Structural strengthening and softening mechanisms in the bonding zone of explosively welded sheets

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Abstract

In this work, the competition between various hardening and softening processes in explosively welded (EXW) metallic sheets was studied by means of transmission electron microscopy (TEM), scanning electron microscopy (SEM) equipped with electron backscattered diffraction facility (EBSD) as well as synchrotron diffraction. Special attention was paid to the explanation of the mechanism of phases transformation in the clads composed of reactive metals (Ta, Ti, Mg, Nb or Zr) in various metals combination. We concluded that several important and beneficial mechanical features are strongly linked to the complex and hierarchical structure of the reaction regions and strain-hardened and recovered/recrystallized layers of the parent sheets/plates.

The most important phase transformations upon EXW occur because of local melting and high-speed cooling, which lead to the formation of ultra-fine-grained or amorphous phases with high hardness. TEM analyses show that the amorphous regions were found along with disordered and coexisted nanograins ranging below 100 nm in diameter with a parent crystal structure of pure metals. Upon further annealing, the migration of atoms inside solidified melt (mostly due to spinodal decomposition) and across the interface leads to the formation of layers composed of equilibrium intermetallic phases. All these phases are distributed along the entire length of the welding interface. SEM/EBSD orientation measurements revealed that the interfacial layers of the parent sheets underwent severe plastic deformation. It is shown that energy stored in severely deformed areas provides the driving force for recovery and recrystallization already during clad manufacturing, which then led to clad softening due to new stress-free grains formed close to the interface. Based on experimental results a new explanation for the reaction region formation is proposed and a significant modification of the description of the interfacial microstructure of parent sheets is performed.

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