

Influence of Features of Cylindrical Parts Set by Interference Fit on Assembly

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Abstract – Automation of the assembly processes increases productivity and, respectively, reduces labour-intensity of assembly. In many cases, in particular, in the assembly of small products, the equipment of automatic assembly takes less space than machines of assemblers performing the same process manually. Notwithstanding the advantages and indicators of productivity increase, the assembly processes in comparison to other technological processes are less automated. The aim of the present research is to compare interference obtained in the experiment with the calculated one by the developed method of engineering calculations for interference fit and to provide conclusions.

Keywords –accuracy, automatic assembly, details basing, geometric parameters and pressing force.

I. INTRODUCTION

Mainly, theoretical studies of automation of the technological process cover the issues of the assembly technological process safety and accuracy of mutual orientation of assembly details, since the possibility of automation of the assembly process as such and its usefulness depend on these aspects. Researches such as A. Gavrilov, P. Bulovsky, B. Balakshin, B. Korsakov, A. Malov, M. Novikov, A. Rabinovich, K. Muceniaks, Fr. Sudnieks and other authors devoted their research to the solution of these issues.

The method of technological process development in the automated manufacturing includes the following stages:

- analysis of the product adaptability to manufacturing considering the volume of its output and features for automated processing;
- mechanization and automation for all working and auxiliary movements during processing;
- methods for ensuring the accuracy of the assembly product;
- choice of basing scheme;
- defining assembly conditions;
- mutual orientation of detail axes in space.

In the automatic assembly, the concept of adaptability of a structure to manufacturing covers both the structure of the complete part or product and structural features of separate details, which define their suitability to the automatic orientation, supply, and placement on the base detail. Simultaneously, the issues of adaptability of machines, equipment, and their parts to manufacturing, as well as the issue of simplification of the automatic equipment have to be solved. Possibilities to improve the adaptability of a structure to manufacturing in assembly have been described in detail by A. Gavrilov, I. Pavlov, A. Paknis, V. Ivanov, and V. Smilansky by analyzing a considerable amount of device joint structures,

where connections are fastened applying different methods. As P. Bulovsky emphasizes, by improving the adaptability of the structure of assembly elements to manufacturing different indicators of the assembly process also improve. A positive example is a reduced number of details in a joint (product), which in its turn permits decreasing the amount of operations, simplifying the process, and averting (completely or partially) additional operations of mechanical processing during the assembly. In addition, a technologic structure improves the quality of the assembly and the accuracy of connection.

In the process of elaboration of the research it was stated that the available scientific papers had not researched the condition of automatic assembly of cylindrical parts set by interference fit $\delta_{\Sigma} \leq \varepsilon_{allow}$. Methods for providing the assembly of mutual orientation of axes of cylindrical details in position in automatic equipment are less effective because of the reduction of the roughness of the surface profile of mating details during pressing. The reviewed papers have not considered surface roughness parameters Ra and Sm, which affect the process of assembly significantly.

The method of calculation for fit with interference (S. P. Timoshenko) includes one of the surface roughness parameters Ra, although the contact of cylindrical details is a dimensional object and it shall be viewed considering 3D surface roughness parameters. Therefore, further parts of this article are devoted to the analysis of the technological process of assembly and parameters of contact of assembly details.

II. DETAILS BASING AT AUTOMATIC ASSEMBLY

Basing of parts is one of the components of the automatic assembly orientation phase. Preparation of basing may be temporary, or between the orientations of the movement, which is a characteristic component of linear, flat or 3-d displacement. In some cases, basing can take place without guidance. However, the deviations from the overall scheme should be treated as special cases.

Basing in automatic assembly (Fig. 1) is very similar to the basing of parts in machining, however it has its own specifics. In particular, there are specific ways of basing. In automatic assembly basing can be stationary and non-stationary. In addition, basing is achieved resulting in an automatic movement, and in most cases without efforts to fixate significant parts. In some cases, the parts do not need to get fixated, it is enough to place the component in the base position. Basing also depends on the assembly mode: base details are located in accordance with rigid conditions; component details are located in a different way –it depends on the flexibility for appropriate orientation.

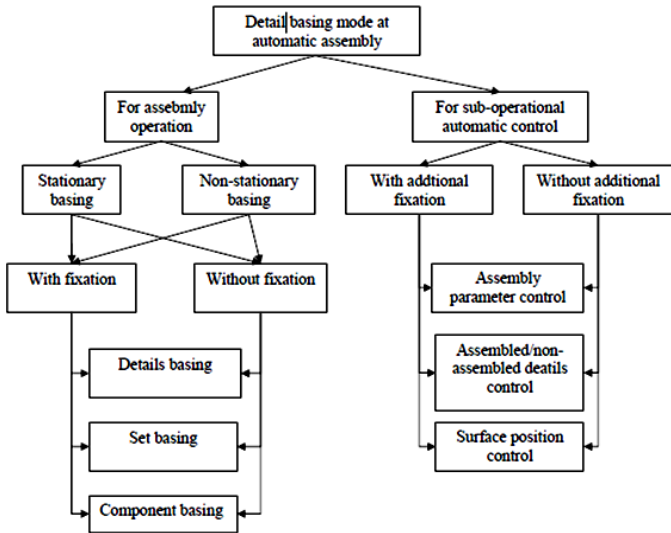


Fig. 1. Automatic assembly details basing classification scheme

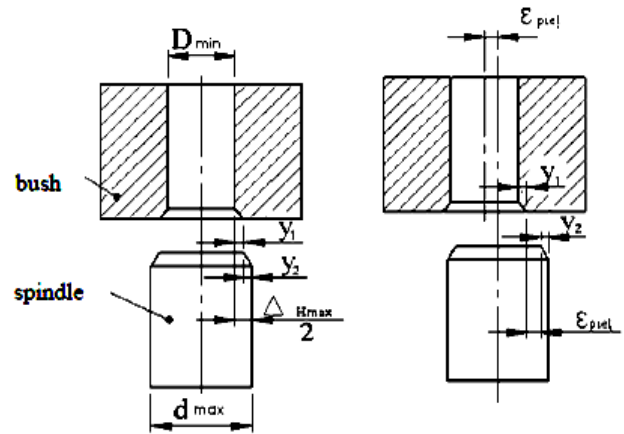


Fig. 2. Scheme of the mutual layout of axes for spindle and bush

It is recommended to form entrance phases at the ends of cylindrical assembly details. Minimal dimension of phases y is defined as follows:

$$y_1 + y_2 \geq \frac{\Delta H_{max}}{2}, \quad (1)$$

where: y - phase dimension of spindle and bush; if $y_1 \sim y_2$, then $y_1 + y_2 = 2y$;

$$\Delta H_{max} = d_{max} - D_{min}. \quad (2)$$

Phase y has to be as large as possible. In praxis, most commonly recommended phases for spindle and clutching detail is under angle $30^\circ \div 45^\circ$. However, it is limited by the thickness of the bush wall and structural demands. Admissible failure ϵ_{allow} of mutual orientation of axes of bush and spindle, at which assembly is still possible, in this case depends on dimensions of phases and can be calculated as:

$$\epsilon_{allow} \leq 2y - \frac{\Delta H_{max}}{2}, \quad (3)$$

In addition to the value of admissible failure of axes layout, the actual value of the failure shall be defined, namely, the value of failure occurring to the assembly object (the reason is the failure in manufacture) and to the chosen method. The abovementioned researches of mutual layout prove that actual failure of mutual layout of two details in the automatic assembly equals to:

$$\epsilon_{real} = q_{p.b.k.} + q_{k.b.k.} + \Theta_{k.b.k.p.}, \quad (4)$$

where: $q_{p.b.k.}$ - failure in basing of drill,
 $q_{k.b.k.}$ - failure in basing of spindle detail,
 $\Theta_{k.b.k.p.}$ - failure in mutual layout of drill and spindle.

Any couple of details is automatically assembled if $\delta_\Sigma \leq \epsilon_{allow}$. In case this condition is not followed, most of the details are not assembled although they are usable for the assembly of the product. In this case, unassembled details are

III. ACCURACY DETERMINATION OF TECHNOLOGICAL PROCESS FOR AUTOMATIC ASSEMBLY

In the given chapter, as a result of research of the assembly processes of cylindrical parts set by interference fit, admissible failure in assembly position of mutual layout of detail axes was defined, which provides the choice of the basing scheme needed to ensure accuracy and the choice of method for reaching the connection accuracy. The choice of basing scheme affects accuracy and the quality of assembly of the given connection, complexity and function of automatic assembly equipment as well as economic indicators of the established system.

The definition of accuracy of the automated assembly processes has been developed on the basis of the works of N. Borodachev [1] on determination of allowances and failures of dimensions and cinematic circuits, the works of P. Dunajev on the methodology of calculation of dimension circuits as well as the works of other authors devoted to the definition of accuracy of the assembly technological process of separate details. The obtained calculation of accuracy of the process of automatic assembly consists of several stages, from defining of the summary failure δ_Σ of assembly in position of the mutual layout of axes of assembly details before their connection and its comparison with the admissible value. The main methods ensuring reduction of δ_Σ are structural and technological methods, for example, accurate regulation of equipment of automatic assembly, increase of accuracy of manufacturing of separate elements of assembly details, and rational choice of basing schemes.

The expressions for defining of the admissible failure of positioning of the mutual layout of axes of cylindrical details have been obtained, where the automate in the automated assembly together with assembly details will form such dimensional circuit, in which distance between the axes of details does not exceed the admissible allowance. A fixed connection is provided if it is possible to assemble spindle and bush with interference ΔH_{max} (Fig. 2).

resent to loading devices, which ensure their assembly. It requires additional time and impacts the total expenses of manufacturing; therefore, it is important to choose the correct basing scheme satisfying provisions of the assembly in advance.

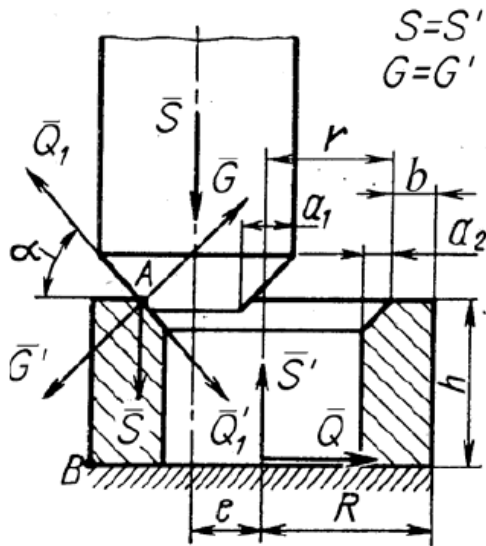


Fig. 3. Scheme of detail contacting by phases

In this article, the scheme of detail contacting by phases is developed (Fig. 3). In accordance with the scheme, axes of assembly details are parallel. In the tangency point A, the spindle works on the bush, which is freely located on a horizontal plane, with force S while the related force G tries to move the bush to the left; consequently, it impacts orienting of the bush and spindle. The bush moves to the needed direction if:

$$F \geq Q + Q_1 \cos \alpha, \quad \operatorname{tg} \alpha_1 \geq f + f_1, \quad (5)$$

where: Q and Q_1 – friction forces, accordingly, between the support surface and the bush and between the spindle and the bush; f and f_1 – accordingly, friction coefficients Q and Q_1 ; $\alpha > \alpha_1$.

By finding the force value S , we will obtain:

$$\operatorname{tg} \alpha_2 \geq \frac{f_1 + f_2}{1 - f_2 f_1}. \quad (6)$$

It shall be considered that equation (6) is true under condition that layout of axes $e = O_1 O_2$ does not exceed the sum of $a_1 + a_2$, where a_1 and a_2 – dimensions of phases of the bush and spindle.

Such scheme may be applied for mutual orientation of short bushes (discs), where the risk of turning over under the impact of the force G is excluded. In contrast, turning over of the bush occurs around point B, by composing equations of moments of these forces in the respective point B, it will be provided that the bush will not lose its stability if:

$$\frac{b}{h} \geq \frac{\operatorname{tg} \alpha - f_1}{1 + f_1 \operatorname{tg} \alpha}, \quad (7)$$

where: $b \leq R - r$ – thickness of the bush wall.

In case we insert $\alpha = 45^\circ$ in formula (7), we will obtain $h \leq \frac{1 + f_1}{1 - f_1} b$. Consequently, in case when inequity $f_1 = 0$, the equation $h \leq b = R - r$ should hold true. This condition also takes place if the bush diameter exceeds its height twice. By assuming value $f_1 = 1$, we will obtain $h \leq \frac{2 + f}{f} b$. In case values f and f_1 do not exceed 0.3, we will obtain coherence with failure not more than 20%: $h \leq \frac{1}{f} b$.

It is established that the force needed for orientation of the details in the necessary position depends on friction forming between the details in the contacting point. Friction coefficient is mainly defined by surface roughness, which changes in the process of friction. However, in the process of assembly, changes in micro-roughness are not admissible because they impede further assembly of the details and affect the durability of connection. In addition, friction forces between contacting surfaces have to be minimal. Following the research of J. Rudzitis [2, 3], in the formula

$$p_i = \frac{k_q^{el} Ra}{S m \theta} F(\gamma), \quad \gamma > 1 \quad (8)$$

we can see that the load between the surfaces depends on proportion of $Ra/S m$. It means that in contact, the main role is played not by the highness and step of the surface roughness separately but by their proportion. In addition, material elasticity constant E and μ shall be considered in calculations.

IV. PRESSING FORCE AND GEOMETRIC PARAMETERS OF CYLINDRICAL PARTS

In this chapter, the impact of pressing force and geometric parameters of details on the accurate assembly of details set by interference is analyzed. As it has been proven by the experimental research presented in the article, the results obtained in practice do not always coincide with the calculated ones, which are affected by characteristics of the surface roughness and manufacturing failures of the assembly details. Thus, the development of the assembly method for connection control is topical. This part offers a pressing system for control of the assembly process for automated manufacturing. The system controls the depth of pressing, force of pressing-in, and its character during the pressing. It is stated that the development of the process ensuring assembly accuracy is related to obtaining and processing of experimental data. Conducting experiments with different parameters of pressing and correlating with curves of the pressing force – pressing length and uniformity of products, optimal parameters of pressed connection can be obtained. It is important to control the needed pressing force to guarantee the necessary force limit

between surfaces of the connected details in the process of assembly. Thus, the data on the needed interference are obtained.

Ability of details to bear considerable loads in pressed connections depends on interference. Currently, to increase connection durability and safety of the equipment operation, calculation of interference fit (S. P. Timoshenko) is performed following the largest admissible interference. It is stated that such method of calculation of the mating character is unwelcome; and it has been proven by research results obtained during experiment. Often, the calculated interference has a big reserve at the given external forces. Thus, it impacts consumption of useful material by choosing geometric parameters of details to provide the required durability of the connection.

At present, for calculation of the contact pressure by interference, Lama Formula developed by S. P. Timoshenko [4] is used. However, the application of this formula asks for many corrections related to different proportions of length and nominal diameter of the connection, uneven tension in length of the detail to be clutched, and manufacture failures. These factors affect the actual value of the pressure in contact. It was stated that in the current calculations, standard parameters of surface profile roughness Ra and Sm are not considered, which are important values characterizing the surface roughness profile and deformation type of contact of rough surfaces. These parameters define also the choice of the needed type of processing [5,6]. Introduction of more accurate processing technologies into modern manufacturing permits to obtain the details with the desirable surface roughness parameters.

V. CONCLUSIONS

- 1) After literature review, it was stated that scientific papers available during the period of elaboration of the research have not sufficiently researched the condition of automatic assembly of cylindrical parts set by interference fit $\delta_{\Sigma} \leq \mathcal{E}_{allow}$. The methods for providing the assembly of mutual orientation of axes of cylindrical details in position in automatic equipment are less effective because of the reduction of roughness of the surface profile of mating details during pressing. The reviewed papers have not considered surface roughness parameters Ra and Sm , which affect the process of assembly significantly.
- 2) As a result of research of the assembly processes of cylindrical parts set by interference fit, admissible failure in assembly position of mutual layout of detail axes was defined, which provides the choice of basing scheme needed for accuracy and the choice of method to ensure connection accuracy. The choice of the basing scheme affects the accuracy and quality of assembly of the given connection, complexity and function of automatic assembly equipment, as well as economic indicators of the established system. The given article offers the most appropriate methods for basing and fixing of cylindrical details in automated assembly lines.

- 3) It was stated that the assembly process is mainly influenced by two surface roughness parameters Ra and Sm by orienting details in position of assembly. It was defined that values characterizing the mating contact of cylindrical details (load, approximation of surfaces, and value of interference) do not depend only on separately taken parameters of surface roughness Ra and step Sm but also on the proportion of Ra/Sm . A contact 3D model of cylindrical parts set by interference by using 3D regular case field theory in description of surfaces has been developed. It was stated that the method of interference fit calculation (S. P. Timoshenko) is not precise considering that cylindrical details are a dimensional object [7-9]; therefore, profile roughness parameters corresponding to real surfaces shall be defined. One parameter Ra is not enough to characterize the surface roughness. Current calculations have not considered the proportion of parameters of surface roughness profile Ra/Sm , which is an important value characterizing surface roughness profile and defining deformation type of the contact of the rough surfaces.

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The main research fields are calculations of friction and wear in machines and design of apparatuses.

Zita Dreija, Natālija Mozga, Oskars Liniņš. Cilindrisko detaļu mezglu ar uzspīlējumu īpašību ietekme uz salikšanu.

Salikšanas procesu automatizācija palielina darba ražīgumu un attiecīgi samazina salikšanas darbietilpīgumu. Tāda situācija, kad pie ātriem apstrādes automatizācijas tempiem salikšanas darbietilpīgums palielinās, nevar ilgi pastāvēt, vai arī, ievērojami paplašinot izstrādājumu ražošanu, var būtiski pieaugt montētāju skaits. Daudzos gadījumos, it īpaši, saliekot mazgabarīta izstrādājumus, automātiskās salikšanas iekārtas aizņem mazāk vietas nekā montētāju darba galdi, izpildot to pašu procesu manuāli. Priekšrocība ir ievērojama saliekamo izstrādājumu kvalitātes paaugstināšanās, tādējādi, ka vairākums saliekamo automātu var strādāt tikai tad, ja uz salikšanu nonāk kvalitatīvas detaļas. Tādā veidā tiek nodrošināta stabilāka saliekamo izstrādājumu kvalitāte. Neskatoties uz priekšrocībām un darba ražīguma paaugstināšanas rādītājiem, salikšanas procesi, salīdzinot ar citiem tehnoloģiskajiem procesiem, ir automatizēti vismazāk. Šajā rakstā tiek pētīta presēšanas spēka un detaļu ģeometrisko parametru ietekme uz precīzu detaļu salikšanu ar uzspīlējumu.

Зита Дрейя, Наталия Мозга, Оскарс Лининш. Влияние свойств узлов цилиндрических деталей с натягом на сборку.

Автоматизация сборочных процессов повышает производительность труда и соответственно уменьшает трудоемкость сборки. Ситуация, когда при быстрых темпах оптимизации обработки трудоемкость сборки увеличивается, не может больше существовать, как и то, что при значительном увеличении производства изделий может существенно увеличиться число монтажников. Во многих случаях, и особенно при сборке малогабаритных изделий, автоматическое сборочное оборудование занимает меньше места, чем рабочие места монтажников, выполняющих тот же самый процесс вручную. Как преимущество можно отметить повышение качества сборочных изделий, так как многие сборочные автоматы могут работать, только если на сборочную позицию поступают качественные детали. Таким образом обеспечивается стабильное качество сборочных изделий. Несмотря на преимущества и показатели повышения производительности труда, сборочные процессы, в сравнении с другими технологическими процессами, автоматизированы меньше всего. В данной статье исследуется влияние силы запрессовки и геометрических параметров деталей на сборку с натягом качественных деталей.