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Review

Recent developments in explosive welding

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ABSTRACT

Explosion welding (EXW) is one of the joining methods consisting of a solid state welding process in which controlled explosive detonation on the surface of a metal. During the collision, a high velocity jet is produced to remove away the impurities on the metal surfaces. Flyer plate collides with base plate resulting in a bonding at the interface of metals. The metal plates are joined at an internal point under the influence of a very high pressure and causes considerable local plastic deformation at the interface in which metallurgical bonding occurs in nature and even stronger than the parent metals. Similar and dissimilar materials can be joined by explosive welding. In this paper, after detection the theories of welding and wave formation, experimental research and numerical studies on explosive welding are reviewed for the last four decades. Also, future developments in explosive welding are predicted and criticized in an outlook.

1. Introduction

Current developments in advanced technologies are required for new materials with superior properties such as corrosion, wear resistances for industrial applications. Therefore, numerous works have been carried out to develop new materials for such purposes. As low carbon steel has low corrosion resistance therefore, it may be cladded with the materials such as aluminium, titanium and stainless steel that can be suitable for using in corrosion environment. Explosive welding is a well known for its capability to directly join a wide variety of both similar and dissimilar combinations of metals that cannot be joined by any other techniques. Furthermore, the process is capable of joining with high surface areas due to its ability to distribute the high energy density through explosion [1–4]. Up to now, similar metals (low carbon steel, steel to steel, Al–Al, stainless steel to steel) [5–8], dissimilar metals such as steel and aluminium [9–12], steel and titanium [13–18], nickel film and aluminium alloys [19], iron and copper [20,21], aluminium, copper and magnesium [22–24], copper, titanium and steel [25–29], aluminium and copper [30–32] and also metallic glasses [33–35] were cladded successfully.

There is a considerable demand for cladded plates in both chemical and nuclear industries due to its good corrosion resistance and mechanical properties. Over 260 various similar and dissimilar metal and alloy combinations can be welded by using explosive welding techniques [8]. Explosive selection and detonation velocity are important to obtain the good welds. The collision velocity V_c and the plate velocity V_p should be less than the velocity of sound in either welding component [1,2]. The velocity of sound in engineering materials is typically 4.5–6 km/s, whereas the detonation velocity in common explosive (plastic explosive) is typically 6–7 km/s. [1,2]. A mixture of ammonium nitrate and fuel oil (ANFO) and an inert substance such as sand or perlite is often used with detonation velocity typically between 2 and 3 km/s for this purpose [1,2]. The explosive must supply uniform detonation so as to achieve a collision velocity that will be uniform from the start to finish of the weld. The explosive type and amount per unit area is selected to accomplish the necessary detonation energy [15–17].

In the plate collision zone occurs the pressure impulse within the range of a dozen or so GPa. This process consists of the loading and unloading stage. During a loading process occurs the wavy joint surface and the interpass. The results of unloading are wavy tensile stresses in the plate material and in the joint as well. The both stages influence configuration of joint area. The joint area in the wave joint consists of wave joint surface, interpass and adjoining strain layers of bonded materials. For the joints in initial state those layers are strengthened [1,2].

The bonding interface in explosive and impact welding presents three morphologies: wavy, straight and melted layer. These morphologies have received a lot of attention and discussions [5–15]. For technical purposes, these morphologies depend on the impact velocity and angle. The interface developed is related to two important phenomena that take place during bonding: rarefaction wave interaction and mechanical friction. The propagation of compressive and tension waves inside the material due to the impact and shock induced by the detonation, as well as their interaction, is responsible for the first phenomena. Sliding due to the acceleration of the flyer plate onto base plate, as well as the jet formation and its interaction with both flyer and base plates is responsible for

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