УДК 669.2/.8-034.7
Shalomeev V.V.[1], Ulanov S.O.[2], Shalomeev A.V.[3]
[1] graduate student, NU «Zaporizhzhia Polytechnic», Zaporizhzhia
[2] cand. of techn. sciences, associate professor, NU «Zaporizhzhia Polytechnic», Zaporizhzhia
[3] graduate student, NU «Zaporizhzhia Polytechnic», Zaporizhzhia

THE INFLUENCE OF GAS ISOSTATIC PRESSING ON THE QUALITY OF MAGNESIUM ALLOY CASTINGS FOR STRUCTURAL ELEMENTS OF UNMANNED AERIAL VEHICLES

The complexity of the design and the need to increase the technical capabilities of unmanned aerial vehicles (UAVs) lead to the emergence of additional equipment in them, which leads to an increase in their efficiency. UAV manufacturers now widely use alloys based on aluminum and steel, which are not completely effective through their supernatural energy. Therefore, the priority direction of light tracking from the development and design of modern UAVs is changing their focus on the development of new materials [1]. Magnesium alloys are a promising material for the production of various structural elements of UAVs. This is especially important for UAVs, where it is critical for range and maneuverability. At the same time, magnesium alloys have a high strength, which allows them to effectively cope with mechanical stress during polishing [2].

Magnesium alloys have high thermal conductivity, which allows for efficient heat transfer from electronic components and other UAV systems. This is especially important when using highly productive components that generate a lot of heat. In addition, they have good electromagnetic properties, which is important for the use of electronics and radio equipment in UAVs [3,4]. They provide less electromagnetic interference and damage, which ensures stable operation of electronic systems and communications. At the same time, the operational reliability and durability of magnesium alloy castings are significantly affected by defects that form during the manufacture of castings [5]. Such defects include macro- and microporosity, gas cavities and non-metallic inclusions. The most common defect in magnesium alloy casting is porosity. Therefore, eliminating this type of defect is an important and urgent task.

For obtaining critical magnesium casting, the most widely used alloys are Mg-Al-Zn and Mg-Zr-Nd systems, the production of which includes smelting the alloy, refining the melt and heat treatment. At the same time, in castings of complex configuration, there may be areas with microporosity, which leads to the rejection of products and entails a decrease in the yield of suitable castings and an increase in the percentage of defects. One of the promising areas for eliminating the porosity of castings from magnesium alloys can be the use of gas-isostatic pressing (GP) technology. When using this technology, welding of the pore walls occurs as a result of high-temperature creep and diffusion of the metal. At the same time, GP contributes to the grinding of the structural components of the alloy, their more uniform distribution and an increase in the physical and mechanical properties of the metal. The use of GP to correct defects in casting from magnesium alloys requires additional study.

Therefore, testing the technology of GP castings from magnesium alloys to improve their quality and physical and mechanical properties is an urgent task.

One of the important conditions for obtaining high-quality magnesium casting is obtaining a metal of increased density without porosity and looseness. Therefore, castings from magnesium alloys undergo hydrostatic testing, as a result of which some of them do not withstand it and are rejected. The quality of castings from magnesium alloys in industrial conditions was determined by non-destructive testing methods.

X-ray inspection of defects in magnesium alloy castings was carried out using RAP-150/30, RUP 400-5 and MIRA-2D devices.

Luminescent testing of castings was carried out using the LUM-17-P and LUM-K methods, using capillary penetration of a luminescent liquid into the cavity of a product defect.

For color flaw detection of products, a layer of indicator penetrant was applied to the pre-cleaned surface of the product. After holding, as a result of which the penetrant filled the surface defects, the surface was treated with OZ-2 liquid and removed with a mixture of 70% transformer oil or MS-8P and 30% TS-1 or RT fuel. A developer was used to fix the defect.

Samples for metallographic testing and determination of mechanical properties were made from castings containing microporosity before and after HIP. Gas isostatic pressing was carried out in a QUINTUS model gasostatic press at a temperature of 395±5 oC and a pressure of 9.2 MPa for 1.5 hours.

The ultimate strength and relative elongation of the samples were determined on a R5 tensile testing machine at room temperature.

Long-term strength at a temperature of 150 °C and a stress of 80 MPa was determined on an AIMA 5-2 tensile testing machine on samples with a working diameter of 5 mm.

The macro- and microstructure of the alloys under study was studied using «Neophot 32» and «OLYMPUS ИХ 70» light microscopes.

The low-density sections of the magnesium alloy castings had a uniform fine-grained macrostructure. At the same time, micro-cracks in the magnesium alloy castings were separated by sections with normal density and had a uniform decrease in density.

The microstructure of the heat-treated alloy of the Mg-Zr-Nd system was a δ-solid melt with the presence of a spherical eutectic (δ+γ(MgZr12Nd)). The microstructure of the Mg-Al-Zn alloy was characterized by the presence of a δ-solid solution, eutectic δ+γ(Mg17Al12) and single intermetallics γ(Mg17Al12). The size of the intermetallic phase was up to 2.0 μm, and the distance between the axes of second-order dendrites was up to 10 μm.

Metallographic analysis showed that GP did not affect the sizes of macro- and micrograins of magnesium alloy castings. At the same time, metal compaction occurred and micropores were closed. GP contributed to the strengthening of the metal of the surface layers of castings due to their deformation. The microhardness of the metal in the surface zone of the castings was significantly higher than in its central part. The mechanical properties of the alloys under study showed an improvement in their physical and mechanical characteristics and heat resistance after HIP.

HIP of magnesium alloy castings containing microporosity made it possible to eliminate it and obtain a metal with mechanical properties that meet the requirements of regulatory and technical documentation.

Thus, gas isostatic pressing is an effective technology for eliminating some defects in magnesium alloy castings. It has been established that the use of GP eliminates microporosity in castings, increases their density by 10...15%, ultimate strength by ~ 15%, plasticity by ~ 25% and heat resistance by ~ 20%. The use of this technology allows to reduce the percentage of defects and increase the yield of profitable production and ensure reliable and durable operation of aviation equipment.

References

1. Development of a High Strength Magnesium Alloy for Wire Arc Additive Manufacturing. Stefan Gneiger, Johannes A. Österreicher, Aurel R. Arnoldt, Alois Birgmann, Martin Fehlbier. Metals 2020, 10(6), 778. https://doi.org/10.3390/met10060778

2. Microstructure and Mechanical Properties of Mg–Gd–Y–Zn–Zr Alloy Prepared by Repetitive Upsetting and Extrusion. Zhimin Zhang, Yue Du, Guanshi Zhang, Zhaoming Yan, Jianmin Yu, Mu Meng. Materials Transaction, 2018 V. 59, I. 4, P 669-673. https://doi.org/10.2320/matertrans.M2017323

3. Microstructure–Mechanical Properties and Application of Magnesium Alloys. Talal Al-Samman, Dietmar Letzig , Sangbong. Metals 2021, 11(12), 1958; https://doi.org/10.3390/met11121958

4. Microstructure and Mechanical Properties of Magnesium Matrix Composites Reinforced by In Situ Reduced Graphene Oxide. Feixiang Liu, Zhaohui Wang, Xian Du,Shubo Li, Wenbo Du. Materials 2023, 16(6), 2303. https://doi.org/10.3390/ma16062303

5. Surface Modification of WE43 Magnesium Alloys with Dopamine Hydrochloride Modified GelMA Coatings. Yang Ji, Mengdie Hou, Jin Zhang,Tianlin Wang, Can Cao 1, Huazhe Yang, Xiaodong Zhang. Coatings 2022, 12(8), 1074. https://doi.org/10.3390/coatings12081074