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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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THE METHOD OF SELECTING THE OPTIMAL LAYOUTS OF THE SIZE LIMIT DEVIATIONS DURING ASSEMBLY

Abstract. The development of mechanical engineering in recent years has led to a special focus on the processing of functionally connected surfaces. In world practice, more attention is paid to the creation of methods, techniques, technological processes, tools, measures, etc., which would reduce the complexity of processing and assembling functionally connected surfaces (FCS) of details and connections.

Currently, the connection between the dimensions and positions of surfaces is not standardized for all details. These details include body parts and frames that have V-shaped surfaces and associated planes. Apparently, this is due to the large variety of functionally connected surfaces and the complexity of controlling the technological support of dimensions.

When coupling details of metal-cutting machines FCS, it is necessary to ensure simultaneous contact of two combined surfaces of the guides.

This article provides a method for selecting the optimal layouts of the size limit deviations when assembling details with FCS. The influence of the location of the size limit deviations on the complexity of the fitting operation when assembling two combined surfaces of details is considered. Possible layouts of the size limit deviations are shown, as well as a diagram of the relative position of the two combined surfaces before the fit operation, depending on the values of the size limit deviations.

Some recommendations are given for choosing the optimal layouts of the limit deviations of the dimensions of the adjacent planes:

- the position of the adjacent planes depends on the size values and their deviations;
- the position of the adjacent planes is significantly affected by the position of the size deviations of the connected planes;
- depending on the location of the limit deviations of the size of the joints, the amount of removed allowance varies considerably and leads to a significant change in the labor intensity of the scraping process.

Key words: Functionally connected surfaces, scraping, limit deviations, adjacent plane, fitting, allowance.

Introduction. The creation of numerical control machines, measuring machines of various foreign companies, created prerequisites for reducing the complexity of manufacturing and monitoring details and connections with functionally connected surfaces (FCS) [1,2]. However, not all problems of ensuring accuracy and reducing the complexity of processing and assembling such surfaces are solved. The FCS includes the surfaces of mobile and fixed joints, when the coupling is performed simultaneously on several surfaces, and the accuracy of their coupling is determined by the contact norms [3,4].

Table 1 shows classes of details with functionally connected surfaces [5]. For some details, such as gears, spline shafts, threaded surfaces, and others, there are standards that normalize the connection of the FCS [6,7].

Table 1 – Classification of details with surfaces that have functionally related dimensions

№	Name of details	Surfaces with functionally related dimensions	Note
1	Cogwheels	Ring gear	GOST standard 1643-81 and etc.
2	Splined parts	Slotted surfaces	GOST standard 1139-80 and etc.
3	Chain wheels	Ring gear	_____
4	Threads and screws	Helical surface	GOST standard 16093-81 and etc.
5	Case details	Flat and V–shaped flat surfaces	_____
6	Case details	The surface of the “dovetail” type	_____
7	Frames	Flat and V–shaped flat surfaces	_____
8	Other details	Rack, key and other surfaces	_____

Table 1 shows that there is a wide variety of details with functionally connected surfaces. Moreover, the surfaces may have a certain regular profile, for example, in gear wheels: involute, Novikov’s, arch, etc. In other cases, it may be flat surfaces, for example, in spline shafts with a straight-line profile, or screw surfaces in threads, running screws, etc. [8-10].

Such surfaces for metal-cutting machines are guide frames and calipers. Phenomena that occur in the joints of V-shaped and flat guide machines significantly affect the accuracy of machining, vibration resistance of machine components and the quality of the machined surfaces of parts [11,12].

The accuracy of the position of the parts when moving along the guides is due to errors in the guide from the theoretical given shape. The reasons for deviations in the shape of the guides depend on the process. Deviations of the guides from the theoretically specified shape are formed by errors in the processing of the guides and their assembly. Machine guides lose their shape during operation under the influence of forces and external factors (humidity, dust, etc.) and temperature fields in the machine during processing of details [13,14].

In machines, in the nodes of machines, devices, technological equipment and other structures, it is very common to have problems of ensuring the fit of the FCS simultaneously on several planes located relative to each other in parallel or at certain angles. Several known methods are used to ensure that the planes fit in production conditions [15-17]. In cases where it is necessary to ensure high accuracy of fitting, a locksmith operation is used – manual scraping [18,19]. Manual scraping is a very time-consuming process that takes from several hours to several shifts of work [20,21]. Figure 1 shows a diagram for checking the surface to be treated when scraping.

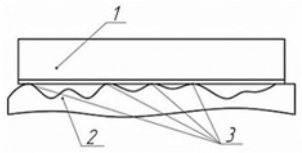

Figure 1 – Scheme for checking the surface to be processed when scraping. 1 - ruler; 2 - guide surface; 3 - paint

The scraping begins with a thin layer being applied to the surface of the ruler or plate (1 ... 2 microns) easily removed paint (for example, typographic or blueing). After that, the ruler 1 is moved along the surface of the guides 2, while the paint 3 is transferred to the protrusions (figure 1), and the hollows remain unpainted. Painted protrusions are treated with a scraper. For one movement of the scraper, a hole up to 5 microns deep should be formed during preliminary scraping and up to 1.5 microns during final scraping. After processing all the protrusions, a second check is made "for paint" and, if it is necessary, repeat the scraping. The pre-scraping is carried out "pushing away from oneself", and final is made on the direction of "pulling towards oneself".

Scraping is an extremely unproductive method of processing. The use of a mechanized tool with pneumatic or electric drive is possible only with preliminary scraping. The performance of scraping depends to a large extent on the size of the allowance. The allowance must be minimal, but sufficient to obtain the required technical accuracy and surface roughness. The allowance for scraping guides up to 1000 mm in length should not exceed 0.05-0.1 mm [22].

The working surfaces of high-precision machines are scraped with a shallow penetration of the scraper into the metal (0.5-1.5 microns), providing large areas of contact with large intervals, which allows you to bring to the minimum values of the moving parts movement force. The working surfaces of heavily loaded guides are scraped when the scraper penetrates into the metal to a fairly significant depth (4-5 microns) [22,23]. The complexity of scraping operations depends mainly on the amount of allowance to be removed. In the literature, information on allowances for approval is almost not described. Each company, based on its experience and some data on the processing technology of such compounds in related enterprises, independently sets the allowances, and at the same time the size and limit deviations between the planes of fit. In this regard, the development of a method for choosing the optimal layout of the size limit deviations is an **actual problem**.

The methodology of optimal choice of layouts extreme deviations of dimensions and discussion of the results. Due to the lack of detailed data in the literature on the features of the technology for ensuring the accuracy of the planes of fit, we have considered and given some recommendations for choosing the optimal layout of the limit deviations of dimensions. Figure 2 shows a diagram of the relative position of the two planes of fit and the two parts to be assembled. For simplicity of the image and description of these details, they are shown in a simplified form.

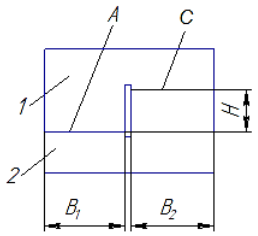

Figure 2 – Diagram of the relative position of two combined surfaces of details after fitting. 1 – the first part; 2 – the second part; A - one of the adjacent plane; C – the other adjacent plane; B_1 – width of the adjacent plane of A; B_2 – the width of the adjacent plane of C; H – the dimension between the adjacent planes

Figure 2 does not show the length of the adjacent planes. The designations for the length of the adjacent planes will be used later in the text. If the width of the adjacent planes is equal, the designation B is used. If the length of the adjacent planes differs, the following notations are used: $B_{1\text{-}1}$ and $B_{1\text{-}2}$ for the first part, $B_{2\text{-}1}$ and $B_{2\text{-}2}$ for the second part. Figure 3 shows the layout of the dimensions and the designation of the adjacent planes of 1 and 2 parts.

Figure 3 – Layouts of the dimensions of the combined surfaces of parts. *a - part 1; b- part 2*

Figures 3a, 3b, A_1 and C_1 show the adjacent planes of the part 1, and A_2 and C_2 of the part 2. Dimensions H_1 and H_2 are the dimensions between the adjacent planes of the 1 and 2 parts.

When connecting 1 and 2 parts, we can consider a simple dimensional chain consisting of two constituent links H_1 and H_2 and a closing link, which we mark as H_Σ.

If the nominal values of the dimensions H_1 and H_2 are equal, then the nominal value of the closing link H_Σ will be zero, and its limit deviations will depend on the value of the limit deviations of the dimensions H_1 and H_2.

Figure 4 shows the layouts of the size limit deviations H_1 and H_2, as well as four possible layouts of the size limit deviations.

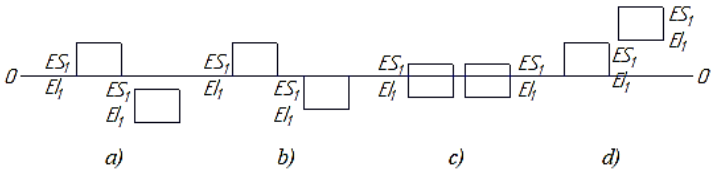

Figure 4 – Diagram of possible locations of size deviations before the fit operation.
a - mobile landing with guaranteed clearance; *b* - mobile landing with zero clearance;
c - transitional landing; d - tight landing

These schemes differ in the relative location of the limit deviations. There can be an infinite number of location schemes. The chosen schemes meet the requirements of three types of landings – mobile, transitional and tight landing.

The choice is conditional and is made only for a more visual presentation of the proposed method for selecting the layouts of the limit deviations of dimensions. The schemes for mobile landing are shown in two positions. Figure 4*a* shows the "guaranteed clearance". Figure 4*б* shows a possible "zero" clearance. Figure 5 shows four diagrams of the relative position of two pairs of combined surfaces of details which dimensions between the adjacent planes have deviations according to the four diagrams shown in figure 4.

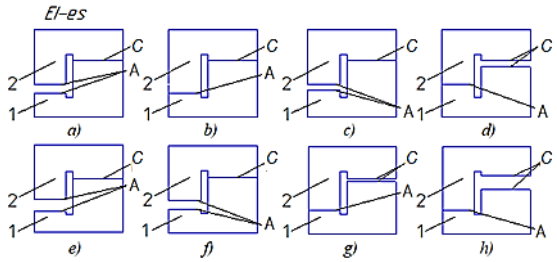

Figure 5 – Diagram of the relative position of two combined surfaces before the fitting operation, depending on the values of the size limit deviations

If the accuracy of the adjacent planes is provided by the locksmith operation of one of the connected parts – as scraping, then for the four connection schemes shown in figure 5, you can come to the following conclusions. When ensuring accuracy by scraping the planes of part 1, there are the following options. According to figure 5*a* and e, the accuracy must be ensured by scraping along the $Б_1$ plane for all parts 1, since $H_1 > H_2$. According to figure 5b and f, the accuracy must be ensured by scraping along the $Б_1$ plane for parts 1 while size is $H_1 > H_2$. According to figure 5c and g, the accuracy must be ensured by scraping along the planes either A_1 or C_1, depending on the values of the dimensions H_1 and H_2. According to figure 5d and h, the accuracy must be ensured by scraping along the A_1 plane for all parts 1, since $H_2 > H_1$. It should be noted that if, after mechanical treatment, the requirements for the accuracy of the contact surfaces do not meet the number of contact spots, then it is necessary to provide a minimum allowance for scraping, after removal, which ensures the requirements for the accuracy of the adjacency. This allowance value can be designated as Z_{min}, and its value can be defined as a value that depends on the amount of roughness and macro-roughness. Then for each of the processed surfaces it can be written

$$Z_{\min} = R_z + \Delta, \quad (1)$$

where R_z - is the height of the profile irregularities; Δ - deviation of the surface shape.

For the scraping surfaces of two parts, the total value of the minimum allowance can be determined using the formula:

$$Z_{\sum \min} = (R_{z1} + R_{z2}) + (\Delta_1 + \Delta_2), \quad (2)$$

In formula (2), the indexes 1 and 2 refer to the two adjacent surfaces of each part.

For the two scraping surfaces of one detail on the size of the H, the greatest value out of two Z_{min} needs to be provided. Ensuring the accuracy of the adjacency, as a rule, is carried out either by scraping

both planes, or one of the planes. Depending on this, the amount of removed allowance varies. In the case of ensuring the accuracy of the adjacency by scraping the plane of one of the two parts, the maximum allowance is determined by the formula:

$$Z_{\max} = \left(ES_1 - EI_2\right) + Z_{\min}, \quad (3)$$

In the case of ensuring the accuracy of the adjacency by scraping the planes of both of the parts, the maximum allowance is determined by the formula:

$$Z_{\max} = \left(ES_1 - EI_2\right) + Z_{\sum \min}, \quad (4)$$

Formulas (3) and (4) are valid for the positions of the limit deviations shown in Figures 3*a* and 3*b* and are possible for the positions shown in figure 3c when $(ES_1 - EI_2) > (ES_2 - EI_1)$. In the case where the position of the limit deviations will correspond to the figure 3*d*, in the formulas (3) and (4) of the Z_{max} calculation, instead of $(ES_1 - EI_2)$ it is necessary to write $(ES_2 - EI_1)$.

Figure 5 shows that at the same tolerance values, but at different locations of the size limit deviations, the allowance value changes. However, the labor intensity of the scraping operation is affected by the amount of allowance, as well as the volume of the removed metal. To determine the volume of the removed metal, it is necessary to consider the size of the allowance, the length and width of the processed surface. So, it can be written as:

$$V_{\max} = Z_{\max} \times L \times B, \quad (5)$$

where V_{max} is the maximum amount of removed metal during scraping.

Conclusions:

- the position of the adjacent planes depends on the size values and their deviations;
- the position of the adjacent planes is significantly affected by the position of the size deviations of the connected planes;
- depending on the location of the limit deviations of the size of the joints, the amount of allowance removed varies significantly and leads to a significant change in the labor intensity of the scraping process.
- depending on the location of the limit deviations of the size of the joints, the amount of removed allowance varies considerably and leads to a significant change in the labor intensity of the scraping process.

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ҚҰРАСТЫРУ КЕЗІНДЕ ӨЛШЕМДЕРДІҢ ШЕКТІ АУЫТҚУЫ ОРНАЛАСУЫНЫҢ ОҢТАЙЛЫ СҰЛБАСЫН ТАҢДАУ ӘДІСТЕМЕСІ

Аннотация. Машина жасауды дамыту жағдайы соңғы жылдары функционалдық байланысты қабаттарды өңдеуге ерекше назар аударта бастады. Әлемдік тәжірибеде әдістеме, технологиялық үдеріс, құрал, өлшеуіш және т.б. жасауға айрықша назар аударылды, олар бөлшектер мен қосылыстардың функционалды байланысқан қабаттарын (ФБҚ) өңдеу мен құрастырудың еңбек сыйымдылығын азайтуы мүмкін.

Қазіргі уақытта қабаттардың өзара байланысты көлемі мен жағдайы бөлшектердің бәрінде бірдей нормаланған жоқ. Мұндай бөлшектерге корпустық бөлшектер мен V-үлгілі қабаттарды және соған байланысты жазықтықты жатқызуға болады. Бұл функциональды байланысты қабаттардың көптеген жағдайда түрлі болуымен және көлемін технологиялық қамтамасыз етуді бақылаудың күрделі болып келуімен түсіндірілуі тиіс.

Метал кескіш станок бөлшектерінің жанасуы кезінде ФБҚ бағыттаушылардың қосарланып араласқан қабатының бір мезгілде байланысқа түсуін қамтамасыз етеді. Бұл мақалада FKS-тен бөлшектерді жинау

кезінде өлшемдердің шекті ауытқуларының оңтайлы орналасуын таңдау әдісі келтірілген. Өлшемдердің шекті ауытқуларының орналасуының бөлшектердің екі біріктірілген бетін жинау кезінде сәйкестендіру жұмысының күрделілігіне әсері қарастырылады. Өлшемдердің шекті ауытқуларының ықтимал орналасуы, сондай-ақ өлшемдердің шекті ауытқуларының мәндеріне байланысты сәйкестендіру операциясынан бұрын екі біріктірілген беттің өзара орналасу схемасы көрсетілген.

Іргелес жазықтықтар өлшемдерінің шекті ауытқуларының оңтайлы орналасу схемасын таңдау бойынша кейбір ұсыныстар берілген:

- жазықтықтардың орналасуы Өлшем мәндеріне және олардың ауытқуларына байланысты;
- іргелес жазықтықтардың орналасуына жанасатын жазықтықтардың өлшемдерінің ауытқу позициясы айтарлықтай әсер етеді;
- қосылыстар мөлшерінің шекті ауытқуларының орналасуына байланысты алынатын жәрдемақының мөлшері айтарлықтай өзгереді және кесу процесінің күрделілігінің айтарлықтай өзгеруіне әкеледі.

Түйін сөздер: функционалды байланыстағы қабаттар, тегістеу, шекті ауытқу, жанасу жазықтығы, қиюластыру, өңдеу әдібі.

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МЕТОДИКА ВЫБОРА ОПТИМАЛЬНЫХ СХЕМ РАСПОЛОЖЕНИЯ ПРЕДЕЛЬНЫХ ОТКЛОНЕНИЙ РАЗМЕРОВ ПРИ СБОРКЕ

Аннотация. Развитие машиностроения в последние годы привело к уделению особого внимания к обработке функционально связанных поверхностей. В мировой практике всё большее внимание уделяется созданию методик, технологических процессов, инструментов, мерителей и др., которые бы привели к снижению трудоёмкости обработки и сборки функционально связанных поверхностей (ФСП) деталей и соединений.

В настоящее время связь между размерами и положением поверхностей не стандартизирована для всех деталей. Эти детали включают в себя детали кузова и рамы, имеющие V-образные поверхности и связанные с ними плоскости. По-видимому, это связано с большим разнообразием функционально связанных поверхностей и сложностью управления технологическим обеспечением размеров.

При соединении деталей металлорежущих станков ФТС необходимо обеспечить одновременный контакт двух совмещенных поверхностей направляющих.

В данной статье приводится методика выбора оптимальных компоновок предельных отклонений размеров при сборке деталей с ФКС. Рассмотрено влияние расположения предельных отклонений размеров на трудоемкость операции подгонки при сборке двух совмещенных поверхностей деталей. Показаны возмож-ные схемы расположения предельных отклонений размеров, а также схема взаимного расположения двух совмещенных поверхностей перед операцией подгонки в зависимости от значений предельных отклонений размеров.

Даны некоторые рекомендации по выбору оптимальной схемы расположения предельных отклонений размеров плоскостей прилегания:

- положение плоскостей прилегания зависят от значений размеров и их отклонений;
- на положение плоскостей прилегания существенное влияние оказывают положение отклонений размеров контактируемых плоскостей;
- в зависимости от расположения предельных отклонений размеров соединений величина снимаемого припуска существенно меняется и приводит к значительному изменению трудоёмкости процесса шабрения.

Ключевые слова: функционально связанные поверхности, шабрение, предельные отклонения, плоскость прилегания, пригонка, припуск.

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