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New approach on controlling strain distribution manufactured in sheet metal components during deep drawing process

Dipl.-Ing. Martin Barthau[a]*, Prof. Dr.-Ing. Dr. h. c. Mathias Liewald MBA[a]

[a]*Institute of Metal Forming Technology University of Stuttgart, Holzgartenstraße 17, 70174 Stuttgart, Germany*

Abstract

The production of irregularly shaped deep drawing parts with high quality requirements, which are common in today's automotive car body production, consistently challenges production processes. The more and more complex requirements of design, light weight construction and crashworthiness lead to a more narrow process window for deep drawing production and thus the manufacturing process robustness is decreasing and hence the necessary use of high strength steels. Modern metal forming technologies deals with these challenges using highly sophisticated methods to control the material flow or adjustable process parameters by use of controllable machine or tool axis. Multiple control loop methods in deep drawing technology have been investigated during the recent two decades in order measure and to control the material flow in deep drawing processes. These methods only allow any control intervention between two strokes which itself is regarded as a simple open loop control system because a none process variable is a feed back to the controller. The method that was developed at the Institute for Metal Forming Technology (IFU) at the University of Stuttgart allows any control intervention during the deep drawing stroke for every blank holder design.

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1. Introduction and state of the art

Metal forming processes suffer from conditions of uncertainty due to parameter variation and imperfect process understanding as mentioned by Allwood [1]. These uncertainties lead to inconvenient products which do not meet customer specifications. In deep drawing of irregular shaped parts these problems are boosted by lightweight construction requirements and complex shapes of today's car body shell designs. Meeting such various challenges in

* Corresponding author. Tel.: +49 (0) 711-685-83979; fax: +49 (0) 711-685-83839.
E-mail address: martin.barthau@ifu.uni-stuttgart.de

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stretch and deep drawing technology during the last two decades, different methods for controlling the material flow-in by open loop control in combination with different sensors and actuators were investigated. Measuring the edge draw-in of the part flange outline is the commonly used one for gaining the most sensitive state variable. Siegert [2] used an induction coil for measuring the edge draw-in. For influencing the edge draw-in, two different approaches were used, a segment elastic blank holder and height adjustable drawbeads. Segment elastic blank holder contain ten hydraulic pistons in his work, so hydraulic pressure can be adjusted independently to deliver local blank holder forces to each separate blank holder segment. The adjustable drawbeads were moved by a servomotor in order to retain flange material by rise of its height. Neugebauer [3] measured the draw-in by laser displacement sensors. He used piezoelectric actuators to manipulate the local blank holder force according to measured flange draw-in. However, both approaches are not valid to influence the deep drawing process *during* movement of ram towards BDC. Furthermore, the piezoelectric actuators used are less suitable for harsh production processes. Faaß [4] also developed a process control system for deep drawing operations. The measurement of the edge draw-in by laser displacement sensors was also used as state variable and height adjustable blank holder distance blocks for influencing the material flow-in locally. Kraft [5] uses a similar approach, but the draw-in of the whole part is measured visually after the deep drawing stroke in order to adjust the blank holder force for the next ram stroke. Danckert [6] developed a closed-loop control for deep drawing processes, disclosing a first approach with a closed-loop. Danckert measured the edge draw-in as state variable with laser displacement sensors and used a hydraulic cushion in the blank holder to modify blank holder force. Despite of being the first published closed-loop control on deep drawing, his system lacks of some disadvantages. The measurement of the draw-in was proved not as robust as needed and the shimming system is not applicable when complicated part shapes with a curved blank holder design must be manufactured. The main drawback of the system he proposed was found in limited sensitivity of flange draw-in with respect to strain distribution induced in part bottom and part wall zone during ram stroke which displays the quality of drawn shell authentically .

Another kind of sensor for only monitoring the deep drawing process was presented by Beck [7]. In his work a piezo force transmitter was developed for measuring the part wall stress. This allows measuring the stress in the part wall *during* the deep drawing stroke. This measurement enables conclusions on the part quality during the process. This kind of sensor was improved in the works done by Liewald [8] and Blaich [9], so that it can be located in every part of the forming die. Blaich studied the signal dynamics of the part wall stress and demonstrated its validity for state description of deep drawing process.

Except for Danckert the formerly developed approaches are limited on control intervention between two working strokes of the press ram. Unfortunately, many formerly published approaches were applicable under lab conditions. The used state variables suffer also from lack of measurement robustness and applicability on spatially curved blank holder designs which are common in industrial applications. The closed-loop control system presented in the following work will settle this scientific deficiency. The following closed-loop control approach is capable to provide a control intervention during the deep drawing stroke by using a feed forward trajectory follow-up control concept. Additionally, the part wall stress that is used as state variable in this work and which is based on the established sensor concept [8] enables proper and robust measurements directly in the critical areas like the bottom and part wall area of a deep drawn part.

2. Tool Design

The tool geometry used for the experimental setup at the author's institute is based on part geometry according to Häussermann [10]. Within the scope of this paper the experimental tool was equipped with a segment elastic blank holder (SEB) in order to apply different amounts of blank holder force locally. The SEB features 10 hydraulic pistons which control blank holder pressure in each blank holder segment by using 10 servo valves (Fig. 1). Each hydraulic piston provides a force up to 250 kN which sums up to a maximum blank holder force of 2500 kN in total. Each hydraulic piston is dedicated to one segment of SEB, so, increasing the hydraulic pressure in the piston evidently leads to stronger local blank holder force acting at the corresponding segment (Fig 1a).

One of the major tasks of designing a proper closed-loop control system for deep drawing objectives is the defintion of a valid and most sensitive state variable which governs the process close to part quality requirements. Thus the state variable has to be measurable in a robust manner and has to describe the system behaviour as sufficiently as