ELECTRON BEAM WELDING IN PRODUCTION OF STEEL-ALUMINIUM JOINTS OF TRANSITION PIECES OF DISSIMILAR METALS

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New design-technological solutions for producing of dissimilar welded joints of aluminium alloy–stainless steel materials by electron beam welding are presented. Variants of heavy-section welded joints, optimal parameters for their welding and examples of application in structures are given.

Keywords: *welded structures, electron beam welding, steel-aluminium joints, bimetallic transition pieces, armor shielding, macrosections of joints*

One of the priority trends in development of modern machine building is decrease of mass of structures and devices with simultaneous preservation of their technical characteristics and service reliability at the high level. Application of different grades of steels and aluminium alloys allows optimal reacting of a product to the effect of loadings, temperatures or aggressive environments existing under service conditions. During realization of modern design solutions the welding of aluminium and its alloys with other metals is widely applied.

In welded joints of dissimilar metals aluminium is one of the most hard-to-weld metals. At the same time manufacturing of welded structures of aluminum joined with other metals is especially rational, as it allows considerable decrease of mass of the product.

Nowadays many fields of industry are in growing need of reliable methods for joining dissimilar metals and alloys. Many specialists deal with the development and creation of aluminium-steel transition pieces. The result of many year investigations allowed creating different technologies for production of sheet bimetal aluminium-steel for manufacturing transition pieces in the structures of different purpose (Figure 1). The largest volume of bimetal production accounts for metallurgical industry where it is produced by rolling of two sheets. Bimetal is produced also by explosion treatment in spite of specific conditions for realization of this process, by diffusion welding, brazing, friction welding and resistance welding. However, all these processes are limited only by negligible volumes of production of aluminium-steel transition pieces.

A new welding method using high-speed impact finds also ever wider application [1]. Sometimes transition pieces are not used and the welding-in of aluminium parts to the steel ones is directly performed. However, to realize this welding process the edges of steel to be welded should be previously subjected to aluminizing, i.e. to their coating with molten aluminium by dipping into a liquid melt.

In most cases the application of mentioned methods for production of bimetal concerns the application of thin-sheet components, i.e. in total the thickness of bimetal can reach 10 mm and a bit larger. It is more difficult to realize the process if the transition pieces of thickness, for example, of aluminium of 20 mm and larger are required.

Even more complicated problem for producing the bimetallic transition pieces is the presence of intermetallic brittle interlayers [2, 3] on the interface of two metals. These can be phases FeAl, Fe_2Al_5, as well as oxides and suboxides Al_2O_3, Al_2O, AlO which are always present on the surface of aluminium and its alloys.

All these compounds have high heat resistance and are not destroyed even during heating of the interface up to the temperature of 1600 °C and higher. The presence of such interlayer in the aluminium-steel joint of even 50–100 μm thickness considerably influences the embrittlement of a joint, the tearing strength of which decreases from 300–350 down to 50–100 MPa [2].

Application of such bimetallic transition pieces in welded structures [4], when other structure elements are welded to any of the metals using arc methods, results in high temperature heating of transition zone

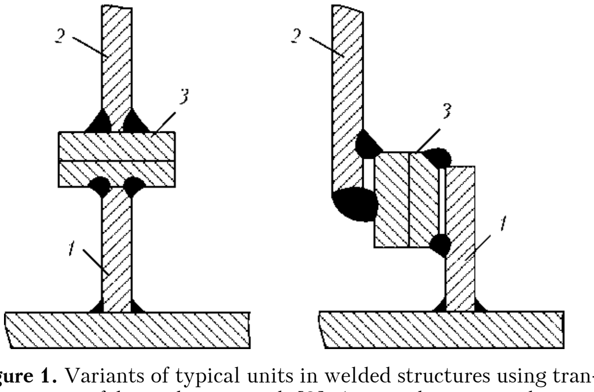

Figure 1. Variants of typical units in welded structures using transition pieces of dissimilar materials [2]: *1* — steel structure element; *2* — aluminium element; *3* — bimetallic aluminium alloy–steel transition piece

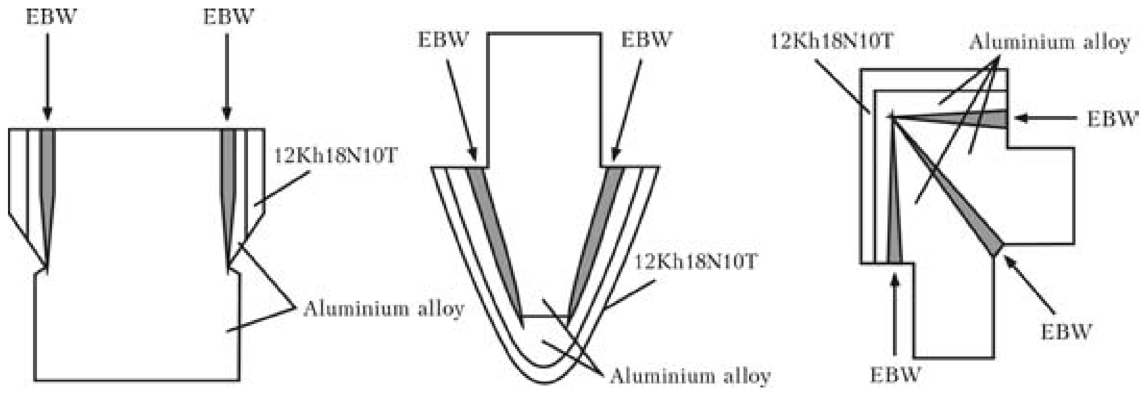

Figure 2. Schemes of welded joints of transition pieces of large thickness

which additionally increases the intermetallic interlayer. Moreover it becomes less dense and as a result not only its strength but also corrosion resistance decrease both under the influence of liquid and gas environment.

The solution for this situation can be application of bimetallic transition pieces produced using explosion welding. In explosion process of producing of bimetal in a certain range of flying speed parameters (2000 m/s and higher) at the interface of metals being welded the wave-formed swirlings appear [5, 6]. Due to increase of impact toughness of near-surface metal layers, the crushing of intermetallic interlayer at the interface and their localization in single areas of metal swirlings occurs. Bimetallic transition piece produced according to this technology is not almost subjected to embrittlement and loss of strength during its further heating in welded joint with other metals.

Also the method of welding steel with aluminium alloys is known when application of bimetallic transition piece is not required [7]. The welding is performed directly by flashing of an edge of aluminium semi-product on the steel edge of a butt, which is previously subjected to coating of intermediate film of modifier elements. Coating of these elements is performed by depositing from the vapor phase in vacuum. These can be titanium, zirconium, nickel and other. The thickness of a film is usually 5–10 μm, but it has continuous metallic bond with a steel, and after flashing on the surface of aluminium edge the modifier elements transform into solid solution of liquid aluminium melt and strengthen it. The strength of these joints of steel with aluminium alloys is at the level of 300–350 MPa. In spite of all advantages of this method, its wide application is limited due to complexity of technological process and large economic costs.

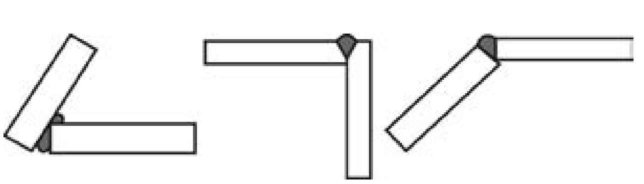

Figure 3. Variants of typical joints during manufacturing of transition pieces for heavy-loaded welded structures of dissimilar materials [3]

Therefore, in welding of products, when application of structure elements with large thickness of welded edges is required, the best variant to be considered is manufacturing of transition pieces using explosion technology. However even in this case in order to avoid at least partial formation of intermetalic solid interlayer along the interface of metals, the best further technology for joining will be the electron beam one. This solution is based on the fact that in electron beam welding the heat input is much lower than in other methods of fusion welding. Consequently in this situation the heating of the interface during welding will be the least. And possibility of welding edges of larger thickness using electron beam and for one pass prevents repeated heating of delimitation zone due to making beads using arc methods on the groove.

During development of design-technological solutions for creation of transition peaces of a large thickness, their further application in the certain structures of products was also considered.

In Figure 2 the variants of typical transition pieces in the structures with an aluminium body and steel framing are presented. Such transition pieces can be applied for example in aircraft building. In heavy transport aircrafts, wear-resistant guides for moving the loads should be located along the floor of fuselage. Except of wear resistance these elements should not increase the weight of a structure in general, therefore it would be more reasonable to produce them in a bimetallic variant.

Another kind of problems appeared during creation of large-sized transport means manufactured of aluminium armor in army subdivisions. These machines of light type are in popular demand especially when using at swampy, sandy soils or in the jungle. Figure 3 shows variants of typical welded joints produced in different spatial positions at a large thickness of elements being welded. Naturally it is necessary to perform welding by multi-pass welds, which is accompanied by considerable overheat of the interface while using bimetallic transition pieces. There is also one more problem to be solved while creating structures of that type. Welded joints of high-strength aluminium alloys, including armor plates, have impact

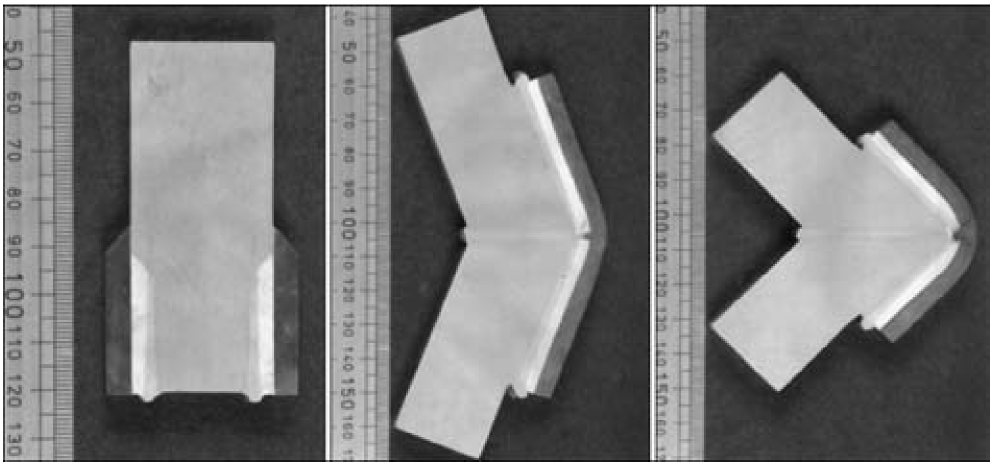

Figure 4. Macrosections of transition pieces manufactured according to new technology using electron beam welding

Conditions of EBW of bimetallic transition pieces of alloy D16

Penetration depth, mm	Welding current I_w, mA	Focusing current I_f, mA	Welding speed v, mm/s	Amplitude of circular scanning A, mm
33	128	618	12	2
41	175	618	12	2
44	185	618	12	2
40	170	618	12	2

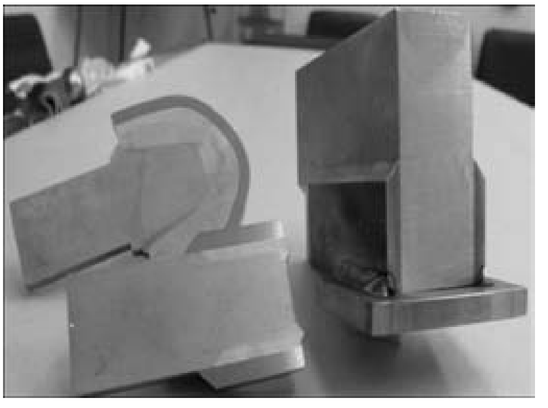

Figure 5. Macrosections and appearance of an assembly after welding-on of transition piece to steel structure elements

toughness of the joints almost twice lower than that of base metal. In this case at local loading of a weld, for example, during hit of a bullet or a shell, a weld is cracked reaching a very large length from the place of loading. Therefore to provide high design strength of these products, the steel armor shield of welds of aluminium armor along the whole length [8] is required. The solution of this task is possible using bimetallic transition pieces shown in Figure 2.

In Figure 4 macrosections of transition pieces of a large thickness of aluminium elements are given manufacturing of which was performed using electron beam in vacuum. The power source with accelerating 60 kW voltage was applied. Welding conditions of transition pieces with different thickness of aluminium edges are given in the Table. Figure 5 shows macrosection of a joint in welding-in of transition pieces to steel structure elements.

The application of principally new solutions for using transition pieces for joining of dissimilar metallic materials in welded structures will provide solution of the problems in many cases during designing and manufacturing of highly-loaded products of light alloys.

CONCLUSIONS

1. The radically new design-technological solutions during manufacturing of steel-aluminium transition pieces as-applied to creation of welded assemblies and products of dissimilar materials of a large thickness have been developed.

2. The variants of typical assemblies and joints of semi-products of aluminium alloys to the steel parts and assemblies during creation of complex heavy-loaded welded structures are given.

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