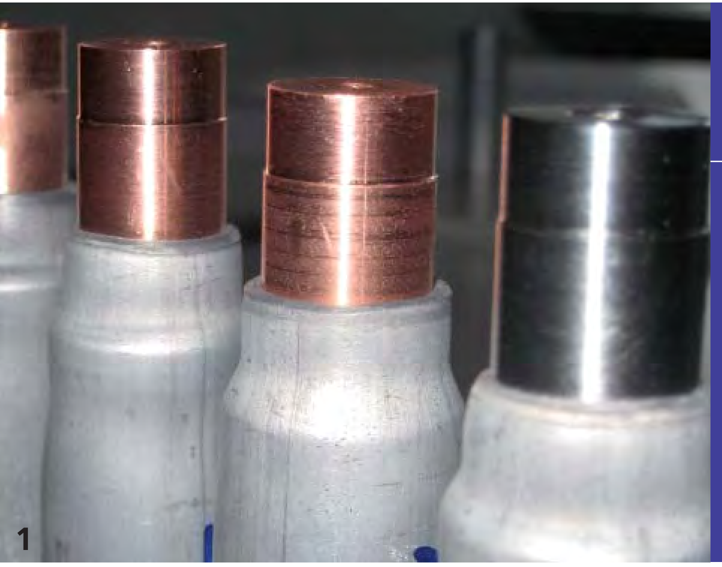


1

ELECTROMAGNETIC PULSE WELDING TO FABRICATE MIXED MATERIAL JOINTS

THE TASK

Today it is unimaginable to not have melt-based welding processes in modern manufacturing environments. In particular, laser beam welding processes are the method of choice to efficiently join materials with high quality. However, melt-based processes face difficulties if the materials to be connected are significantly different such as aluminum and copper. Such materials form intermetallic phases in melt conditions, which can limit the achievable strength of the joint. Similar challenges occur when welding alloys are prone to hot cracking. Here the sequential melting and solidification steps lead to a crack-laden material structure, substantially weakening the resulting joint.

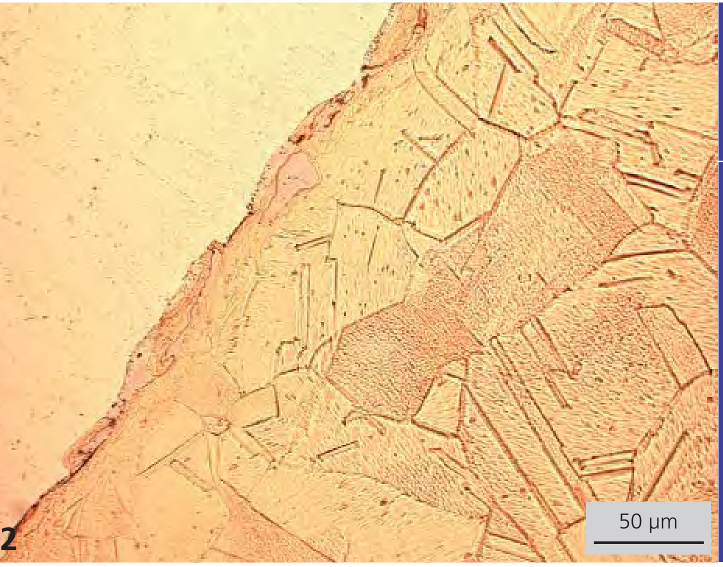
The goal is to establish alternative processes for manufacturing critical mixed material joints in industrial applications, which connect materials without generating localized melts and achieving high strength seams.

OUR SOLUTION

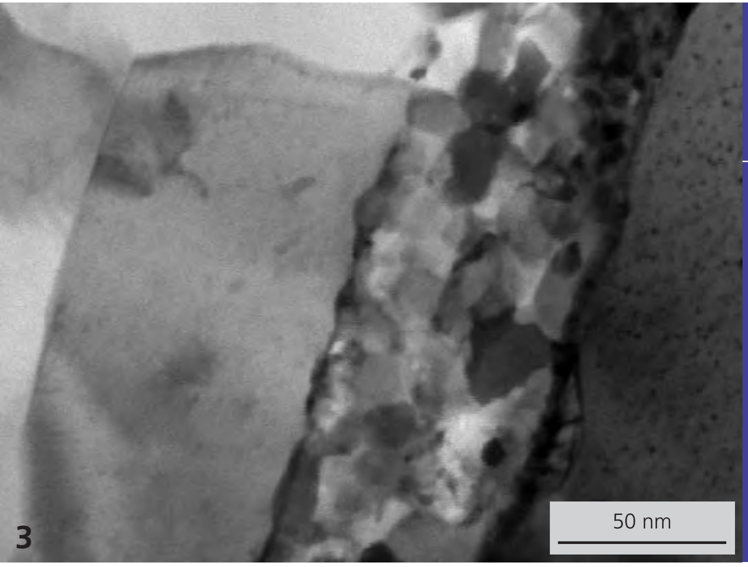
It is known from explosion welding that extreme localized pressures may lead to quasi melt-free welding of virtually any metallic material combination. This process has disadvantages such as high costs and time consumption as well as limited application in terms of geometry. However, the same physical principle is applied during the so-called electromagnetic pulse welding. The localized pressure pulse is generated in the part itself through the interaction with a contactless magnetic field pulse. The technology is mostly known as a contactless forming and form fitting process for metals. However, when selecting the appropriate process parameters it is also possible to generate an atomic level weld connection (electro magnetic pulse welding, EMPW).

The IWS process uses a current carrying tool coil, which couples via its magnetic field to the workpiece (i.e. the end of a pipe) and induces eddy currents. The interaction of the externally applied magnetic field and the generated eddy currents causes Lorentz forces, which suddenly compress the pipe. When the inner surface of the collapsing pipe hits, for example, a shaft at sufficient velocity, it is possible to achieve a material bond with extremely low heat input and without generating a heat influence zone.

The implementation of the processes requires special systems engineering, which was developed in cooperation with the "Dresden High Magnetic Field Laboratory" at the Helmholtz-Zentrum Dresden Rossendorf. IWS engineers use the equipment to perform research on the basic process itself as well as process development and optimization work to address industrial tasks such as the welding of mixed materials. Of particular interest during such investigations is the interface between the different materials, since this region is key to the strength of the joint. The investigations help to improve the process and also to adapt and optimize it to achieve the desired properties.



2



3

RESULTS

Mixed material joints of different combinations (Fig. 1) were analyzed with respect to their properties over a broad parameter range. It was confirmed that the process is capable of atomically welding drastically different metals. Metallographic analysis (Fig. 2) in combination with SEM and TEM studies (Fig. 3) demonstrated welded mixed material joints in Al / Cu and Al / steel interfaces made of nanoscale intermetallic phases seemingly free of transition zones. Both the phase seam thickness as well as the phase type depended on the coupled pulse energy. High resolution TEM analysis confirmed that such seams occur everywhere along the connection with thicknesses as thin as 50 nm – 200 nm. If the seams get as thick as 5 µm cracks may occur.

Optimizing the process parameters and in particular minimizing the pulse energy showed good results for all of the studied material combinations. The formation of intermetallic phases was reduced and the seam quality of the axial symmetric joint was high. It is also important to study the material in close proximity to the interface region and to identify potential changes. In copper-aluminum seams there appeared a pressure or forming induced recrystallization zone. This zone consists of an ultra fine-grained material structure in the direct vicinity of the interface. This structure formation is a side effect of the physical principle and improves the joint strength.

1 Pipe-tap joint, mixed material joints from aluminum / copper and aluminum / steel

2 Detailed optical microscopic image of atomically welded aluminum-copper interface

3 Transmission electron micrograph of an interface between aluminum and copper with nanoscale fine grain structure

DRESDEN concept

CONTACT

Dr. Gunther Göbel

phone +49 351 83391-3211

gunther.goebel@iws.fraunhofer.de