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Analysis of fundamental dependencies between manufacturing and processing Tailored Blanks in sheet-bulk metal forming processes

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Abstract

Forming of parts with thick-walled functional elements out of sheet metal requires innovative manufacturing methods and a fundamental and holistic process understanding. The sheet-bulk metal forming process applied in this investigation is a single-stage combination of deep drawing and upsetting. It enables the manufacturing of cups with circumferentially arranged functional elements, such as gears or carrier geometries. The basic geometry is formed in a deep drawing operation. During the subsequent upsetting, the gearing is manufactured. Potentials and limitations for the application of conventional blanks were identified, the interactions between process parameters and semi-finished product properties were analyzed and the influence on part properties was quantified. Previous investigations have shown that the application of blanks with a varying sheet thickness is expedient to enable improved die filling and preventing the grooving of the cup wall as well as the radial material flow from the cup wall into the bottom of the cup. However, material thinning at the drawing punch radius induces folding of the material in the upsetting process. To prevent such process failures and improve the properties of the final component, a process adapted blank geometry was identified. The Tailored Blanks are experimentally manufactured in an orbital forming process and resulting effects on the properties of the functional component are investigated. In this context, an analysis of geometrical and mechanical properties of both Tailored Blanks and functional components is the prerequisite for a deeper process understanding in sheet-bulk metal forming.

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Keywords: Cold forming, Deep drawing, Tailored Blank

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1. Introduction

Nowadays, economic and ecologic framework conditions necessitate the efficient production of lightweight components [1]. The production, as well as the utilization of vehicles, faces major challenges regarding the saving of resources [2]. By using forming processes, a better material efficiency can be achieved as, in contrast to machining, the whole material volume is used to create the desired shape [3]. Also, the load-bearing capacity can be enhanced significantly when steel material is formed at room temperature [4]. Unlike other materials, steel offers both high strength and formability. Constraints, which typically exist on the process side, can be resolved by innovative forming concepts, such as sheet-bulk metal forming (SBMF) processes. This approach allows the combination of specific advantages from both forming classes, sheet and bulk forming [5]. In particular, the application of bulk forming to sheet metal enables forming of functional elements with a thickness higher than the initial sheet thickness of the material. Tailored Blanks represent a promising and commonly applied approach not only to provide the material required but additionally enhance the control of the material flow and improving the quality of the final component [6]. This experimental investigation presents the manufacturing and processing of different semi-finished products in a process SBMF process to manufacture functional components free from process failures.

2. Forming concepts, Tailored Blank and part dimensions

The Tailored Blanks applied in the subsequent forming operation are manufactured in the orbital forming process described in [7]. For the investigation presented in this paper the mild deep drawing steel DC04 with an initial sheet thickness of t_0 = 2.0 mm was used as workpiece material. As one criterion for the evaluation of the manufactured components is the resulting strain hardening, the initial hardness of the DC04 before the forming operations was 124.5 HV0.05 ±7.4. Additionally, the grain structure was investigated by etching the cutting edges of grinded and polished samples with a 3% nittal etchant.

The process parameters for the orbital forming process were set according to [8] with a forming force of F = 3,000 kN and 15 tumbling cycles in total. The Tailored Blanks with an outer diameter of d = 100 mm have a local thickening in the outer area starting from d = 70.4 mm which is necessary for subsequent processing for a proper filling of the gearing [9]. The corresponding tool insert with the relevant geometric dimensions is depicted in Fig. 1a). The Tailored Blanks are further applied in a combined deep drawing and upsetting operation described in [10]. The target geometry of the functional component is presented in Fig. 1b). The cup has a circumferentially arranged external gearing consisting of 80 teeth with a flank angle of 90°. The inner diameter amounts to 75.50 mm and the outer diameter to 82.72 mm. The cup height varies depending on the maximum upsetting force, as the process proceeds force-controlled. In this investigation, a maximum upsetting force of 1,000 kN is applied.

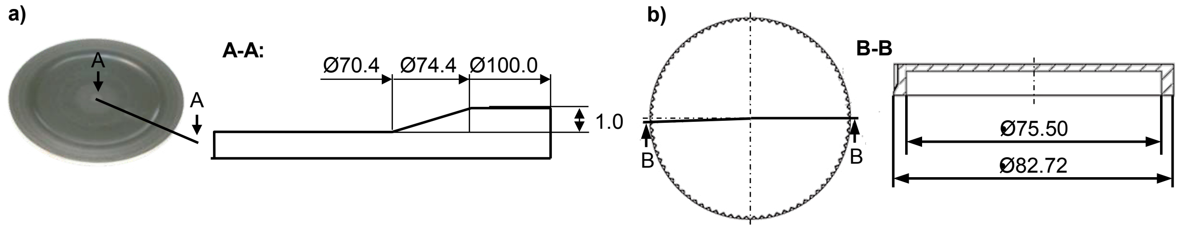

Fig. 1. Geometric dimensions of a) Tailored Blank and b) functional component.

3. Analysis of the mechanical properties of Tailored Blanks and functional components

3.1. Orbital forming of Tailored Blanks

In order to achieve a comprehensive process understanding as well as to identify the interaction between the orbital forming and the subsequent deep drawing and upsetting, the resulting properties with regard to the geometry, the grain structure and hardness of the Tailored Blanks were investigated. In the thickened outer rim area an average sheet thickness of t ≈ 2.5 mm was achieved. As presented in [11], cold forming of Tailored Blanks goes along with a