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Profitability of Production of Stainless Steel + Zirconium Metals Combination Adapters

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Abstract. The main difficulty in obtaining adapters from stainless steel + zirconium metal combination lies in the formation of fragile intermetallic compounds at the weld border. By its properties, zirconium is very close to titanium, and therefore the manufacture of tubes from this combination, as well as pure titanium, is considerably difficult. Optimum explosion welding parameters have been developed, ensuring the highest adhesion strength compared to the existing production methods. At the weld border, a structure characteristic of compounds of dissimilar metals was revealed. The permissible heating temperatures for this combination are determined. The fundamental possibility of using the explosion energy as a factor stimulating the connection of dissimilar metals in order to obtain high-quality multilayer tubes, billets and products for various purposes is demonstrated, resulting in the introduction of environmentally friendly technology. Economic analysis of the manufacturing technology of bimetallic tubes by welding explosion was carried out. The cost-effectiveness of manufacturing technology of bimetallic stainless steel + zirconium metal compound nozzles, which is based on the use of high-pressure gradients and loading velocities to create production, was evaluated.

Introduction

National economic growth within the framework of modern competitive environment is possible through the revival of the country's industrial complex. The main task in this case is to develop effective management systems that will create the conditions for the dynamic growth of such sectors of the real economy as machine tools, instrument making, electrical and electronic industries, through the introduction of advanced technologies, the use of the latest management approaches and the introduction of scientific justification for management decisions.

Engineering, aviation, shipbuilding and a number of other industries use a large number of tube products of a wide assortment.

The pursuit of leading positions in the economy encourages the leaders of countries and large companies, as well as other influential stakeholders of today to develop innovative approaches to the organization of business processes in order to increase the efficiency of economic activity and profit. Implementation of innovative approaches will allow to increase business efficiency, at the same time, traditional approaches and methods should be adapted to the development conditions modern society.

A characteristic feature of the development of modern engineering is the increase of the equipment unit capacity, which leads to increase in labor productivity and production profitability. With increasing power and complexity of the operating conditions of products, the risk of brittle fracture of structures and machine parts increases. Under these conditions, the ability to resist the propagation of instant and fatigue cracks becomes an important indicator of the reliability of highly loaded structures. Therefore, the creation of crack-resistant compositions, which allows to slow down or prevent destruction, is an important and urgent problem.

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Depending on the quality characteristics of the working environment, steel transitions are made from different grades of steel. Enhanced requirements for the oxidation of aggressive environments include the use of adapters from the combination of X18H10T+Zr metals.

Bimetallic tube products have special physicochemical properties which cannot be obtained in single-layer products but only through special compositions. In industry, there are several methods for producing bimetallic tubes based on the joint plastic deformation of welded metals at high temperatures: pressing, deformation on piercing and drawing mills, thermal diffusion welding, centrifugal casting, and several others. Each method has its drawbacks, advantages and limitations.

The fundamental disadvantage of the existing methods is that the setting process of metals proceeds at high temperatures, at significant shutter speeds, as a result of which there is a diffusive redistribution of elements between the metals being welded over considerable distances from contact surfaces. The above disadvantages were a prerequisite for the search for new and more effective methods of manufacturing bimetallic tubes.

One of the new technological processes for creating composite materials is the explosion welding method based on oblique high-speed collision of metal contact surfaces [1-7]. This method makes it possible to produce bimetallic sheets, tubes from metals of various combinations, which can hardly be obtained with existing welding methods. This method opens up the possibility of using a new type of energy for the production needs – explosion energy of blasting explosives, the use of which will save traditional energy resources.

Zirconium has a small capture radius of thermal neutrons due to which it is one of the promising structural materials for nuclear reactor engineering [8-14].

Its perspective is emphasized by the fact that aluminum and magnesium having similar properties are not recommended at elevated temperatures up to several hundred degrees, at which zirconium still sustains its strength.

The valuable qualities of bimetal stainless steel + zirconium, combining the strength and the indicated properties of zirconium, make it possible to adopt this bimetal in the construction of atomic reactors [15-19].

The main difficulty in obtaining this combination is the ability of the main elements of the system to chemical interaction and the formation of brittle intermetallic compounds at the fit-up border.

Goal of the research. The goal of this work was to identify a better and more effective solution for obtaining bimetallic tube billets from a combination of stainless steel + zirconium metals and to study the effect of explosive parameters on wave parameters and the quality of welding of bimetallic tubes.

Materials and results of the research. In terms of their chemical properties, zirconium is very similar to titanium, and the formation of their alloys largely submit to the same laws, therefore the manufacture of tubes from this combination, as well as pure titanium, is considerably difficult. The main steel 1H18N10T components are iron, nickel and chromium.

According to the state diagram, the zirconium-iron system has two labels: γ-Fe + $ZrFe_2$ и Fe_2Zr + β-Zr, crystallizing at temperature 1335°C and 934°C, and containing respectively 16% and 83% of zirconium.

Chemical compound Fe_2Zr consists of 57% Fe and 43% Zr, melting point is about 1600°C [20-24]. Another chemical compound is formed in the iron-zirconium system Zr_4Fe. Iron solubility in β-Zr at room temperature 0,02%, at 800°C is 4%. Maximum solubility is achieved at 934°C [25-31].

Zirconium solubility in α-Fe is very less, γ-Fe is 0.6% [32-34]. At 808°C eutectoid decomposition of solid solution β-Zr takes place. Nickel and zirconium form intermetallic compounds Zr_2Ni, ZrNi, $ZrNi_3$ which contain 25, 39 and 65% of nickel. There is one intermetallic phase in the zirconium-chromium system $ZrCr_2$, which contains 43% Cr with melting temperature at 1675°C and two eutectics β-Zr + $ZrCr_2$ with melting temperature at 1300-1630°C, containing 18 and 70% of chromium respectively.

Thermal methods for manufacturing bimetal stainless steel + zirconium is of little use, since when heated above certain temperatures, a continuous brittle transition layer can form, which sharply reduces the adhesion strength.

The adhesion strength of 1H18N10T + Zr bimetal, manufacture manufactured by existing methods is the following: at broaching 10 – 15 kgf/mm^2, at fusion 7 – 14 kgf/mm^2, at friction welding 7 – 15 kgf/mm^2 [35-37].

The analysis of the considered zirconium phase diagrams with the key elements of X18H10T steel, demonstrates that the formation of solid solutions, eutectic alloys, and intermetallic phases can be expected when welding by zirconium explosion with 1H18N10T steel [38-41].

However, explosion welding at optimal parameters is accompanied by the formation of only disjoint microvolumes of the transition layer, which do not adversely affect the adhesion strength of bimetal.

The study was tasked with obtaining bimetallic tube billets from a combination of metals 1H18N10T + Zr.

1H18N10T stainless steel tubes of 104x5x200 mm size were welded with 125 zirconium alloy tubes of 88x4x200 mm size.

As the result of the studies, the border of the minimum values of the contact point velocity was established (Fig. 1), at which the cut out bimetallic rings withstood, without delamination, a single flattening test to four thicknesses of the bimetallic ring. The ammonium nitrate mixture charge of 60-66 mm diameter, containing 0,7-1% of TNT, and the rest of the ammonium nitrate was used.

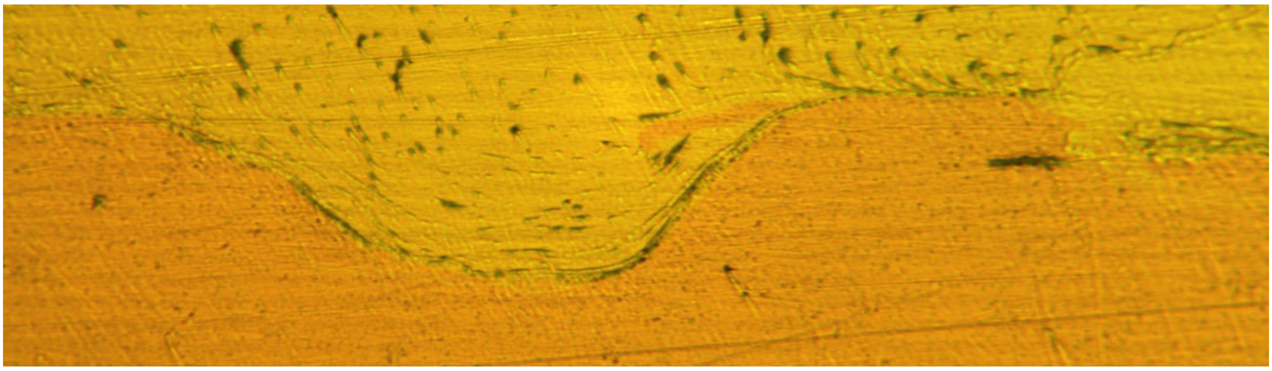

Fig. 1. Connection zone border view

To determine the adhesion strength of bimetal, the samples were cut from different places of the tube. The analysis of the obtained test results demonstrates that the most stable adhesion strength is typical for tubes prepared according to the following protocol: the charge diameter is 62 mm, the content of TNT in the mixture is 1%, and on average is 55 kgf/mm^2.

With an increase in the diameter of the charge to 66 and the percentage of TNT in the mixture to 2%, the adhesion strength ranged from 63-67 kgf/mm^2 [42-43].

Therefore, the optimal parameters for explosion welding 1H18N10T + Zr in this standard size is considered to be: charge diameter 62 mm, the content of TNT in the mixture is 1%. This charge provides a contact point velocity of 1.9 km/s.

The microstructure of the zirconium and 1H18N10T steel welding border zone studies demonstrate that separate sections of the structure are formed at the border, which differ in color of the etch and microhardness from the welded metals (Fig. 2).

For both of the given parameters, the fused sections at the welding border are characterized by a micro hardness of 800–1250 kg/mm^2.

As a result of the studies on the nature of hardening of bimetallic work pieces of the 1H18N10T + Zr combination, it was established that regardless of the charge magnitude, the metal of both the main and clad layers harden after the explosion welding treatment. The maximum hardening is observed at the contact surface and at a certain distance (Fig. 3).

However, with an increase in the TNT percentage in the charge, the 1H18N10T stainless steel hardens more and the microhardness of zirconium remains unchanged [44-45].

According to published data, heating of bimetal within the 500-700°C temperature range leads to the change in the microstructure and strength of the connection of zirconium and 1H18N10T steel.

The heating temperature increase to 700 °C causes an increase of the diffusion layer growth rate at the border between the joined materials by around 40 times.

Even short-term heating up to 0,25 hours at a temperature of 700 °C reduces the adhesion strength by 2,5 times.

The tendency of zirconium compounds with 1H18N10T steel obtained by explosion welding to lower its strength due to temperature influences requires a careful selection of technological processes for their subsequent processing when using this material as structural.

Explosion welding of bimetallic 1H18N10T + zirconium alloy 125 tube billets production was tested at the workbench. A structure typical for the joining of the dissimilar metals by explosion welding was revealed in the joining zone.

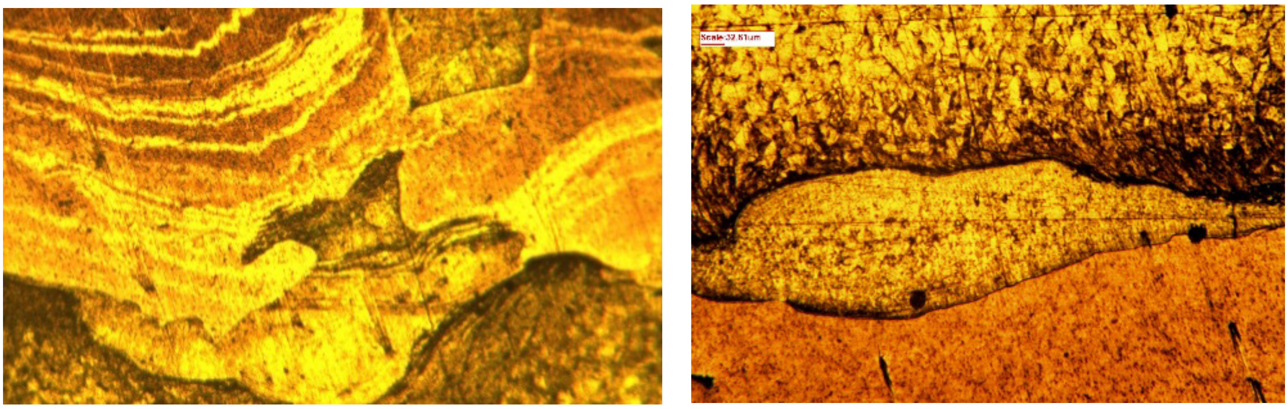

Fig. 2. Distribution of melted areas along the border

Thermal elasticity tests, ten-fold thermal cycling of the tube samples in vacuum according to the 20°C – 550 °C – 20°C protocol, demonstrated no noticeable changes in the geometry and stability loss of the work piece.

The cost-effectiveness of manufacturing technology of bimetallic 1H18N10T + Zr metal compound nozzles, which is based on the use of high-pressure gradients and loading velocities to create production, was evaluated. Marketing strategy implies offering international quality standard product at a price of 5–10% less than market price. Economic analysis of the manufacturing technology of bimetallic tubes by welding explosion was carried out. The fundamental possibility of using the explosion energy as the factor stimulating the connection of dissimilar metals in order to obtain high-quality multilayer tubes, billets and products for various purposes is shown, an environmentally friendly technology was introduced.

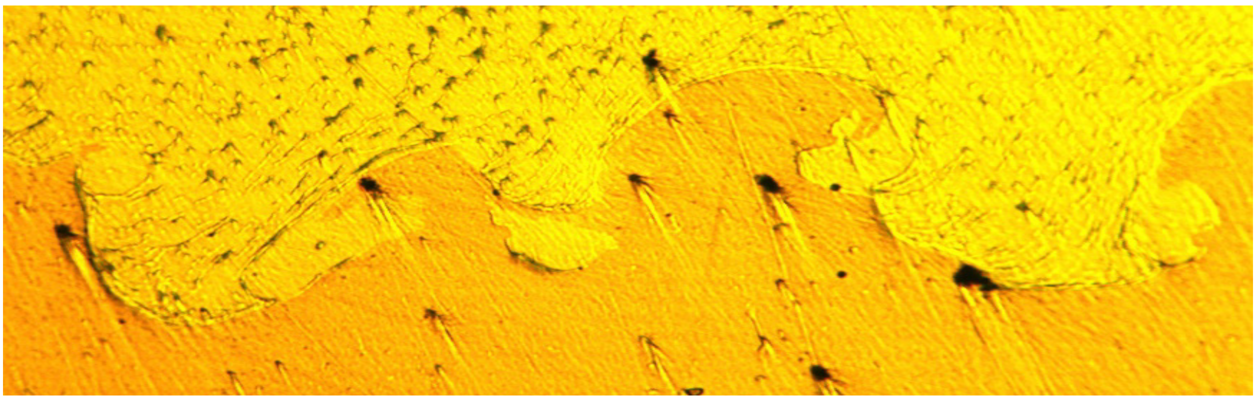

Fig. 3. Typical wave crest

Summary

Explosion welding was carried out according in compliance with the internal cladding process at the optimal parameters for this combination of metals: contact point velocity of 1.9 km/s, relative weight of the explosive at 0.35-0.43, and the collision angle at 7°20 '.

The use of explosion welding in the manufacture of bimetallic nozzles from a combination of 1H18N10T + Zr metals leads to the formation of fragmented sections of the transition layer at the weld border which do not adversely affect the adhesion strength of bimetallic tubes.

The optimal parameters of explosion welding of 1H18N10T + Zr combination bimetallic tube billets, ensuring the highest adhesion strength (yield strength 55 kgf/mm2) in comparison with existing production methods, were established. A structure typical for the joining of the dissimilar metals by explosion welding was revealed in the connection zone. The permissible heating temperatures for this combination were determined.

The cost-effectiveness of manufacturing technology of bimetallic 1H18N10T + Zr metal compound nozzles, which is based on the use of high-pressure gradients and loading velocities to create production, was evaluated.

The fundamental possibility of using the explosion energy as a factor stimulating the connection of dissimilar metals in order to obtain high-quality multilayer tubes, billets and products for various purposes is illustrated; an environmentally friendly technology is introduced.

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