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Heat Generation during Mechanical Joining Processes – by the Example of Flat-Clinching

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Abstract

During mechanical joining processes, high equivalent plastic strains occur in the joint area (e.g., flat-clinching: $\varphi_{eqv} > 3.0$). This causes a high deformation energy within the forming zone. In cold bulk forming, approximately 80 % of the plastic energy is converted into heat due to internal friction at the grain boundaries. Compared to other forming processes, mechanical joining processes are characterized by short process times and high strain rates. Therefore, the converted heat cannot dissipate from the forming zone by heat radiation or heat conduction. For this reason, a significant heating of the joint area is expected. Within the scope of this work, the emerging heat shall be analyzed experimentally as well as numerically. There is an extremely high contact pressure in the joint area, which would result in a destruction of any thermocouple. Hence, it is not possible to determine experimentally the temperature within the forming zone. For this reason, a reference setup was developed for determining the increase of temperature during flat-clinching. This measurement serves as a basis for the verification of the numerical temperature calculation. During the numerical investigations, the influence of the component heating on the forming result and forming forces was analyzed and compared to simulations without consideration of the heating.

Keywords: mechanical joining, flat-clinching, finite-elements, adiabatic heating, dissipation energy

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1. Introduction

The increasing importance of mechanical joining has led to a multitude of new developments in this field. Conventional clinching technology offers numerous advantages, e.g., no thermal distortion and weight reduction by omitting additional complementary joining elements. However, the most significant limitation is the exterior protrusion, which results in a bump jutting out of the sheet plane (see Fig. 1a). Because of this protrusion, conventional clinching technology cannot be used for visible areas (e.g., automotive body shells) or functional surfaces (e.g., sliding surfaces or flange sections with rubber seals). To avoid this problem, the so-called flat-clinching was developed at Technische Universität Chemnitz. Here, in a single step forming process, a punctiform one-sided planar joint is produced (Fig. 1b). Therefore, the cavity-like, split or un-split die (as is used in conventional clinching processes) is replaced by a planar anvil. This allows generating a sturdy, force- and form-closed joint, which now can be used for applications in visible areas and functional surfaces. Fig. 1 shows the schematic cross sections of a conventional clinch joint and a flat-clinch joint, as well as the corresponding geometry parameters: neck thickness (t_n), bottom thickness (t_b), interlocking (f), and protrusion (p).

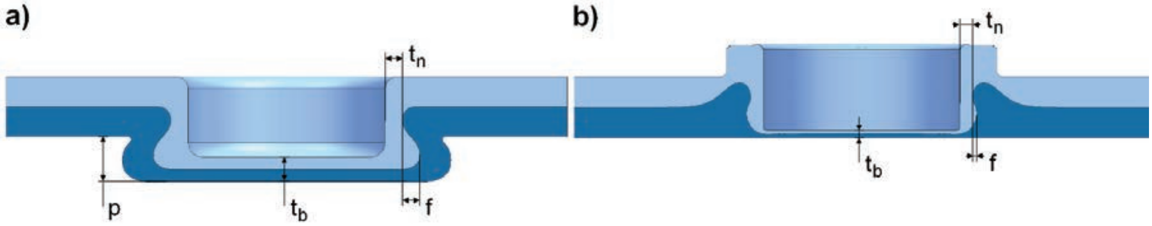

Fig. 1. Schematic cross sections of a conventional clinch joint with exterior protrusion (a) and a planar flat-clinch joint (b).

Fig. 2 shows the working principle of flat-clinching. The two sheet metals are placed upon a planar anvil. Afterwards, the blank holder moves down and fixes the workpieces in place. The blank holder force influences the material flow during the process and depends on numerous parameters, e.g., the used material and sheet thickness. Subsequently, the punch moves down, too, and forms the material so that the characteristic interlocking within the total material thickness is established.

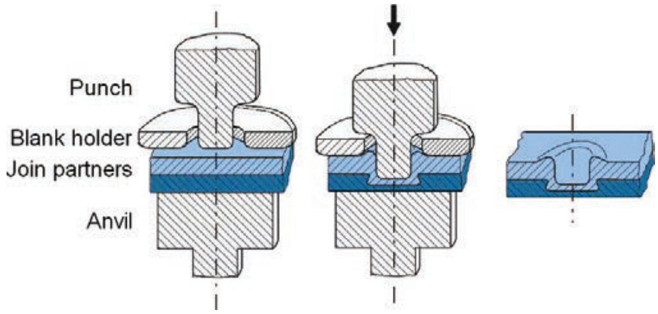

Fig. 2. Working principle of flat-clinching.

There are many research projects dealing with the numerical investigation of conventional clinching. A detailed overview of published research related to the finite element modeling of the clinching process can be found in [1]. Typically, because of the rotational symmetry of the joining area, 2D axisymmetric FEM-models are used for the simulation of the clinching processes [2-5].

For the first time, flat-clinching was numerically simulated in [6-8] by means of the FEM-software Simufact.formingGP V9.0. According to the simulation of conventional clinching and for reducing the computational expense, a 2D axisymmetric model with rigid tools was used. The investigations revealed that for flat-clinching of metals with different tensile strengths the geometry of the blank holder has to be adapted. Furthermore, it has been