THE TASK

Lightweight construction solutions benefit from the flexibility of selecting materials that best match the desired application. The automotive industry is particularly interested in hybrid material constructions made from metals such as aluminum and steel. Thus safely bonding different materials poses a key challenge. The metals need to be firmly bonded since sheet metal components will undergo forming processes during production and final concepts are often exposed to high thermal and mechanical loads as well. Many metal combinations are hard to weld with conventional processes. Intermetallic brittle phases tend to form in the welded joints. This is undesirable since such joints are then difficult to deform, which ultimately limits the usability of the multi-material sheets. The task is to develop welding processes that suppress intermetallic phase formation so that the multi-material metal sheets are suitable for subsequent forming processes. The weld has to be fabricated in a butt joint layout so that conventional forming tools can be used.

OUR SOLUTION

A two-stage process was developed to firmly bond different metals such as steel (DC04) and aluminum (AlMg3). The first step is a laser induction roll-plating process (Fig. 2a, pages 24/25). This process creates a bimetal band of the desired material combination. Two metal strips are inductively preheated and by means of laser radiation, heated to joining temperature. Then both strips are pressed together via roll plating to bond over a large surface area. The result is a semi-finished product with little intermetallic phases that is malleable and can be subjected to forming processes. This part serves as the transition joint to connect two different metal sheets. These are laser welded whereby each metal is joined with its own kind to the transition joint (Fig. 2b, c). Such transition joints can be fabricated by many designs including overlapping and butt joints. Traditionally the joint would have to be made from more similar metals that can be joined via welding, such as in tailored blanks.

Process schematics of the fabrication of steel-aluminum hybrid sheets suitable for forming
RESULTS

Several tests were performed to judge the strength and quality of the transition joints. Metallographic analysis (SEM) showed that the laser induction roll plating process forms intermetallic phases, however, this zone is less than 1 μm thick (Fig. 4). The energy input of subsequent treatments such as laser welding and cataphoretic painting (180 °C, 20 min) does not significantly influence the intermetallic joint zone. Therefore the dimensions of the zone containing intermetallic phases remain small. Such a thin seam presents a high-strength and yet ductile joint.

Tensile testing showed that the joint is as strong as the aluminum itself. The excellent ability to deform the joints was shown in various tests (Fig. 4). In addition, crash tests were performed with box sections made from steel and aluminum sheets. The results indicate that these multi metal constructions are well suited for vehicle structures that may experience sudden impact, such as crossbars. The multi metal construction saves 30% in weight compared to conventionally spot-welded steel sections. And yet, the increased stiffness of the structure guarantees sufficient crash safety despite the use of lightweight aluminum. Designing such structures requires knowledge about the load distribution within the components. These data were obtained via FE simulations. The techniques can also be applied to analyze the fabrication and application performance of specific customer designs. The institute offers to analyze realistic application requirements, to select the appropriate materials and to design the hybrid components. In addition we offer the development of laser induction roll plating and laser welding process as well as testing the joints.

1 Bent steel-aluminum hybrid sheet
3 Steel-aluminum deep drawing part

Polished cross sections of the joint zone in SEM (top) and microscope images (bottom)