Collision welding

Investigation of the formation mechanisms of the bonding zone in collision welding

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Abstract

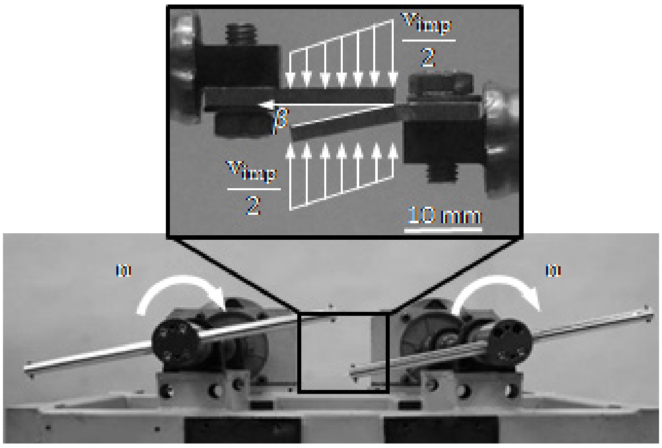
Investigations using a special model test rig provided important insights into the high-speed joining process collision welding. It was shown that, depending on the process conditions, the phenomena occurring in the joining gap can be harmful or beneficial to the formation of the bond.

Project description

Electromagnetic pulse welding (EMPW) is particularly suitable for joining dissimilar metals, since high bond strengths can be achieved. However, the investigation of the interacting phenomena during the welding process in the joining zone is very challenging due to the limited accessibility of the EMPW and its unsteady process conditions. At the beginning of the project, the correlation between input parameters (e.g. material properties) and output parameters (e.g. joint strength) was unknown. As a direct consequence, joints in industrial applications had to be designed empirically, which led to considerable losses in working efficiency.
Therefore, the aim of this project was to close this gap by means of a targeted parameter variation with temporally and spatially highly resolved investigation methods. The core element of the investigations was a special model test rig designed at the PtU (see Figure 1), which combines definable and constant process parameters with good observability. Together with high-resolution high-speed images, new process insights could be gained.

Results

The EMPW process has been successfully reproduced in the model test rig, which was additionally validated by numerical simulations. Based on this, the process parameters (impact velocity and collision angle) as well as different materials, surfaces and ambient media were selected and the effects of their variations were analyzed.
After reaching a minimum impact velocity, a successful bond formation by collision welding depends significantly on the chosen collision angle. The resulting joining gap geometry between the joining counterpart influences the interaction of several mechanisms. Due to the high strain rates, the continuing collision forms a characteristic material stream at the collision front, which is called jet. In addition to the jet, a cloud of particles is formed by dispersed particles (see Figure 2).
For a successful material closed bond, the jet and the particle cloud must be ejected out of the joining gap and must not be slowed down by friction with the inner surfaces of the gap or the gas inside the gap. Otherwise they will be trapped again by the advancing collision front and prevent contact of the activated base material and thus bond formation. On the other hand, they also determine the thermal conditions in the collision region by the stored thermal energy and thus influence the predominant bond mechanism. The results showed that the formation of the bond can be achieved in solid or liquid state, depending on the process parameters and the material properties. This, in turn, influences the mechanical properties of the joint, for example by the formation of pores or intermetallic phases.
These findings could be successfully transferred to the EMPW process. Now it is possible to simplify the design of the EMPW and to optimize the joint properties.



[1] Functional principle of the model test rig: two driven rotors accelerate two joining partners mounted at the ends and lead to collision at an defined impact velocity v_{imp} and collision angle ß.

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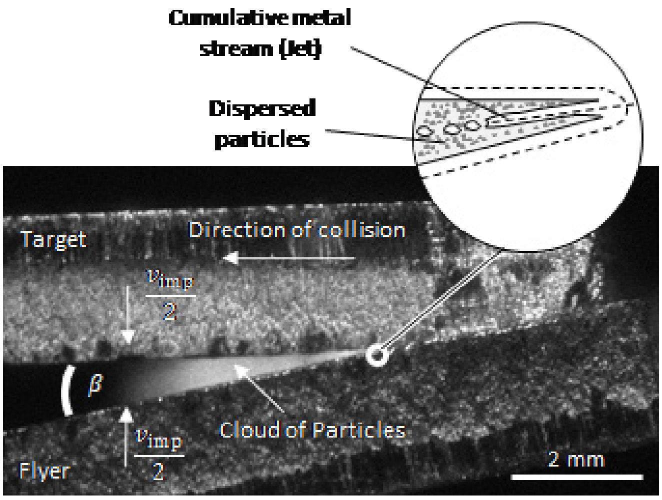

[2] : High-speed image of the joining gap during the collision welding process. In detail: Formation of the jet as a cumulated metal stream and the particle cloud by dispersed particles.

Acknowledgement

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