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STRUCTURE, PHASE TRANSFORMATIONS, AND DIFFUSION

Inhomogeneities of the Interface Produced by Explosive Welding

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Abstract—Results of studying structure of the transition zone for a number of joints produced by explosive welding are presented. The joints of dissimilar metals (titanium–orthorhombic titanium aluminide, copper–tantalum, and others) have been investigated. The welded pairs of metals differ from each other in mutual solubility; moreover, some pairs (copper–tantalum) virtually lack it. The interface was found to be uneven; it contains inhomogeneities, irrespective of whether it is flat or wavy. It is shown that the formation of interfacial protrusions determines the adhesion of materials. A granulating fragmentation has been found near the protrusions. The role of various processes in explosive welding has been discussed. The formation of protrusions does not depend on whether the metals of a pair have mutual solubility or not. However, this factor affects the structure of zones of local melting. The metals that have mutual solubility form true solutions; in the absence of solubility, these zones represent colloidal solutions. It is shown that sometimes the local melting zones do not present a real danger for the strength of the joint. A hypothesis is proposed that the formation of a wavy surface is possible through the self-organization of the previously formed protrusions.

Keywords: explosive welding, joint formation, transition zone, fragmentation, local melting, nanoparticles

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INTRODUCTION

To optimize welding parameters, it is first necessary to study the structure of the joints and, based on it, to determine the regularities of their formation. With all the variety of materials and welding regimes, the central problem is intermixing in the transition zone near the interface [1]. It is the structure of the transition zone that determines the bonding of the materials upon welding.

Intermixing occurs due to a high-intensity force impact which involves large plastic deformation (including pressure, shear components, rotatory moments of the stress, strain inhomogeneity, etc.), surfaces friction, effect of the cumulative jet, and other factors. But it so far remains unclear how, even at such a strong external action, the metals have time to mix in such a short welding time? There arise a whole number of questions:

—Are atomically-clean surfaces required to ensure weldability or not?

—What type of the surface (flat or wavy) is preferable for mixing?

—What is the role played by the melting (local melting or melting that occurs over the entire interface)?

—What is the role played by the mutual dissolution of materials and how the intermixing of immiscible suspensions occurs?

—How does the intermixing occur upon welding of a metal with an intermetallic compound?

—To what extent is melting dangerous during metal–metal welding if intermetallic compounds can form in the melting zone?

The hypotheses on the nature of weldability are based on different physical principles (see, i.e., [2]): either it is assumed that atomically-clean surfaces are required for the formation of metallic bonds; or it is assumed that the surface adhesion after bringing metals together to atomic-order distances is carried out by mass transfer by moving vacancies and dislocations; or assumed that the joint is formed as a result of growing common grains through the interface due to recrystallization. In addition, some models assume the possibility of the formation of active sites on approaching metal surfaces with the subsequent integration of the centers such as, e.g., dislocations.

Without considering these models in detail, we note only the following. The question of when and in which way the thermally activated processes start working is central for the analysis of mixing. It is necessary to find out which of the processes have time to