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Optimum Design and Analysis of Sheet Metal Pulley

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ABSTRACT

It is important to determine the optimum blank shape of a sheet metal part as its deformation during the forming process is very complicated and it is not easy to design the optimum blank shape even by the skilled labor based on the experience of many years. Recently computational analysis for a complex automobile part has been easily accomplished due to improved computer performance and the numerical analysis technique. In the analysis process, all kinds of variables that affect the deformation should be considered. The optimum blank shape leads to the prevention of tearing, uniform thickness distribution and to the reduction of the press load during drawing. If the blank shape is designed optimally, the formability will be increased and the final product will require the least amount of trimming at the end of the process. Therefore, it is desirable to design the blank shape with a uniform flange of its periphery after deep drawing. The literature review provides us information about using roll back method to predict optimum initial blank shape. The method consider difference between final deform shape and target contour shape into account. The method has been successfully applied for various automobile components. My research work utilizes roll back method for sheet metal pulley. Objective of research is to evaluate thickness strain distribution. By achieving said objective by optimization of blank shape productivity can be enhanced.

Keywords— **Blank Shape, Optimization, Thickness Strain distribution, Target Contour**

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I. INTRODUCTION

In order to optimize sheet metal forming processes, the effects of a considerable number of process parameters are evaluated experimentally or analytically. Basically the optimization processes are based on the trial-and-error method owing to the inherent characteristics of metal forming processes. Because of the nature of the trial-and-error method, however, a significant number of iterations are usually required to optimize the processes. In general, sheet metal forming products in modern industries have a complicated shape and the forming process consists of several successive operations until the final shape is formed. Because of the complexity, the use of 3D CAD systems is increasing in the design of sheet metal product. With 3D CAD data, the die surface can be machined by CAM and the deformation process can be analyzed by a CAE technique. In the deep drawing processes, the use of an optimal blank not only saves the material but also it may reduce the occurrence of defects e.g. wrinkling, tearing. However, it is not easy to find the optimal blank because of the complexity of material behaviour. Several methods have been developed to design the optimal blank and there are many different approaches to find the optimal blank. Among the methods, the slip line field method, the geometric mapping method the trial-and-error method based on the FE method the inverse method ideal forming backward tracing the volume addition/ subtraction method and the analogy method are notable. This work presents an optimum design method of blank shapes for the circular cup drawing process considering process variables. An optimum blank shape of circular cup drawing was obtained using the proposed method. Also, it was applied to the deep drawing of an automobile subframe, and an optimum blank shape with a uniform flange at its periphery was determined.

II.LITERATURE REVIEW

1. Hyunbo Shim, Kichan Son, Kwanghee Kim, Optimum blank shape design by sensitivity analysis, Journal of Materials Processing Technology 104 (2000) 191-199

A method of blank shape design based on sensitivity analysis for the non-circular deep drawing process has been proposed. By assuming the final deformation shape to be a drawn cup with a uniform trimming allowance at the flange, the corresponding initial blank which gives the final shape after deformation has been found. With the aid of a well-known dynamic explicit analysis code PAM-STAMP, shape sensitivity has been obtained. To obtain the shape sensitivity numerically, a couple of deformation processes have been analyzed. In order to validate this method, deep drawings of a square cup, a clover shaped cup and an L-shaped cup have been chosen as the examples. In every case converged results have been obtained only after a few times of modification. With the predicted optimal blank, both computer simulation and experiment are performed. Excellent agreement is noted between simulation and experiment in every case. Through the investigation, the proposed systematic method of optimal blank design is found to be very effective in the design of a deep drawing process. A systematic method of optimal blank design based on sensitivity analysis for the non-circular deep drawing process has been proposed. From the results of deformation process, the shape sensitivity has been obtained numerically. With the shape sensitivity and the shape error, initial blank has been modified in order to obtain the final drawn cup shape. The numerical and experimental results of the three kinds of cup drawing demonstrate that the present method provides excellent prediction of the blank shape and the blank shape gives the target shape almost exactly. Through the investigation, the proposed systematic method of optimal blank design is found to be very effective.

2. M. Azaouzi, S. Belouettar, G. Rauchs, A numerical method for the optimal blank shape design, Materials and Design 32 (2011) 756–765

This paper describes a numerical procedure for the blank shape design of thin metallic parts obtained by stamping. The objective is to determine the initial blank shape knowing the geometry of the desired 3DCAD part. The numerical procedure consists of two stages: At first, an estimation of the initial blank shape is given using the one step inverse approach (IA). Then, update of the blank shape is continued by iterations combining optimization algorithms and finite element analysis (FEA). The numerical procedure for the blank shape design is tested in the case of an industrial stamping process where the part is formed using a manual press without blank-holder. The proposed numerical procedure can provide very quickly the optimal blank shape in a few iterations. Combining aspects such as large strain plasticity, high local field gradients, residual stresses and complex tool kinematics, numerical design of the blank shape of high precision thin metallic part represents a challenging task. Design of the optimal blank shape using numerical procedure based on the combination between finite element analysis and optimization algorithm has been presented in this paper in the case of a thin metallic part obtained by stamping in two stages. The optimization algorithm is generated with an object-oriented programming language (Python) allowing to execute rapidly the scripting interface. It is obvious that the numerical procedure has demonstrated its efficiency to provide an optimal solution in a few iterations with very high accuracy. The optimization algorithm based on the finite element analysis can be generally applied for various geometries. It can make the designer work easier by reducing considerably the design period and material cost.

3.H. Naceur , Y.Q. Guo, J.L. Batoz, Blank optimization in sheet metal forming using an evolutionary algorithm, Journal of Materials Processing Technology 151 (2004) 183–191

In this paper, the authors present a new numerical approach to optimize the shape of the initial blank, which plays an important role on the quality of the final 3D workpiece obtained by the deep drawing of thin sheets. This new approach is based on the coupling between the inverse approach used for the forming simulation and an evolutionary algorithm. The preliminary results dealing with the optimization of the blank contour in the case of a square cup (the Benchmark test of Numisheet'93) show the efficiency and the potential interest of the proposed approach. An evolutionary structural optimization (ESO) method has been developed for the optimization of the contour of the blank in sheet metal stamping. The method consists simply in eliminating material elements subjected to a only small plastic deformation. A criterion based on the plastic work density was chosen and a limitation on the total eliminated material was imposed. The present technique needs a fine mesh. The ESO method has two important advantages. The first is that it does not require computations of gradients: only mesh data (node coordinates, connectivities) and classical element outputs such as strains, stresses and plastic work density are needed. The second advantage is that this method is independent of the forming simulation solver. Although, the authors used a simplified inverse approach (a one-step code), it is possible to couple the ESO method with any industrial simulation code. Several aspects will be studied in the future, such as the improvement of the convergence speed (reduction of the number of iterations), the use of quadrilateral elements to obtain a smoother contour of the blank and the choice of other optimization criteria to evaluate their influence on the final solution. The authors believe that the ESO method is an attractive approach for the optimum design of 3D addendum surfaces in the industrial sheet forming process. As in many other forming problems, the definition of the best quality functions with constraints for the optimization of process parameters remains one of the key issues. This important aspect needs close cooperation between the shop floor die engineers and the software developers to achieve some practical solutions at the preliminary design stage or at later try-out stages.

4. Mohammad Habibi Parsa, Payam Pournia, Optimization of initial blank shape predicted based on inverse finite element method, Finite Elements in Analysis and Design 43 (2007) 218 – 233

For stamping of sheet metals and converting them to specific product shapes without failure, the initial blanks should be correctly designed. Therefore, initial blank design is a critical step in stamping design procedure. In the present paper for calculating the total deformation gradient and its relation to each step's deformation gradient tensor *(F)*, a modified kinematics formulation will be introduced. This formulation has been used in connection with the ideal forming theory for predicting the initial blank shape of the specified products with defined thickness. In the ideal forming theory, each material element is prescribed to deform in a minimum plastic work path and ideal process is obtained when the deformations are most evenly distributed in the final products. The latter has been assumed for developing an inverse finite element method (FEM) code to predict the blank shape and size in one step, which has been applied for rectangular cup. Even the results show the capability of the new algorithm in designing the initial blank shape for stamping products but the predicted blank shapes are oversized. For overcoming such problem, some kind of optimization must be applied. By considering all the conditions, forward FEM has been selected for optimization of blank shape and size. The accuracy of optimized blank shape and size has been evaluated using experimental work. For strain measurements, over the surface of blanks square grid have been printed. The results of experimental work confirmed the applied procedure for defining the shape and size of rectangular blank. The examination of thickness strain using printed grids show the superiority of optimized blanks. Modified formulation has been introduced for predicting the initial blank shape by using some simplified assumptions. The introduced modified formulation has been implemented as an inverse FEM code and its capability has been evaluated by calculating initial blank shape for different rectangular shapes in one step. Examination of initial blank shapes and sizes show some discrepancy between the calculated and experimental results. This discrepancy can be attributed to the simplifications such as disregarding the tractions at boundaries, neglecting the intermediate deformation path, assumption of ideal forming and ignoring anisotropy. Therefore, some kind of optimization becomes necessary and forward simulation has been selected as optimization tool. Selected method not only leads to the optimization of initial blank shape and size but also takes into account the effect of neglected parameter during inverse calculation. Therefore, in the applied procedure that consists of prediction and forward simulation cycles, all effective parameters on the stamping process can be taken into account. In the case of rectangular cups, using forward simulation as a tool for finding the necessary correction factors is a simple technique for optimization of blank shape and size. Strain distribution results show that any degree of optimization leads to the more uniform product besides the reduction of material consumption that proves the applicability of introduced procedure. In the case of full optimized blank, simulation and experimental results show that the uniformity of strain distribution is highly increased.

5.S.H. Park, J.W. Yoon, D.Y. Yang,, Y.H. Kim, Optimum blank design in sheet metal forming by the deformation path iteration method, International Journal of Mechanical Sciences 41 (1999) 1217-1232

Optimum blank design methods have been introduced by many researchers to reduce development cost and time in the sheet metal-forming process. Direct inverse design method such as Ideal Forming for optimum blank shape could play an important role to give a basic idea to designer at the initial die design stage of the sheet metal-forming process. However, it is difficult to predict an exact optimum blank without fracture and wrinkling using only the design code because of the insufficient accuracy. Therefore, the combination of a design code and an analysis code enables the accurate blank design. In this paper, a new blank design method has been suggested as an elective tool combining the ideal forming theory with a deformation path iteration method based on FE analysis. The method consists of two stages: the initial blank design stage and the optimization stage of blank design. The first stage generated a trial blank from the ideal forming theory. Then, an optimum blank of the target shape is obtained with the aid of the deformation path iteration method which has been newly proposed to minimize the shape errors at the optimization stage. In order to verify the proposed method, a square cup example was investigated.

A new method of optimum blank design has been proposed by using the ideal forming theory and the deformation path iteration method. The method was integrated in the finite element modeling of sheet metal-forming process. The design procedure is composed of two stages; The first stage is the initial blank design stage based on the ideal forming theory and the design modification stage introducing the proposed deformation path iteration method combined with the rigid-plastic finite element method for sheet metal-forming. The second stage involves the iterative procedure to optimize the initial blank.

Deep drawing of a square cup has been treated as an example. It has been found out that with two iterations the deformed contour shape becomes almost coincident with the target shape and the optimized blank demonstrates the improved formability as compared with the usual square blank. It has been thus shown that the proposed method is an elective tool for optimum blank design with improved formability and can be further applied to optimum blank design of other practical sheet metal-forming problems.

6.Jong-Yop Kim, Naksoo Kim, Man-Sung Huh, Optimum blank design of an automobile sub-frame, Journal of Materials Processing Technology 101 (2000) 31-43

A roll-back method is proposed to predict the optimum initial blank shape in the sheet metal forming process. The method takes the difference between the final deformed shape and the target contour shape into account. Based on the method, a computer program composed of a blank design module, an FE-analysis program and a mesh generation module is developed. The roll-back method is applied to the drawing of a square cup with the flange of uniform size around its periphery, to confirm its validity. Good agreement is recognized between the numerical results and the published results for initial blank shape and thickness strain distribution. The optimum blank shapes for two parts of an automobile sub-frame are designed. Both the thickness distribution and the level of punch load are improved with the designed blank. Also, the method is applied to design the weld line in a tailor-welded blank. It is concluded that the roll-back method is an effective and convenient method for an optimum blank shape design.

In this paper the roll-back method that designs an optimum blank shape is proposed. Based on the method, a computer program composed of a blank design module, an FE-analysis program and a mesh generation module is developed and it is applied to the deep drawing of a front sub-frame. The results of the present paper are summarized as follows:

1. To verify the validity of the proposed method it is applied to the deep drawing of a square cup. The outer contour may be drawn to the target contour.
2. The roll-back method is applied to the optimum blank design of a left member of an automobile sub-frame. The thickness distribution and the load level are improved. When the initial blank shape, the final shape and thickness distribution are compared, the results predicted by the roll-back method have a good agreement with the experimental results. It is concluded that this method can be applied to the deep drawing of the complex automobile parts.
3. The analysis of No. 2 member with a tailor-welded blank is performed. The position of welding lines on the initial blank is designed. The roll-back method can be applied to the design of the welding line position.
4. In most cases, the edge of blank takes the shape of the target contour within a few iterations, which shows that the roll-back method is an effective and convenient method for an optimum blank shape design.

III.CONCLUSION

It is important to determine the optimum blank shape of a sheet metal part. However, because its deformation during the forming process is very complicated, it is not easy to even by the skilled labor based on the experience of many years. The optimum blank shape leads to the prevention of tearing, uniform thickness distribution and to the reduction of the press load during drawing. If the blank shape is designed optimally, the formability will be increased and the final product will require the least amount of trimming at the end of the process. Therefore, it is desirable to design the blank shape with a uniform flange of its periphery after deep drawing. Several numerical solutions for the deep drawing process of Circular & non-circular components have been reported.

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