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Research Paper

Experimental investigation of explosive weld of bimetal ribbed plate based on boss charging

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ABSTRACT

The large-area Cu/SS ribbed plate is very significant for the fusion engineering but is difficult to produce by regular cold or hot processing. This thesis takes Cu-alloy plate and 316L SS ribbed plate as materials and adopts a new form of charging to carry out the deepened study and optimization of the supporting formwork from perspectives of design, filling scheme and welding parameters. It prepares a large-area dual-metal ribbed plate by the explosive weld and conducts the shear strength test, metallographic observation, scanning electron microscopy and micro-hardness test of the weld interface. The result indicates that most weld interface is the wavy metallurgical bond interface of the direct transition of Cu/SS but “coronary” vortexes containing metallic oxide exist on both sides of the crest. Crystalline grains near the bond interface are lengthened and thinned, the micro-hardness is increased significantly and the bond strength of interface is even greater than that of copper.

1. Introduction

The building of a fusion facility needs a large area of 1500 mm × 2500 mm × 6 mm ribbed plate. The ribbed Plate is mentioned light weight structural workpiece which is composed of thin CuCrZr alloy faceplate and SS ribs. The CuCrZr alloy faceplate is used as Heat sink material in fusion facility, and stainless steel ribs can be welded on to other SS plate, thus forming hypervapotron for cooling. Such design meets special requirements on the device but creates difficulties in the production.

The ribbed plate is a kind of metallic composite, and common technologies of metallic composite include hot isostatic pressing, braze welding and fusion welding. Restricted by the device, hot isostatic pressing may not be used to produce the large-area Cu/SS ribbed plate as it is too expensive for popularization [1]. Braze welding has to introduce the brazing flux with a low melting point to the weld interface but the interface is weak in the bond strength and heat resistance that it may not be used to produce the heat-resisting heavy-load structure [2]. Fusion welding is simple in operation that is quite suitable for the large-scale production but it only applies to the welding of dissimilar materials with similar performance. While Cu and SS differs greatly in the melting point and thermal conductivity in the welding, macro-crack usually appears in the joint, and as melted copper and steel may generate the metal brittle compound, bond strength of the joint is quite low and liable to suffer the brittle fracture [3]. It can be seen that the large-scale Cu/SS ribbed plate is difficult to produce by regular cold or hot processing and there is no mature process or technology with this respect yet.

Explosive weld, is a high-energy processing technology which drives metal structures of two similar or dissimilar materials by detonation to give rise to the high-speed oblique collision and generate the high-speed jet flow to remove the oxide film and absorption layer on the metal surface, thus throwing two clean metal surfaces in the close contact to form the solid-state bond [4]. Many scholars have studied the upper and lower limit of charging of the explosive weld, wave-forming mechanism of the interface and microscopic structure of the weld interface from theoretic perspectives to explore the welding mechanism and improve the quality of explosive weld [5–7]. With respect to the application, there has been explosive weld of nearly 300 different metal plates [8], and even successful explosive weld of multiplayer metal foil, amorphous alloy, as well as the hard and brittle alloy [9–11].

Although there are many dual-metal materials produced by explosive weld at present, such materials are limited to dual-metal composite plates, pipes and bars. Studies on the explosive weld of ribbed plate are seldom reported mainly because that the explosive weld of ribbed plate differs from that of common plates greatly, especially that the internal space of ribbed plate needs to be filled, which is quite complicated and difficult to complete [12].

This thesis carries out the deepened study on the optimization of design, filling scheme, charging form and welding parameters of the

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Fig. 1. Photo of Explosive Weld of Ribbed Plate.

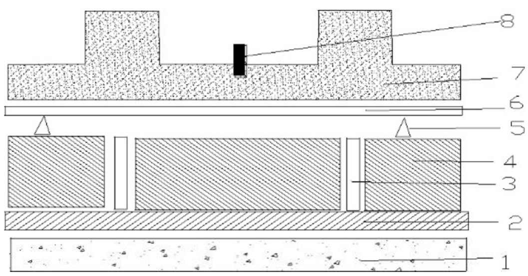

Fig. 2. Schematic Diagram of Explosive Weld Device.
Foundation 2 Base plate 3 Ribbed plate 4 Filling formwork 5 Gap column 6 Faceplate 7 Boss charging 8 Detonator.

Table 1
Shear Strength Test Data of Explosive Weld Test Plate.

Interval (mm)	Shear strength (MPa) Strengthened charging depth (d_{e2},mm)			
	45	50	55	60
10	0 (A1)	0 (A2)	154 MPa (A3)	221 MPa (A4)
12	133 MPa (B1)	281 MPa (B2)	313 MPa (B3)	303 MPa (B4)
14	241 MPa (C1)	387 MPa (C2)	366 MPa (C3)	354 MPa (C4)
16	251 MPa (D1)	265 MPa (D2)	281 MPa (D3)	181 MPa (D4)

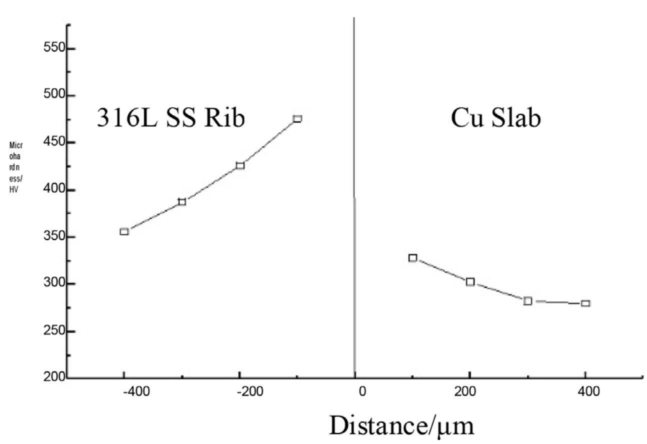

Fig. 3. Micro-hardness Test Result.

formwork to overcome those technical difficulties mentioned above, produces a large-area dual-metal ribbed plate (shown in Fig. 1) by the explosive weld and studies its weld interface.

2. Experimental procedure

2.1. Materials

The test adopts 800 mm × 500 mm × 6 mm Cr-Cu alloy plate and 800 mm × 12 mm × 28 mm 316L SS ribbed plate.

The test adopts emulsive explosive produced by Jiangnan Industries Group Co., Ltd., whose explosion velocity is about 3600 m/s and falls to 2450–2500 m/s when added with the appropriate halite.

2.2. Design and filling scheme of supporting formwork

Explosive weld of the ribbed plate takes the ribbed plate as the base plate and takes the faceplate as the cladding plate, and the ribbed plate should be filled with the supporting formwork. Design and filling scheme of the supporting formwork are quite important but also are very difficult. Influencing factors below should be considered with respect to the high-quality welding: (1) Selection of the material of supporting formwork. On one hand, the supporting formwork should be made of the material whose strength is similar with the rib, otherwise the faceplate may become caved or destroyed. On another hand, the jet flow generated from the collision is bound to carry the composition of supporting formwork that would be retained at the interface in the bonding, so the composition of supporting formwork should be similar with the rib to avoid polluting the weld interface. (2) Mutual clamping. Ribbed plate and supporting formwork would be extended and deformed under the explosion impact and are liable to clamp each other. Therefore, a certain gap should be reserved between the ribbed plate and formwork when the formwork is filled, otherwise the cladding plate may become caved or destroyed by the impact. (3) Prevention of "sticking formwork". As materials of supporting formwork and ribbed plate are the same or similar with each other, supporting formwork and faceplate would be welded under the explosion load. As a result, anti-sticking agent should be painted to prevent the welding between the supporting formwork and faceplate.

In view of those problems mentioned above, the test gives consideration to the characteristic of welded materials, characteristic of materials of the supporting formwork, mechanism of the explosive weld and there mutual influence, and compares design parameters of several supporting formworks and the effect of several filling schemes. Details include: (1) It compares the filling effect of several materials and selects 45# steel plate as the filling material Because its strength is close to that of 316L stainless steel. (2) It is counted that the ribbed plate would be widened for about 5% after being impacted, so the reasonable gap between the ribbed plate and supporting formwork should be about 5% of the width of the ribbed plate. (3) According to the comparative test of the welding resistance of water glass, butter and asphalt with different depth, 0.2–2.25 mm of water glass is selected to be the anti-sticking agent because it could prevent the jet from producing from the Filling formwork and the faceplate.

2.3. Boss charging

Arrangement of explosive is limited to a plane in the common plate-and-plate explosive weld. When ignited, the explosive would form a stable detonation on the surface of the plane to push the cladding plate to bend and form an appropriate impact angle to impact the base plate fiercely. When the velocity and impact angle of the cladding plate meet proper welding conditions, it would generate the jet flow on two metal surfaces to weld such surfaces.

However, it is discovered in the explosive weld test of ribbed plate that the plane charging makes the non-welding area of the faceplate meet welding conditions and generate the jet flow. Although the area is not welded with the formwork due to the welding resist, such jet flow creates plenty of accumulated burl-like metal structures on the surface of the faceplate to damage the smoothness of its lower surface.