Theoretical Aspects of Production of Products by Hot Isostatic Pressing

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Abstract. The role of powder metallurgy in the modern world is increasing every year. The introduction of new technologies in powder metallurgy contributes to the successful solution of complex problems in creating parts that have completely new, progressive properties. The development of powder metallurgy is mainly because its technological operations are relatively simple, and the effect achieved with their help in many cases is striking. One of the most promising methods for forming powder materials is the hot isostatic pressing method. This method allows the manufacture of materials and products with special compositions, structure and properties. However, to ensure the necessary characteristics and to eliminate defects in the finished product, it is necessary to strictly observe all technological operations of hot isostatic pressing.

1. Introduction
The use of powder metallurgy in the modern world is increasing every year, since the classical version of producing cast products for various purposes is accompanied by the presence of shrinkage porosity, gas saturation, discontinuity (dislocation) and others in castings of defects [1,2]. If we consider the production of castings using modern methods of foundry technology, you can apply casting in a metal mold (chill mold), injection molding and its varieties, centrifugal casting, injection molding under all-round pressure and others. However, as a result, we have defects in cast products, because during the melting of metals, alloys, and especially special alloys, segregation of alloying elements and a necessary condition for the formation of a liquid phase are possible. In the liquid phase, such processes as gas saturation of the melt, the influence of the lining, the oxidation of alloying elements, porosity, shrinkage defects, and other processes are possible; therefore, upon receipt of a workpiece — special-purpose products and high “ideal” quality, the use of powder metallurgy is necessary.

2. Relevance
The improvement of powder metallurgy contributes to a very high result due to the relatively simple technological operations [3,4].

The technological operations of powder metallurgy mainly consist of three stages: the production of metal powder, giving it the desired shape (molding) and heating the workpiece (sintering). The combination of basic and additional technological operations allows us to solve two major problems using powder metallurgy that determine the direction of its development at present:
1) To produce materials and products with special compositions, structure and properties that are unattainable by other methods of production;
2) To produce materials and products with the usual compositions, structure and properties, but with much more favorable economic indicators of production [5,6].

There are several dozen known technologies for the production of finished products from powders that differ from each other by pressing method, using heat. However, pressing has many problems. One of them is to ensure a uniform distribution of the density of the powder in the workpieces of complex shape, to preserve the grain structure during sintering. One of the most promising methods for producing products of the final form in powder metallurgy is the use of hot isostatic pressing (HIP).

According to a number of researchers [7,8], the use of the hot isostatic pressing method makes it possible to manufacture products of complex shape, as well as to avoid defects such as shrink pores and shells.

3. Theoretical part
The HIP method is one of the methods of compacting metal powders by applying high isotropic pressure at a high temperature below the melting point of the material. This method is used in two cases:
1) To eliminate closed porosity in the workpiece;
2) Powder consolidation in a closed metal container.

Hot isostatic pressing includes the following basic operations:
- Design and manufacture of capsules;
- filling powder into capsules;
- sealing capsules by welding;
- Isostatic pressing of powders in capsules at high temperatures and pressures;
- Removal of the remains of capsules;
- finishing operations (machining, heat treatment, etc.).

Spray powders of a spherical shape from a variety of metal alloys are most often used for HIPs. Capsules are thin-walled shells that are close in shape to molded products. Such products can have both simple forms of a cylindrical or flat ingot for subsequent forging or rolling, and complex shapes of shaped parts that do not require additional deformation. Typically, capsules are made from well-weldable low-carbon sheet steel.

The ISU process proceeds in gas baths, Fig. 1.
The gas thermostat is a pressure vessel with gas supply and heating systems. After loading the capsule with the powder, the working chamber of the gas thermostat closes and air is pumped out of it. Then, heating and argon supply are turned on. High pressure in the gas chamber is created by the compressor. After reaching the calculated values, the temperature and pressure are maintained at a constant level throughout the exposure time. Then, the capsule with powder is cooled with a decrease in pressure [9].

The process of HIP powders occurs at a pressure of 100 - 200 MPa and temperatures from 900 to 2250 ° C. High gas pressure acts uniformly in all directions, which provides 100% density and isotropic properties of pressed materials. The gas temperature is usually lower than the solidus temperature of the processed material by approximately 20% to prevent possible segregation of alloying elements and the formation of a liquid phase [10-12].

The process of hot isostatic pressing consists of the following stages, Fig. 2.

The HIP allows you to achieve the final shape in the manufacture of complex parts from various metals and alloys. Equal pressure in all directions leads to isotropic properties. The application of high pressure provides the final density of the material, the elimination of defects such as porosity and shrinkage shells [13].

Due to this, the ISU, as a rule, makes it possible to more accurately influence the microstructure of the material and allows to obtain parts with unrivaled performance characteristics.

**Figure 2. Stages of hot isostatic pressing.**

4. Conclusions
Traditional processes of powder metallurgy make it possible to manufacture products weighing up to 10 kg, using HIP technology it is possible to obtain high-quality products weighing 10 tons or more [14-16]. In this regard, based on the Ruspolimet PJSC enterprise, a project has been developed to create an import-substituting production of metal powder billets based on industrial technology of hot isostatic pressing [17-20].

5. References
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