DEVELOPMENT OF COLLECTOR ULTRASONIC MOLD FOR INDUSTRIAL TECHNOLOGY OF THE UNIAXIAL DRY PRESSING OF CERAMIC POWDERS

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Abstract

This paper presents a new mold on principle of the collector method. The collector mold of spiral type has been developed and created. The design of industrial collector tools requires the computer modeling and optimization of the kinematic scheme of the movement of the die shaping members. It has been done using the Cosmos Works software package of the Solid Works simulation software. The CAD system application has allowed to design the process and to prepare the preproduction design documentation for industrial collector mold. The displacement isoline and deformation of green compact of powder compacted under die wall friction force are investigated by finite element modeling (FEM). A new collector mold of spiral type consists of the most important parts with 6 alternating, oppositely-moving parts of the passive shaping surface with sliders, twisted at an angle of 80 degrees. The results of comparative simulation with FEM showed that the comparison of the displacement isoline and dispersion of deformation of the ceramic powders with conventional mold, collector mold and new collector mold of spiral type. The dispersion of deformation of the green compacts made by collector mold of spiral type has been compared with collector mold. The dispersion of deformation of collector mold of spiral type is reduced 4–20% under condition of friction coefficient, μ=0,1 and reduced 7–25% under condition of friction coefficient, μ=0,02. Thus, density distribution can be minimized by increasing the degree of twist angle of passive elements forming the collector of the mold and an increase the number of moving parts opposite of passive shaping surface. This method decreases density gradients. It was shown a necessity to use high-efficiency computational approaches of computer simulation for transfer of the novel compaction methods to industrial scale and for development of basic designs of pressing tools.

Keywords: Nanopowder, ceramic powder, collector pressing

Introduction

There are many different approaches and methods of modeling and compacting ceramic powders, including nanopowders [1,2,3,4]. These include a variety of pulse techniques, as well as pressing the imposition of ultrasonic [5,6]. The intensive development of research in the field of nanomaterial due to the needs of modern industries in the quality of new materials. Among them are important products of the structural and functional nanoceramics for mechanical engineering, electronics, communications, nuclear, aerospace engineering etc. The friction force occurring between wall of mold and green compact was considered widely by uniaxial traditional compaction with conventional mold. Non-uniform density is an important problem in the quality and performance of net shape. A method for compacting powder materials into articles and a mold for implementing the method based on the “Method of Collector” was introduced and invented by E. S. Dvilis, O. L. Khasanov, V. M. Sokolov and J. P. Pokholkov in 2005 [7]. This method for a satisfactory uniformity in the density distribution in the moulded volume of the powder compact may be achieved by elimination of the die wall friction effects. And this is importance of obtaining nanostructures with predominantly of large-grain boundaries, as in this case there is a qualitative change in the properties of materials nanostructure formation, homogeneous throughout the sample volume, the samples should not be mechanical damage in spite of their intense deformation. In this study, SolidWorks program is used for designing, computer modeling and CosmosWorks program is used for analysis of the displacement curve of the green compact (diameter 14 mm, height 20 mm).

The structure of ultrasonic mold under principle of collector method and ultrasonic vibration

A new ultrasonic mold was designed and we called ″Collector ultrasonic mold of spiral type″. It has the component, as shown in figure 1c. Based on the principles of designing mold for compaction of powder materials for the collector method [7], was modeled mold for forming a cylindrical compacts with 6 alternating, oppositely-moving parts of the passive shaping surface with sliders, twisted at an angle,θ. Thus, in the kinematic scheme of the passive movement of the elements forming the collector of the mold has been added to the rotational component, which magnifies the effect of density on the auto-alignment of the body height of the powder.

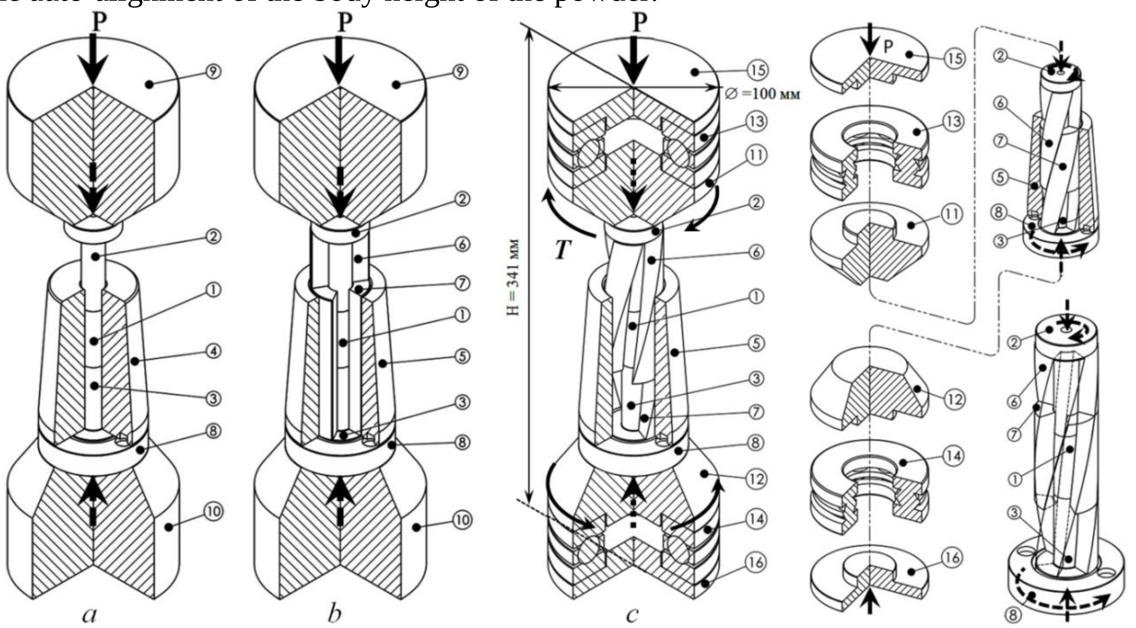


Figure 1. Ultrasonic mold to make uniformly dense ceramic of cylindrical body: (a) – conventional uniaxial single mold, (b) – collector mold, (c) – collector mold of spiral type (Novel mold): 1 – powder body (diameter 14 mm, height 20 mm), 2, 3 – upper and lower punches (plungers), respectively, 4 – matrix traditional mold, 5 – holder collector mold, 6 – parts (slider) of the first passive element, (N1 = 3 pcs.) 7 – parts (slider) of the second passive element, (N2 = 3 pcs.) 8 – centering support, 9 and 10 – the upper and lower support members of the mold, respectively, 11, 12, 15, 16 – element coupling swivel, 13, 14 – bearings top and bottom pivot bearing, respectively, P – direction of compression forces; T – is the torque acting upon on upper plunger.

Schematics of the conventional and collector molds of powder compaction

To achieve the uniformity of displacement isoline in dry powder green compact along the pressing axis the partial redistribution of wall friction forces in pressing direction can be used even without decreasing of these forces. Such approach of powder compacting can be used when the lateral shape-forming surface is divided along the compaction axis in some parts which are moved during compacting in different directions relatively to a powder body. This technique we called as the "collector method" of compaction [5, 6, 7, 8, 9].

Figure 2. Ultrasonic mold of cylindrical body: (a) – collector mold of spiral type (Novel mold), (b) – passive component set for collector mold , (c) – passive component set for collector mold of spiral type

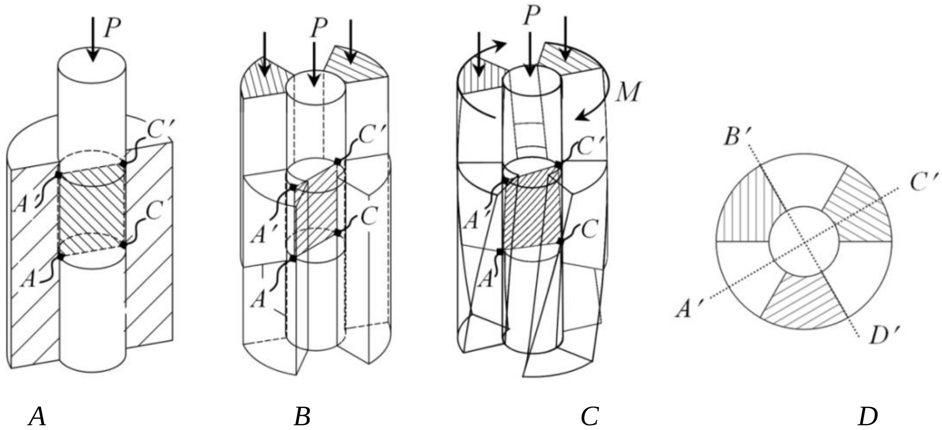


Figure 3. Method of pressing powder materials in closed molds: (a) – conventional uniaxial single pressing, (b) – collector pressing, (c) – collector pressing of spiral type and (d) – cutting line on the top view for inspection

In a case of the conventional compaction (Fig. 1a, 3a) the maximal value of wall friction force and the corresponding maximal value of densification degree of a powder body are achieved in the region of conjugation of a movable top punch and a mold. Because of loss of the compaction force for overcoming the wall friction forces inside of powder body the minimal densification degree is observed in the most distant from the top pressing punch. The distributions of the wall friction forces and the density in a height of powder body are axisymmetric and non-uniform [8].

In a case of the collector pressing (Fig. 1b, 2b, 3b) the bottom punch moves jointly with 3 bottom passive components of the lateral surface, and the top punch jointly with 3 upper passive components. The distributions of the wall friction forces and the density of a powder body are centrally symmetrical, and the average density in the horizontal cross section is invariable along the green compact height. But the non-uniformity of density distribution remains in the horizontal layers of a compact. The increasing the quantity of alternate oppositely moved parts of the passive shape-forming surface results in minimization of the non-uniformity of density distribution in the horizontal cross sections of a powder body.

The spiral type of collector method (Fig. 1c) was developed for dry powder pressing with torsion. A straight line [A′C′] (Fig. 3c) on the surface [A′B′C′D′] was changed to a straight line [AC] on the bottom of the green compact with the twist angle θ. Part of the active shaping surface [A′B′C′D′] is combined with the part of the passive shaping curved surface [A′D′C′CDA] to become the same pressing member. Respectively, the opposite part of the other active shaping surface [ADCB] is combined with the opposite part of the other passive shaping curved surface [ABCC′B′A′] to form the other pressing member.

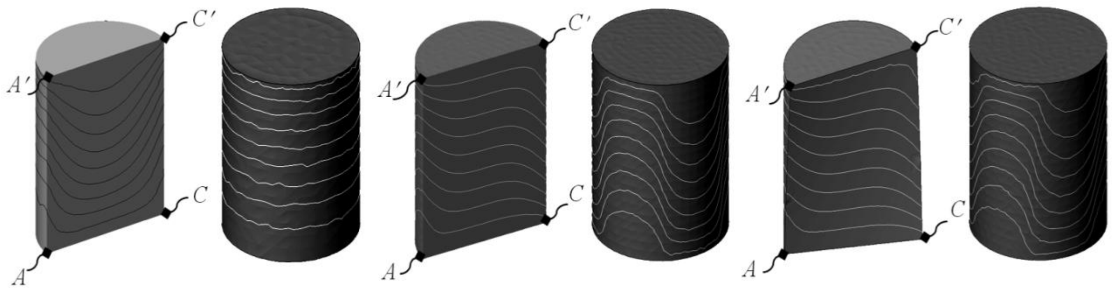
For collector mold and collector mold of spiral type, at any point on the curve lines [A′A] and [C′C], the powder displacement, die wall friction forces and degree of densification will be equal to the average values on the different sides of the conjugation lines. Consequently, the degree of powder densification in the region along the conjugation line of parts [A′A] and [C′C] of the passive shaping surface will be uniform along twist angle.

The experiment, simulation and results

Simulation of the deformation process of powder compact by uniaxial single action static pressing and collector pressing under conditions of die wall friction was carried out using the finite element method (FEM). Fig. 4, 5 show displacement isoline of cylindrical powder compact (only on the surface [ACA′C′]). Comparison of these patterns reveals the displacement isoline and dispersion of deformation of the powder body layers at given conditions. In the case of conventional pressing by means of the long length cylindrical green compact, considerable bending of the layers in the form of a cone can be observed (Fig. 4a, 4b, 5a). It is symmetry along center line of cylindrical green compact.

In the case of collector pressing (Fig. 4c, 4d, 5b), a zigzag type bending of the layers at the circumference of the powder compact was observed. However, already at a short distance from the lateral surface, deep into the green compact, these bending layers reduce to minimum, while the character and the value of the deformation of the layers weakly depend on the distance to the punches. It is depicted that deformation of green compact with collector compaction is lower than with conventional compaction but quite higher than at spiral type of collector compaction.

When compared between the cases of collector pressing (Fig. 4c, 4d, 5b) and its spiral type (Fig. 4e, 4f, 5c) it can be seen that the displacement isoline on the surface [BDB′ D′] of green compact are similar trend but completely different from case of conventional pressing (Fig. 4a, 4b, 5a).



A *B* *C* *D* *E* *F*

Figure 4. Displacement isoline (only on the surface [ACA′C′] and layers at the circumference of cylindrical green compact under conditions of die wall friction for conventional uniaxial pressing (a, b), collector pressing (c, d) and collector pressing of spiral type (e, f) respectively

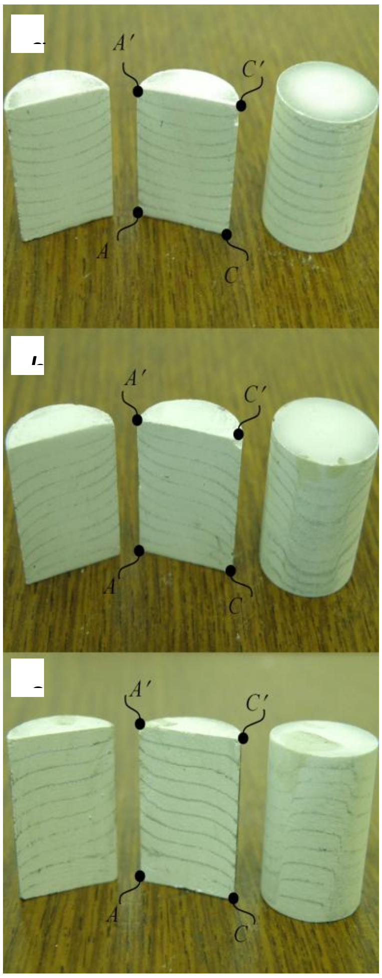


Figure 5. Displacement isoline of cylindrical green compact from experiment (only on the surface [ACA′C′]) under conditions of die wall friction for conventional uniaxial pressing (a), collector pressing (b) and collector pressing of spiral type (c)

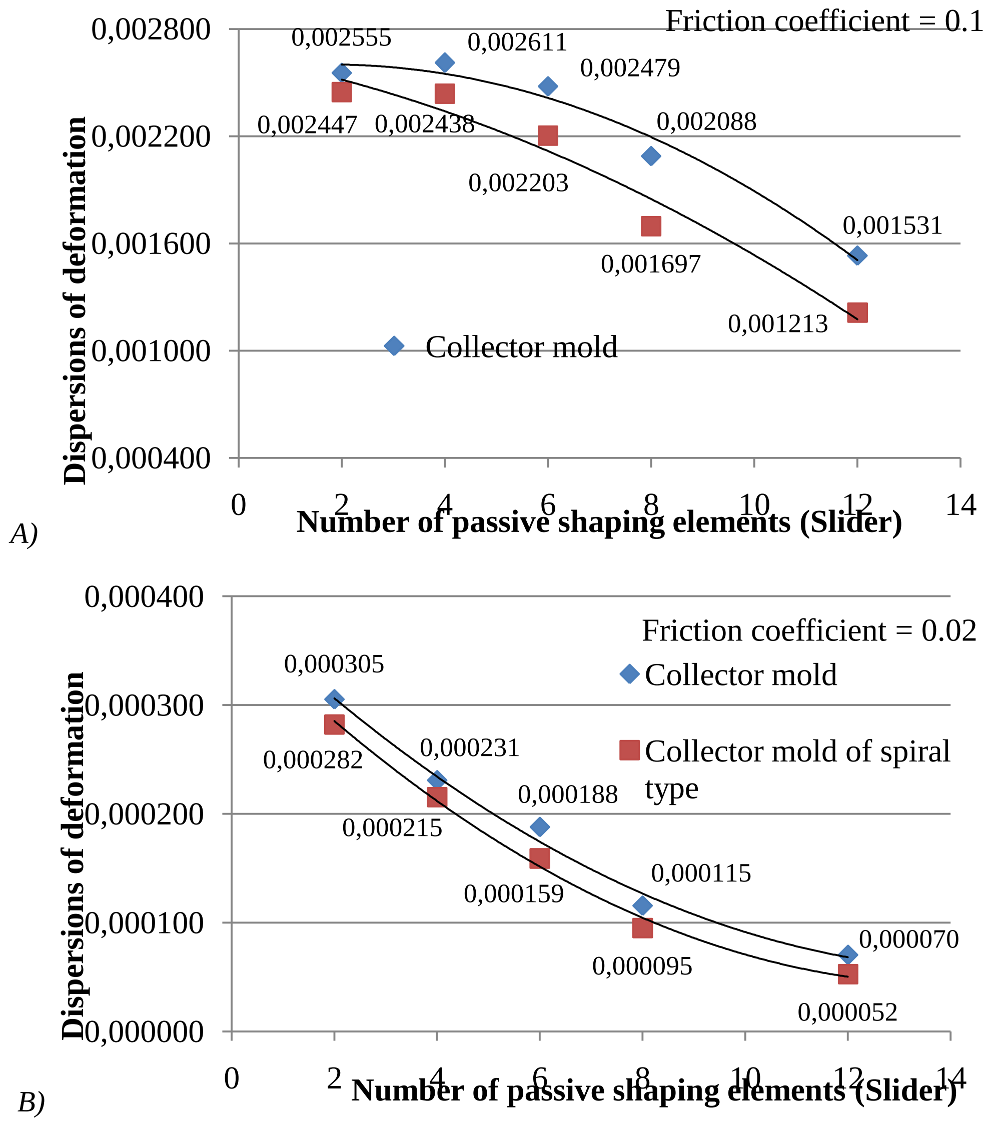


Figure 6. The variance of the local deformations of the powder body, the sealing various schemes pressed on the friction coefficient: (a) – μ=0,1, (b) – μ=0,02

Fig. 6. shows results of comparative simulation, it is possible to take the value of the statistical variance of the local deformations in the volume of the powder body that reflect the local compaction. The dispersion of deformation of the green compacts made by collector mold of spiral type has been compared with collector mold. The dispersion of deformation of collector mold of spiral type is reduced 4% to 20% under condition of friction coefficient, μ=0,1 and reduced 7% to 25% under condition of friction coefficient, μ=0,02.

Conclusion

A numerical analysis of deformation character at dry powder pressing by different techniques was performed using the finite element method. The displacement isoline has been considered under die wall friction force. Collector methods of elimination or redistribution of the die wall frictional forces has been developed for collector mold of spiral type. Its allow pressing into cylindrical shape compacts, with uniform density distribution in the bulk materials. The collector technique involves specially designed molds, where active and passive shaping surfaces are combined in one shaping member of the mold according to the principle of minimizing die wall friction forces and specific rules of collective motion of the shaping members. Collector pressing for collector and collector of spiral type allows reducing the non-uniform deformation to minimum. The collector method can be used for fabrication of uniformly dense powder articles of different shapes including rotor pump, piezoceramic ring, rod piston and etc.

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