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МАШИНОБУДУВАННЯ, АВТОМАТИЗАЦІЯ ВИРОБНИЦТВА ТА ПРОЦЕСИ МЕХАНІЧНОЇ ОБРОБКИ

UDC 621.941-229.3

EXPERIMENTAL RESEARCH OF DEFORMATION ZONE OF ADAPTIVE CLAMPING ELEMENTS FOR LATHE JAWS CHUCKS

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Resume. *The paper deals with the experimental research of clamping surface deformation zone of adaptive clamping jaw to equip lathe jaws chucks during machining work pieces of different diameters. The directly proportional displacement dependence on clamping force for the most deformed part of clamping zone ring segments in work pieces of different diameters machining is obtained. The results of experimental research have verified the theoretical calculations and showed that clamping part of adaptive jaw is being deformed sufficiently for full fitting of the clamping jaw surface and the work piece.*

Key words*: lathe chuck, adaptive clamping element, clamping surface, lathe, flexible, deformation, experimental results.*

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Formulation of the problem. The problem of improving the technical level of modern lathes and automatic machine systems in a multiple production, high-speed and high-precision working conditions of work pieces machining, requires the characteristics improvement of basic mechanisms and components, some of which are clamping mechanisms. At the present stage of the lathe machines development, the main focus is on increasing flexibility of clamping mechanisms (the ability to adapt to the geometry of the machined work pieces) and capabilities of rapid readjustment to different size of machined work pieces [1, 2]. Taking this into account stands a very actual scientific problem to develop new adaptive clamping jaws. Their design allows expanding the range of machined work pieces, clamping diameters in respond to modern requirements for readjustment speed, quality and accuracy of the machined work piece. The paper relates to the scientific subjects of the development of design theory and studies of high-performance, resource-saving methods of automated turning and new high-speed technological equipment.

Analysis of previous research results. Clamp on a cylindrical surface of larger or smaller work piece diameter causes the fact that fitting of the clamping element is taking place only in certain contact areas with high surface pressures. When using a clamping element of the constant cross-sectional geometry in a range of clamping diameters, the following options are possible for its contacting with work piece: full contact, when the work piece diameter and

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the boring diameter of the clamping element are equal; incomplete contact when the work piece diameter is smaller than the boring diameter of the clamping element; contact by the edges when the work piece diameter is larger than the boring diameter of clamping element [1, 2]. Therefore, to ensure full contact the clamping elements need to adapt to the clamping surface in a given diameters range.

One of the fundamental approaches to create new adaptive type designs of clamping jaws is intentional introduction of the deformation zones into their design that ensures full contact between the clamping jaw and the work piece surface [3]. Such zones can be created using heuristic methods of full and partial decomposition of the clamping elements by making voids in the clamping elements etc. [3 – 5]. Based on scheme-structural synthesis a number of adaptive clamping jaws designs were developed. One design among them received a Ukraine patent for utility mode. [6]. The given clamping jaw was created by partial decomposition of its clamping part. That allowed creating the adaptation zone as a circular segment that deforms under the clamping forces and thus provides full contact with the work piece clamping surface.

Series research works of national and foreign scientists deal with the experimental studies of lathes clamping devices with adaptation to the clamping geometry. Papers [1, 2, 7] presented experimental results of force characteristics, accuracy and rigidity of the clamping chucks of plunger type with multi profile positional clamping elements. The paper [8] presents the experimental research results of the force and dynamic characteristics, clamping accuracy and rigidity of collet and uncollet type clamping chucks for rod work pieces clamping. The given results showed that these characteristics for studied clamping jaws are not inferior to traditional ones, of which lathes are equipped in a multiple production working conditions.

The paper [9] deals with the clamping chucks research for clamping of synthetical work pieces in a wide range. In this work, the theoretical and experimental evaluation is conducted of a number of flexible clamping element structures with circular cross-section shapes that self-adjust to the work piece surface in a diametrical cross-section.

The objective. The paper objective is to investigate experimentally the working performance of the adaptive clamping element and to define the displacement dependences of the most deformed part of the annular segment of the clamping zone in the ranges of its clamping diameters and operating clamping forces for the clamping chuck.

Problem and methods of experimental research. To solve the problem stated in this paper the experimental test stand was designed specifically for the experimental research of displacements dependence of the most deformed part of the annular segment of clamping zone in the ranges of its clamping diameters and operating clamping forces. To define the type of empirical dependence obtained by experiment values at nodal points with some error, the method of least squares that is approximation by polynomials was applied.

The scheme of displacements measurement of most deformed part of the clamping adaptive jaw annular segment of clamping zone is shown in Fig. 1. Experimental test stand (Fig. 2) is designed on the base of the turning lathe of 1K62 model.

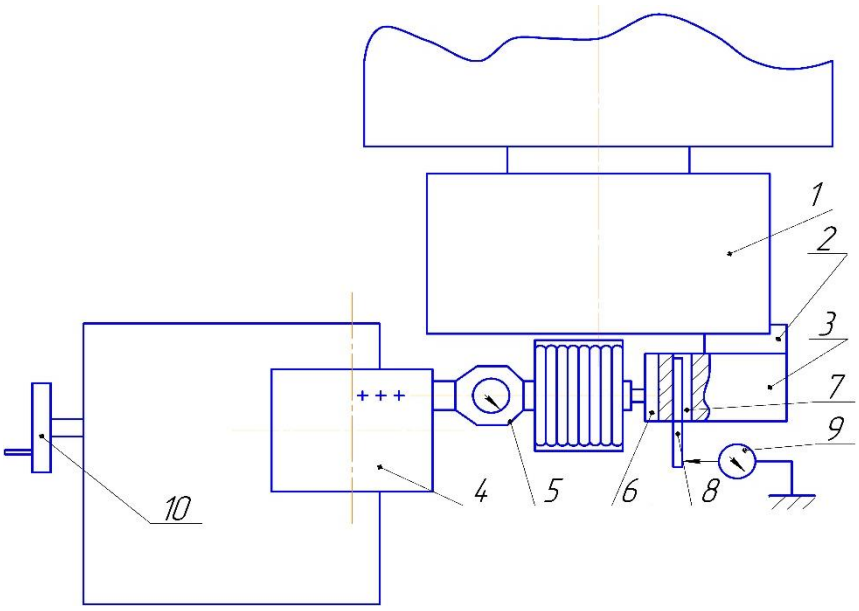


Figure 1. Scheme of displacements measurement of the most deformed part of the adaptive clamping jaw annular segment of clamping zone

To conduct measurements the adaptive clamping jaw 3 was fixed in the self-centred lathe chuck 1, using base jaw 2. In tool carriers of the turning lathe 4 the tuning fork type dynamometer 5 was fixed. This dynamometer in tool carriers moving, using the handle 10, created force load on the clamping surface of adaptive jaw in different work pieces 6 diameters range (Figure 3). To measure the displacement value of the most deformed zone of the adaptive clamping jaw 3 annular segment in its cavity 7, the plate 8 was mounted. The plate transmits the deflection value of adaptive jaw 3 annular segment to the indicator head 9.

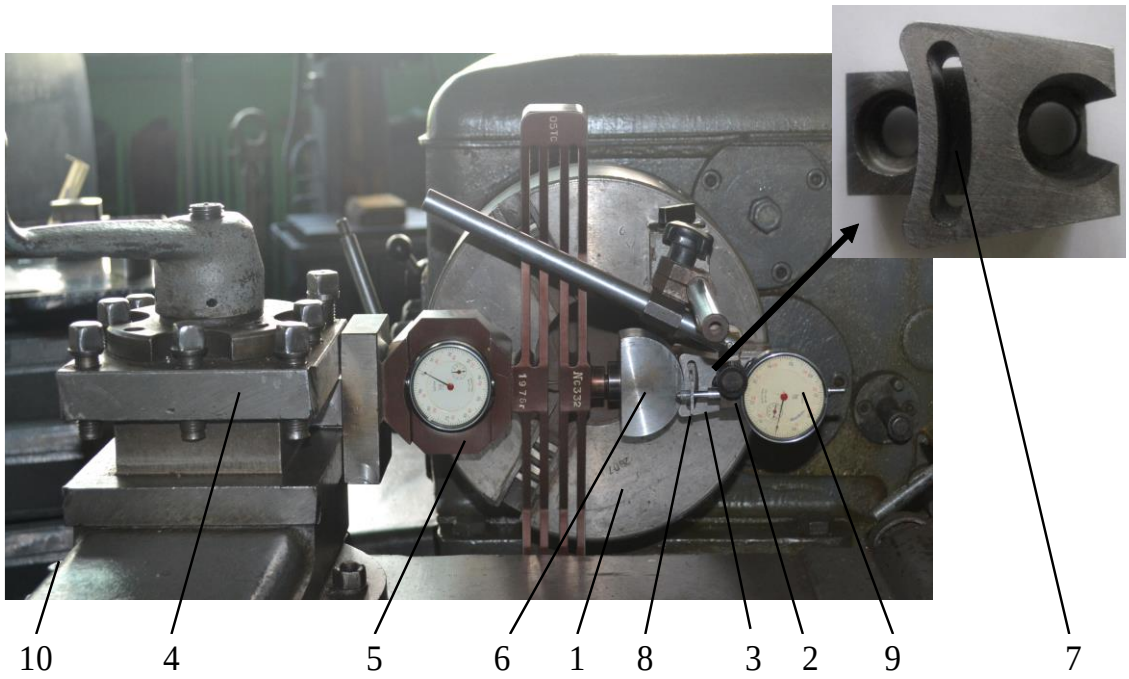


Figure 2. Experimental stand for measuring the displacements of the most deformed part of the adaptive clamping jaw annular segment of clamping zone

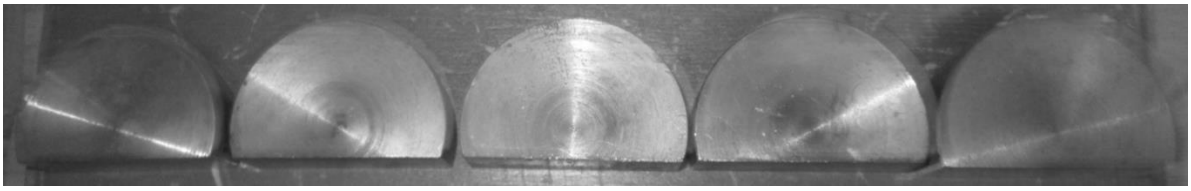


Figure 3. The studied work pieces for the experiment

Experimental studies were conducted for the clamping jaw forces within 500...5,000 N and work pieces diameters within 65...75 mm. Loading by clamping force of the work piece 6 was carried out stepwise. Fixing the displacements of the most deformed part of the adaptive clamping jaw annular segment of clamping zone was displayed on clock type indicator 9 with point value of 0.01 mm installed on the magnetic holder.

Research results. Ten tests in the experiment running for each force value and each work piece clamping diameter were conducted. As a result the values of displacements depending on the load (forces) and the work piece diameter were obtained as well as their averages and dispersions of parallel tests. Verification of homogeneity of dispersions was performed by the Cochran criterion. To define the type of empirical dependence obtained by experiment values at nodal points with some error, the method of least squares that is approximation by polynomials was applied.

As a result of computer experimental data processing the adequate description of first degree polynomials displacements depending on load for different work pieces diameters was described (Fig. 5). The correlation coefficients for dependencies are within the 0.99...0.999. The experiments have resulted in that the displacements dependence on the load is directly proportional as for different diameters of work pieces.

The experimental data and theoretical research data were compared. The mentioned comparison was conducted by computer simulation using finite element method [4]. Simulation cycle basing on CAD / CAE-system includes the following stages: 1) design geometry of clamping element and work piece; 2) choices of finite elements types and entering their parameters; and also partition of the clamping element and the work piece into the finite elements; 3) choices and imposition of boundary conditions, including those that simulate the contact area, and formation of the system loads; 4) verification of model correctness. The results of computer simulation of the clamping element adaptation zone for different clamping diameters under the load of the clamping force are stress (Fig. 4) and deformation (Fig. 5) condition pictures.

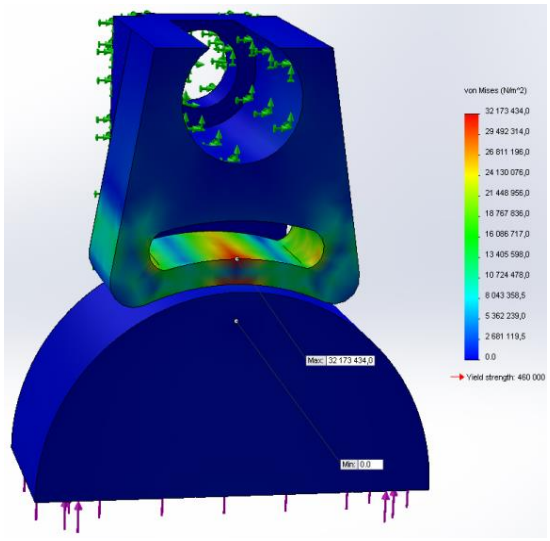


Figure 4. Picture of the stress condition of adaptive clamping element obtained by computer simulation

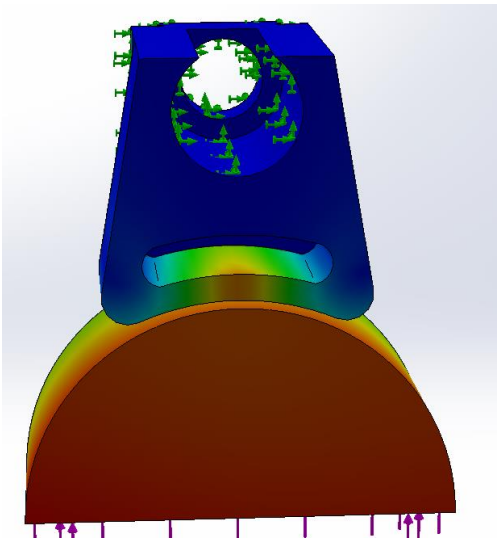
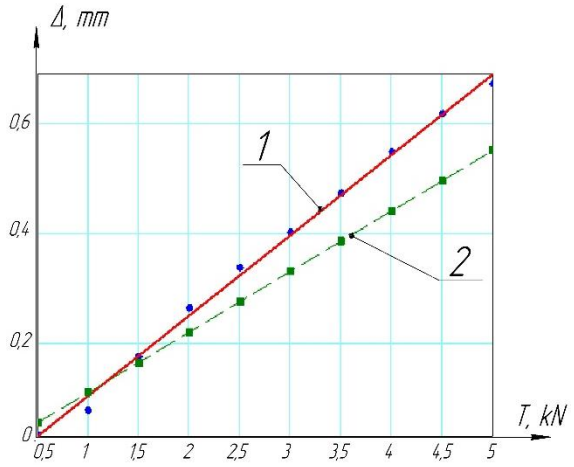


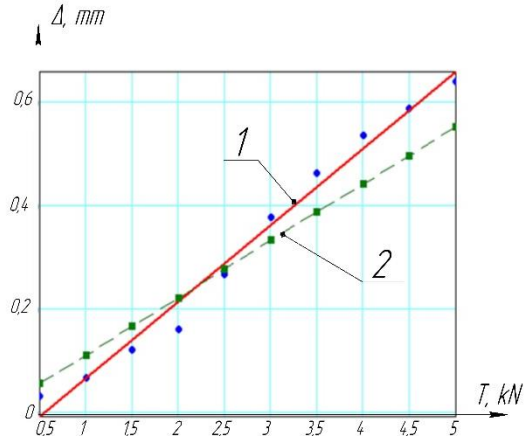
Figure 5. Picture of the deformation condition of adaptive clamping element obtained by computer simulation

Figure 6 presents a comparison of theoretical studies conducted by computer simulation by finite element method and experimental data. As a result of these comparisons it was found that the error between them is from 3 to 25%. This error can be explained by a set of installation mistakes of all elements of experimental equipment and deformations of machine elements under the load. For example, the position of the jaw installed in a three jaws self-centred chuck is slightly changing under the clamping forces.

Theoretical and experimental studies have shown that maximum deformations are observed in the central zone of the annular segment of designed adaptive clamping element. This fact respectively ensures uniform fitting of the whole adaptive element clamping surface to the work piece clamping surface. With increasing the clamping force per one clamping element to the certain values for different work piece diameters the deformation dynamics decreases sharply, indicating the full contact between adaptive element clamping surface and work piece surface.



a)



b)

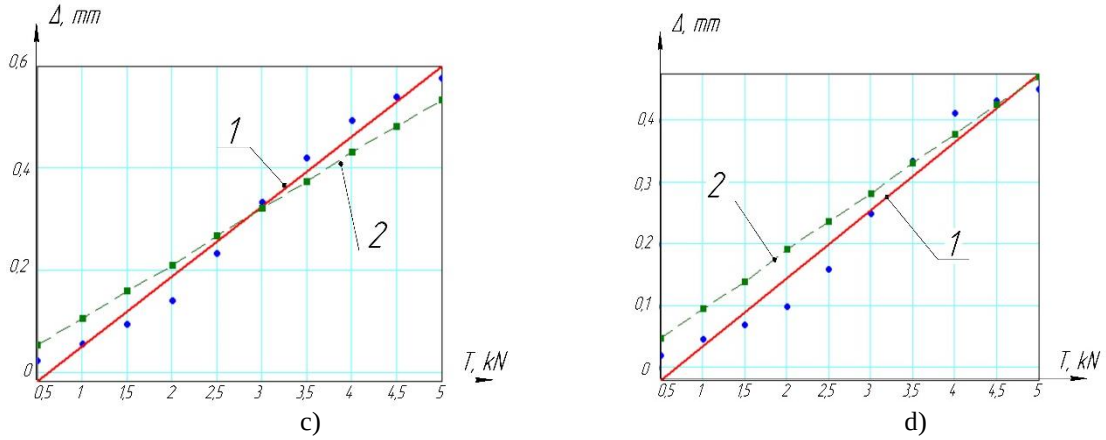


Figure 6. Graphic displacement dependences of the most deformed part of the adaptive clamping jaw annular segment of clamping zone on the clamping force determined experimentally (1) and by theory (2) for the follows workpieces diameters: 65 mm (a), 67 mm (b), 71 mm (c) and 73 mm (d)

Conclusions. The experimental equipment and the methodology of experimental studies were developed in regard to displacements of the most deformed part of the annular segment of clamping zone in the ranges of its clamping diameters and operating clamping forces. The results of the experiment illustrate the directly proportional displacement dependence on the clamping force of the most deformed part of the adaptive clamping jaw annular segment of clamping zone. The results of experimental research verified the theoretical calculations conducted with computer simulation by finite elements method. They showed that clamping part of the jaw is fully adaptable to work pieces of different diameters, and it allows not damaging the work piece clamping surface during finish machining.

Further experimental research is planned for clamping stiffness, radial run out, force push and scroll moment of the work piece installed in the adaptive type clamping elements.

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УДК 621.941-229.3

ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ЗОНИ ДЕФОРМУВАННЯ АДАПТИВНИХ ЗАТИСКНИХ ЕЛЕМЕНТІВ ТОКАРНИХ КУЛАЧКОВИХ ПАТРОНІВ

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Резюме. *Стаття присвячена експериментальним дослідженням зони деформації поверхні затиску адаптивного затискного кулачка для оснащення токарних кулачкових патронів при обробленні заготовок різного діаметра. Встановлена прямо пропорційна залежність переміщень найбільш деформованої частини кільцевого сегменту зони затиску для різних діаметрів заготовок від сили затиску. Результати експериментальних досліджень підтвердили теоретичні розрахунки та показали, що затискна частина адаптивного кулачка деформується достатньою мірою для повного прилягання поверхонь затиску кулачка та заготовки.*

Ключові слова: *токарний патрон, адаптивний затискний елемент, поверхня затиску, верстат, гнучкість, деформація, результати експерименту.*

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