UDC 621.715.4 **doi: 10.20998/2078-7405.2021.94.04**

S. Oliinyk, Kramatorsk, Ukraine, L. Kalafatova, Pokrovsk, Ukraine

TECHNOLOGICAL FIXTURES FOR MACHINING LARGE-SIZED THIN-WALLED SHELLS OF COMPLEX PROFILE

Abstract. *The paper analyzes the structure of technological fixtures for the positioning and fixing of large-sized thin-walled pyroceram shells as a factor affecting the dynamic characteristics of the grinding system. The solution to the problem of ensuring the dynamic stability of the «mandrel-workpiece» subsystem is necessary to increase the efficiency of shell machining in present conditions. Studying the vibrations frequency spectrum of the technological system during grinding has made it possible to determine their sources. The magnitude and frequency of vibrations depend on the mandrel structure - the clamping fixture. The study results are the requirements for a new mandrel structure, considering the dynamic stability of the technological system.*

Keywords: *thin-walled shell; pyroceram; diamond grinding; technological system; structure of fixture - mandrel; vibrations; natural vibration frequency.*

1. INTRODUCTION

Thin-walled shells are a component of rocket and aviation technology. Products have a complex profile (paraboloid of rotation), large dimensions with the following parameters: diameter of 200-500 mm, length of 1000-2000 mm, wall thickness of 5-6 mm, and are made of fragile, difficult to machine material (pyroceram, ceramics). Finished parts must meet the requirements for mechanical strength, heat resistance, radio-technical properties, which is ensured by the accuracy of the detail's profile and its thickness, as well as the characteristics of the surface layer (structure, stresses, waviness, roughness). Deviations from the accuracy of the wall thickness of the finished product should be in the range of ± 0.02 mm, the roughness of the machined surface should not exceed the parameter R_a = 0.08...0.04 μm [1]. Shell workpieces are produced by centrifugal casting. The workpiece is characterized by significant unevenness in wall thickness. This is due to the properties of the material and the instability of the technological molding process parameters [1]. Machining of shells can be performed both using universal and special machines with horizontal and vertical workpiece installation schemes, as well as using modern machines with parallel structures. The latter allows you to change the machining scheme and apply innovative ways to ensure the accuracy of the product surface while reducing the complexity of machining [2].

The technological process of shell machining consists of several stages, during which a significant allowance is removed. The main stages of processing are preliminary and final operations of diamond grinding of the inner contour with basing on the outer contour of the workpiece, grinding of the outer contour with basing on the machined inner surface. At the last stage of machining the outer contour, it is necessary to fulfill the requirements for the accuracy of the wall thickness, waviness, and roughness of the formed surface. However, due to the problems with the dynamic instability of the technological system elements (workpiece, mandrel, tool), these requirements are not met. Therefore, for the final shaping of the product, the operations of finishing with diamond bars of its inner and outer contours are performed. This is a time-consuming manual operation, which reduces the efficiency of the entire technological process. Therefore, the problem of increasing the dynamic stability of the technological system of grinding shells is relevant.

2. ANALYSIS OF THE CAUSES OF THE DYNAMIC INSTABILITY OF THE TECHNOLOGICAL SYSTEM DURING DIAMOND GRINDING OF PYROCERAM SHELLS

For thin-walled shells, the following relationship is characteristic: $h/R_o = 1/20$, where h is the wall thickness of the product, R_o is the minimum curvature radius of its middle surface. According to this parameter, the considered shells can be classified as thin walled. Such products are difficult to install and secure in machining operations. The thin wall of the workpiece lacks static rigidity and dynamic stability when it is subjected to clamping and cutting forces. The result of the analysis of vibrations in the technological system during grinding, presented in studies [1, 3], showed that their level is influenced by beating and deformation of the grinding wheel. The beating of the grinding wheel creates a source of vibration excitation with a frequency that depends on the speed of the wheel rotation. At a wheel speed v = 42 m/s (the wheel speed when machining the outer contour), the frequency of the driving force is 67 Hz. Measurements using a round measuring device showed that during machining, three waves are formed on the working surface of the grinding wheel. This creates sources of oscillation excitation with a frequency of 201 Hz [1, 3], which provokes the occurrence of forced vibrations in the technological system during machining. Their level is influenced by both the parameters of the cutting process (the value of the cutting force and the direction of its components relative to the elements of the technological system), and the parameters of the technological system elements, including the structure of the mandrel - fixture.

The amplitude of forced vibrations depends on the condition of the grinding wheel surface, its wear, geometry of the machined section of the workpiece profile, which can provoke the dynamic instability of such workpieces during grinding and be accompanied by the appearance of parametric vibrations of the shell wall. The amplitude and frequency of such vibrations depend on the geometry of the shell, the way of its fastening in the fixture, the properties of the construction material, the speed and direction of movement of the local moving load during cutting. Certain ratios of external force (cutting force) oscillation frequencies, the speed of its movement on the surface of the workpiece and natural frequencies of the shell cause unstable parametric vibrations in the system. The most dangerous in terms of the appearance of vibrations in the system is the presence of low (up to 1000 Hz) natural frequencies of the shell.

During machining, the shell is positioned and fixed in a fixture, i.e. a mandrel. In this case, even at the finishing stage of machining the outer surface, the basic inner surface of the workpiece, obtained after its final grinding, has a significant error - up to 0.2 mm [1]. Such conditions of basing and fixation determine the values of natural frequencies of the «mandrel-workpiece» subsystem vibrations and influence the level of forced and self-excited vibrations. Therefore, the level of vibrations in the technological system largely depends on the mandrel structure.

In the present work the analysis of mandrel structures for positioning and fixing thin-walled shells during grinding is carried out. The results of the analysis will make it possible to develop the necessary requirements for such fixtures, based on ensuring the accuracy and quality of machining.

3. STUDY OF DYNAMIC CHARACTERISTICS OF THE TECHNOLOGICAL SYSTEM UNDER PRODUCTION CONDITIONS

The paper deals with diamond grinding of the outer contour of a thin-walled pyroceram shell. Overall dimensions of the finished product are as follows: outer diameter is 350 mm, length is up to 1000 mm, wall thickness is 7-8 mm. In production conditions a modernized universal lathe with an aggregate grinding head is used. The workpiece 2 is placed horizontally on a two-supporting mandrel 1 with cylindrical and conic supports (fig.1). The workpiece nose rests on the support 3, which ensures its longitudinal fixation on the mandrel during machining. The support 3 has an elongated design due to the positioning of the aggregate grinding head on the lathe slide.

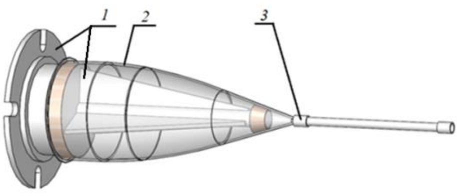

Figure 1 – Scheme of installation of the workpiece during machining

in production conditions

It is difficult to ensure the necessary accuracy of the workpiece positioning in machining operations. This is due to the low accuracy of the base surfaces of the workpiece, errors in the shape and location of its inner surface relative to the outer surface. These errors appear at the preliminary machining of the inner contour and are transferred with a certain degree of refinement to the final machining of the inner surface. The workpiece is based on the tapered and cylindrical surfaces (see Fig. 1) during the grinding operation of the outer contour. Positioning error of tapered surface causes a basic positioning error along the workpiece axis up to 1,13 mm [1]. The error of the cylindrical base surface creates a clearance when basing the workpiece on the mandrel. The study of the positioning error in production conditions has shown that the value of this clearance is 0.1-0.4 mm [1]. This leads to the rotation of the workpiece during machining under the influence of cutting force and vibrations.

To determine the influence of the state of the technological system elements on its dynamic characteristics, we have measured the frequency spectrum of vibrations arising in the process of grinding. The parameters of the frequency spectrum were measured using a vibrometer 795M107B. The vibrometer sensor was installed on the mandrel of the grinding head. The frequency spectrum of the technological system vibrations for the parabolic section of the shell, which is located at a distance of 300 mm along the axis from the workpiece base, is shown in Fig. 2. The main values of technological system vibrations are marked at the frequency spectrum along the axis 0X in the range from 0 to 1000 Hz, the acceleration of vibrations (mm/s^2) are shown along the axis 0Y.

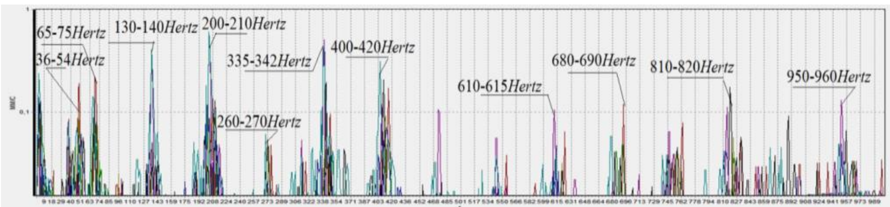

Figure 2 – Frequency spectrum of the technological system vibrations during finishing the outer contour of the workpiece

Table 1 presents the results of the frequency spectrum analysis. For the analysis we have used the measurement results (see Fig. 2) and studies of the dynamic characteristics of a similar technological system, carried out in the research [1, 3].

Table 1 – Analysis of the frequency spectrum of the technological system vibrations

Frequency range, Hz	Source (cause) of the harmonic
Less than 20	Non-synchronous spectrum components (environmental noise; low-frequency spectrum of vibrations of other elements of the technological system)
36-54	Subharmonics resulting from the grinding wheel rotation; natural frequencies of the «spindle assembly – mandrel - workpiece» subsystem
65-75	Frequencies corresponding to the operating frequency of the grinding wheel and the lowest natural frequency of the shell
130-140	Superharmonics, which occurs during the grinding wheel rotation
200-210	Superharmonics, which appears due to changes in the shape of the grinding wheel
260-270	Natural frequencies of the shell workpiece vibration
335-342; 400-420	Natural frequencies of the «spindle - mandrel» subsystem and superharmonics from the grinding wheel rotation caused by its imbalance
610-615; 680-690; 950-960	Natural frequencies of the «mandrel - workpiece» subsystem
810-820	Natural frequencies of the «spindle assembly - grinding wheel»

4. FINITE ELEMENT ANALYSIS OF THE DYNAMIC CHARACTERISTICS OF THE «MANDREL - WORKPIECE» SUBSYSTEM FOR DIFFERENT MANDREL DESIGNS

To assess the impact of the fixture design on the level of vibrations in the technological system when grinding thin-walled shells of a complex profile, an analysis of its dynamic characteristics depending on the type of mandrels used in production and proposed by modern researchers has been conducted.

The theoretical study of the dynamic behavior of the technological system is performed in the Solid Works Simulation software package by the finite element method. Three-dimensional models of mandrels with a workpiece mounted on them have been developed. For the «mandrel - workpiece» subsystem deformations from the local load (cutting force) in its action area has been calculated to determine the subsystem rigidity. Also the spectrum of natural frequencies and vibration modes for the «mandrel - workpiece» subsystem, arising under the influence of the local load (cutting force) have been calculated to determine the dynamic behavior of the subsystem.

Fig. 3 shows the frequency spectrum of vibrations of the «mandrel - workpiece» subsystem and the frequency waveforms when grinding in production conditions (Variant I) obtained by calculation. The workpiece basing has been carried out on the mandrel according to Fig. 1. The calculated model is made for the real conditions: there is a clearance of 0.1 mm on the cylindrical support. The calculated values of vibration frequencies have been compared with the spectrum of vibration frequencies measured in production conditions (Fig. 3, a), and with the frequency of the vibration source.

The shapes of vibration frequencies (Fig. 3, b, c, d) allow us to determine the nature of possible vibrations. Red color shows the greatest deformation of the product relative to the resting state, blue - the absence of deformation, green - intermediate variant of the deformation value. The graphs of the frequency spectrum (see Fig. 3, a) show the frequency in Hz on the axis 0X, and the product deformation, mm, on the axis 0Y.

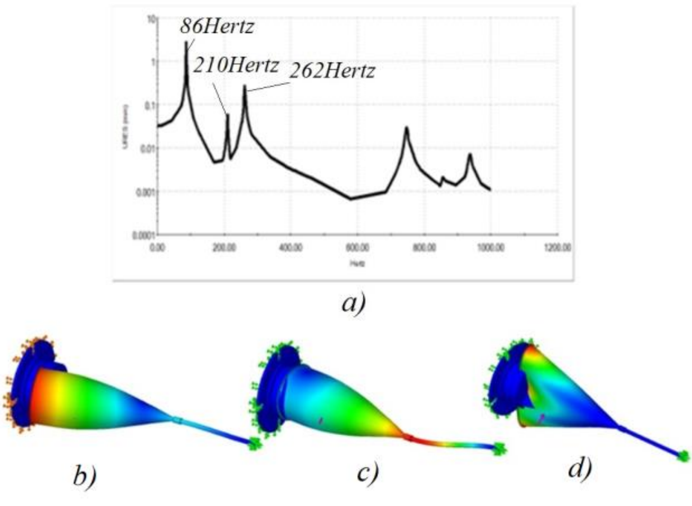

Figure 3 – Calculated frequency spectrum of vibrations of the «mandrel-workpiece» subsystem and the frequency forms for production conditions (Variant I)

The forced vibrations of the «mandrel - workpiece» subsystem and the parametric vibration of the shell are mostly influenced by the frequencies up to 1000 Hz, i.e. the first three natural frequencies (see Fig. 3, a).

To confirm the assumption that the low frequency spectrum is related to the presence of a clearance between the mandrel and the workpiece, the frequency spectrum of vibrations for the virtual mandrel of similar design, but without the clearance (Fig. 4, a, b), as well as the version of the spectrum for the conditions of exclusion of the support 3 (Fig. 4, c, d; Variant II) have been calculated.

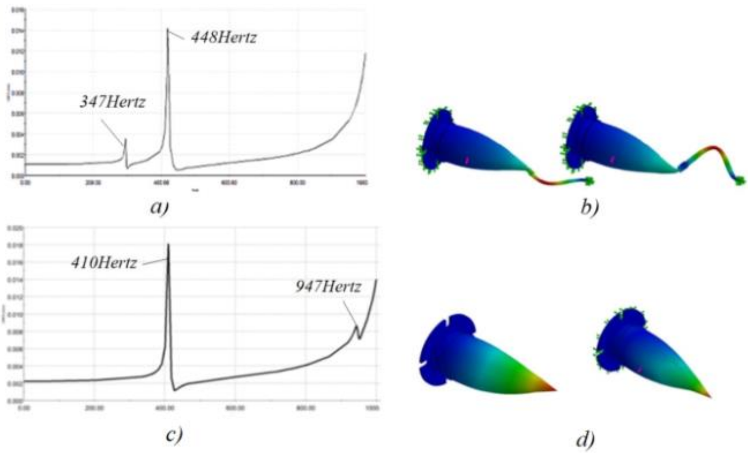

Figure 4 – Calculated frequency spectrum of vibrations and the frequency forms of the «mandrel-workpiece» subsystem (Variant II)

For the models of Variant I and Variant II, the static calculation of the workpiece deformations under the influence of the cutting force is performed. For all variants of the workpiece positioning, the characteristic value of the cutting force, which is 400 N, has been taken for the selected machining conditions [3]. Grinding area is located on the parabolic section of the workpiece at the distance of 300 mm from its' base. The static calculation shows that the workpiece surface displacements under the cutting force in the grinding area is, respectively, 0.12 mm (Variant I), which is close to the measurement results according to [1], and 0.024 mm (Variant II).

The calculated natural frequency of the mandrel is 284 Hz, the measured frequency is 305 Hz. The mandrel 1 (see Fig. 1) has a rather rigid structure. The first natural frequency of the «mandrel-workpiece» subsystem (Variant I) is 86 Hz due to the bending forms of the subsystem vibrations and is a result of the presence of a clearance on the cylindrical support. The first three frequencies have the greatest influence on the vibration amplitude (Variant I). The frequency of 210 Hz (see Fig. 3, a) is close to the frequency of the driving force of 201 Hz. The frequency of 262 Hz has the form of the shell vibrations and their value, close to the bending vibrations of the «mandrel-workpiece» subsystem, is sufficient to cause parametric vibrations (see Fig. 3, d).

The computer model of the «mandrel-workpiece» subsystem (Variant II) has shown that low forms of natural frequencies of the shell vibrations do not occur (see Fig. 4). The lowest frequency in the presence of the support 3 is associated with its bending vibrations (see Fig. 4, a, b). In the absence of the support 3 the low frequency is determined by the presence of bending vibrations of the «mandrel-workpiece» subsystem at the frequency of 410 Hz. For all cases of Variant II, the lowest frequencies are remote from the influence of exciting frequencies from the side of the grinding wheel.

In the present paper we have also analyzed the mandrel structures proposed by other researchers [5-9] for fixing the shells of similar type during the grinding operations.

The mandrel structure [5], shown in Fig. 5, has two main supports 3 - cylindrical and 4 - conical, two additional supports 5 to increase the rigidity of the shell wall and stop 6. It has been assumed that when basing a workpiece on such a mandrel, a clearance may occur due to the low accuracy of dimensions and the shape of the base surface between the cylindrical support 3 and the workpiece 1.

The static calculation has shown that deformation of shell surface under the cutting force in the grinding area is as follows: 0.014 mm in the absence of the clearance on the cylindrical support (Variant III); from 0.018 to 1.4 mm in the presence of clearances, depending on the point of force application (Variant IV).

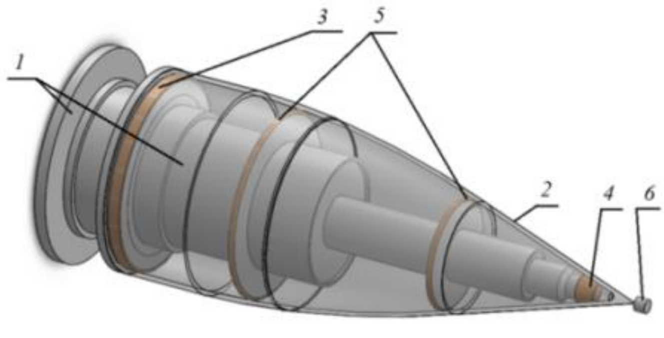

Figure 5 – Structural diagram of the «mandrel workpiece» subsystem
for the mandrel structure according to [5]

The results of calculations by the finite element method in Solid Works Simulation have shown that the natural frequency of the mandrel structure [5] is 195 Hz. The mandrel structure [5] is less rigid than the mandrel shown in Fig. 1. Also, for this mandrel the following has been established by calculating the dynamic characteristics of the system (Fig. 6).

For the «mandrel-workpiece» subsystem according to Variant III (Fig. 6, a), the first natural frequency of vibrations is 331 Hz, which removes the subsystem from the influence of excitatory vibrations, but natural vibrations of the shell, which provoke the parametric vibrations of its wall, still have a rather (below 1000 Hz) small value - 872 Hz. The presence of the clearance lowers the first frequency to 36 Hz, which will cause forced vibrations when grinding the workpiece. Low natural frequencies of vibrations of the shell wall - 244 Hz, can cause the appearance of its parametric vibrations.

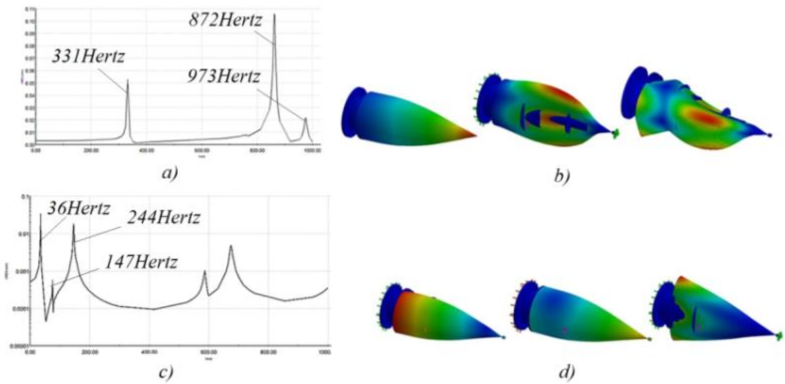

Figure 6 – Calculated frequency spectrum and vibration modes
of the «mandrel-workpiece» subsystem for the mandrel structure according to [5]

The disadvantage of the mandrel [5] is that due to the low accuracy of dimensions and the shape of the inner surface of the shell, i.e. errors in the thickness of a given profile, it is difficult to adjust the fixing unit (cylindrical support) to the size during external grinding operations. As a result, the shell wall is not completely fixed. Additional fixation points increase the stiffness of the product on the limited surface, but the adjustments of these supports to the size of the inner surface have low accuracy.

The design of the mandrel [6], shown in Fig. 7, assumes that in the mandrel 1 there is a rubber chamber 5 between the fixation points (cylindrical support 3 and conical support 4). The chamber is filled with water 6 under pressure, which leads to its gradual expansion and uniform arrangement of the chamber along the inner surface of the workpiece 2, which ensures a uniform support of the shell wall during grinding.

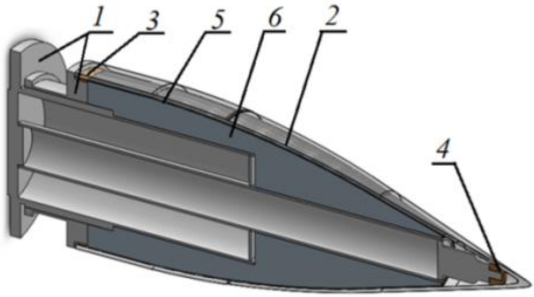

Figure 7 – Structural diagram of the «mandrel – workpiece» subsystem for the mandrel structure according to [6]

The installation and the mechanism of fixing the shell on the cylindrical mandrel has not changed in comparison with Variants III and IV. At the support 3, a clearance is possible. Two computer models have been created: with the clearance (Variant V) and without the clearance (Variant VI). The results of the static calculation (Fig. 8) show that the deformation of the workpiece surface under the influence of the cutting force in the grinding area is 0,004 mm both for Variant V and Variant VI.

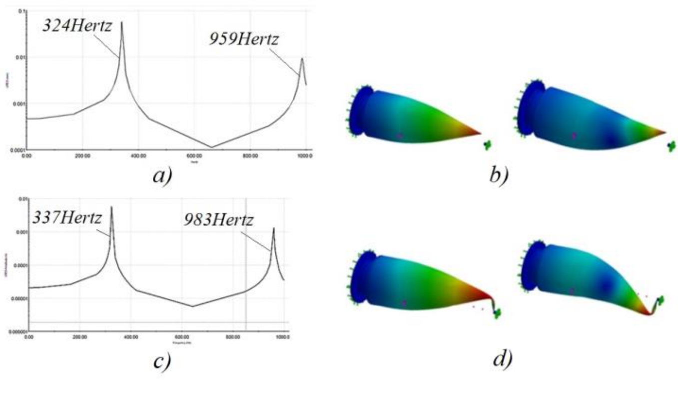

Figure 8 – Calculated frequency spectrum and frequency waveforms of the «mandrel-workpiece» subsystem for the mandrel structure [6]

The structure of the mandrel [6] significantly reduces the deformation of the shell wall, increases the lowest natural frequency, which eliminates the influence of vibrations of the exciting force. At low frequencies (up to 1000 Hz), there are no forms of the shell vibrations, which may lead to the parametric vibrations. The frequency spectra of vibrations for Variant V and Variant VI are similar. However, the vibration amplitude in the presence of a clearance increases by a factor of almost 10 when approaching the resonance frequencies. The disadvantages of this mandrel structure are the necessity to provide its hermeticity, the laboriousness of the workpiece installation on the mandrel and the complexity of manufacturing the rubber chamber.

The mandrel structure [7], shown in Fig. 9, implies a multilayer temporary liner 6, which consists of 3 to 5 sheets of elastomer bonded with adhesive to each other. The liner is placed on the adhesive along the inner surface of the shell. The rubber chambers 5 are filled with air, creating the cavity pressure of 1 to 4 bar [7]. According to the patent [7], the fixture has a reconfigurable structure and can be applied to similar shell structures, which differ in size.

The structure of the fixture (see Fig. 9) has been adapted to the shells considered above when building the model. The authors of the fixture [7] assume machining the shell using machines with a vertical axis of the workpiece installation. This does not change the essence of the study since the influence of the mandrel on the dynamic behavior of the technological system is preserved. In the study [2], the advantages of machining such products using machines with the vertical axis and with parallel kinematics have been considered.

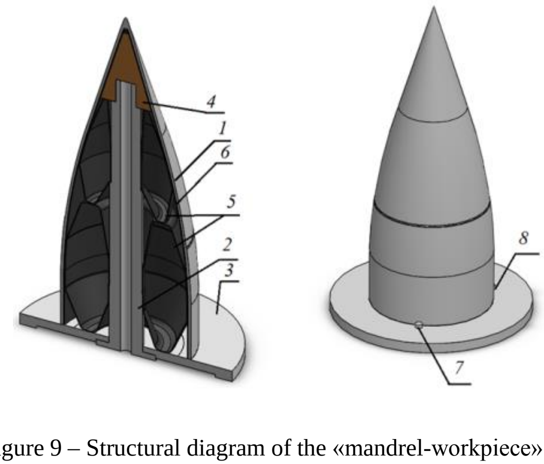

Figure 9 – Structural diagram of the «mandrel-workpiece» subsystem for the mandrel structure according to [7]:
1 - workpiece; 2 - mandrel; 3 - base; 4 - conical support; 5 - chamber; 6 – liner; 7 - support; 8 – clamp

The results of the static calculation (Fig. 10) showed that the workpiece surface displacement under the influence of the cutting force in the grinding area is 0,024 mm when working with a pressure of 2 bar (200000 N/m^2) and 0,022 mm with the pressure of 4 bar (400000 N/m^2) (Variant VII).

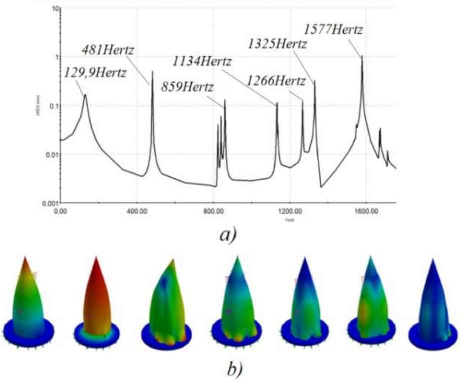

Figure 10 – Calculated frequency spectrum and the frequency waveforms of the «mandrel-workpiece» subsystem for the mandrel structure [7]

The frequency analysis for the variant of setting the workpiece according to the model (see Fig. 10, a) has been performed at the frequency of vibrations up to 1600 Hz to compare the obtained calculation results with the measurement results given in [7]. The results of measuring the frequency characteristics of the shell showed a decrease of apparent vibration peaks at frequencies from 573 to 1000 Hz and decrease of vibration amplitude at all other frequencies. The vibration amplitudes are reduced by 2.5 times at frequencies up to 500 Hz and by 2.67 times at frequencies from 500 to 1000 Hz. Calculations showed the similarity of the obtained frequency spectrum, including complete similarity in terms of the first frequency of the subsystem: 129.24 Hz in [7] and 129.9 Hz, according to Fig.10, a.

The workpiece is placed on the base 3 (see Fig. 9) on supports 7 and pressed to them by clamps 8, which, however, does not provide shell rigidity on the mandrel, leads to a decrease of the first natural frequency of the «mandrel-workpiece» subsystem, creates undesirable force effects on the surface of the workpiece from the clamp and does not allow machining the workpiece along the full contour.

Table 2 presents the calculation results of the dynamic characteristics of the «mandrel-workpiece» subsystem for the considered variants of the clamping fixture designs. The deformation of the workpiece surface from the static load is an indirect indicator of the reduced rigidity of the «mandrel-workpiece» subsystem in the machining area. The value of the first natural frequency is an indicator of the possibility of forced vibrations. The natural frequency of vibrations according to the shape of the shell is an indirect indicator of the possibility of parametric vibrations of the shell wall.

Table 2 – Calculation results of the dynamic characteristics

Mandrel structure variants	Static load strain, mm	First natural frequency of the «mandrel-workpiece» subsystem, Hz	Natural frequency of the shell (up to 1000 Hz), Hz
Variant I	0,12	86	262
Variant II	0,024	410	-
Variant III	0,018	331	872
Variant IV	1,4	36	244
Variant V	0,004	324	-
Variant VI	0,004	337	-
Variant VII	0,022	129,9	859

According to the results presented in Table 2, it can be concluded that the mandrel structures according to Variants II, V, VI provide a stable flow of the cutting process. However, the operation of mandrels according to Variants V and VI is difficult because of the complexity of their structure.

5. SUMMARY

The complex, non-technological shape of the shell affects the peculiarities of positioning its workpiece in the machine and machining. The research has shown that when designing the mandrel, which will provide dynamic stability of the technological system and the required accuracy of machining, it is necessary to ensure the presence of two supports to fix the profile of the workpiece shell over the entire contact surface without a clearance; basing on the end surface; the presence of the positioning scheme allowing to process the full workpiece profile.

Among the examined mandrel structures, Variant II meets these requirements. The wall deformation is within the operational tolerance, and natural frequencies of the «mandrel-workpiece» technological subsystem are not influenced by exciting vibrations. Such conditions are not fully satisfied for the existing structures, so there is a need to develop a new progressive mandrel structure, the use of which will provide the required level of characteristics of the technological system of grinding thin-walled shells.

References: 1. *Pokolenko D. V.* (2014) Pidvyshchennia efektyvnosti obrobky antennykh obtichnykiv iz sytaliv za rakhunok udoskonalennia tekhnolohii almaznoho shlifuvannia [Increase of the efficiency of processing the antenna domes made of cetalss due to upgrading of diamond grinding technology]. Extended abstract of candidate`s thesis. Donetsk (in Ukraine). **2.** *Oliinyk, S.Yu. & Kalafatova, L.P.* (2020). Analiz skhemy obrobky skladnoprofilnykh obolonok obertannia [Analysis of the machining scheme of complex-profiles shells of rotation]. *Rizannia ta instrumenty v tekhnolohichnykh systemakh - Cutting & Tools in Technological System*, no 92, pp.122-135. Retrieved from http://rits.khpi.edu.ua/article/view/2078-7405.2020.92.13. **3.** *Oliinyk S.Yu*. (2014) Zabezpechennia yakosti obrobky tonkostinnykh sytalovykh obolonok shliakhom pokrashchennia dynamichnykh kharakterystyk tekhnolohichnoi systemy shlifuvannia [Ensuring quality of processing the thin-walled shells made of cetalss by improving the dynamic characteristics of the technological system of grinding]. Extended abstract of candidate`s thesis. Krasnoarmiisk (in Ukraine). **4.** *Suzdal'cev E. I., Hamicaev A. S. & Haritonov D. V*. (2003). Ustrojstvo dlya mekhanicheskoj obrabotki krupnogabaritnyh slozhnoprofil'nyh keramicheskih izdelij [Device for machining of large-sized complex-shaped ceramic products]. Patent RF. No 2258596. **5.** *Suzdal'cev E. I., Haritonov D. V. & Suslova M. A.* (2007). Ustrojstvo dlya mekhanicheskoj obrabotki krupnogabaritnyh slozhnoprofil'nyh keramicheskih izdelij [Device for machining of large-sized complex-shaped ceramic products]. Patent RF. No 2313438. **6.** *Zunmin Geng* (2010). Adaptive design of fixture for thin-walled shellacylndrical components. Patent US. No 2010/0164187.

Світлана Олійник, Краматорськ, Україна,
Людмила Калафатова, Покровськ, Україна

ТЕХНОЛОГІЧНА ОСНАСТКА ДЛЯ ОБРОБКИ ВЕЛИКОГАБАРИТНИХ ТОНКОСТІННИХ ОБОЛОНОК СКЛАДНОГО ПРОФІЛЮ

Анотація. *Для забезпечення точності обробки та якості поверхні тонкостінних великогабаритних оболонок з ситалу на операціях алмазного шліфування необхідно підвищувати динамічну стійкість технологічної системи. На динамічну стійкість технологічної системи впливають як характеристики процесу різання, так і динамічні характеристики її елементів. Заготовка – тонкостінна оболонка є нетехнологічним елементом. Стінці заготовки не вистачає статичної жорсткості та динамічної стійкості під впливом на неї сил закріплення у пристосуванні та різання. Рівень коливань стінки оболонки під час обробки залежить від геометрії заготовки, режиму різання та конструкції технологічної оснастки – затискної оправки, яка впливає на власні коливання стінки заготовки. Складність забезпечення точності установки заготовки на операціях механічної обробки пов'язана з низькою точністю її базових поверхонь, похибками форми і розташування внутрішньої поверхні заготовки щодо зовнішньої. Дослідження частотного спектра коливань технологічної системи під час шліфування у виробничих умовах дозволило визначити джерела їх виникнення. Було виявлено, що нижча власна частота коливань підсистеми «оправка-заготовка» в діапазоні від 50 до 200 Гц негативно впливає на вимушені коливання в технологічній системі. Власна нижча частота оболонки (до 1000 Гц) впливає на появу та рівень параметричних коливань її стінки. За допомогою методів комп'ютерного моделювання виконано оцінку впливу існуючих та віртуальних, з необхідними ознаками, конструкцій пристосувань - оправок на рівень вібрацій у системі. Всього було оцінено чотири конструкції оправок та сім варіантів їх реалізації на операції зовнішнього шліфування тонкостінної оболонки. Дослідження показали, що в конструкції оправки, яка забезпечить динамічну стійкість технологічної системи і задану точність обробки, необхідно забезпечити: наявність двох опор для фіксації профілю заготовки оболонки по всій контактній поверхні без зазорів; базування по торцевій поверхні; наявність схеми установки заготовки, яка дозволить виконати обробку її повного профілю. Існуючі конструкції оправок повністю не задовольняють переліченим вимогам, тому є необхідність у розробці нової прогресивної конструкції оправки.*

Ключові слова: *тонкостінна оболонка; ситал; алмазне шліфування; технологічна система; конструкція пристосування – оправки; вібрації; власна частота коливань.*