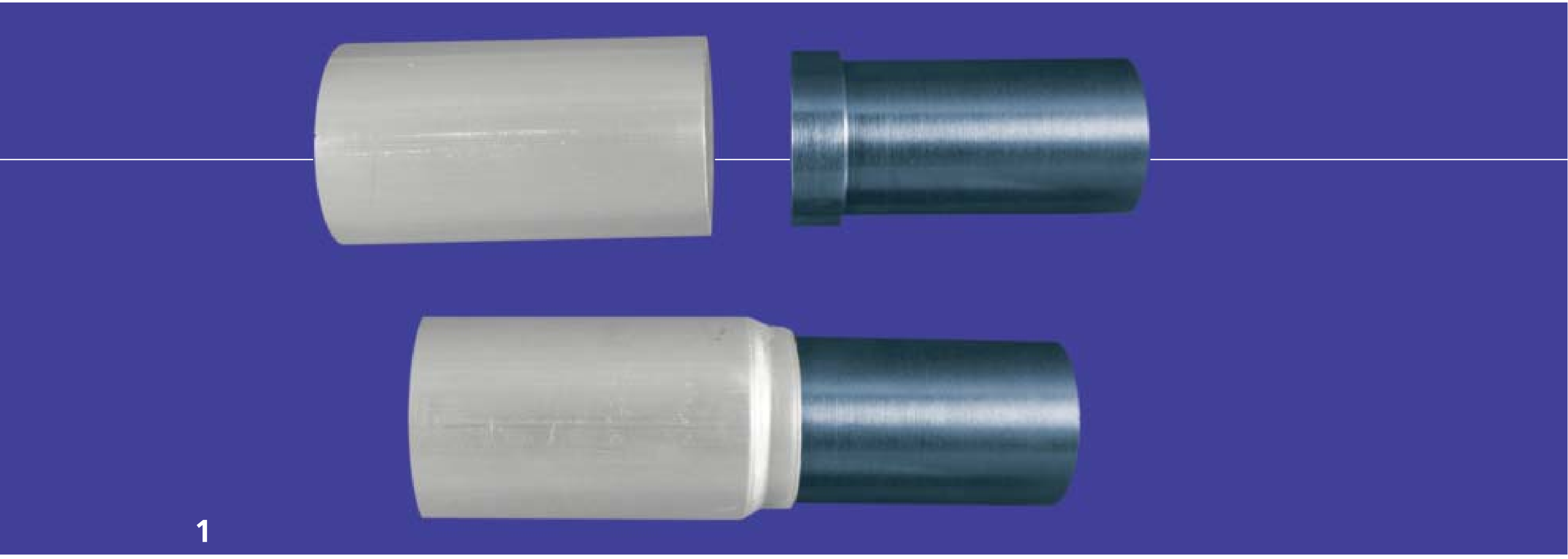


1

MAGNETIC PULSE WELDING – A NEW JOINING PROCESS WITH POTENTIAL

THE TASK

High-speed metal joining processes are increasingly important to industry. High-speed processing implies low thermal loads, which makes them especially suitable for the joining of dissimilar materials.

Magnetic pulse welding (MPW) exposes the part to a transient magnetic field resulting in strong Lorentz forces acting upon the joining region. This process has many advantages over the widely used process of explosive welding. It is a safer and contactless method. The variety of weldable parts is larger and pre- and post-processing steps are simpler. A so-call jet current builds up during the process, which cleans the surfaces from oxides and other contaminations. Collision pressures exceed one thousand MPa to firmly bond mixed metal combinations. Partial melting and the formation of brittle intermetallic phases are subdued and the resulting joints are of high mechanical strength.

Solid-state shock welding processes require accelerations, which can be applied in several ways. The process inherent ever-changing collision conditions make it difficult to achieve homogenous joining regions. However, homogeneous conditions are absolutely necessary to achieve high quality bonding. The task is to find optimal welding parameters as a function of materials and given geometries.

OUR SOLUTION

Fraunhofer IWS engineers have three machines to study magnetic pulse welding processes. A wide parameter range can be applied to identify the most suitable welding setup for a given part. The maximal charge energies of the pulse generators are 32 kJ, 40 kJ and 160 kJ. The corresponding discharge frequencies are 25 kHz, 12 kHz and 20 kHz.

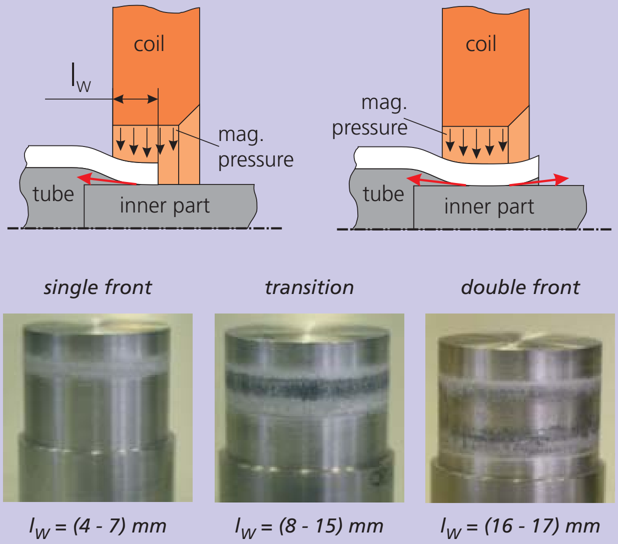
The electric current rises in fractions of a second and causes a strongly changing magnetic field inside an inductive coil where a conductive tube is located with a part inside of it. Following Lenz’s rule, a current is induced inside the conductive part as well. This current carries a magnetic field opposite the magnetic flux of the coil, which results in a mechanical force. This Lorentz force acts towards the coil as well as toward the part.

The deformation velocities can reach several hundreds of meters per second. The kinetic energy of the accelerated tube is sufficient to firmly bond it with a part inside of it. An important parameter is the position of the tube, which was studied in a DFG project (Priority Program 1640). The varied working length l_w denotes the axial position of the tube towards the edge of the coil.

RESULTS

The study analyzed data from numerical magnetic field simulations, velocity measurements and metallographic studies of the joining zone. Several dependencies became apparent. The energy input is important and needs to be adjusted accounting for the stiffness of the material. The working length l_W is also critical. For example, a variation of l_W for a coil of a width of 15 mm yields clear differences in the crimping behavior of the tube.

Crimping behavior and front propagation as a function of working length l_W and photos of the inner parts (bottom row)



single front *transition* *double front*

$l_W = (4 - 7)$ mm $l_W = (8 - 15)$ mm $l_W = (16 - 17)$ mm

2

Increasing working length causes a transition from single to double front lines (Fig. 2). The red arrows show the jet current. In the transition region (middle of Fig. 2) there is no jet current since the materials collide flat. The collision front does not propagate sideways as in the other cases. This suppresses the formation of a firm bond.

The opposing propagation directions of the collision fronts can be advantageous. They reduce the risk of shearing during the crimping process. Therefore adjusting the effective length helps to tailor the process to different material combinations. This technique was used to create special joining processes for industrial applications with high requirements for leak tightness and electric conductivity.

1 Magnetic pulse welded mixed material joint (bottom) consisting of steel and aluminum tubes

CONTACT

M.Sc. Amanda Leigh Lorenz
phone: +49 351 83391-3716
amanda.leigh.lorenz@iws.fraunhofer.de