Next-Generation Technologies of Manufacturing of Waveguides from Aluminum Alloys.

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Introduction

Waveguides are used in different radio engineering devices to transferelectromagnetic oscillations. They represent metal circular- and rectangular-sectioned tubes in which electromagnetic waves are transmitted [1].

The modernization of existing and creation of new machines and devices has required the development of complicated configuration parts with regard to which strict accuracy requirements are imposed. They include waveguide unit parts, including corner castings. Waveguides represent thin-walled parts of different forms and sections that are mainly used in the radio-electronic industry.

One of the most promising processes of manufacturing of waveguide corners is casting by the lost-wax process. Among various modern casting methods, casting by the lost-wax process takes a special position due to its main feature consisting in manufacturing of complicated configuration castings from various alloys [2].

Today, technologies allow us to manufacture waveguides from standard aluminum and brass shapes and various sectioned and configurated pipes according to OST 92-8381-73, OST 92-8382-73. However, new modern technologies are constantly being sought after due to increased manufacturing volumes.

The purpose of this work is to develop technologies of manufacturing of corner castings and solder alloy compositions for their soldering to waveguide tubes.

Summary of Results

A waveguide tube of section 20×10 mm, made of aluminum alloy and shown in Figure 1 has been chosen for researches.

Figure 1. Waveguide tube. General view

This waveguide tube has a curve of 90° for which corner castings (Figure 2) made of analogous alloy D712 have been used.

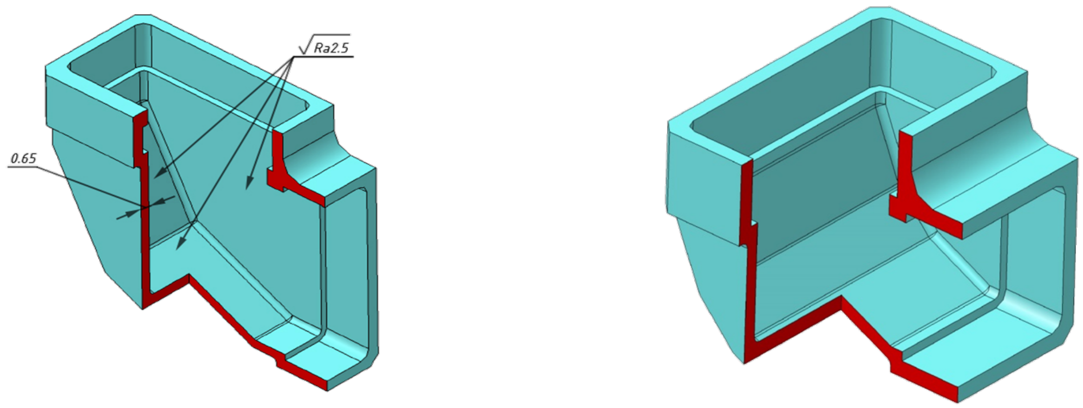


Figure 1. Waveguide corner castings. 3D model

The suggested alloy (analogous alloy D712) has a sweating temperature (solidus) – 610°C, effectively prevents any uncontrollable grain growth when soldering corners to the waveguide tubes. A crystallization interval of this alloy lies within the range of ≈ 615,5–640,5 °C.

The technology of creation of corner castings includes:

– Development of a running and supply system;

– Choice of a jointing plane of a flexible rubber mold;

– Setting of an optimum temperature for filling molten salt into the core box;

– Choice of a releasing agent (silicone grease) for the purpose of eliminating adhesion of salt alloy with the core box's working surfaces with preserved high purity of the surface of a core being formed;

– Setting of an optimum temperature of wax and a necessary pressure when injecting into the mold cavity;

– Setting of an optimum angle when fastening the wax model to the supply riser;

– Setting of an optimum temperature of the casting mold and the aluminum casting smelt when casting waveguide corners;

– Validation through elaboration of a finishing operation technology.

Corner castings have been manufactured by way of casting by the lost-wax process, with application of the salt cores volumetrically modified by the Krasnoyarsk Territory fields' nanostructured graphite (Figure 2) the preparation modes of which have been described in detail in the works [4].

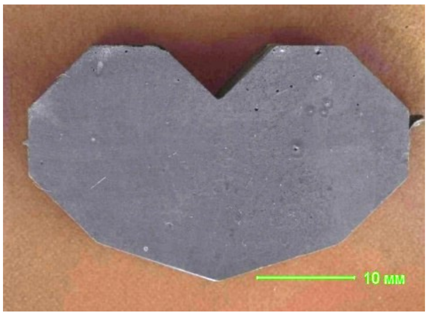


Figure 2. Salt core volumetrically alloyed by nanostructured graphite [3].
General view

The fact of introducing nanostructured graphite into the salt core results in redistribution of the gas hole in its center to a small gas porosity evenly distributed along the whole section due to the emergence of active particles of graphite that sorb gases coming out from the salt mixture in the course of its preparation. The results of the researches of the influence of graphite content on salt cores' roughness have shown that the most optimum amount of graphite introduced into the salt core is 5 % (R_a decreased from 0.538 to 0.08). The increase in graphite content up to 20% results in re-grouping and reduction of the quantity and size of pores, and simultaneously in reduction of the core's surface hardness.

Aluminum-zinc alloys with working soldering temperatures of 555-575 and 565-590 °C in the form of different-sectioned wires [5] have been developed for soldering corner castings to waveguide tubes.

After analyzing the double charts of states and polythermal cuts of multicomponent aluminum-based systems with regard to experimental approbation as alloying complexes of solder alloys meeting required working temperatures, the following systems have been accepted: Al–Si–Mg, Al–Si–Ag, Al–Si–Cu, Al–Ge–Ag. In order to quickly find an alloying complex of solder aluminum-based alloys, they have developed the Politermo software product in the Object Pascal programming language that allows us to calculate and construct polythermal cuts of three-component systems, to simulate temperatures of liquidus – solidus for various systems, to keep results in the database, which allows us to analyze results of creation of polythermal cuts in a specifically assigned point with an assigned step interval. With the use of this software product, a number of alloying complexes that can be a basis of solder aluminum-based alloys has been calculated.

The experimental test has shown that the best technological properties are attributed to the Al-Si-Zn system's alloys obtained by way of modifying alloy AK12 with zinc. The melting temperature of these alloys with an increase of zinc by 10% decreases from 572 to 552°C.

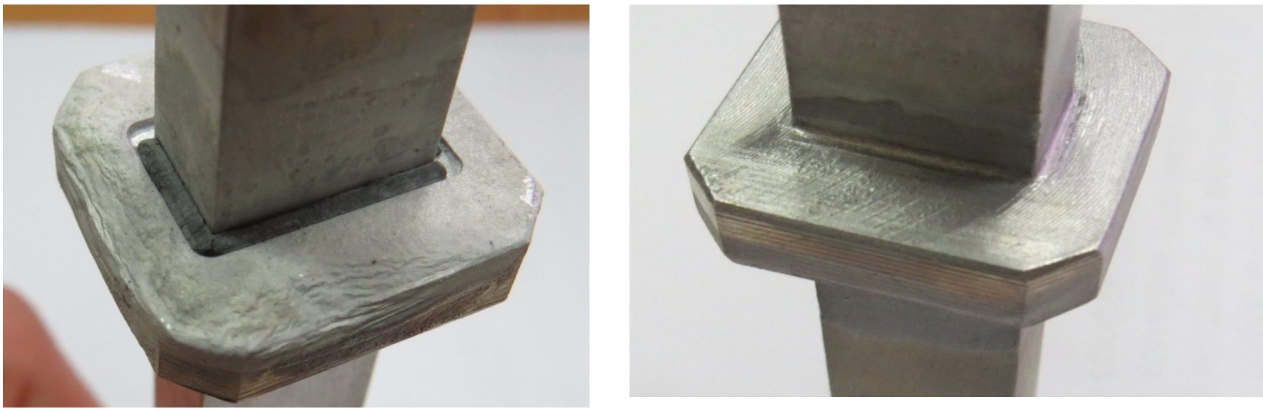
The developed alloys' microstructures are presented in Fig. 3. The analysis of the presented microstructures shows that all the structures are eutectic ones and are similar to the double modified eutectic system's structure, i.e. aluminum – silicone. It should be noted that with an increased zinc content, a share of solid solution increases, and its inclusions become more disperse, which in turn results in increasing the solder alloy's mechanical properties.

a *b*

Figure 3. Microstructures of alloys (×500) containing zinc:

a – with low zinc content; *b* – with high zinc content

The solderability with the developed solders is excellent, the solder flowing is uniform, the soldered gap filling is free of defects (Figure 4).



a *b*

Figure 4. Soldered connection executed by the Al-Si-Mg system's solder (a)

and by the developed solders (*b*)

The analysis of the microstructure of the soldered connection's cut (Figure 5) has shown that the soldered seam is dense, no erosion of the waveguide tube is identified.

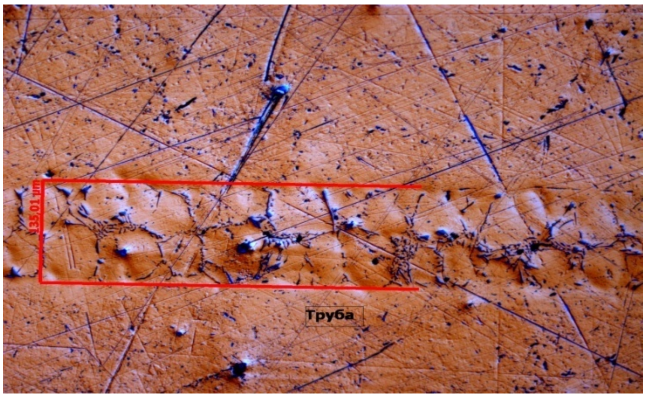


Figure 5. Microstructure of the soldered connection

The analysis of the obtained results shows that the most promising alloying complex to obtain a soldering wire is the Al-Si-Zn system. By changing the zinc content, it is possible to obtain various temperatures for melting an alloy, to change its mechanical characteristics. It has been established that an increase in the zinc content in an alloy with 12% of silicone proportionally decreases its melting temperature and increases its mechanical properties, preserves the alloy's high plastic properties, which allows us to process these alloys with a high deformation extent. The obtained alloys' structure is of eutectic type, which gives alloys high flowability ensuring high soldering properties.

Conclusion

Therefore, the technology of manufacturing of corner castings for waveguide tubes have been developed within the performed work. In order to improve quality of the corner casting's internal surface, it has been suggested to use the salt core that is volumetrically modified by the Krasnoyarsk Territory fields' nanostructured cryptocrystalline graphite. In order to solder corner castings to waveguide tubes, the solder alloy compositions of the Al-Si-Mg, Al-Si-Ag, Al-Si-Cu, Al-Ge-Ag systems meeting the following requirements have been suggested: working soldering temperatures of 555-575 and 565–590°C, increased quality of solder connections, improved radio engineering characteristics of waveguide ducts. The method of calculations of polythermal cuts of multicomponent systems has been used to accelerate the process of development of main alloying complexes meeting required working temperatures.

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