Finite Element Analysis of V – bending Process- A review

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***Abstract*— The V-bending process is very common in sheet metal bending. During bending, when the load is removed there is a shape discrepancy due to elastic recovery referred to as spring back. Accurate estimation of spring back is essential to maintain geometric tolerance in the finished parts. In recent years finite element modeling and simulation has become an important tool in engineering practice. The purpose of this paper is to overview the recent works on finite element analysis of V-bending process from the view point of spring back prediction.**

Keywords— V bending, Finite element Analysis

INTRODUCTION

Bending process is the most common operation used in the sheet metal industry .Bending consists of uniformly straining a flat sheet metal around a linear axis. The bending operations can be done in several ways. The V-shape bending is used frequently because it is simpler and cheaper to manufacture. The V-bending is classified into air V-bending and closed die V-bending. In closed die bending, the punch forces the sheet completely into the die and at the end of the bending process, the punch, the sheet and the die are in solid contact. The major limitations in this method is that more tools are required for a certain work range as the angle of punch and die must be accurately matched for any specific bend. In air bending, the sheet surface is touched by the tools in three points: punch surface and two die corners. The punch does not force the sheet completely up to the bottom of the die cavity, leaving the space. Air bending is commonly used in automotive stamping and fabrication industries in air bending, the different bend angles can be produced by adjusting the punch travel alone into the die without the need for tool changes and this makes the technique more flexible than closed die bending. During bending, the load is applied to bend the part in the expected shape. The bending tool bends the metal into a required bend angle. After bending, when the tool is removed, there is a dimensional change in the bent part, widening the angle and this increasing angle is referred to as spring back. The spring back cannot be eliminated but can be compensated to obtain to accuracy the finished product. The over bending technique or modification of die design is adopted to compensated the spring back.

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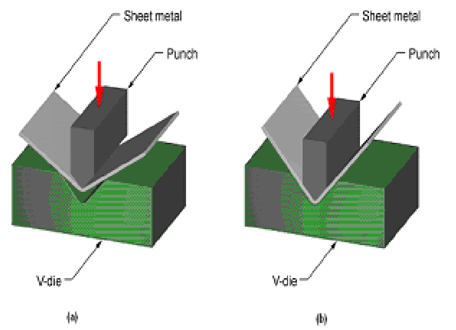

Figure 1. (a) Air bending (b) Closed die bending

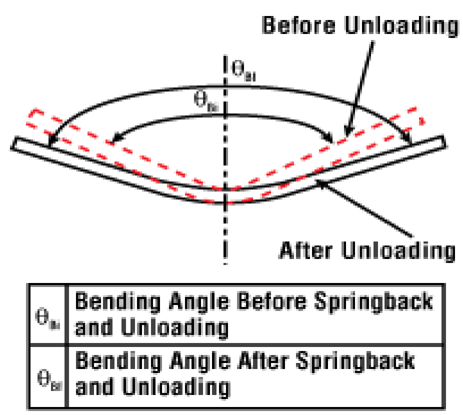

Figure 2. Springback

In the present quality era as closer tolerance are insisted, spring back prediction becomes vital to obtain accurate bend parts. In the past trial and error methods are employed by the designers to predict and compensate spring back analytical models has been developed by various researchers to predict spring back using beam or plate bending [1]. These models are unable to provide more accurate predictions as they use simplified assumptions. Recently with development of computation technology, sheet metal bending process can be analyzed and spring back predictions can be done using finite element method [2].

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FINITE ELEMENT MODELING

The sheet metal industries are interested in reducing the time for development of newer products and tool sets for saving the resources and costs. Over the last decade, in the product development, concurrent engineering has been introduced in the design to reduce the lead time and cost. Finite element analysis and simulation allow reduction of costly experiments and time to meet these requirements.

In the case of sheet metal bending process, FEM simulation codes are used for modeling the process and die design and also the process parameters can be optimized to improve the product quality. Depending on the geometrical complexity, two dimensional or three dimensional analyses is required in the sheet metal bending process. For accurate prediction of spring back, a proper material model has to be chosen. In most of the simulations, tool materials are considered as rigid, thus the die and punch deformations are neglected.

Finite element simulation of spring back employs two methods, the implicit and explicit. The implicit method uses larger time steps and involves the assembly and solution of a system of equations, which is iterative. Therefore, the computational time per load step is relatively high. The explicit method uses much smaller time steps since it is conditionally stable. However, it involves no matrix solution and is non-iterative. Therefore, the computational time per load step is relatively low. Three groups of finite element simulation of spring back are available. The first one is, fully implicit scheme applied for both loading and unloading phases. This method is very complex and time consuming, in particular for 3D bending simulations. The next one is fully explicit procedure employed for loading-unloading process. The explicit approach will not allow to analyze springback since when the contact surfaces are removed, the deform sheet would start to oscillate. Hence the damping is introduced to reach the equilibrium. It is very difficult to estimate the amount of damping and sometimes longer CPU time is needed to reach the equilibrium. The third method couples both the methods, that is , an explicit approach for the loading phase and implicit for unloading [3] . The explicit approach calculates the stress state at the end of loading and the information is supplied to implicit scheme to evaluate spring back. This procedure is widely used in the present research for obtaining accurate spring back values with less CPU time.

LITERATURE REVIEW

A.AIR V BENDING

The researchers concentrated on the development of FE models to predict the springback in air bending. The researchers are reviewed and summarised briefly. Singh,Maiti, Date and Narasimhanl (2004) developed 3D finite element models of air bending tools for the prediction of the elastic distortions in the tools and thereby the distortion to the accuracy of the formed part. It was found that the springback due to elastic deformation of the bending tool increases as the blank thickness is increased. The suggestions were made to improve the stiffness of the tools which would lead to improve the product accuracy. Fei and Hodgson(2006) simulated the air V-bending process by Gajjar, H.V., Gandhi, A.H. and Raval, H.K., ―Finite element analysis of sheet metal air bending using Hyperform LS-DYNA‘, PWASET, Vol. 26, pp. 92-97, 2007.

the implicit FEM code Abacus/standard compared with experimental results Gajjar,Gandhi and Raval (2007) performed a 3D FEA of air bending process using Hyperform LS-DYNA and compared the results with published 3D FEA results of Ansys LS-DYNA and experimental stress strain results. It was found that the results were in good agreement. They further analyzed the air bending problem in 2D FEA with symmetric boundary conditions in width by assuming plane strain conditions. It was concluded that simplification of air bending problem from 3D to 2D was more efficient and practical.

TABLE I LITERATURE ON AIR BENDING

Author and year	Type of analysis	Result obtained	Software used
Singh,Maiti, Date and Narasimhanl (2004)	elastic distortions in the tools and the distortion to the accuracy of the formed part	The spring back due to elastic deformation of the bending tool increases as the blank thickness is increased	ABACUS
Gajjar, H.V., Gandhi, A.H. and Raval, H.K.,.	Stress and Strain	Marginal reduction of stress and strain	HYPER FORM LSDYANA
Fei, D. and Hodgson, P 2006	Young's modulus Friction coefficient	Better accuracy is obtained	ABACUS

B.CLOSED DIE V-BENDING

The Finite element analysis of springback in closed die V bending has been attempted in the past years and they are briefed. Nilsson,Melin and Magnusson (1997) performed the FE simulations with Nike2D implicit FE code. In the simulations elastic-plastic isotropic hardening material model was used. The materials used were aluminium, stainless steel, low carbon steel and hot rolled steels. It was concluded that there was a small discrepancy between simulation results and experimental results and it could be improved by proper element selection and meshing. Uemori, Okada and Yoshida (1998) analyzed the springback in v bending process considering the Bauschinger effect. Three different material models were employed such a isotorpic hardening model, linearly kinematic hardening model and a combined model. The authors developed a FE code based on r-min method and explicit time integration procedure was adopted. The simulations were carried out for stainless steel- aluminium clad sheets. It was inferred that the type of material model considerably affects the calculated springback values. Chan, Chew, Lee and Cheok (2004) studied the effect of punch radius, punch angle, punch displacement and die lip radius on Commerical softwares such as Patran(for modeling the sheet and die/punch), Abaqus/Standard (for simulating punching process) and Abacus/CAE (for analyzing the results) were used . The die-tool set and workpiece were defined as master surface and slave surface respectively. A linear elastic-linear strain hardening plastic model was adopted to represent the material property. The results provided the insight of springback behaviour with different parameters. Hamouda,Abu Khadra and Hamdan (2004) developed a finite element model using MARC/MENTAT commercial software to analyse the springback of different grades of stainless steel materials and validated with published experimental data. The effect of friction on the bending force, effective plastic strain and von Mises were investigated. Yunng-Ming Huang (2007) developed an elasto-plastic incremental finite element code to stimulate V-bending under the plane-strain conditions. The friction was introduced by modified Coulomb‘s friction law. Groze Achimas,Lazarescu and Ceclan (2007) developed a finite element model to anlayse the effect of parameters :dimension of raw part, georemetry of tools and elasto-plastic behaviour of material on springback in v bending. The analysis was carried out in two steps using the commericial code ABAQUS/Explicit. Sousa (2007) presented an optimization method for v-bending process. The genetic algorithm developed in FORTRAN code and FE simulation with ABAQUS were integrated. The method was applied to design optimal tool parameters, punch displacement and blank holder force in v bending. Thipprakmas(2010) used FEM to investigate the effects of punch height on bending angle in the v-bending process. The model was a two dimensional plain strain and the analysis was carried out in DEFORM-2D , a commercial static implicit finite element code. The work piece material was set as elasto-plastic type and the material used was aluminium alloy A1100-O. The simulation results revealed that the effects of punch height on bending angle were clarified based on material flow analysis and stress distribution. Osman Shazly,El-Mokaddem,.and Wifi,(2010) carried out finite element experiments using ABAQUS/Explicit and standard modules for finding the springback and compared the results with analytical and experimental results. Grizelj (2013) analysed using FEM, the effect of materals (high strength steels), sheet thickness and punch radius on springback for two different v bend angles and presented the results.

TABLE II LITERATURE ON CLOSED DIE BENDING

CLOSED DIE BENDING				
Author and year	Material Model	Material chosen	Type of analysis	Software used
Nilsson, Melin, Magnusson	Elastic-plastic isotropic hardening	Aluminum, Stainless steel,	2D Implicit	FEM
Uemori, Okada, Yoshida	Isotropic Hardening Linear Kinematic	Aluminium Stainless Steel	Lagrangian formulation	Indigenous
Chan,Chew,Lee,Cheok (2004)	Isotropic, Linearly elastic-linearly strain	Aluminum alloy 2024 – T3	--	ABAQUS
Hamouda, Abu Khadra and Hamadan	Isotropic Hardening	Stainless steel.	2D Lagrangiian - Implicit	MARC/MENTAT
Yunng-Ming Huang (2007)	Elasto-plastic anisotropic	Cold rolled carbon sheet	Lagrangi-an formulat	--
Groze, Achimas, Lazarescu,	Plain-strain	Deep drawing quality steel	--	ABAQUS
Sousa (2007)	Isotropic Elasto-plastic Hill	Mild steel	Explicit - Implicit	ABAQUS
Thipprakmas (2010)	Elasto Plastic	Aluminum alloy	Implicit	DEFORM -2D
Osman Shazly, El-Mokaddem,. and Wifi,	Isotropic linear elastic	Cold rolled low carbon steel	Explicit	ABAQUS/STAN - DARD, ABAQUS/Explicit
Grizel, Cumin,	Ludwik-Hollomon model	high strength steels	--	MARC

DISCUSSION

The early researchers carried out the analysis using the indigenously developed codes and the present researches have been using the commercial softwares, in particular, ABAQUS and LS-DYNA. Different material models have been used by them but elasto-plastic strain hardening model is the most common among them. Though the springback for different materials were analysed varying the tool and process parameters, the FE analysis has not been attempted much for coated and laminated sheets. The phenomena such as anisotropy effect, Bauschinger effect, friction are not introduced in the FE models. Some of the researchers attempted to introduce friction as constant coefficient of friction values and proper friction models are not included. The table I and table II depict the spectrum of research in FE analysis in V bending.

CONCLUSION

From the review, it is revealed that the FEM simulation is suitable for modeling the v bending process and predicting the springback. As new materials have been introduced in the industries, it becomes a need to apply this technique for them for better understanding of their behaviour during bending. The high standard accuracy of the simulation can be achieved with proper material models and meshing, introduction of the important assumptions such as anisotropy, friction in the simulation. The efficient FE simulation will reduce the costly tryouts to predict spring back and help in improving the process performance and product quality.

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