Figure 2. In the automatic system, a power-circuit control with feedback was used for manually set correction variable increments of the level of adjustment of the milling drum bearings.

It is established that as a result of power milling with vertical force stabilization, the processed (milled) surface turns out to be buried, in the form of a chute, and also uneven. The unevenness is primarily due to the fact that force deformations are produced during milling, caused by the variable height of the rollers of the track bulges, which is depicted by the displacements of the characteristic in Figure 2.

An analogy was made between similar processes in metalworking (milling) and asphalt concrete milling. A diagram of the forces acting on the milling drum is shown in Figure 3.



a - the scheme of forces in milling; b - the scheme of forces with elastic elements

Figure 3 - Diagram of the forces acting on the milling drum

PB - pressure force on the tool (drum); PT - longitudinal thrust force; PR - is the reaction force from the shear layer; S - s the thickness of the layer to be cut; α-angle between reaction force of cut layer and horizon. You can see that:

$$\alpha = \arccos\left(\frac{R}{R-0{,}5*S}\right) \qquad 1)$$

Force opposing longitudinal movement of the:

$$P_{RT} = P_R \cos\alpha \qquad 2)$$

Lifting force:

$$P_{RB} = P_R \sin\alpha \qquad 3)$$

The reaction force PR depends on the thickness of the shear layer, the speed of the longitudinal movement and the modulus of elasticity of the pavement material. The analysis of forces will not be complete, if we do not take into account the elastic characteristics of the system. The gravity of system P and two elastic elements of KC - hardness of ARC system and KM - gesture-bone of pavement are added. Analysis of the elastic interaction system of the cutter - tool - of the treated coating shows that provided that the stiffness of the material KM is greater than the stiffness of the mechanical system of the road cutter Kc, the elastic system of the road cutter will deform to a greater extent, and accordingly the milling drum will rise from the given zero treatment line. If the KM is larger than some critical value, determined by the weight of the road cutter in terms of the pressure exerted on the drum axis, not only the tool, but the entire ARC will rise above the zero treatment line. In this case, the tool (drum) will enter the "glide" mode. On the other hand, when the stiffness of the material is reduced and the pressure on the side of the road cutter is maintained, the milling drum will be buried more than a predetermined value.

The dashed line shows the level of pavement prior to milling. The idea of the MTC system is offered (a mill - the tool - a covering), mathematical modeling of process of milling is carried out and the mathematical dependence allowing to determine the optimum depth of milling taking into account elasticity of the MTC system is developed.

The differential removal equation by milling the variable allowance of the re-mounted pavement, depending on the influencing factors, can be recorded, taking into account the results of the work of Professor A.N.Vasin /6/, as:

$$\frac{dz}{d\tau} = S - \frac{dy}{d\tau} \qquad 4)$$

where dτ is the elementary time period; *S* - speed of movement of working tool of road cutter; *dy* - elementary elastic deformation of the process system (pre-cutting cutter - tool - road surface); *z* - allowance removal value

Nominal actual speed of pavement allowance removal:

$$S_Z = S - S_y \qquad 5)$$

where *Sy* - is the rate of elastic deformation.

$$J_{TC} = \frac{P_y}{y} \quad J_P = \frac{P_y}{S_Z} \qquad 5)$$

where JTC - is the rigidity of the technological system "road cutter - tool - road surface"; JP - estimation of rigidity of the gauge recesses; Py - normal cutting force; y - is the driving force of the milling cutter working element movement during elastic deformation.

The results of mathematical modeling of the removal of the allowance depending on the time, the speed of movement of the ARC cutting tool, the assessment of the rigidity of the road surface bulges and the rigidity of the technological system are shown in Figure 4. The results show, for example, that the feed rate of 100 mm/min (1.66 mm/s) corresponds to the milling allowance (discharge height) for the steady state in the diap zone up to 50 mm (3000/60 = 50) /7,8,9/.

As a result of the conducted research, it was found that the problems of controlling the milling of the track and its protrusions on existing road cutters arise from the lack of feedback, so it is possible to build an adaptive road surface milling system if the milling system is supplemented with feedback sensors and appropriate software. The principle of operation of the software complex of computational modeling is proposed, which allows determining the recommended height of the removed allowance of the track bulge for the initial conditions of the steady-state mode. The software package of computational modeling allows us to determine the recommended increase in the height of the removed gauge allowance for the initial conditions of the steady-state mode:

$$\Delta Z = b\int_0^\tau S_Z d\tau = S\int_0^\tau\left(1-e^{-\frac{J_{T.C.}}{J_P}\tau}\right)d\tau = S\left(\tau-\int_0^\tau e^{-\frac{J_{T.C.}}{J_P}\tau}d\tau\right) = S\left[\tau-\frac{J_P}{J_{\text{ТС}}}\left(1-e^{-\frac{J_{\text{ТС}}}{J_P}\tau}\right)\right] \qquad 6)$$

where ΔZ - is the increment of the height of the track clearance allowance to be removed, and b - is the adjustment coefficient (from 0 to 1,0).

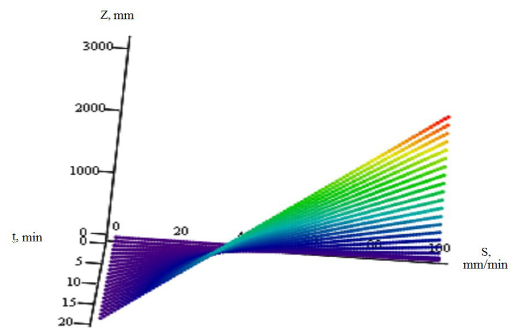
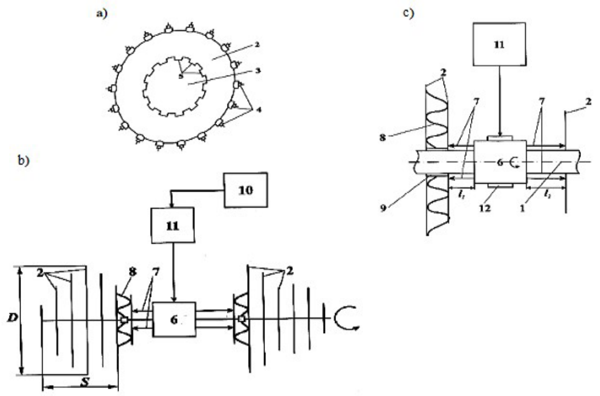


Figure 4 - Results of numerical simulation of the milling process

In this way, the goal of improving the accuracy of milling the track and its edges on the road using a road cutter can be realized by improving the milling technology and ensuring the required properties of the road cutter in real conditions of changes in the dimensional and mechanical parameters of the road surface and the operating modes of the cutter.



a - cutting ring; b - milling drum; c - ring with elastic-deformable element;

1-cylindrical body; 2-cutting rings; 3-mounting holes; 4-cutting element; 5-rectangular spline surfaces;

6-adjustable drive device;7-rods; 8-elastic-deformable elements; 9-landing holes; 10-depth sensor;

11-micro-processor control device; 12-current collector;

Figure 5 - Milling drum design

A schematic diagram of the control of an automatic milling machine is proposed, which consists in expanding the functionality of a road milling machine operating in the construction and road construction machines (Figure 5).

Milling drum containing a cylindrical body with cutting rings in the form of discs with the base mounting holes located on the peripheral parts of the disc cutting elements in the form of rotating cutters, characterized in that the mounting holes of the cutting rings from further prepared rectangular spline surfaces on the outer surface of the case is made additionally rectangular spline slots with minimal clearance at the width groove interacting with rectangular spline surfaces of the holes of the cutting rings, the composition of the milling drum included Central symmetrically along the axis of the drum is adjustable drive unit with extendable along the axis of the drum in both directions stocks that interacts with end surfaces closer to the stocks located to cutting rings with locking reached lengths of extension rods, elastic deformed elements in the form of, for example, one- or two-wavelength thin-walled corrugated elements with a Central base to bore, gauge the depth of milling and microprocessor-based control device, with cutting ring combined in different configurations correspond to the maximum depth of cut layer sets variously diametrically opposed cutting rings, elastic deformed elements are placed between the cutting rings with the opportunity to interact with their end surfaces, and the sensor output of milling depth is associated with the input of the microprocessor, the output of which is connected to the input of the adjustable drive device.

As a result of the work of the road machine with the proposed milling drum, due to the feedback from the milling depth sensor and the regulating correlating effect from the sliding rods, the required milling depth of the defective layer of the road surface is removed with a high quality of surface treatment of the road section under repair. By changing the configuration of the sets of cutting rings, it is possible to remove any amount of allowance (depth of milling), provided that the force load on the cutting elements of the rings is uniform and their wear is minimal.

Results. Experimental studies of automated road milling cutter control methods and practical results are presented. After processing the results of the experiment, mathematical dependences were obtained (the feed force on the milling depth and feed speed, the average value of the milling resistance was determined, the drive power was determined taking into account the tool diameter and the angular speed of rotation.

The experimental stand is implemented on the basis of a horizontal milling machine by changing it and equipping it with a removable table for fixing asphalt concrete samples (Figure 6). The model of the road milling cutter is a typical set milling cutter. A procedure for measuring deformations and measuring vibrations of a sample of asphalt pavement using a universal magnetic measuring head has been developed.

Two series of experiments were carried out with elastic (Figure 6, a) and rigid (Figure 6, b) closure. In the first case, a 20 mm thick rubber sheet was placed between the clamping device and the milling machine table. In the second case, the clamping device was rigidly attached to the table of the milling machine. A disc cutter, a sample of asphalt concrete with an uneven surface, was selected. Milling was carried out towards the direction of movement of the surface to be processed

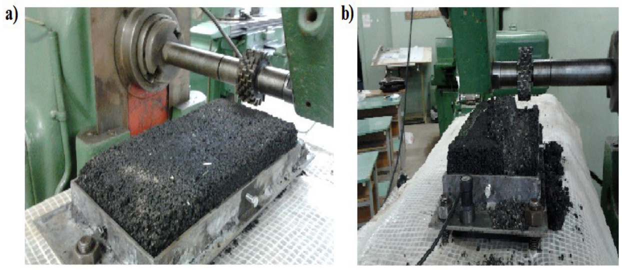


Figure 6 - Experiment on simulation milling of asphalt concrete samples

Two modes were investigated:

- with an elastic element (rubber). The fastening was carried out by a clamp with a submerged elastic element. In this case, there was an increased spread of deviations in the milling dimensions and an increase in the average height of the milled surface.

- in the case when the sample with asphalt concrete was fixed rigidly, lower average values and a variation in the deviation of the milling size by 1.9-2.3 times were observed. This confirms the effectiveness of the transition from force closure to coordinate closure or displacement control. Simulation (computational modeling) was carried out) in which different control methods were compared with pulsating sub-adjustments.

On the vertical axis, the number of measurement points is plotted in increments of 0.1 mm, and on the horizontal axis, the number of the measurement point is plotted. The KP-514 mobile road diagnostic laboratory (before and after the use of the Wirtgen road milling cutter) was used for driving along a 1200-meter section of the highway. Based on the results of the passes, the values of evenness for each 50 m of the measured section were obtained. The variance of the samples of the average evenness values for the measured section with a length of 1200 m and the standard deviations for the initial and milled road surface confirm the effectiveness of the method.

Conclusion.

The milling machines mass-produced by leading companies and the modern technologies of road surface milling developed on their basis are best suited for performing a whole range of specific practical tasks for the repair of road surfaces with variable trackage.

Proposals have been developed to select optimal methods for milling road surfaces with variable dimensional and mechanical characteristics and new arrangements of road cutters based on non-mechanical kinematic connections.

An improved technology for using a road cutter as an automatized road technological manipulator is proposed, which realizes correlation of the level of dimensional adjustment with vertical changes in the position of the working tool and formalized adaptive pulsating climbs of the dimensional adjustment of the tool based on feedback on deviations of the level of milled over the required values.

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АВТОМОБИЛЬ ЖОЛДАРЫНДАҒЫ ЖОЛТАБАНДЫ ФРЕЗЕРЛЕУ ӘДІСТЕРІН ЖЕТІЛДІРУ

Аннотация. Асфальтбетон жамылғыларын фрезерлеуге арналған көліктер Қазақстан Республикасының автокөлік жолдарында шамамен он жыл бұрын пайда болды. Бұған дейін ескі асфальт жамылғысын ауыстыру ұру балғаларының құлақ тесер шуының арқасында жүзеге асырылатын. Жол фрезалары бұл ескірген технологияны асфальтбетон жамылғысын профильдеумен алмастыруға мүмкіндік берді.

Жұмыстың бұл түрі суық фрезерлеу әдісімен асфальт жамылғысы қабатын алып тастауға келіп тіреледі. Жол фрезасының типтік сипаттамалары: жұмыс жылдамдығы 5-7м/ мин, 3,5 мм-ден 5 см-ге дейін өңдеу тереңдігін дәл сақтауды қамтамасыз етуге қажетті жеткілікті қуат, тарту күші және орнықтылық; нивелирлеу арқалығының немесе сырықтың көмегімен автоматты теңестіру жүйесі; бағыттаушы арналардың көмегімен фрезерлеу тереңдігін бақылаудың автоматты жүйесі; берілген көлденең еңісті ұстап тұру мүмкіндігі; берілген өңдеу жылдамдығы кезінде ұсақталған материалды (асфальт түйіршігін) таңдауға арналған қосалқы жабдық; фрезерлеу жолағының жұмыс аймағының ені 2-4 м.

Ескі асфальтбетон жамылғысын профильдеу - бұл берілген көлденең және бойлық профильді қалпына келтіру, төмпешіктерді, шұңқырларды, тозу аймақтарын, сондай-ақ жамылғының басқа да ақауларын алып тастау және нәтижесінде қозғалысты жылдамдатып бастауға немесе жаңа жамылғы төсеуге мүмкіндік беретін бетті алу үшін оны суық фрезерлеудің автоматты түрде басқарылатын процесі. Қазіргі заманғы жол фрезалары ескі жамылғыны тегістеуге, оның бетін текстуралауға, оған жоғалтқан ілінісу және шуылдан қорғау қасиеттерін бере отырып, ескі жамылғыны қабаттап (мм-ге дейінгі дәлдікпен) немесе бірден бүкіл тереңдікке алуға, жерасты құбырлары мен байланыс желілерін төсеу орындарын мұқият ашуға, құдықтар люктерін ескі жамылғыдан босатуға және тіпті өндірістік ғимараттардағы бетон едендерді тегістеуге мүмкіндік береді.

Зерттеліп отырған жұмыста бұл мәселені жол фрезасын ауыспалы жол жамылғыларын жөндеу үшін жалпыланған технологиялық координаталарда жұмыс істейтін автоматтандырылған жолдық көліктік-технологиялық манипулятор ретінде ұсыну арқылы және жолтабан шығарғыштарды фрезерлеудің технологиялық сұлбасының серпімді (күштік) тұйықталуынан қатаң (координаталық) тұйықталуға өту арқылы шешу болжамы қарастырылған.

Түйін сөздер. Жол фрезасы, жол техникасы, жолтабан, кескіш элемент, кескіш сақиналар.

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СОВЕРШЕНСТВОВАНИЯ МЕТОДОВ ФРЕЗЕРОВАНИЯ КОЛЕИ НА АВТОМОБИЛЬНЫХ ДОРОГАХ

Аннотация. Машины для фрезерования асфальтобетонных покрытий появились на автомобильных дорогах Республики Казахстан около десяти лет назад. До этого замена старого асфальтового покрытия происходила под оглушающий треск отбойных молотков. Дорожные фрезы позволили заменить эту устаревшую технологию профилированием асфальтобетонного покрытия.

Данный вид работ заключается в удалении слоя асфальтового покрытия методом холодного фрезерования. Типовые характеристики дорожной фрезы: рабочая скорость 5-7 м/мин, достаточная мощность, тяга и устойчивость для обеспечения точного выдерживания глубины обработки от 3,5 мм до 5 см; автоматическая система выравнивания при помощи нивелировочной балки или струны; автоматическая система контроля глубины фрезерования при помощи направляющих салазок; возможность поддержания заданного поперечного уклона; вспомогательное оборудование для подбора измельченного материала (асфальтового гранулята) при заданной скорости обработки; ширина рабочей зоны полосы фрезерования 2-4 м.

Профилирование старого асфальтобетонного покрытия - это автоматически управляемый процесс его холодного фрезерования для восстановления заданного поперечного и продольного профиля, удаления бугров, выбоин, зон износа, а также других дефектов покрытия, и в итоге получения поверхности, допускающей немедленное начало движения или укладку свежего покрытия. Современные дорожные фрезы позволяют планировать старое покрытие, текстурировать его поверхность, придавая ей утерянные сцепные и шумозащитные свойства, снимать старое покрытие послойно (с точностью до мм) или сразу на всю глубину, аккуратно вскрывать места прокладки подземных трубопроводов и линий связи, освобождать от старого покрытия люки колодцев и даже выравнивать бетонные полы в производственных помещениях.

В работе данную проблему предполагается решить за счет представления дорожной фрезы, как автоматизированного дорожного транспортно-технологического манипулятора, работающего в обобщенных технологических координатах для ремонта дорожных покрытий с переменной колейностью и за счет перехода от упругого (силового) к жесткому (координатному) замыканию технологической схемы фрезерования выпоров колеи.

Ключевые слова: дорожная фреза, дорожная техника, колея, режущий элемент, режущие кольца.

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