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The Specifics of Producing Steel to Brass Bimetal Using Explosion Welding

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Abstract

It was experimentally proved that explosion welding of large sheets of brass to steel leads to separation of the near-surface brass layers into phase components in shock-compressed gas. This causes the termination of the formation of bonding over a length of more than 1 meter. The paper proposes the procedure for gas saturation with zinc vapor and molten dispersed copper and brass particles and their separation in the gas flow in the explosion welding.

Keywords

Brass, oxides, typical dimensions, explosion welding, shock-compressed gas, zinc.

Introduction

Bimetals with cladding layers of nonferrous metals and their alloys, such as titanium, copper and brass are widely used in nuclear and power engineering. In particular, the tube grids for heat exchangers and condensers of steam turbines are made of steel to brass bimetal. The thickness of the tube grids can reach 100 mm, and the area can be over 2 m^2. Explosion welding can be used to produce bimetal of such dimensions.

The effectiveness of using explosives in technological processes for the production of bimetal is not in doubt, as the technology allows creating materials that are difficult or impossible to produce using other traditional methods. It is assumed that the processes occurring during explosion welding are stationary due to the detonation steady state, the velocity of the projected plate, and the periodicity of the resulting wave coupling. However, in practice, especially in the manufacturing of large-sized products by the explosion welding various flaws can appear. Bimetals made from layers with quite different properties have the following flaws: disruption of bond continuity, areas of reduced strength, formation of intermetallic compounds.

Brass refers to materials that are well bonded to steel by explosion welding if the thickness of the brass layer does not exceed 8 mm. The practice of cladding 10–14 mm thick large-sized steel grids with L14 brass showed that flaws in the form of discontinuities may appear if the weldability window is in the coordinates γ–V_k [1] at a distance of more than 1 m from the start of the process.

The purpose of this article is to identify the causes of flaws in welding of thick steel to brass bimetal.

Methods and experiments

In the experiments, we used energy-condensed systems based on industrial explosives of a mixture of ammonium porous nitrate of the MP brand with diesel fuel in a ratio of 96 : 4 by weight.

The materials used for the experiments included:

– 09G2C low-alloy structural steel, with dimensions of 86×1100×2300 mm;

– L63 brass, with dimensions of 14×1200×2400 mm.

The explosion welding parameters $r = 1$; $V_k = 3800$ m/s; $V_0 = 880$ m/s were used to produce a welding joint.

The method of ultrasonic testing showed that bonding between the layers was formed at a length of 1 m, and then it was missing (Fig. 1). With the increasing impact parameters, the length of the bonding zone decreased.

Fig. 1. The view of bimetallic sheet after explosion welding

From the zones of strong bimetal bonding and zones of discontinuity flaws, we selected samples, the structure of which was studied by optical and scanning electron microscopy. The composition of the flaws was examined by constructing X-ray element distribution maps and by microspectral spot analysis.

Results

The metallographic studies of bimetal showed that when the distance from the beginning of the process increased, the number of cast inclusions in the bond increased. In the zone adjacent to the discontinuity flaws, the cast inclusions formed by a continuous strip with a large number of pores were observed. It is noteworthy that the process of wave formation practically ceased.

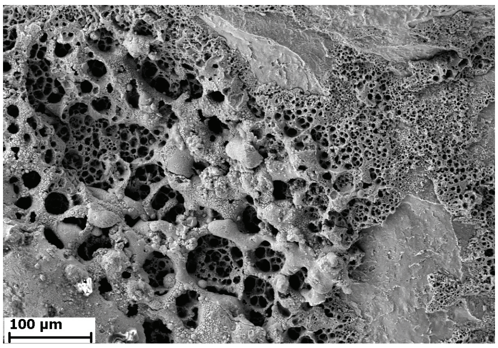
The layers of steel and brass in the place where there was no bond (over a length of more than 1 meter), were separated. Visual inspection revealed a change in the color of the surface of the layers: those on the surface of steel became yellow, and those on the surface of brass became light gray.

The microspectral analysis of the samples cut from the discontinuity zones revealed that the yellow coating on the steel surface was an evenly sprayed microlayer of brass, 100–150 microns thick.

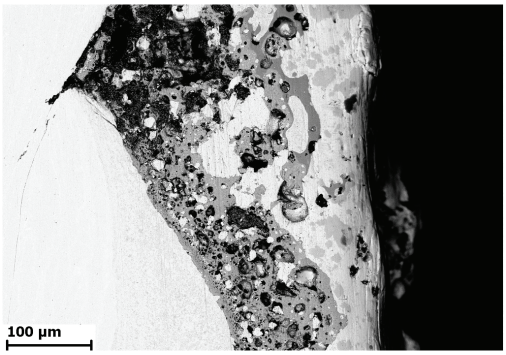
The study of the gray coating on the surface of brass revealed the presence of a continuous microlayer of “foamed” material, variable in thickness and composition (Fig. 2 *a*). A layer of 100–300 μm in thickness had areas varying in structure: dense gray areas located on the surface of brass and porous areas with dark inclusions (Fig. 2 *b*).

In a dense gray structure, clusters of dispersed coagulated dark particles, whose dimensions did not exceed 1 μm were observed. The X-ray spectral analysis of these particles showed that they contained iron. The gray matrix was an alloy with a reduced content of copper and zinc or brass, respectively. Thus, the porous mass was a copper frame with a reduced content of zinc with inclusions of iron and oxides.

The X-ray maps of the distribution of elements on the surface showed the areas with a thin continuous layer of zinc and its oxides (Fig. 3). This indicated that during the explosion welding ahead of the point of contact (before the formation of the joint), the surface brass melting and the substitution of zinc occurred, but the presence of a large impact area (over 1 m^2) apparently prevented the metal particles from escaping from the welding gap when the shock-compressed gas flew to the sides.



a)



b)

Fig. 2. The porous microlayer on the brass surface (*a*) and the cross-section (*b*)

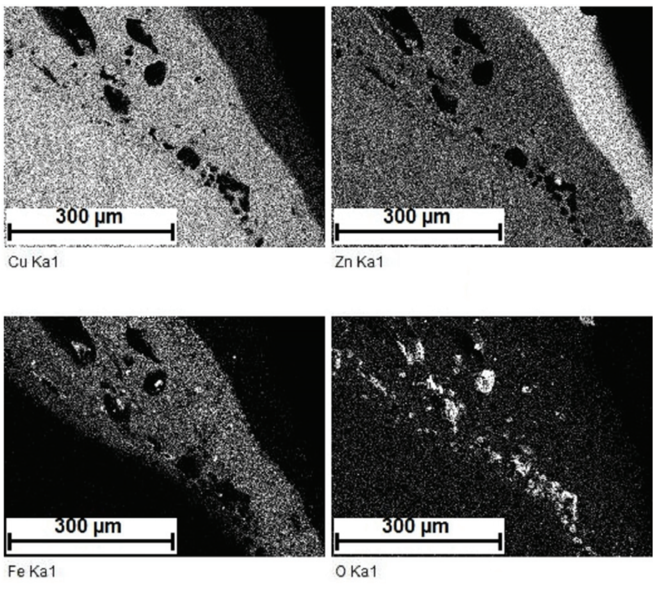


Fig. 3. X-ray map of distribution of elements on the surface of brass (cross section)

The impact in the process of explosion welding on a liquid surface excludes the formation of a strong joint. This is due to the increase in the time of formation of the metal joint during the solidification of the melt, as compared to welding in the solid phase. After the pressure is removed, the joint is delaminated during the liquid phase. This is evidenced by the microstructural analysis of the stratification zone. These experiments showed that the process of explosion welding of steel and brass can be provided only by the conditions of formation of the bond in the solid phase.

Discussion

It follows from the Cu – Zn state diagram [2] that at 910 °C evaporation of zinc from the surface layer can begin. Brass at this temperature goes into a liquid state, and the high reactivity of Zn with atmospheric oxygen contributes to its evaporation from the melt.

Using calculations from the procedure in [3, 4] we found that if a contact point speed was more than 3500 m/s, the contact surface of brass heated to a depth of more than 200 μm to the temperature above 1000 °C, causing separation of zinc from the solid solution, its evaporation and formation of zinc oxides. As the welding process progressed, the shock-compressed gas ahead of the contact point was saturated with zinc vapor, as well as with molten dispersed particles of copper, iron and their oxides. Gravity forces caused the separation in the flow: the vapor of zinc and its oxides were in the upper part of the flow, and the molten disperse particles of brass and steel were in the lower part of the flow. When the vapors came into contact with the "cold" surface of brass and steel, the liquid zinc layer and its oxides were condensed on the brass surface, and the molten brass particles were on the steel surface. The formation of a liquid melt of zinc and its oxides on the brass surface entailed a decrease in the strength of the compound or led to its complete absence due to the low strength properties of zinc.

Thus, since alloys containing low-melting components are used as the cladding layer, a high-pressure shock-compressed gas stream moving in the gap at high speed carries a low pressure fluid (low-melting phases). As a result, the strength of the bonding decreases and may lead to incomplete inter-run penetration, as well as disturbed phase (chemical) uniformity of the layers in the heat affected zone

Using the experimental data and theoretical calculations, optimal regimes for obtaining steel to brass bimetal by explosion welding were found. Reduction in the impact parameters to values $r = 0.7$; $V_k = 3550$ m/s; $V_0 = 640$ m/s allowed bonding along the entire length of bimetallic sheets. A pilot batch of high quality tube sheets with dimensions of $100\,(14+86)\times 1100\times 2300$ mm was produced by joining layers throughout the workpiece area.

Conclusions

1. In the explosion welding of 09G2C steel + L63brass, the influence of the temperature and the state of the welded surfaces on the processes occurring in the welding gap in the explosion welding of alloys containing low-melting constituents in a solid solution was revealed.

2. Formation of a liquid melt of zinc and its oxides on the surface of brass leads to a decrease in the strength of the welded joint or its complete absence due to low strength properties of zinc.

3. The choice of optimal welding regimes by calculating the parameters of the shock-compressed gas allows improving the quality of the resulting thick-plate material of a larger area.

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