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Stamping Process Parameter Optimization with Multiple Regression Analysis Approach

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Abstract

Stamping is very important manufacturing process used for producing component from the metal sheet. In stamping process, the force applied by a punch on the blank and make it flow into the die cavity. At the time of blank deformation, it experiences the complex stresses, tensile as well as compressive. The excessive compressive stresses of sheet metal result in wall thickening and wrinkling in flange region, while tensile stresses initiate thinning in the wall region of the cup. The excess thinning causes cracking or fracture of a sheet. The faulty process design ultimately produces nonconforming products. The successful design of stamping process involves designing of the tooling and identification of the optimum level of the process parameters. Finite Element Method (FEA) immensely used in design and analysis of the stamping process, considered as avery important tool for predicting the stresses likely to be developed in the stamped components before the tryout of the process. While multiple regression analysis (MRA) is am athematical technique used to establish are lation between the response and the predictors. The proposed methodology combines two techniques, FEA, and regression analysis to study the impact of various parameters and their interaction on the thinning of the sheet metal. Regression analysis is used to optimize the parameters to minimize the thinning of the blank. The usefulness of methodology for optimization of stamping process parameter validated with experimental production of the component.

*Keywords:*Material thinning, FEA, multiple regression analysis, Taguchi orthogonal array, punch radius, die radius, optimization.

1. Introduction

The sheet metal forming process used for producing a large variety of components comprising automotive parts, aerospace components, consumer products like home appliances, cans, sinks, boxes[1].

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Nomenclature

A	Punch radius (*mm*)
B	Die radius (*mm*)
C	Blank holder force (*Ton*)
D	Draw tonnage (*Ton*)
E	Binder stroke (*mm*)
F	Drawbead height (*mm*)
G	Contact coefficient of friction

Stamping process encompasses operations like blanking/forming/drawing and deep drawing, which include a wide spectrum of operations and material flow conditions. Successful process design for sheet metal forming depends on more than forty parameters and their interaction. Even after many years of practice of stamping process, it is more of expertise than a science. Parameters related to blank geometry, work material, die and press are the some of theimportant process variables.

The design of successful sheet metal forming process requires expensive and time-consuming prototype testing along with actual try out to arrive at a competitive product [2]. Drawing is one of the important operation of the stamping process. By drawing operation, sheet metal is formed against the die by the punch/upper die, while the blank holder applies a predetermined force to control the material flow into the die. In drawn component the forming errors like wrinkling, cracking, and thinning of material are commonly observed at the tool tryout stage[3,4]. The material drawn over various surfaces and variable radii makes the anticipation of defects complicated. The Finite element simulation is extensively used for sheet metal forming to eliminate forming defects, and to predict stresses of blank for avoiding failure [5,6]. It is very difficult to determine the effect of the process parameters on the final product quality. These process parameters are required to set at the optimal level for better yield of the process[7]. The traditional methods of determining the optimal level of the process parameter are time consuming and expensive. It relies heavily on trial-error and the expertise of the workers. The inappropriate setting of theparameter can lead to manufacturing of defective products.

The main objective of stamping process designer is to design and manufacture forming tools and set process parameter in such a way that, the process can be used dependably for the production of defect-free products within the desired dimensional tolerances and with the required surface quality. In present research workFEA used for predicting the thinning of the component at a various setting of punch radius, die radius, blank holder force (BHF), draw tonnage, binder stroke, drawbead height, contact friction. Then, theMRA used to establish the relation between response and predictor parameters[8,9]. The validation of proposed methodology done with experimental production of the component at theset level of parameters.

2. Significant parameter

2.1. Punch radius

In sheet metal forming, punch applies pressure on blankand induce deformation. The punch radius has a vital effect on the material behavior, the excess large radius results in stretching of the sheet around the radius, while thetoo small radius of punch causes shearing of the sheet between die and punch. The appropriate selection of punch radius depends on material properties and thickness of a blank[10–12].

2.2. Die radius

The die profile radius is the influencing parameter of drawing operation, where the flat blank holder is used. If the die radius kept too small, the split of material may take place due to the high restraining forces as a consequence of bending and unbending of the sheet over a small radius. Also, this bending and unbending generatea large amount of heat during the operation.However wrinkling of blank occurs as a result of a large die radius [13].

2.3. Blank holder force (BHF)

The inappropriate flow of material in dieresults in stretching and ultimately in tearing of blank. Conversely, the excess flow causes wrinkling of blank. Therefore, optimum setting of blank holder force can avoid tearing and