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Applicability of blasted blanks for adaption of tribological conditions in sheet-bulk metal forming

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Abstract

Manufacturing by sheet-bulk metal forming (SBMF) leads to varying stress and strain states that significantly influence the geometrical component accuracy. To improve the product quality, control of the material flow is needed. A suitable approach is given by adapting the surface properties of tool and/or workpiece and the associated tribological conditions. The study investigates blasted blanks as a method to achieve suitable frictional behavior. The influence of different grit sizes and pressures during abrasive blasting on the surface integrity was analyzed. Based on these results, the tribological behavior of the blasted blanks was evaluated using a pin extrusion test. Finally, functional cause-effect relationships to identify the mechanism of blasted blanks regarding a control of the material flow during SBMF processes were derived. The results revealed that a pressure increase and growing grit sizes lead to an enhanced material removal rate during blasting and thus a roughening of the surface. The strengthening increases with increasing blasting pressures and grit size. The surface integrity significantly influences the frictional behavior and thus the material flow. Thus, blasted blanks with rough surfaces and a high strengthening in the near surface area positively affect the material flow what improves the process results of SBMF processes.

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Keywords: Sheet-bulk metal forming; Tribology; Surface modification

1. Introduction

Global competition as well as the legal requirements associated with ecological challenges and growing customer expectations force the manufacturing industry to upgrade their products. A promising approach to deal with the existing requirements for higher product quality, lightweight construction and material use minimization is given by close tolerance highly integrated functional components. Conventional bulk and sheet metal forming processes often reach their limits in producing those parts [1]. An innovative approach to overcome the existing challenges is represented by sheet-bulk metal (SBMF) forming which is characterized by the application of bulk and sheet forming processes on sheets or plates [2]. This combination leads to globally and locally spatial and temporal variation of load conditions. These significantly influence the material flow during the forming operation and often lead to challenges in control of the material flow.

2. Material flow in sheet-bulk metal forming processes

SBMF processes are generally characterized by a complex interaction of zones with different stress and strain states [2]. This is due to the fact that components manufactured by SBMF often contain bulk formed features like gear teeth or carrier elements, and functional areas manufactured by sheet forming operations. Thus, within one single SBMF process low contact normal stress, with values below 100 MPa occur in combination with long sliding paths, which are typical for sheet metal forming operations [3]. Simultaneously contact normal stresses with values up to 2500 MPa and short sliding paths which represent bulk forming conditions can also occur [3]. These conditions influence the material flow during

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forming and can result in a reduced product quality. Possible solutions to overcome this challenge are to use higher process forces or geometrical flow-restrictions. Both methods result in increased tool loads leading to a premature tool failure. Another approach is material flow control by adapting the surface properties of tool and/or workpiece to change the tribological conditions. The current study investigates abrasive blasting of the workpiece processes to adapt the surface properties and thus to influence the material flow in SBMF. This process has been chosen due to the high potential for topography control and improved efficiency. Fig. 1 illustrates the effectiveness of locally blasted blanks to improve the geometrical accuracy of a gear component. The initial blanks are blasted in the area of the cup bottom what acts as a material flow restriction into the cup bottom. Due to the restrained material flow into the cup bottom cup height and die filling are increased. Thus, a targeted controlling of the material flow leads to an improved product quality what will positively influence the operational behavior. Additionally to the improved geometrical accuracy the surface integrity will be influenced in the blasted areas. An increases strengthening in the area of the cup bottom will be expected.

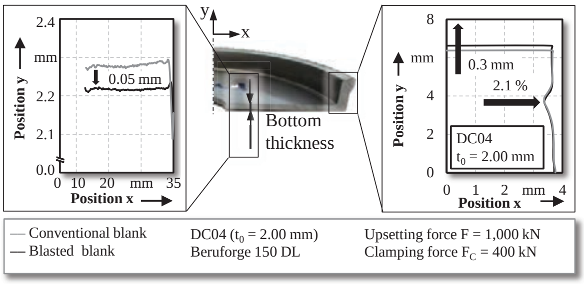

Fig. 1. Comparison of conventional and blasted blanks for a combined deep-drawing and upsetting process

After having demonstrated effectiveness, an investigation of the mechanisms which affect the impeded material flow due to blasting is needed. To realize this, the surface conditions and the tribological behavior of differently blasted blanks are analyzed and cause-effect relationships are derived.

3. Realization and analysis of blasted surfaces

To generate different surface properties the blasting parameters pressure and grit size are varied. These two parameters were chose due to their high potential in realizing different surface properties which affect the tribological behavior and thus the material flow.

3.1 Blasting of blanks

The principle of blasting processes is visualized in Fig. 2. For the current investigation a white aluminum oxide with three different grit sizes was chosen. According to the manufacturer the used grit sizes have median diameters of 88 µm with a range of 35µm, 303 µm with a range of 105 µm and 718 µm with a range of 246 µm. Varying pressures values of 0.1, 0.3 and 0.4 MPa are studied. Pressure above 0.4 MPa increases the risk of blasting grit cracks. Values below 0.1 MPa are not high enough to modify the surface properties.

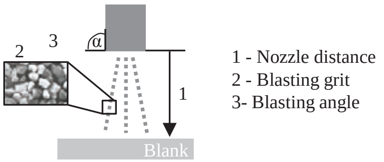

Fig. 2. Principle of blasting process

The nozzle distance, blasting angle and blasting time are chosen to be constant. 90° is used as blasting angle. The distance between nozzle tip and specimen was 40 mm. Blasting time was 15 sec. After this time the roughening was maximized. The initial workpiece material, which is used for blasting, was the mild deep drawing steel DC04 with an initial sheet thickness of 2 mm and an EDT surface. To detect the influence of surface properties on the tribological conditions, an analysis of the surface integrity was needed. As the surface roughness and the near surface strengthening are mainly influenced by blasting processes, these two characteristics are analyzed [4].

3.2 Analysis of surface roughness

The surface roughness is fundamental for the tribological behavior during forming [5]. The roughness values were measured using a confocal laserscanning microscope KEYENCE VK-X 200. Fig. 3 illustrates the surface topographies and averaged profile depth of blasted DC04 blanks for all pressures and grit sizes. Fig. 3 reveals that a change in grit size and pressure influences the roughness of the blasted blanks.

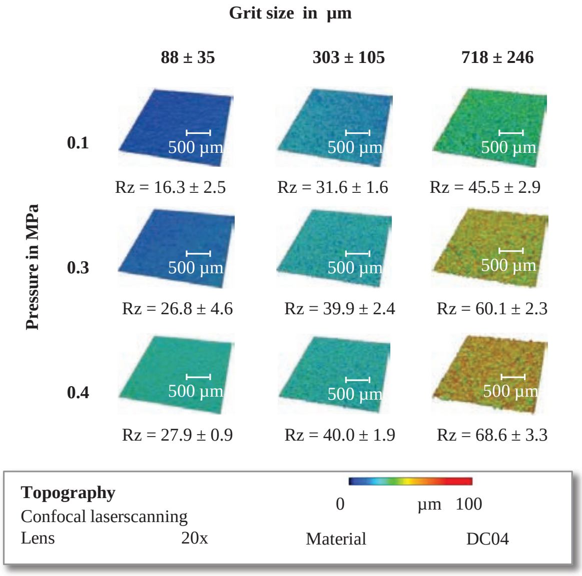

Fig. 3. Surface topographies and averaged profile depth of blasted blanks