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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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CONTROL'S ACCURACY IMPROVEMENT AND REDUCTION OF LABOR CONTENT IN ADAPTING OF WAYS OF METALCUTTING TOOLS

Abstract. As a result of the conducted researches it was revealed that the bottle neck in the production of metal-cutting machine tools is the provision of the norms of fitting the functionally connected surfaces of the guide support and foundation slab. Adherence of functionally connected surfaces is carried out by a labor-intensive locksmith operation-scraping. In this case, the fit of functionally connected surfaces can take from several hours to several days. It was also found that the imperfection of the system for setting the dimensions of the functionally connected surfaces of the guiding metal cutting machines is a problem. Imperfection of the existing system of dimensioning leads to the fact that dimensions are laid with very high tolerances. This leads to the removal of large allowances during scraping on metalwork operations and, consequently, to an increase in the laboriousness of fitting work. In order to solve this problem, the authors developed a new system for setting the linear and angular dimensions of functionally connected surfaces, as well as the design of instrumentation and devices. In the given article results of statistical researches of stability of results of measurements by control rulers of a special design are resulted. The data of the conducted experiments showed that the accuracy of the arrangement of the angles of the V-shaped guide parts of the lathe HT-250I with the help of control rulers can be increased by more than 10 times in comparison with the deviations given in the drawing.

Keywords: functionally connected surfaces, machine guides, scraping, control ruler, V-shaped surface, measurement accuracy, labor, hidden base, allowance.

Introduction. The development of engineering has led to paying more attention to the processing of functionally connected surfaces in the recent years. In the world practice, more attention is paid to the creation of methodologies, technological processes, tool wares, measurer, etc., which would have led to the reduction of a labor content of processing and assembling of functionally connected surfaces (FCS) of the parts and junctions. However not all the problems connected with ensuring of accuracy and reducing of labor content as well as assembling of such surfaces are solved. As a rule when checking the geometric accuracy of the tools there appear the errors in the size among FCS [1-6].

The FCS with the movable surfaces relative to each other are of particular importance. Adapting pedestal bases and slide assembly are considered to be such surfaces in the metalcutting tools. One of the problems is caused by the imperfection of the dimensioning system of FCS directing metalcutting tools. The imperfection of the existing system of dimensioning leads to the fact that the dimensions are placed with very high tolerances. It leads to the removal of large allowances for scraping on the plumbing operations and, consequently, to increasing of the complexity of fitting works. In the machine tool industry in the assembly of metalcutting tools, V-shaped rails and planes of engagement of the slide

assembly have a mirror image of the guiding of the pedestal base of the tool, and are adjusted by manual scraping on spots of adjoining to the pedestal base [7, 8].

In conjunction of the guiding of the pedestal base and slide assembly, the problem is to ensure the accuracy of fit of contacting surfaces. Thus, according to the literary data, arrangement can take some time from several hours to several days [9-11]. Therefore, the bottleneck in the production of metalcutting tools is to ensure the norms of adjoining of the guiding of the pedestal base and slide assembly. Typically, the engagement is made by a scraping operation. In such provision of accuracy of engagement to ensure the performance of plumbing work affects the value of the allowance taken from each surface of engagement [12-14]. The scraping process is carried out in the places of contact of FCS and, as a rule, in one of the elements that adjusting in the contiguous details. The arrangement of engagement surfaces in precision compounds, such as metalcutting tools, is brought to that time while on the square 25 mm to 25 mm will not be 20-25 spots of the contact [15, 16].

Methodology of solving the tasks of the research. There are shown the slip plane *A, B* and *V* of the carriage of the tool NT-250I on the figure 1. These planes are functionally related. The dimensions among FCS which determine their relative positions are tabulated. The planes B and C form a V-shaped surface. We have made an analysis of existing schemes of the dimensions among the FCS, which has showed that the dimensioning among the planes of the guiding practically does not occur. To dimension an additional sending of a certain size which is located on a V-shaped surface is used (figure 1).

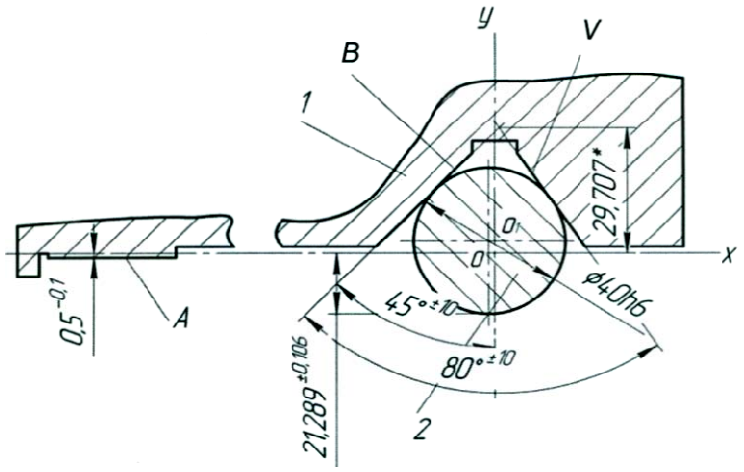

Figure 1 – The existing scheme of dimensioning between the FCS, the carriage of the tool NT-250I:
1 – carriage of the tool; *2* – arbor, axis OX and OY

On the drawing carriage machine NT-250I the position of the plane A and the planes of the V-shaped surface are connected by the following dimensions:

1. The position of the plane A is determined by the size of 29.707* mm, 21.289 ± 0.106 mm, and 0.5-0.1 mm.
2. The position of the plane B is determined by the size of the angle of the V-shaped surface of 45° ± 10' from the axis of OY.
3. The position of the plane C is determined by the size of the angle V-shaped surface of 80° ± 10' from the position of the plane B.
4. The OX axis is at the distance of 21.289 ± 0.106 mm from forming a cylindrical mandrel.
5. The OY axis goes through the top of V-shaped surface and is perpendicular to the OX axis.

According to the existing scheme of dimensioning position of the plane passing through the OX axis is determined by the size of 21.289 ± 0.106 from the forming mandrel *2*. The plane passes through the OY axis and it is determined by the position of the axis at the apex of the angle V-shaped surface of the guide carriage. Analysis of the provisions of the "hidden databases" relational to FCS has showed that there is a degree of freedom of the mandrel *2* and relational to the element *1*. Figure 2 shows the scheme arrangement of "hidden databases" according to the existing scheme of dimensioning.

The analysis of the dimensioning scheme on the figure 2 shows the following:

1. The position of the coordinate plane which is passing through the OX axis is determined by the size of 29.707* mm of the P point of V-shaped top surface and the distance of 21.289 ± 0.106 mm from forming a cylindrical mandrel. The size of 29.707* mm is a reference and can not determine the position of the plane F. Thus, we can assume that the position of the plane F is not defined.

2. The angle of 45° ± 10' from the plane is given by Q, the position of which depends on the position of the plane F. The uncertainty of the plane *F* leads to the uncertainty position of the plane *Q*.

3. The uncertainty of the position of the plane *Q* leads to the uncertainty of the provisions of the planes *B* and *V*.

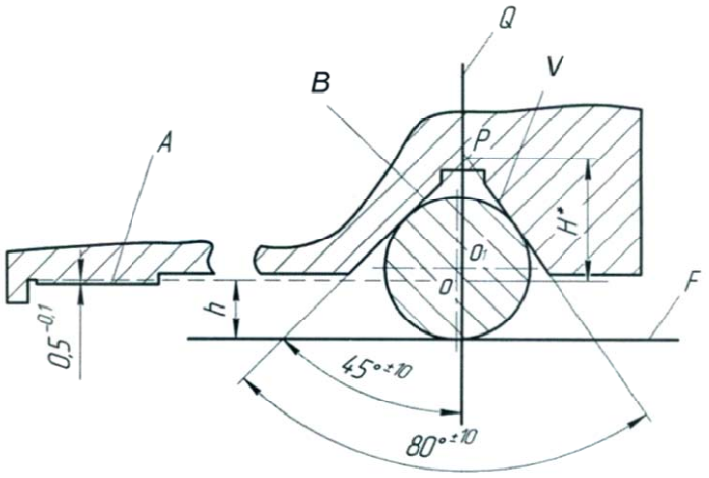

Figure 2 – An arrangement of "hidden databases" on the existing scheme of dimensioning

The imperfection of the existing system of dimensioning leads to the fact that the dimensions are laid with large tolerances. For example, as it is shown on the figure 1, the size of 21.289 ± 0.106 mm is inserted according to 12 quality classes of accuracy, the angular dimensions of 45° and 80° to 13 degree of accuracy. It leads to the removal of large allowances for scraping on the plumbing operations and consequently to increasing of the complexity of the fitting works. We propose a different system of measurement of dimensions between FCS guiding rectilinear movements of metalcutting tools [17]. Whether to design or to project the technological process the explicit and 'hidden base' are used. Structurally designed planes belong to "Explicit bases". "Hidden databases" include "... the coordinate planes, perpendicular to the mentally performed databases of the part which are designed and structurally processed to bring their total up to three" [18]. Figure 3 is a hidden base of the plane *Q*, passing through the OX axis. The planes carried out along the axes OX and OY as well as coordinate plane XOY and which are perpendicular to each other and run parallel and perpendicular to the direction of motion can be called as "hidden databases". Figure 4 show a new scheme to dimension among FCS carriage tool NT250-I.

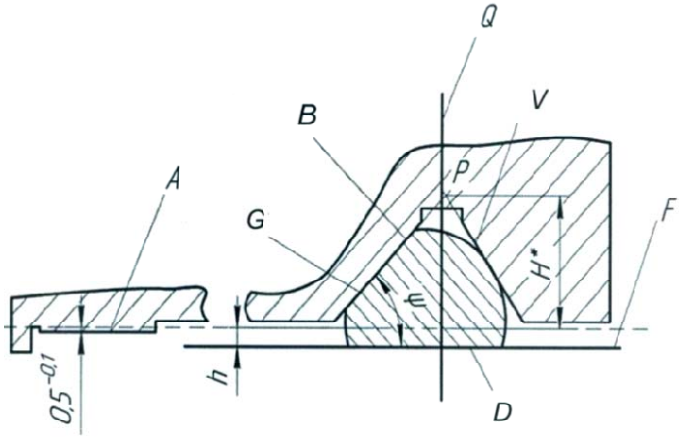

Figure 3 – An arrangement of "hidden databases" on the new scheme of dimensioning

The following examples of schemes above show that the linear and angular dimensions might be with higher deviations. The usage of CL lets us define the plane of the surface F with respect to the carriage with the size of h. Certainty of the plane of the surface F leads to a definite position of the plane *Q*.

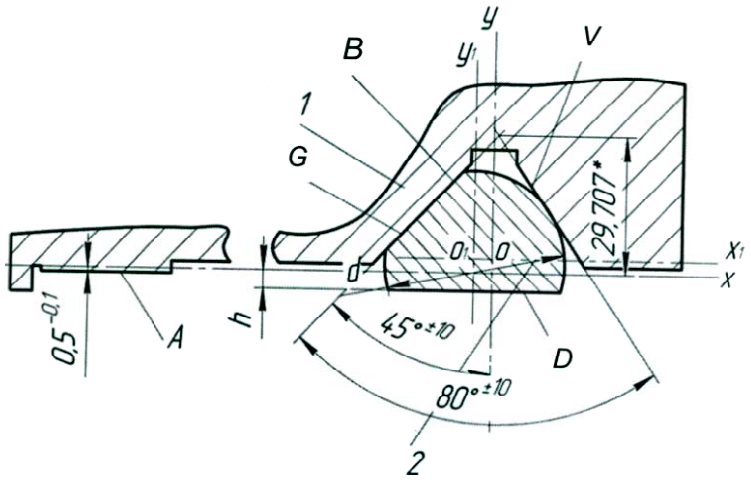

Figure 4 – A new scheme of dimensioning of the tool carriage among FCS and NT-250I:
1 – carriage of slide assembly, *2* – the control line; *D* and *G* – wrench flats on the control line

Summing up all above said it follows that when using the CL we obtain a new measurement system that would ensure certain provisions of the "hidden databases". Development of the CL [19] and the method of controlling the angles of the V-shaped profile guides tools [20, 21], as well as a new system of dimensioning among FCS [11] have introduced a new way to make out details of the working drawings of metalcutting tools and re-dimensioning exercise among the FCS. The CL is designed to test the stain on contact and consistently, both planes of V-shaped flat rail and also to control the angle between the planes of V-shaped guide. CL provides simultaneous control of flatness and the angle between the planes of V-shaped surface. This is achieved by the fact that the CL is made of cylindrical shape with two longitudinal wrench flats located at an angle:

$$\Psi = \frac{180^0 - \varphi}{2}, \tag{1}$$

where ψ is the angle between the wrench flats of CL and φ is the angle equal to half the angle of V-shaped surface.

Figure 5 shows a sketch of the CL for the control of one part of the angle of V-shaped surface of the prism.

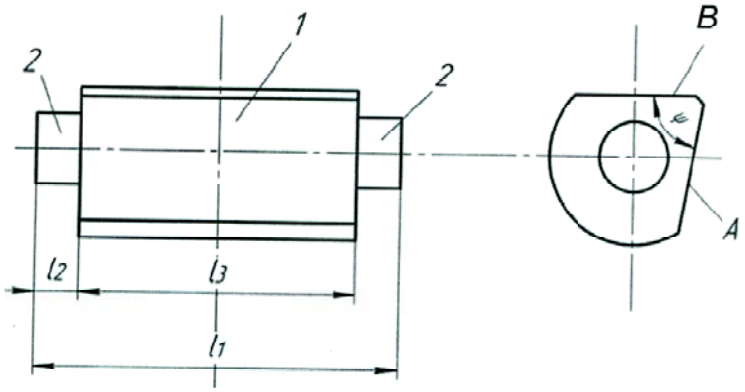

Figure 5 – The sketch of the CL for the control of one of the part of the angle V-shaped surface of the prism:
1 – CL; *2* – neck; *A* – a flat to control the flatness; B – a flat to control the angle;
φ – a half of the angle of V-shaped surface; ψ – an angle between the flats A and B;
l_1 – total length of the CL; l_2 – length of the neck for the capture; l_3 – length of working part

The measurement is carried out in two positions of CL with respect to V-shaped surface. Flatness is checked against the contact surfaces on each of two positions in the CL. The angle of V-shaped surface is checked in accordance with the size of the largest discrepancy of the same flat in two positions with respect to the planes controlling by V-shaped surface.

Figure 6 shows two positions of the same CL with respect to V-shaped surface.

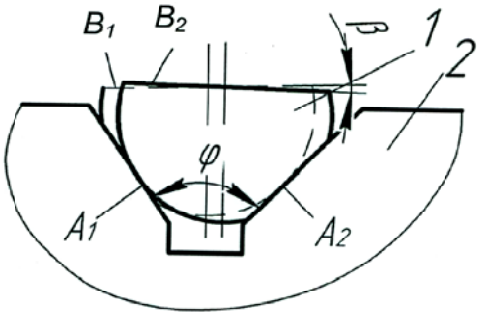

Figure 6 – Scheme of the relative position of a CL in two relative positions:
1 – CL; *2* – controlled V-shaped surface; A_1, B_1 – the positions of flats of CL in the first set;
A_2, B_2 – the positions of flats of CL in the second set; β – the angle mismatch of flat B in two positions

Designation of flat surface accuracy and angle of the V-type surface of verification jig (VJ) is performed in a following way. VJ *1* (figure 5) with the help of neck for acquisition *2* is overlapped on V-type surface. In advance the flattened surface *A* is covered by thin layer of paint. By lengthwise movements of VJ and according to the number of contact spots the flat surface accuracy of V-type surface flat is defined. In case of VJ location change the flat surface accuracy of another V-type surface flat is defined. The angle of V-type surface is designated according to the value of flat B mismatch in two positions. If the angle of V-type surface is equal to the doubled value of the φ angle, then angle $\beta=0$. In case of V-type surface angle departure from value 2φ the flattened surface position mismatch on angle β is appeared. By the value of angle β the real value of V-type surface angle is counted by the following formula

$$2\varphi_r = 2\varphi \pm \beta\,, \tag{2}$$

where $2\varphi_r$ is a real value of V-type surface angle.

Experimental researches. The usage of VJ gives background to the maintenance of labor intensity decreasing by means of prescription and size drift holdings by different processing techniques. The developmental VJ prototypes were created (figure 7).

Figure 7 – Images of verification jigs

To determine the stability of the values the statistical analyzes were carried about the point deviations of a given distance in the transverse and longitudinal directions of VJs. The measurement was carried out on the control plate with the indicator rack and dial gauge with a scale 0.001 mm (figure 8).

We measured the angular values of V- type groove of guide plate tailstock lathe NT-250I. The following parameters of the measurements stability were determined in case of deviation with the help of VJ:

- statistics of mercer clock gauge deviations at two points of the positioning at the distances of 26 mm for an angle of 45º and 22 mm for an angle of 35º in the transverse direction and longitudinal directions, respectively, a distance of 155 mm and 165 mm;
- statistics of the deviations of the control plane, which characterize the angular deviations in the transverse direction and the deviation of V-type surface in the longitudinal direction of the above-mentioned distances.

Indicator head with a scale division of 0.001 mm was mounted on a magnetic rack mounted on the spindle surface grinding machines (see figure 8).

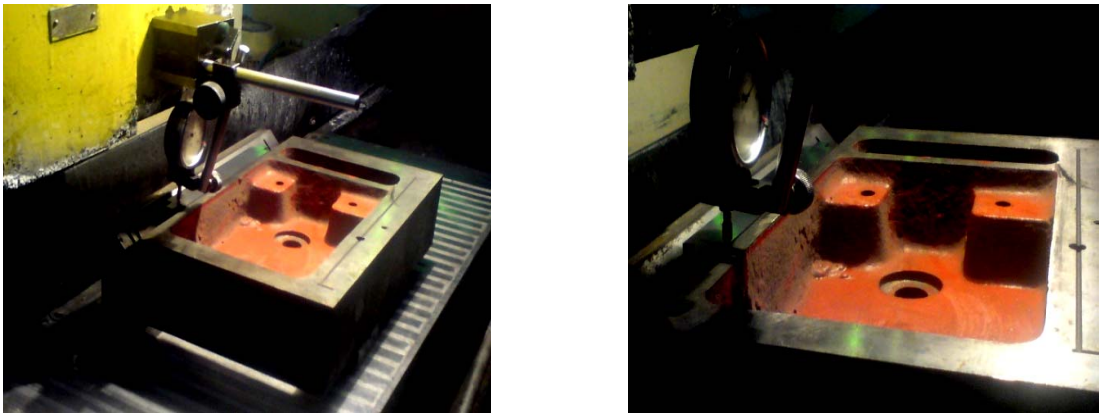

Figure 8 – Images of the control detail, VJ and display rack with mercer clock gauge

Lateral movement of the indicator bar was carried out manually by moving the wheel head. Longitudinal movement of table movement is undertaken in the machine. In the issue of the following data measurements were obtained:

- spread of dial gauge readings at the control deviations in the cross section at a distance of 26 mm and 22 mm respectively, was 2 mkm and ± 1.5 mkm;
- measurements in the longitudinal direction of the CR showed variation within ± 1 mm;
- angle of 45º and 35º in the measurement can be determined with an accuracy of no less than ± 30″.

In table 1 the results of statistical consistency analysis in workshop conditions for above mentioned experiments for one VJ are quoted.

Table 1 – Results of statistical consistency analysis in workshop conditions

Calculated parameters	Designation of parameters	Deviation in the values in mkm	
		In the longitudinal direction L = 165 mm	In the transverse direction L = 22 mm
Field of deviations dissipation	ω	0.002	0.004
Average square deviation dissipation	σ	0.0004	0.0005
Possible admission to the size of the line	T_r	0.0024	0.0030
Possible admission to the size of the tailstock board	T_d	0.005	0.009
Possible quality accuracy on the size of plates tailstock	q.ac.	3÷4 q.ac.	4÷5 q.ac.

Table 1 shows that the measurement was carried out in the transverse and longitudinal directions in the planes of V-shaped surface. It follows that the permissible deviation from linearity in the plane and of the longitudinal Δ_{ld} and transverse Δ_{td} areas must be calculated using the following formulas.

In the longitudinal direction

$$\Delta_{ld} = 6\sigma_{ld} \frac{L_{ld}}{L_{ldVJ}} . \quad (3)$$

In the transverse direction

$$\Delta_{td} = 6\sigma_{td} \frac{L_{td}}{L_{tdVJ}} , \quad (4)$$

where σ_{ld} is standard deviation of measurements in the longitudinal direction; L_{LD} is the size details of the longitudinal V-shaped surface area; L_{ldVJ} is the size of the wrench flats VJ in the longitudinal direction; σ_{td} is standard deviation of measurements in the transverse direction; L_{td} is the size of the parts in the direction transverse to the surface of the V-shaped end; L_{tdVJ} is the size of the wrench flats of VJ in the transverse.

On the basis of experimental data is also possible to determine the tolerances of the angular size of the V-shaped surfaces of the guide carriage plate and tailstock.

On the basis of the formula (3) the possible angular deviation of V-shaped surface of the formula is determined:

$$\Delta_v = \frac{\Delta_{td}}{l_V} , \quad (5)$$

where l_V is the length of wrench flats of control lines in cross-section in contact with the plane of the V-shaped surface.

Increase of the accuracy demands driven by parts leads to a decrease in the value of finishing the shooting of allowance for processing forms, such as scraping. For details of the machine driven by NT-250I the sizes of the removed allowances were calculated. Table 2 shows comparative data on the value of allowances in the processing of parts of the factory drawings with high accuracy requirements driven by the surfaces of parts.

Table 2 shows that the processing of parts with dimensions 8 of the degree of accuracy, made on the new drawings, in comparison with factory allowances are reduced by more than an order of magnitude.

Table 2 – Comparative data on the value of allowances
in the processing of parts of the factory drawings with high accuracy requirements driven by the surfaces of parts

Workable surface	The maximum value of oversize	
	Factory drawing	New drawing
The plane of carriage adjoining	0.3 mm	0.021 mm
Plane adjoining of V-shaped block surface	0.6 mm	0.025 mm
Plane adjoining of plate tailstock	0.5 mm	0.018 mm
Plane adjoining of V-shaped surface of the plate tailstock	0.2 mm	0.018 mm

However, when designing the details with new drafts it is necessary to introduce one additional finishing treatment which will provide increased demands on the accuracy of processed dimensions. The introduction of additional mechanical operations do not significantly affect the complexity of the difference of work performed.

Conclusions.

1. Dimensional analysis of FCS-type lathe 1K62, HT-250I, for example bed and slide, shows that the linear dimensions of the height of the prism slide affixed between two planes, and the angle - from the axis of the prism is perpendicular to the plane of the adjoining of between the cylinder and the plane of the control mandrel adjoining of, not structurally designed on the drawing detail that is not possible to measure their numerical values.

2. Developed and proposed for measuring the angles of the VJ side surfaces of the V-shaped guides ensure accuracy in the range from 5" to 10", which significantly exceeds the accuracy of existing unproductive purpose of measuring and extends the measurement of angular and linear dimensions as well as determine the deviation in the manufacture and control of functionally related surfaces of machine tools.

3. It is found that application of the method of control angle V-shaped surface of the guide tools allows:

- to improve accuracy and achieve the determination of the angular values of the V-shaped guide surfaces of metal-cutting machines within a few seconds;
- to stabilize the value of allowances for final processing by reducing the tolerance for the angle of V-shaped surface;
- to reduce the complexity of finishing treatments by reducing the quantities of allowances for final processing.

4. The data of the experiments showed that the accuracy of the location of the V-shaped guide part of the machine NT-250I with VJ can be increased by more than 10 times compared to the deviations specified on the drawing.

5. A new technique for measuring the angles of the V-shaped grooves of directing machines and special VJ structures have been developed and put into production.

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МЕТАЛЛ КЕСУШІ БІЛДЕКТЕРДІҢ БАҒЫТТАУЫШТАРЫН ҚАЛЫПТАСТЫРУ ЕҢБЕКСЫЙЫМДЫЛЫҒЫН ТӨМЕНДЕТУ ЖӘНЕ БАҚЫЛАУ ДӘЛДІГІН АРТТЫРУ

Аннотация. Жүргізілген зерттеулер нәтижесінде металл кесу білдектерін өндіруде ең аз қамтылған орын ол құралкүймешік және тұғырдың бағыттаушы беттерінің функционалды байланысының нормаларын қамтамасы ету екені анықталды. Функционалды байланысқан беттердің жанасуы күрделі қырғыштау-операциясымен орындалады. Сонымен қатар функционалды байланысқан беттерді қиылыстыру бірнеше сағаттардан бірнеше тәуліктерде жүргізілуі мүмкін. Сонымен қатар, металл кесу білдектері бағыттаушыларының функционалды байланысқан беттерінің өлшемдерін қою жүйесінің жетілмегені проблема болатындығы анықталды. Қолданыстағы өлшемдерді қою жүйесінің кемшіліктері әсерінен үлкен шақтамалар жобаланады. Ал бұл шеберханалық операциялардағы қыру кезіндегі үлкен әдіптерді алуды талап етеді. Осы проблеманы шешу мақсатымен авторлар функционалды байланысқан беттердің сызықтық және бұрыштық өлшемдерін қоюдың жаңа жүйесін, сонымен қатар бақылау-өлшеу құрал конструкциясын құрастырды. Бұл мақалада арнайы конструкциялы бақылау сызғышымен өлшеу тұрақтылығын статикалық зерттеу нәтижелері келтірілген. Жүргізілген тәжірибелер нәтижесінде токарь білдегінің V-тәрізді бағыттаушы тетіктерінің орналасу бұрышының дәлдігін бақылаушы сызғыш көмегімен сызбадағы ауытқулармен салыстырғанда 10 есе жоғарылатуға мүмкіндік беретіні анықталды.

Түйін сөздер: функционалды байланысқан беттер, білдектердің бағыттаушылары, қыру, бақылау сызғышы, V-тәрізді бет, өлшеу дәлдігі, еңбексыйымдылығы, жасырын база, әдіп.

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ПОВЫШЕНИЕ ТОЧНОСТИ КОНТРОЛЯ И СНИЖЕНИЯ ТРУДОЕМКОСТИ ПРИГОНКИ НАПРАВЛЯЮЩИХ МЕТАЛЛОРЕЖУЩИХ СТАНКОВ

Аннотация. В результате проведенных исследований выявлено, что самым узким местом в производстве металлорежущих станков является обеспечение норм прилегания функционально связанных поверхностей направляющих суппорта и станины. Прилегание функционально связанных поверхностей осуществляется трудоемкой слесарной операцией – шабрением. При этом пригонка функционально связанных поверхностей может занимать от нескольких часов до нескольких суток. Также установлено, что проблемой является несовершенство системы простановки размеров функционально связанных поверхностей направляющих металлорежущих станков. Несовершенство существующей системы простановки размеров приводит к тому, что размеры закладываются с весьма большими допусками. Это приводит к удалению больших припусков при шабрении на слесарных операциях и, следовательно, к увеличению трудоёмкости пригоночных работ. С целью решения данной проблемы авторами разработана новая система простановки линейных и угловых размеров функционально связанных поверхностей, а также конструкции контрольно-измерительных средств и устройств. В данной статье приведены результаты статистических исследований стабильности результатов измерений контрольными линейками специальной конструкции. Данные проведенных экспериментов показали, что точность расположения углов V-образных направляющих деталей токарного станка НТ-250И с помощью контрольных линеек может быть повышена более чем в 10 раз по сравнению с отклонениями заданными по чертежу.

Ключевые слова: функционально связанные поверхности, направляющие станков, шабрение, контрольная линейка, V-образная поверхность, точность измерения, трудоемкость, скрытая база, припуск.

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