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Review of isostatic pressing methods

Tomsk Polytechnic University

Timofey Alishin [a]

[a] School of Engineering for New Manufacturing Technologies

Abstract

In modern society, it is vital to improve quality process and in addition, to reduce cost. This paper is devoted to the production technologies of ceramic products of complex shape, namely, isostatic pressing methods. The information presented in the paper is intended to help the reader to get a sense of isostatic pressing methods; in addition, it can be used when choosing the production technology of an article made from powder materials. The paper describes the main isostatic pressing methods of powder materials, namely, hydrostatic and gasostatic pressing, as well as various methods of quasi-isostatic pressing, which include pressing in thick-walled elastic shells, pressing in thermoplastic polymers and others. The characteristic features, applications, advantages and disadvantages of each method are presented and described. Particular attention is paid to the analysis of the possibility of a particular technology to produce ceramic products of complex shape. In addition, the study compares technologies included in the group of isostatic methods.

Keywords: Isostatic pressing, powder technologies, complex ceramic products;

1. Introduction

Ceramic products of complex shape are used in many areas of science and technology. These products are in demand in medicine, since prostheses and implants (dental implants, endoprosthesis, cranial and facial implants), as a rule, must have a complex shape. At the moment, several technologies are used for the production of such products from ceramic materials: slip casting, selective laser sintering, turning operations of workpieces on CNC machines and isostatic pressing. The most promising technology used for the production of complex ceramic products is isostatic pressing. Isostatic methods make it possible to use the material much more efficiently in comparison with selective laser sintering or turning operations, as well as to produce high-strength ceramic products with minimal porosity, in contrast to slip casting. In isostatic methods, dynamic media is used for pressure transmission [7], and this leads to the comprehensive compaction of the powder body. This effect provides a high uniformity of the density distribution over the compact volume, which contributes to uniform shrinkage during sintering and positively affects the mechanical characteristics of ceramics.

2. Methods of isostatic pressing

Isostatic pressing methods are classified according to the medium transmitting the pressure. The media used in isostatic pressing can be divided into four groups: liquid, gaseous, elastic and plastic.

Hydrostatic pressing. The first group of methods includes hydrostatic pressing. In this method, a liquid is used as a pressure transmitting medium (water, oil, or other fluids based on these liquids). The powder is pressed in thin-walled elastic shells made of rubber or polyurethane. The hydrostat diagram is shown in Figure 1.

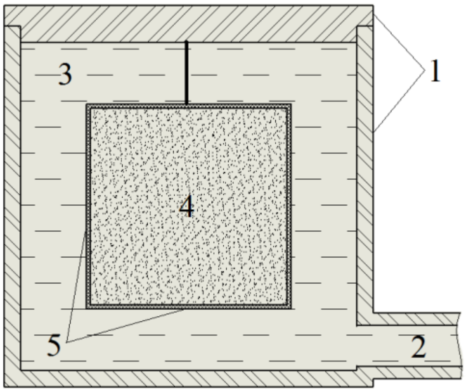

Fig. 1. the working chamber of the hydrostat: 1 – pressure-tight chamber, 2 - fluid input, 3 - working fluid, 4 - powder, 5 - elastic shell

The method allows one to obtain compacts with a high uniformity of the density distribution due to the volume. It is difficult to create high pressures in a hydrostat (above 150-200 MPa), therefore the number of materials that can be effectively pressed by this method is limited. The main disadvantage of hydrostatic pressing is the nonlinear deformation of the powder body during the pressing process, since any body tends to reduce its free energy, and in these conditions it is beneficial to do by reducing the surface area and with any shape of the shell, the component part will "tend to become a ball."

Gas-static pressing. The pressure transmission medium in this method is gas (nitrogen, argon or helium). There are methods of cold and hot gas-static pressing. Hot gas-static pressing is characterized by the pressing process that is carried out at a temperature that significantly affects the rheological characteristics of the pressed material (900 - 2250 ° C depending on the material [1]). The gas-static pressing scheme completely corresponds to the hydrostatic pressing scheme, except that gas is used instead of fluid, and heating elements are present in the hot gas-static pressing scheme. The pressing of powders is carried out in pre-evacuated sealed thin-walled metal shells made of well-welded carbon steel, aluminum or other ductile metal. The pressure used in this method, as well as it is in the hydrostatic method, does not exceed 200 MPa. After the completion of the pressing process, the shell is removed by mechanically processing.]. Gas-static pressing is used to produce workpieces from powder high-speed and die steels for further swaging or stamping of shaped products from cobalt and nickel steels [1]. In addition, workpieces obtained by gas-static pressing have a shape close to the final shape of a product with a complex shape made of metal or ceramic powder materials, for example, millers.

The disadvantages common to both technologies are the need to use expensive equipment, the low speed of the process and the difficulties in its automating.

Pressing in thick-walled elastic shells. The medium transmitting pressure to the powder in this method is an elastic body made of rubber, polyurethane [10] or other elastic materials. The shell is placed in a rigid mold and transfers pressure from the punches to the powder body located in the cavity inside the shell. The scheme of the method is presented in Figure 2.

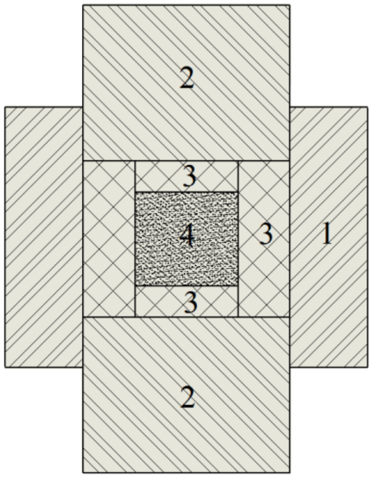

Fig. 2. Pressing in thick-walled elastic shells: 1 - matrix, 2 - punches, 3 - elastic shell, 4 - cavity with powder

Elastic shells are easily and quickly made and are able to last a large number of pressing cycles. The longevity of the shells depends on the material used and the quality of the rigid mold. A mold with minimal gaps between the forming elements provides the maximum possible service period of the shell. By pressing in thick-walled elastic shells it is possible to produce a wide range of products of various shapes: balls, disks, flanges, shafts, glasses, crucibles, bushings, pipes, etc. [6]. Due to the simple scheme and the ability of the elastic shell to restore its shape, the pressing process can be easily automated.

However, the method has some disadvantages. Nonlinear deformation of the shell during pressing is a cause of distortion of the compacts shape [2], so this factor should be taken into account when designing tooling. Several scientific papers have been devoted to the deformation modeling of a powder body during pressing in thick-walled elastic shells [11, 4]. In addition, the range of product shapes that can be manufactured by pressing in thick-walled elastic shells is limited. This is due to the destruction of compacts with thin elements and an irregular cross section during reverse elastic deformation (Figure 3d) of the shell after pressure reduction [5, 6]. The last group includes methods where plastic materials are used as the medium transmitting pressure. In the paper presented by Chaika E.V. [5], a method for producing long ceramic products with thin elements (screws, drills) is described. The authors used a thermoplastic polymer as a medium for transmitting pressure. The scheme of the method is presented in Figure 3.

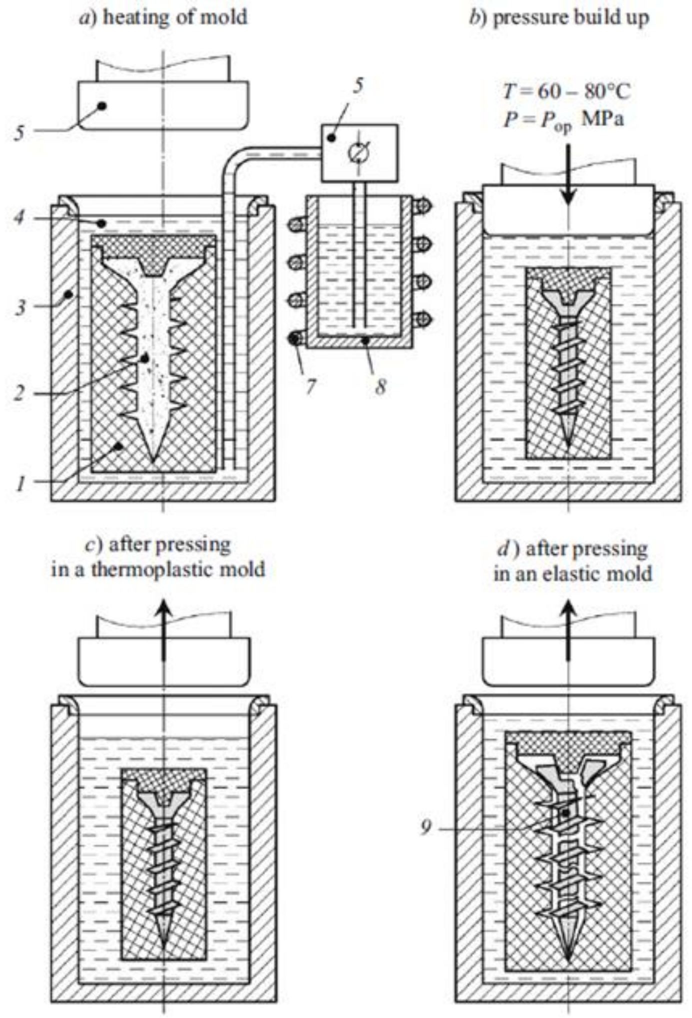

Fig. 3. CIP scheme: 1 – thermoplastic mold; 2 – ceramic powder; 3 – high-pressure container; 4 – working liquid; 5 – pusher; 6 – pump; 7 – heating element; 8 – tank with working liquid; 9 – example of a broken compact in the case of pressing in an elastic shell [5].

In contrast to the elastic shell, the thermoplastic polymer does not deform elastically after pressing and polymerization with decreasing temperature, so compacts with thin elements and / or differences in cross-section are not wrecked (Figure 3b). This allows manufacturers to get products of different forms. . The complexity of manufacturing equipment from a thermoplastic polymer is comparable to the complexity of manufacturing elastic shells. The disadvantages of the technology are energy costs caused by the need to heat the polymer to a plastic state and the inability to reuse the shell. Moreover, powders or mixtures of powders of various compositions (graphite [12], aluminum + graphite [11, 9]), which can be considered as a plastic medium, are used as a medium transmitting the pressing pressure. The use of refractory granules allows quasi-isostatic pressing at high temperatures, for example, together with SPS- [3] or SHS synthesis [8, 11]. The SPS with quasi-isostatic pressing is shown in Figure 4.

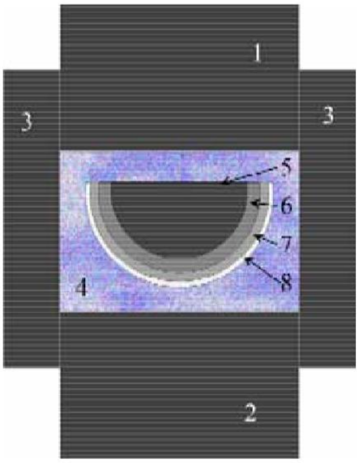

Fig. 4. SPS scheme with quasi-isostatic pressing: 1, 2 - punches; 3 - matrix; 4 - medium transmitting pressure; 5 - steel insert; 6 - titanium base; 7 - gradient layer of a mixture of Ti + NaCl; 8 - a layer of salt [3]

However, granules are not able to transmit pressure as uniformly as the aforementioned media and it is the reason for the uneven distribution of density over the volume of the product. The products obtained by this method have a low surface quality and require additional machining. . Nonlinear deformation in granular media also requires consideration to obtain the product of the required shape. A mathematical model presented by Olevsky E.A. and others [9] describes the deformation of granular media that transmit pressure.

3. Conclusion

In conclusion, we can say that isostatic pressing methods are promising for producing products of a complex shape from powder materials and allow manufacturers to produce a fairly wide range of products. However, they are not without drawbacks, the common drawback for all methods is the nonlinear deformation of the shape of the powder body during the pressing process that requires observation for obtaining products of a given form.

The information presented in the paper can be useful in choosing the technology for the production of a product from powder materials with certain characteristics.

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