ADAPTATION OF LATHE CHUCKS CLAMPING ELEMENTS TO THE CLAMPING SURFACE

АДАПТАЦИЯ ЗАЖИМНЫХ ЭЛЕМЕНТОВ ТОКАРНЫХ ПАТРОНОВ К ПОВЕРХНОСТИ ЗАЖИМА

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Abstract: *The scientific paper deals with the theoretical investigations of turning clamping chucks adaptive clamping elements made by intentional imposition of deformation zones in their design. The estimation of clamping conditions in the contact zone between adaptive clamping elements and clamping surface was carried out with a help of CAD/CAE systems. The stress state of the given clamping jaw adaptive zone was analyzed.*
***KEYWORDS**: LATHE CHUCK, ADAPTIVE CLAMPING ELEMENT, CLAMPING SURFACE, LATHE, FLEXIBLE, SIMULATION*

1. Introduction

The problem of engineering level increasing of modern automatic lathes and automatic metal cutting systems in a multiple production as well as high speed and high precision processing requires performance improvement of machine tools main mechanisms and components, one of which is clamping mechanisms.

Setting the workpiece and its holding during the work processing is accompanied by the set of the following physical effects: elastic deformations in the clamping mechanism (CM) drive and in the system chuck-workpiece; elastic and residual deformation of workpieces and joints and physical connections damage between them; thermal and other phenomena. CM abilities to perform work functions during the change of work conditions depend significantly on their adaptation possibility to variable external influence [1, 2]. Therefore the development and research of the clamping mechanism that could adapt to the workpiece characteristics as well as loading and dynamic effects is a very actual scientific problem.

One of the most important adaptation trends is CM adaptation to the workpiece diameters. The traditional mechanical lathe chucks with clamping elements sets are used for different clamping diameters. At the same time in automated flexible production conditions the need for equipments to their accumulation and quick interchange arises. These all impacts on the cost of changeovers.

A lot of scientific papers of scientists in the field of mechanical engineering and metal processing deals with the CM adaptation to different clamping diameters. For example, the papers [1-5] lay the scientific basis of creation of self-adjusting, wide-range, quick-adjusting and multifunctional CM and the differential-morphological method of structural-schematic synthesis is proposed. It allows creating the new structure of clamping chucks expending technological possibilities of automated devices for turning and machine modules based on it. The papers [4, 5] deal with the clamping problem of rod workpieces in a wide range of diameters. These investigations theoretically substantiate and experimentally prove of the wide range collet clamping principle and the principle of a number of transmitting-amplifying units in the CM use. It allows clamping rod workpieces in a small diameters range. The papers [1-3] show that in a wide range clamping it is advisable to implement CM structure with discrete-continuous schemes for coverage of clamping diameters. It leads to the clamping elements number reduction as well as time decrease for readjustment. The papers [6, 7] deal with the problem of creating and researching of clamping chucks for single workpiece clamping in a wide range of diameters. They estimate the design of flexible clamping elements with cross section circular shape, which can self-adjust to the workpiece surface in the diametric section. These clamping elements have rather complex structure and high cost.

At the same time the problematic issue is at the root of the fact that if there is the discrepancy between the clamping surface diameter and the clamping diameter of clamping elements the high surface pressures result at the contact zone, which could damage the surface on which the clamp performs. Therefore, adaptation of clamping elements to the clamping surface with different diameters is a very actual scientific problem of lathe chucks flexibility increasing.

2. Preconditions and means for resolving the problem

Existing methods for diameter workpieces coverage via clamping chucks in automated equipment for turning and modules based on it are implemented in the three main schemes [3]: discrete; continuous; discrete-continuous. In these coverage schemes implementing the cross-sectional geometry of clamping element is made under a certain clamping diameter. The clamp on the cylindrical surface of larger or smaller diameter leads to the fact that adjoining of the clamping element does not perform on the entire surface of the clamp. When clamping the workpiece on the rough bases such phenomena is acceptable, but when clamping on the finishing bases during the final operations of manufacturing process it can damage the surface of the clamp reducing the accuracy and rigidity of clamping.

The only important solution to the problem of the clamping elements adaptation to the clamping surface in a certain range of workpieces diameters is the creation of new designs of clamping elements on the basis of the deliberate deformation zones introduction into their design. This will ensure adjoining of the clamping element contacting surface to the clamping workpiece surface of different diameter.

3. The solution considered problem

3.1. Development of the adaptive clamping elements design schemes

Lathe clamping chuck as a technical system should provide the main function - workpiece basing and fixing. This basic function is divided into a number of subordinate functions, which are implemented by particular functional subsystems [1, 3]. One of these subsystems is a subsystem of direct influence on the fixing object. Structurally, the system of direct influence is made in the form of the clamping elements system which interacts for clamping force transfer with kinematic subsystem of the lathe chuck (transfer-amplifying units), and are in certain way located in the case of the chuck.

When implementing typical kinematic structures of clamping chucks with discrete-continuous schemes of wrapping workpieces in order to create a clamping elements system with adaptation to the clamping surface the new approaches are required. Kinematic structures carry information about of the kinematic members location sequence and their numbers, transmission ratio and also the number of clamping elements and the readjustment number [1, 3].

Clamping chuck kinematic structure with discrete-continuous scheme of a range of diameters coverage (fig.1) is realized through continuous coverage of a narrow range of diameter ΔD and transfer to the desired dimensional range by clamping elements or their sets manipulation (replacement or repositioning) [1, 3]. Coverage of range ΔD is carried out due to the such lathe chuck parameters as the working stroke length of the input member $X_T = X_{Tmax} - X_{Tmin}$ and transmission ratio of transmitting-amplifying units i_t.

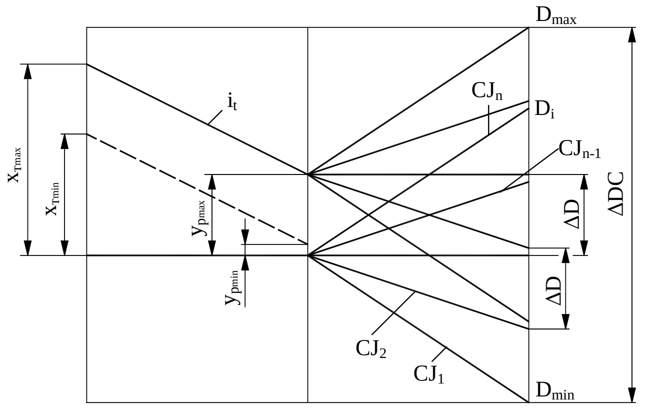


Fig 1. *Kinematic structure of clamping chuck with discrete-continuous scheme of coverage with one kinematic chain:* X_{Tmax}, X_{Tmin} *– max and min working stroke of the input units;* i_t *– transmission ratio of transmitting-amplifying units;* y_{Pmax}, y_{Pmin} *- max and min working stroke of the clamping elements;* CJ_1-CJ_n *– clamping elements;* ΔD *– clamping range without clamping elements interchange*; D_{max}, D_{min} *– max and min clamping diameters;* ΔDC *– range of clamp workpieces via clamping chuck*

When using a clamping element with "rigid" cross-sectional geometry in the ΔD range the following options of contact with a workpiece are possible (fig.2): full contact ($R_з = R_к$); incomplete contact ($R_з < R_к$); contact by edges ($R_з > R_к$). Therefore to provide the full contact the clamping elements CJ1, CJ2, ..., CJn (fig.1) must adapt to the clamping surface exactly in the range ΔD.

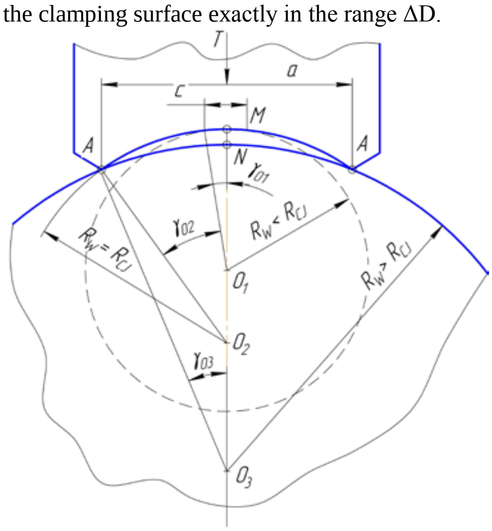


Fig 2. *Options for the jaw contacting with a smooth cylindrical surface:* R_{CJ} *–radius of a jaw clamping surface;* R_W *– radius of workpiece clamping surface,* T *– clamping jaw force*

The principle approach of clamping elements adaptation in the ΔD range is proposed, which lies in the deliberate deformation zones introduction into their design. It provides adjoining of contacting surface of the clamping element to the workpiece clamping surface. These zones can be created using heuristic methods by complete and incomplete partition of clamping elements, making voids in the clamping element material, using ring segments capable of deformation and others. Fig.3 depicts a clamping jaw synthesized by removing material from the solid jaw as a ring groove, and fig.3,b and fig.3,c - clamping jaws synthesized by incomplete partition of their clamping part. Clamping jaws with ring segments capable of deformation are shown in fig.3,d,e.

Based on the structural scheme (fig.3,a) the adaptive jaws designs were developed and prototype model was manufactured to equip the lathe wedge clamping chuck with a housing diameter of 150 mm (fig.4).

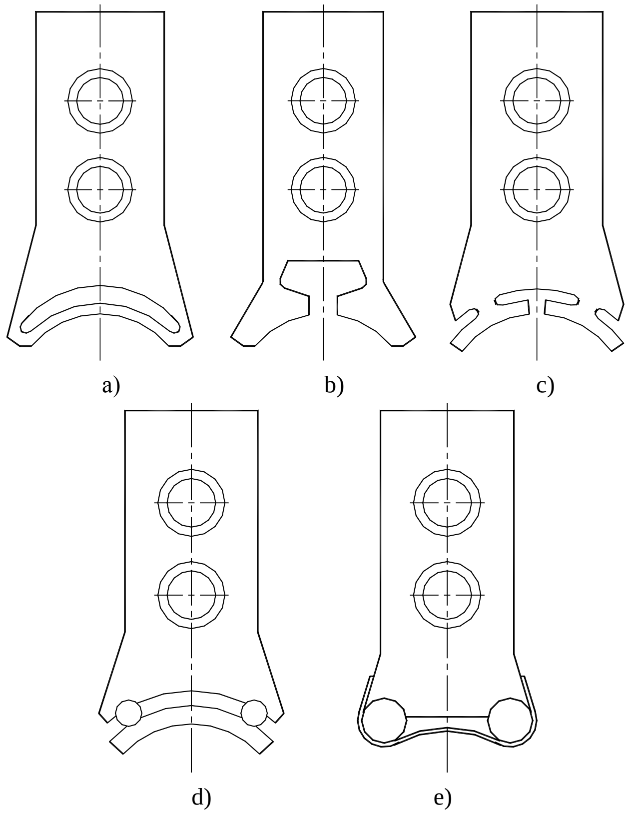


Fig 3. *The structure schemes of synthesized adaptive clamping elements*

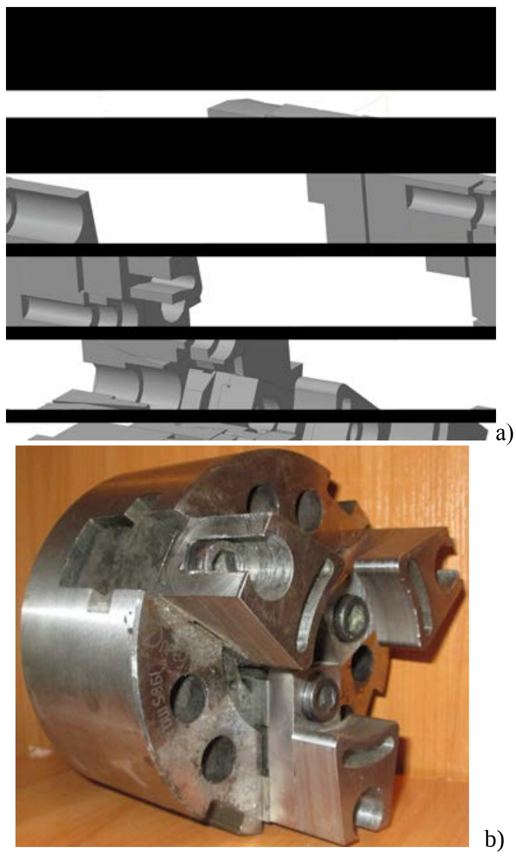


Fig 4. *Lathe wedge chuck with adaptive clamping elements: a - CAD-model; b – prototype model*

3.2. Computer simulation of clamping elements adaptation zone

Due to the complex geometry of the synthesized clamping elements the analytical study of the clamping conditions in the contact zone between clamping element and clamping surface and also the evaluation of the stress-strain state was performed and the CAD / CAE-system was applied. Simulation cycle using CAD / CAE-system includes the following steps [3]:

1) clamping element and workpiece geometry model development;

2) finite elements types selection and their parameters data input as well as the clamping element and the workpiece partition on the finite elements;

3) formulating of boundary conditions, including that modeling contact zone and the loads system formation;

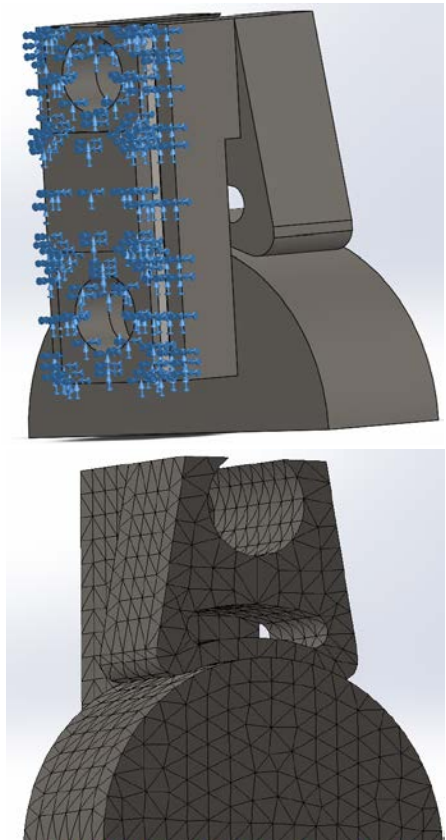
4) finite elements model verification;

5) contact conditions and adaptive clamping elements stress-strain mode simulation;

6) visualization and analysis of simulation results.

To study efficiency of adaptive clamping elements for equipment of three jaws mechanical wedge chuck with a housing diameter of 150 mm the simulation of a stress-strain mode was carried out. Fig.5 illustrates the automatically generated finite-element mesh, boundary conditions, system of loads applied and the zone of workpiece contact with the adaptive jaw, that correspond to the real operating conditions during the clamp process. The geometry of the workpiece and the jaw is described as tetrahedral finite elements.

Clamping force applied to the jaw varies in the range from 500 to 5000 N. This corresponds to the total clamping force of jaws of lathe clamping chuck respectively: 1500 - 15000 N. During the simulation the workpieces clamp in ΔD=10 mm range was imitated. The design parameters of the given lathe chuck size define this range.



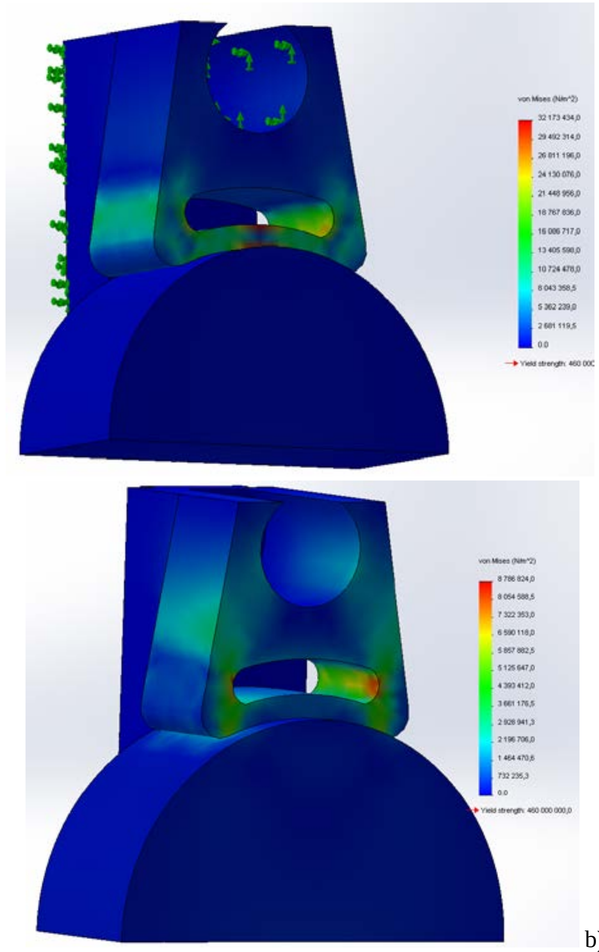
a)

b)

Fig 5. *Boundary conditions (a), generated by finite-element mesh with contact zone of workpiece and jaw, and the applied load system (b)*

4. Discussion of results

As a result of the simulation the equivalent stress values were found in regard to the adaptive clamping elements for different clamping diameters, loaded with different clamping forces. These stress values were calculated according to the Richard von Mises changing the shape energy hypothesis and displacement. As an example, fig.6 shows the picture of the stress condition of adaptation zone of clamping element for clamping diameter of 65mm with jaw clamping force of 500 N.



a)

b)

Fig 6. *Pictures of the stress conditions in the zone of jaw adaptation during workpiece clamp by the clamping force of 500 N, a - with a diameter of 65 mm; b - with a diameter of 75 mm*

As the result of computer simulations it was appeared that the stress-strain modes for other workpieces clamping diameters and clamping forces are similar.

The stress distribution picture analysis in the jaw adaptation zone size shows that the greatest stresses occur in the central and outer zones of the jaw where the clamping ring part connects with the body of the jaw.

As a result of the computer modeling the maximum equivalent stress in the adaptation zone of clamping jaw under various clamping force and clamping diameters are shown in fig.7.

The results of simulation show that together with clamping force increasing per one jaw from minimum to maximum (ie 10 times), the maximum equivalent stress also increases almost in 10 times. So the directly proportional linear relationship between the load and maximum equivalent stress is observed.

Herewith higher stress is typical for smaller clamping diameters. This is due to a smaller contact zone of the small diameter workpieces and their contact conditions, that are caused by greater radial deformation of adaptive clamping jaw. With increasing clamping diameter from 65 to 73 mm, maximum equivalent stress at maximum jaw clamping force decreases in 1.28 times. This can be explained by the increasing of contact zone during the larger diameter workpieces clamp. In full contact of workpiece with the clamping part of jaw (d = 75mm) the adaptation zone is not working, and therefore stress in the contact zone is much smaller. Analysis of simulation results showed that the clamping part of the adaptive jaw with clamping force loads in a range of 500 ... 5000 N works in the area of elastic deformation and ensures its full contact with the workpiece in a given diameters range during the clamp.

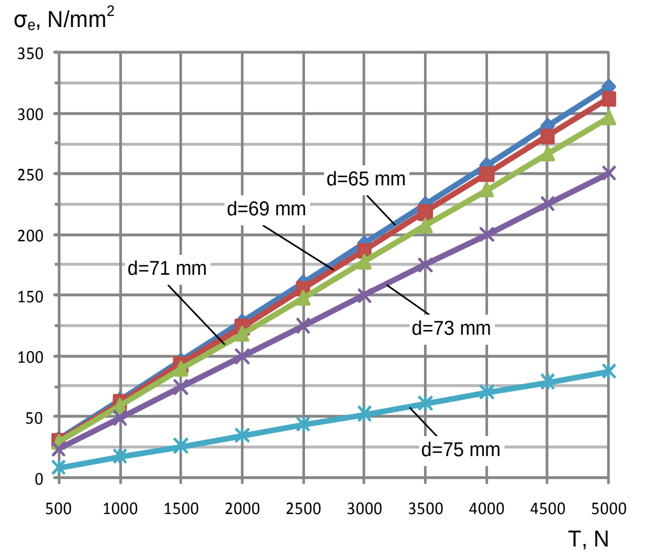


Fig 7. *The dependence of the maximum equivalent stress* σ_e *in the jaw adaptation zone from clamping force* T *and clamping diameter* d

3. Conclusion

Analyzing the foregoing, we can make the following conclusions.

Operation analysis of the lathe chuck with clamping elements with defined geometry of the cross section has showed that their contact process with the workpiece with incomplete contact and contact on the edges leads to the heterogeneity of the surface pressure between the workpiece and, in some cases, damage of the clamping surface. To avoid such effects a new principle of adaptive clamping elements creation was proposed. The essence of this principle lies in the deliberate introduction into the clamping elements design the deformation zones allowing full adjoining of clamping element contacting surface to the workpiece clamping surface. Based on the proposed principles design schemes of adaptive clamping elements were developed, which include deformation zones, and are based on standard clamping elements. Using CAD / CAE-system the clamping conditions in the contact zone between adaptive clamping elements and clamping surface were evaluated. The stress zone status of adapting clamping jaws of the proposed design was analyzed. It showes that clamping part of the jaw operates in a zone of elastic deformation in a given range of clamping force and provides in a given range of diameters its full contact with the workpiece during the clamp.

In the future we plan to carry out theoretical and experimental study of the influences of contact zones stiffness on the distribution of contact pressure on the clamping surface in statics, steady rotation mode and in the turning process. The contact stiffness of the following joints are to be discussed: a)of adaptive jaw with a basic jaw; b)of a basic jaw with the guides of the lathe chuck housing. The experimental studies of clamp accuracy in regard to workpieces and lathe chucks with adaptive clamping elements will be also conducted.

4. References

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