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Forging of Lightweight Hybrid Metallic-Plastic Components

Marcel Graf*, Sebastian Härtel, Carolin Binotsch, Birgit Awiszus

Technische Universität Chemnitz, Professorship Virtual Production Engineering, Reichenhainer Str. 70, 09126 Chemnitz

Abstract

With the focus of lightweight constructions, the process line from producing of semi-finished products up to the second processing step of forging was investigated for composite of plastic (PA6) and aluminium alloy (EN-AW6060). Especially the material or deformation behaviour were determined fundamentally. For analysing the temperature-dependent material flow, the three basic kinds of forging (upsetting, rising and spreading) were considered under laboratory conditions by using an oil-hydraulic forging press. The results show that the temperature profile over the cross-section of the composite and the ratio between aluminium and plastic is sensitive for the process stability and the forging of faultless components. Due to the decomposition temperature of the plastic, a gradient temperature is necessary for the forging of hybrid plastic-metal composites. It must also be regarded that the diameter-height-ratio is important to eliminate the risk of buckling during upsetting. Additionally, the physical simulation takes into account for the identification of the process window for forging. The potential for weight reduction of the plastic-metal-hybrid is approximately 30 % higher in comparison to a monolithic aluminium component.

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Keywords: bulk forming; upsetting; flow curve; EN-AW6060; PA6; FEM

1. Introduction

The lightweight design plays a more and more important role, because it is the most important part with regard to efficiency increase and resource protection and amounts therefore decisively for the CO_2 reduction for over decades. In general, this aim can be taken into account by topology optimisation or material substitution. Above all the use of

* Corresponding author. Tel.: +49-371-531-31796; fax: +49-371-531-8-31796.
E-mail address: marcel.graf@mb.tu-chemnitz.de

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"new" materials or hybrid composites will be put to metal forming processes repeatedly before new challenges. On the one hand, the high strength materials, which are often difficult to form, are used to have to dimension the components with the same load more slightly. On the other hand, lightweight alloys are processed meanwhile, which have mostly a lower mechanical loading capacity up to the failure/fracture in comparison to steel. However, they are not suited for crash relevant components but for lightweight constructions. The necessary technologies for the production of semi-finished products as well as for the second processing step (component manufacturing incl. joining) are not completely available.

For manufacturing of an interlocking connection and substance-to-substance bond composites of plastic and metal the metal component has the function to increase the mechanical properties of the plastic with its toughness and strength as well as its ductile material behaviour. The plastics in the hybrids have the opportunity to reduce the weight and reinforce critical regions of force initiation so that failures can be prevented early. Compared to monolithic metals or plastics, the combination of metallic and polymeric materials offers better overall properties than the individual materials, depending on the application area and application [1]. In the field of sheet metal forming processes, there are some basic investigations of hybrids consisting of thin cover sheets (thickness 0.2 – 0.25 mm) of aluminium or steel with high content of titanium and an intermediate layer of non-reinforced polypropylene (PP, thickness 0.4 – 0.8 mm) [1, 2, 3, 4]. On the basis of a deep drawing process in which plastic-metal laminates were deep drawn, the known failure modes of conventional deep drawing processes (wrinkles, sheet thinning, cracks) occurred in additional effects such as slipping, residual stress minimisation and delamination of the single layers. [2, 5]. The compensation of these defects was achieved by combining a deep drawing process with injection moulding or the use of the liquid plastic for hydroforming processes, whereby the metal-polymer composites can be produced in a one-step process and this makes a contribution to shortening the process chain [6, 7, 8].

In almost all cases, composite productions are supported by the additional use of adhesion promoters with different chemical characters. An experimental and numerical investigation of the process limits of a shortened process chain was used for the production of hybrid components (e.g. gear wheels) by precision forging. Thereby, the focus was on the inductive heating of the hybrid semi-finished product. Additional, an interlocking connection and substance-to-substance bond have to be realised within a few process steps, whereby the monolithic initial materials were put together. There was no bond before deformation (Fig. 1) [11].

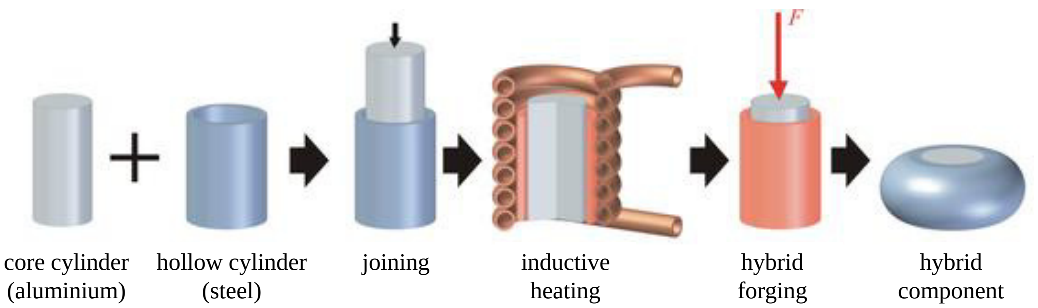

Fig. 1. Process chain for hybrid forging corresponding to [11]

The following investigations analyse the basic forging processes during die forging to identify the formability of metal plastic hybrids. For plastics, the general deformation behaviour has to be characterised and modelled. Thereby, the physical simulation was used to develop a forging technology for hybrids without adhesion promoter.