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Prediction and optimization of thinning in automotive sealing cover using Genetic Algorithm

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Abstract

Deep drawing is a forming process in which a blank of sheet metal is radially drawn into a forming die by the mechanical action of a punch and converted to required shape. Deep drawing involves complex material flow conditions and force distributions. Radial drawing stresses and tangential compressive stresses are induced in flange region due to the material retention property. These compressive stresses result in wrinkling phenomenon in flange region. Normally blank holder is applied for restricting wrinkles. Tensile stresses in radial direction initiate thinning in the wall region of cup. The thinning results into cracking or fracture. The finite element method is widely applied worldwide to simulate the deep drawing process. For real-life simulations of deep drawing process an accurate numerical model, as well as an accurate description of material behavior and contact conditions, is necessary. The finite element method is a powerful tool to predict material thinning deformations before prototypes are made. The proposed innovative methodology combines two techniques for prediction and optimization of thinning in automotive sealing cover. Taguchi design of experiments and analysis of variance has been applied to analyze the influencing process parameters on Thinning. Mathematical relations have been developed to correlate input process parameters and Thinning. Optimization problem has been formulated for thinning and Genetic Algorithm has been applied for optimization. Experimental validation of results proves the applicability of newly proposed approach. The optimized component when manufactured is observed to be safe, no thinning or fracture is observed.

Keywords: Thinning; Prediction; DOE; Regression

1. Metal forming – Introduction

Sheet metal forming is a significant manufacturing process for producing a large variety of automotive parts, aerospace components as well as consumer products (kitchen sinks, cans, boxes, etc.). These are broadly classified as forming/drawing/stamping and deep drawing operations, which include a wide spectrum of operations and flow conditions. Deep drawing is a compression-tension forming process [1]. With the greatest range of applications involving rigid tooling, draw punches, a blank holder and a female die. In this process the blank is generally constrained over the draw punch into the die to give required shape of cavity.

The sheet material is subject to a large plastic deformation combined with a complex flow of material. Design in sheet metal forming, even after many years of practice, still remains more an art than science. This is due to the large number of parameters involved and their interdependence. These are material properties, machine parameters such as tool and die geometry, work piece geometry and working conditions. Research and development in sheet metal forming processes requires lengthy and expensive prototype testing and experimentation in arriving at a competitive product.

In deep drawing of a cup the metal is subjected to three different regions of deformations. Fig. 1 represents the deformation and stresses developed in a pie-shaped section. The metal at the center of the blank under the head of the punch is wrapped

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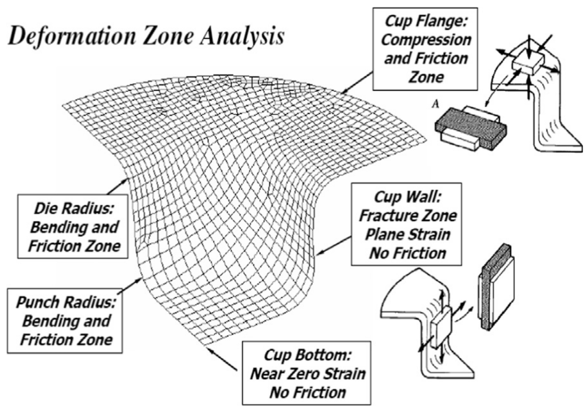

Fig. 1. State of stress in deep drawing.

around the profile of the punch. The metal in this region is subjected to biaxial stress due to the action of the punch. The metal is bent over the Punch Radius which causes friction. At the center of cup there is no strain and no friction. Metal in the outer portion of the blank is drawn radially inward towards the throat of the die [2]. However, as the metal passes over the die radius, it is first bent and straightened, while at the same time being under tensile stresses, this causes considerable friction. As it is drawn in, the outer circumference must continuously decrease from that of the original blank, to that of the finished cup. This means that it is subjected to a compressive strain in the circumferential or hoop direction and a tensile strain in the radial direction.

As a result of these two principal strains, there is a continual increase in the thickness as the metal moves inward in the flange region. This plastic bending under tension results in considerable thinning; this modifies the thickening due to the circumferential shrinking. The proposed innovative methodology combines two techniques for optimization of thinning in automotive sealing cover. Taguchi design of experiments and analysis of variance is used to analyze the influencing process parameters on thinning. Mathematical relations have been developed to relate input process parameters and thickness reduction. Optimization problem has been formulated and Genetic Algorithm is applied for optimization. There are a lot of Evolutionary and Bio Inspired optimization algorithms available nowadays, such as Particle Swarm Optimization, Ant Colony Optimization, etc. Genetic Algorithm has its own advantages and capabilities which have been discussed in the following sections.

2. Major influential parameters

Four major process variables have been studied in Numerical Investigations for Sealing Cover to understand the effects of these parameters and their interaction on thinning. These are blank holder force, lubrication condition i.e. coefficient of friction, die profile radius and punch nose radius.

2.1. Lubrication

Lubrication is normally expressed in terms of coefficient of friction. In deep drawing all areas where sheet and tool slide are relative to each other and plastic deformation occurs with complex state of friction [3]. The sheet is stretched over the stamp; in this case the friction between the stamp and the sheet to a large extent determines the deformation. In some positions where the sheet slides over the edge of the die with a simultaneous shearing of the sheet material, the friction between die and sheet influences the coefficient which is assumed between 0.05 and 0.15. Schey [4] distinguishes a total of six contact and friction regions in deep drawing. Too low a friction involves a poor control of the sheet flow, because sheet will flow easily with a risk of wrinkling. While too high a friction leads to a risk of crack formation, because the slow movement of sheet can result into tearing and cracking.

2.2. Blank holding force

The blank holder force is applied to control the flow of material in the die. Blank holder force has significant contribution on the product quality. Appropriate blank holder force evolved through a process results in controlling the thickness variations in a deep drawn part and thus the quality of the part. An optimal blank holder force eliminates wrinkling as well as tearing, the two major phenomena that cause failure in formed parts. During numerical investigations, a constant blank holder force is applied during a forming process to minimize mechanisms in the forming tools.

2.3. Punch nose radius

The draw punch applies the required force onto the sheet metal blank in order to cause the material to flow into the die cavity. The critical features of the draw punch include the punch face and Punch Nose Radius. Punch Nose Radius cannot be too small as it will try to pierce or cut the blank rather than force the material to bend around the radius [5]. The minimum punch-nose radius depends on material type and thickness. It is equally important to understand that, as the punch-nose radius is increased the blank will tend to stretch on the punch face rather than draw-in the blank edge.

2.4. Die profile radius

The die profile radius and die-face surface are probably the most influential features in a draw tool that uses a flat blank holder [6]. If the draw radius is too small the part may split as the material deforms. This is due to the high restraining forces caused by bending and unbending of the sheet metal over a tight radius. Drawing over a tight radius also produces a tremendous amount of heat. This can lead to microscopic welding of the sheet metal to the tools, known as galling. On the other hand, an excessive die radius causes the blank to wrinkle in the unsupported region between the punch face and the die face. It is apparent that there must be some range of die radii to select from that will work; not too small and not too big.