https://doi.org/10.26160/2474-5901-2020-22-94-97

WAYS TO IMPROVE THE QUALITY OF PRODUCTS USING HOT ISOSTATIC PRESSING

Manyanin S.E., Vaxidov U.Sh., Maslov K.A.

Keywords: powder metallurgy, hot isostatic pressing, pressure, heating.
Abstract. In modern mechanical engineering, cast parts from various alloys are widely used. However, the use of technological processes that are associated with casting, having complex gating-feeding systems, does not ensure the production of castings without defects of shrinkage origin. The reason for the appearance of such defects in castings is the difference in the volumes of the liquid and hard alloy and the deficiency of the liquid phase at the crystallization front, especially in separate massive zones of the casting adjacent to relatively thin walls. A known method of compacting a cast structure by minimizing shrinkage porosity is hot isostatic pressing (HIP). The most widely used HIP is for the production of dense, non-porous products from metal powders, as well as for the sealing of shaped castings. 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.

ПУТИ ПОВЫШЕНИЯ КАЧЕСТВА ИЗДЕЛИЙ С ПРИМЕНЕНИЕМ ГОРЯЧЕГО ИЗОСТАТИЧЕСКОГО ПРЕССОВАНИЯ

Манянин С.Е., Вахидов У.Ш., Маслов К.А.

Ключевые слова: порошковая металлургия, горячее изостатическое прессование, давление, нагрев.
Аннотация. В современном машиностроение широко применение получили литые детали из различных сплавов. Однако применение технологических процессов, которые связаны с литьем, имеющие сложные литниково-питающие системы, не обеспечивает получение отливок без дефектов усадочного происхождения. Причиной появления в отливках такого рода дефектов служит разница объемов жидкого и твердого сплава и дефицит жидкой фазы у фронта кристаллизации, особенно в отдельных массивных зонах отливки, сопредельных со сравнительно тонкими стенками. Известным способом уплотнения литой структуры за счет минимизации усадочной пористости является горячее изостатическое прессование (ГИП). Наиболее широко ГИП применяется для производства плотных изделий из металлических порошков, а также для уплотнения фасонных отливок. Однако для обеспечения необходимых характеристик и для устранения дефектов готового изделия, необходимо строго соблюдать все технологические операции горячего изостатического прессования.

In recent years, hot isostatic pressing has attracted more and more attention due to the possibility of creating products of a more complex shape, which is often disadvantageous or even impossible to obtain by traditional methods. Obtaining a product even of a simple shape by traditional methods (casting, plastic deformation, heat treatment, mechanical processing) takes a long technological cycle, which can reach several months. In a number of cases, with objective calculations of real costs, additive technologies turn out to be less expensive than traditional ones [1].

The following well-known technologies (casting, machining) have been and remain analogues of the hot isostatic pressing method.

All methods have their own disadvantages and advantages. It can be seen that HIP is used where there are significant material costs during processing and high requirements are imposed on the final shape of the products.

Tab. 1. Technologies for the production of products for mechanical engineering

	Casting	HIP	Mechanical restoration
Product quality	Low	High	High
Material loss	Low	Low	High
Labor costs	Low	Low	High

Isostatic pressing requires high-pressure vessels (HPV), in which the pressure of a compressed inert gas or liquid is applied either directly to the object to be treated or to the surfaces of a capsule filled with powder.

Safety problems have been solved by creating installations in which the radial forces are taken up by a one-piece forged steel cylinder, prestressed with a kilometer long winding of strong steel wire, and the axial forces are transmitted by two movable covers to the outer frame, which is also in a prestressed state created by the wound wire. The negative pre-stresses in the SVD, created by the wound wire, are calculated so that the most critical components of the presses (SVD and the frame) are in a somewhat compressed state even when maximum pressure is created inside the vessel. Thanks to this technical solution, the presses have reduced weight, high resistance to destruction under cyclic loads, and therefore are practically safe [2].

In order to improve the quality of products, it is necessary to control three processing parameters - pressure, temperature and time. They are selected so that the object acquires full density as a result of this impact. Depending on the goals of the process, the pressure and temperature in modern HIP equipment can reach 200MPa and 2000°C, respectively, but for special applications, equipment has been developed that allows creating temperatures up to 3000°C and pressure up to 300MPa in the working volume.

One of the important features of the HIP technology is a significant decrease in the temperature required for sintering (up to 10–15%), which is a consequence of the applied pressure. This circumstance is of considerable interest from the point of view of the technology of metals and ceramics, since in these materials, after barothermal treatment, a fine-grained crystal structure remains, which largely determines their mechanical properties. The high thermal conductivity of the gas, which at high pressure has a density close to that of water, is the main factor in the cooling process. This leads to two advantages: a noticeable reduction in the cooling process time.

Consolidation of metal powders is the most common HIP application. The reason for this is that traditional casting techniques, in particular ingot casting and continuous casting, involve rather long cooling steps of the ingots, during which the atoms of the elements that make up the alloy diffuse from the outer regions of the ingots to the inner ones. As a result, inhomogeneities are formed, both in the chemical composition and the microstructure of the ingots, which complicates the further processing of the metal and reduces the physical and mechanical properties of the products. Powder metallurgy allows solving this problem by converting molten metal into microscopic ingots during its dispersion [3].

The role of the HIP in the removal of defects in cast metal blanks is also noticeable. While powder consolidation is one of the most promising areas of HIP, improving the quality of metal castings is a widely used operation on an industrial scale. Improving the quality of castings by the HIP method is associated with the removal of internal defects such as porosity, internal shrinkage and interdendritic cracks that form during the solidification of the metal. The HIP eliminates these defects by first closing the walls of the voids according to the mechanisms of creep and plastic deformation, and then by diffusion welding of the pore surfaces brought into contact. Thus, the casting acquires a homogeneous, completely dense structure. In general, the properties of metal castings after HIP become very similar to those of similar objects obtained using deformation technologies.

Currently, using hot isostatic pressing, it is possible to achieve a number of unique properties of materials and to solve various technological problems:

- preservation of a fine-grained crystal structure of metal and ceramic products, which determines their mechanical properties;
- the use of a high cooling rate of the processed products and the possibility of using hardening, achieved by the high thermal conductivity of the gas under high pressure;
- elimination of non-uniformity of castings that occurs during conventional casting and caused by diffusion of product layers due to the long duration of their cooling;
- removal of shrinkage and internal cracks formed during metal cooling;
- removal of porosity of metals, including those near the surface of castings, which significantly improves the quality of the machined surface, gives improved wear resistance and reduces friction during the operation of parts;
- communication to metals of properties that were previously obtained only during their deformation processing;
- improvement of resistance to gas pressure at welding points, reduction of the number of centers initiating corrosion;
- removal of microcracks that appear during repair welding, for example, when repairing turbine blades.

Considering the above, as well as the fact that the method of hot isostatic pressing can be used to optimize many traditional technological processes, as well as to create parts that cannot be manufactured by other methods, the HIP method is currently the most promising direction in material processing [4].

Traditional technologies for producing products in foundry have a rather long duration and laboriousness of the process, but with the use of HIP technology, high-quality products with a mass with improved properties can be obtained. In this regard, based on PJSC Ruspolymet, a project has been developed for the creation of an import-substituting production of blanks from metal powders based on industrial technology of hot isostatic pressing using additive technologies.

The work was carried out with the financial support of the Ministry of Education and Science of the Russian Federation within the framework of the project “Creation of high-tech production of materials, products and equipment using additive technologies and gas-conditioning technologies on the basis of PJSC RUSPOLIMET under Agreement No. 075-11-2019-084 of 18.12.2019 (Resolution of the Government of the Russian Federation of April 09, 2010 No. 218).

References

1. Euro PM 2014, Salzburg. HIP its origins, its status and its future / Olle Grinder. PM Technology AB, Sweden.
2. Euro PM 2014, Salzburg. HIP its origins, its status and its future / Olle Grinder. PM Technology AB, Sweden.
3. Pakhomova Ya.D. Isostatic pressing processes / Edited by I.I. Papirov. – M: Metallurgy, 1990. – 193p.
4. Kaplan M.A. Research of the structure of spherical powder of corrosion-resistant steel 316L for additive manufacturing // Materials of the XV Russian annual conference of young researchers and graduate students "Physicochemistry and technology of inorganic materials". Moscow, 2018. P.468-469.

Список литературы

1. Euro PM 2014, Salzburg. HIP its origins, its status and its future / Olle Grinder. PM Technology AB, Sweden.
2. Euro PM 2014, Salzburg. HIP its origins, its status and its future / Olle Grinder. PM Technology AB, Sweden.
3. Пахомова Я.Д. Процессы изостатического прессования / Под ред. И.И. Папирова. – М: Металлургия, 1990. – 193с.
4. Каплан М.А. Исследование структуры сферического порошка коррозионностойкой стали 316L для аддитивного производства // Материалы XV Российской ежегодной конференции молодых научных сотрудников и аспирантов «Физико-химия и технология неорганических материалов». М., 2018. С. 468-469.

Манянин Сергей Евгеньевич – доктор технических наук, профессор кафедры Строительные и дорожные машины, sergmanian@yandex.ru	**Manyanin Sergey Evgenievich** – doctor of technical sciences, professor of the Department of Construction and road machinery, sergmanian@yandex.ru
Вахидов Умар Шахидович – доктор технических наук, профессор кафедры Строительные и дорожные машины, ngtu-cdm@mail.ru	**Vaxidov Umar Sagitovich** – doctor of technical sciences, professor of the Department of Construction and road machinery, ngtu-cdm@mail.ru
Маслов Константин Александрович – кандидат технических наук, доцент кафедры Металлургические технологии и оборудование, kosta_maslov@mail.ru	**Maslov Konstantin Alexandrovich** – candidate of technical sciences, associate professor of the Department of Metallurgical technologies and equipment, kosta_maslov@mail.ru
Нижегородский государственный технический университет имени Р.Е. Алексеева, Нижний Новгород, Россия	Nizhniy Novgorod State Technical University named after R.E. Alekseev, Nizhniy Novgorod, Russia

Received 26.10.2020