

# ALUMINUM-STEEL SHEET JOINTS – ENABLED BY MPW

## THE TASK

Electromagnetic pulse welding (MPW) is a new process to bond different types of materials in their solid state phase. The physical principle is to accelerate conductive materials by means of magnetic pressure caused in variable magnetic fields. Due to the strong acceleration, the material deforms and ultimately collides with a second material. During impact the collision zone experiences strong deformation and high collision pressures, which lead to cold welding of the materials.

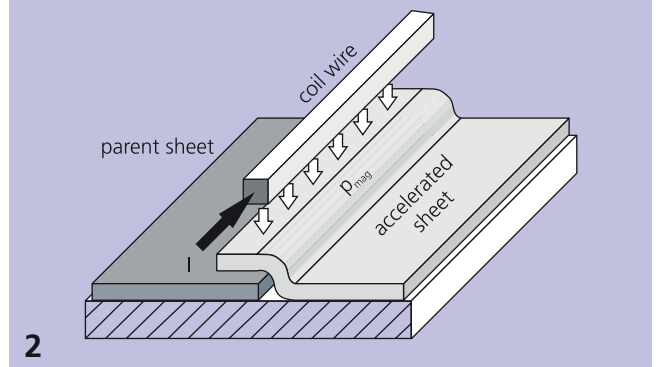
At the Fraunhofer IWS Dresden this principle was applied to develop a joining process for rotationally symmetric parts in overlapping configuration. The process was successfully demonstrated for aluminum-steel, aluminum-copper and copper-steel combinations whereby the welded joints were free of brittle intermetallic phases. The coil dimensions are designed for high mechanical loads so that they accelerate the outer tube to high velocities for forming. Thus the coils can be used for many forming pulse cycles.

It is also possible to apply magnetic pulse welding to join flat metal sheets. However, the design of the coils is a particular challenge. The coil wire needs to be very strong but should also have a small cross section so that it produces high magnetic fields. Resolving these opposing factors requires novel coil designs.

## OUR SOLUTIONS

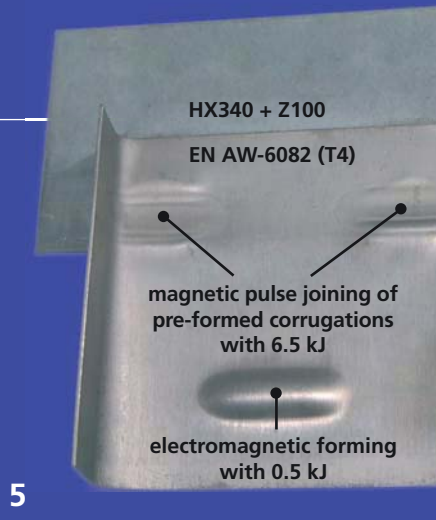
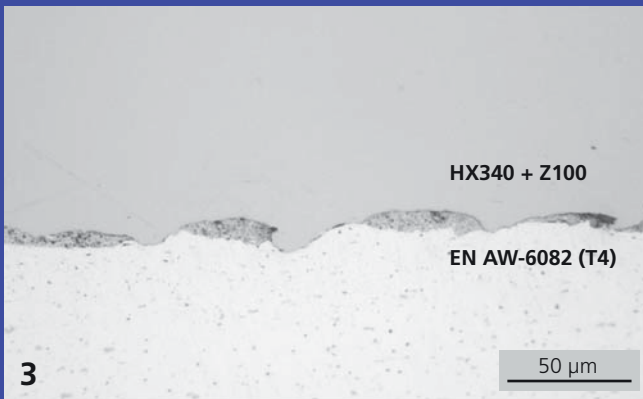
A new coil was developed for electromagnetic pulse welding processes for metal sheets. The coil design considers the required currents as well as the occurring electromagnetic forces. The principle is shown in Figure 2.

*Schematics showing the functioning of a flat coil for the electromagnetic pulse welding of metal sheets*



Initial experiments showed that a single welding process takes about  $30 \mu\text{s}$  and that this time is independent from the length of the weld seam. A high speed camera system was used to measure the collision velocities of the sheets (Fig. 4). These were as high as  $300 \text{ m s}^{-1}$ .

These results served as input data to numerically simulate the expected impact loads, which are transferred to the support structure of the parent sheet. Fraunhofer IWS performed additional FEM simulations to optimize the complex distributions of magnetic pressures and current densities aiming at highest process efficiency.



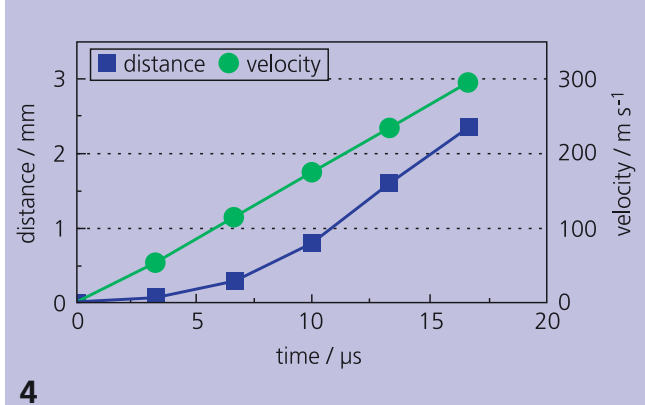
## RESULTS

The coils were designed with the required flexibility to adapt them to the particular joining task. The fixture can hold coils of different widths and contours. The magnetic pressure intensity distribution is adjustable to work for the selected material combinations and thicknesses.

The support structure for the parent sheet is designed so that it is possible to weld nearly unlimited lengths of overlapping material. The structure can be adjusted for height so that sheets can be welded with different thicknesses and also joined in combination with profiles.

Figure 3 shows the polished cross section of a linear joining zone between galvanized steel and aluminum sheets. The wavy interface is typical for electromagnetic pulse welding processes. First mechanical tests have shown that the joint strength exceeds the strength of the aluminum. This can be attributed to strain hardening effects that occur during high velocity forming and collision.

Measured position of the accelerated sheet during electromagnetic pulse joining (high speed image with 300,000 images per second)



The process is very fast and does not require complex pre- and post treatments, which is a great advantage. The method is useful to fabricate semi-finished products as well as for assembling products. The different kinds of materials are welded as lap joints and are immediately ready for further processing.

The process is also useful for car body construction. Here lap joints are typically welded with resistance spot welding of two overlapping steel sheets. Magnetic pulse welding can also firmly bond different materials in this configuration. The welding gap is used for accelerating the material toward the joining zone. Unnecessary positioning efforts are avoided by placing corrugations into the sheet. Subsequently the sheets are placed together without additional gap just like in conventional welding. Finally, the magnetic pulse welds the sheets together where the corrugations are. Figure 4 shows a part with bead-like corrugations as well as the magnetic pulse welded stitched seam between aluminum and steel sheets.

- 1 Copper coil with centered coil bar
- 3 Microscope image of the joining zone
- 5 Steel aluminum hybrid sheet fabricated with dual stage welding processes

## CONTACT

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