

Simulation & Modelling of Deep Drawing Process of SMA Material

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Abstract— This research work presents modeling of deep drawing of square cup. The sheet forming materials considered in study is NiTi shape memory alloy. The finite element analysis has been useful tool in simulating complex industrial forming operations. A simulation program has been carried out to study, effect of main process parameters such as blank holding pressure, coefficient of friction between sheet and die, on the thickness variation of cup wall and flange and to get maximum height of cup with minimum defects. The results of the study shows that uniform thinning of cup can be obtained by selecting proper combination of various process parameters.

Index Terms— Deep Drawing, Shape memory alloy, mechanical properties, square cups, Hypermesh,.

1 INTRODUCTION

One of the most common industrial processes in sheet metal forming is deep drawing. It can fabricate a variety of objects with cylindrical cups, rectangular cups even complex shapes. [1],[2]. Deep drawing process (DDP) is defined as a manufacturing process in which a sheet metal work piece is pressed into a die cavity as seen in figure 1. In this process metal sheet is subjected to tensile and compressive stresses. The aim of successful deep drawing process is to produce a product with greater final depth as well as with less defects. When the length of drawn cup is greater than a half of the drawing punch diameter, the product is said to be deep drawn; otherwise the product is classified as a shallow part. In order to prevent the material blank from flowing freely into the die cavity through the process, a third forming tool, which is named blank holder, is employed to hold down the blank. This technique can be widely applied to manufacture metal products with an aspect ratio larger than unity. Currently, the deep drawing process has an extensive role in aerospace and automobile industries to manufacture structural components. There are many industrial products manufactured by sheet metal like car bodies, airplane wings, roofs, lab table and many more. To reach the new market requirements targets for the aerospace, rocket components, automotive body development, process integration since the early concept development phases until the start of production, must provide a streamlined scalable environment that encompasses every step in the process from early design feasibility to the process final validation. High safety standards, high reduction of weight that improves fuel consumption, emissions and performance trends, a world class quality at reasonable production costs and schedule timing are changing the development chain in the aerospace and automotive industry.

Mainly regarding automotive lightweight construction based on the use of lightweight materials having low specific density and high-strength can be used. Automotive engineers and designers are being challenged every day and through the introduction of many new materials requirements can be fulfilled. Vehicle body complains usually complex geometry, irregular pressed parts. Forming these blanks is normally a combination of deep drawing and stretching and bending. A detailed analysis and judging of the forming process with conventional processes requires a lot of energy for most cases. Process simulation in the forming technique with the Finite Element analysis is an efficient and low cost tool for simulation of the forming process before production. During all stages of the forming process before production the Finite elements analysis simulation enables a detailed judging of forming material, the optimal tool form and the process the control. A variety of effects such as strain rate dependence of the material as well as different friction conditions at contact areas are describable and corresponding friction conditions are put at disposal by the programs. In this sense a consequent use of stamping simulation enables: Saving of development time by securing the development course and to reduce costs as well as a quality improvement of stamping parts by optimization of process parameters, material choice, blank and forming steps of the deep drawing process.

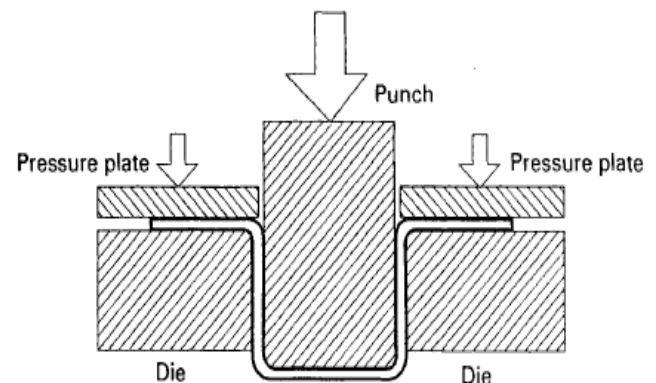


Figure1:- Forming Process

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2 DEEP DRAWING SIMULATION

2.1 Materials & Material Properties

In this present research work NiTi Shape Memory alloy is used. A NiTi Shape Memory Alloy (SMA) is able to memories and recovers its original shape, after it has been deformed by heating above its transformation temperature. The unique effect of returning to an original geometry after a large inelastic deformation (nearly about 10%) is known as the NiTi Shape Memory Effect [3]. The properties of NiTi and other SMA alloys are fairly different, due to their different micro-structure. Because NiTi alloys have much higher strength, larger recoverable strain, better corrosion resistance and most importantly higher reliability than other shape memory alloys. NiTi alloys are the standard choice for space and several other applications. Materials and structures in many aerospace systems have mainly been responsible for large performance improvements, because of reduction in gross weight and operating costs. In the future these systems have to be small, inexpensive and fast. The self-expanding antenna is one of the example that demonstrate SMAs have made inroads in the industrial world [4]. Another technological challenge is an intelligent, self-healing vehicle where the SMA can be imbedded in the skin or substructures. It can detect damage and respond with an external stimulus for self-repair [5]. A commercially this technique can be used in automobile industries to make vehicle body parts. A vehicle part made of SMA can regain its shape on heating if damaged. Smart rotorcraft blades and aircraft wings will be one of the first applications of smart material in aerospace [6]. They could increase the maneuverability and controllability by changing the shape of their control surface. In this way it is possible to manipulate lift and twist. Or it can be used to reduce drag. In future aerospace vehicles will be made from programmable multifunctional materials and structures that will have the possibility to adjust their shape and mechanical, electromagnetic, optical and acoustic properties on demand [7].

The material used in this study is smart material NiTi shape memory alloy. The mechanical properties are given in Table 1. E is the young's modulus, Poisson's ratio and Y is the yield stress of the material etc.

TABLE 1
THE MECHANICAL PROPERTIES OF NiTi MATERIALS

Young's modulus	E	62 GPa
Yield strength	Ys	1058 Mpa
Ultimate tensile strength	Ts	1330 Mpa
Poisson's ratio	Pr	0.03
Cyclic strain hardening exponent	n	0.1
Cyclic strength coefficient	K	733 Mpa
Fatigue strength exponent	b	-0.06

Fatigue coefficient	strength	F	705 Mpa
Fatigue exponent	ductility	c	-0.6
Fatigue exponent	ductility	€f	0.68

2.2 Finite Element Model

A finite element simulation of deep drawing of "square cup" has been conducted using the high performance computer commercial software Hypermesh 12.0. Hypermesh provides manufacturing one step finite element analysis, which is competent for the computer aided analysis of sheet metal forming processes. The moldel geometry was drawn in 1:1 scale for the numerical model. The blank model was fine meshed and with 15979 elements. The drawing depth is 42mm and more than 42 mm, the contact gap was taken as 0.4 mm. A finite element model of the geometry has been shown in figure 2.

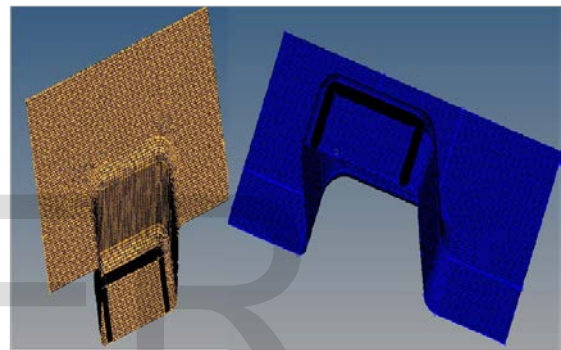


Figure 2:- FEA Model of Fine Meshing using Hypermesh

2.3 Simulation of deep drawing of square cup

Through Finite element simulation of square cups for different set of process parameters (blank holding force and friction between blank and die) have been observed. The Process modeled has been considered free from bulging and the compression, which can be occurred in actual practice. The FEM models are shown in Fig. 2, the blank was meshed using square shell elements with anisotropic material under plane stress conditions. The finite element simulation parameters of NiTi sheet have been given in the table.2.

TABLE 2
THE FINITE ELEMENTS PARAMETERS OF NiTi SHEET MATERIALS

Material of sheet metal	NiTi SMA
Blanks of loads	10, 12,15 kN
Coefficients of friction	0.12,0.15, 0.20
Sheet Thickness	1 mm
FE meshing elements	Square
FE Meshing Size	1

Sheet Metal	Anisotropic
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In the study the effect of blank holder force and friction coefficient have been investigated, for this the values of blank holder force has been taken as 10kN, 12kN, 15kN. Different blank holder force was selected to evaluate material flow rate, defects and drawing length.

3 RESULTS AND DISCUSSION

The blank holder force is the most important parameter in the sheet metal forming process. When blank holder force is insufficient, there will be possibility of formation of wrinkles with poor quality of surface. If blank holder force is above some limiting value than there will be possibility of crack formation which leads to drawing failure. To determine the appropriate blank holder force, the blank holding device is loaded with 10kN, 15kN, 20kN and different coefficient friction respectively. The forming thinning ratio is achieved through post processing, as shown in Figure.3, 4 and 5. The forming thinning ratio and the maximum drawing height with various blank holder forces are shown in Table.3.

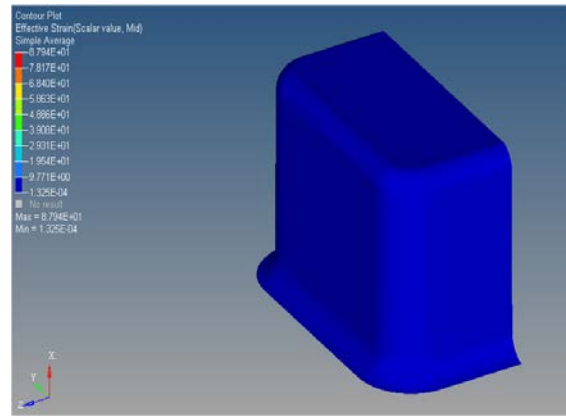


Figure 4:- The forming thinning ratio at load 15kN at Coefficient of friction is 0.205

TABLE 3
 FORMING THINNING RATIO AND MAXIMUM DRAWING HEIGHT

Step	Blank Holder Force	Maximum Thinning Ratio	Minimum thinning Ratio	Height of cup
	kN	%	%	mm
1	10	9.5	-2.0	42
2	12	8.0	-3.0	45
3	15	8.7	1.3	48

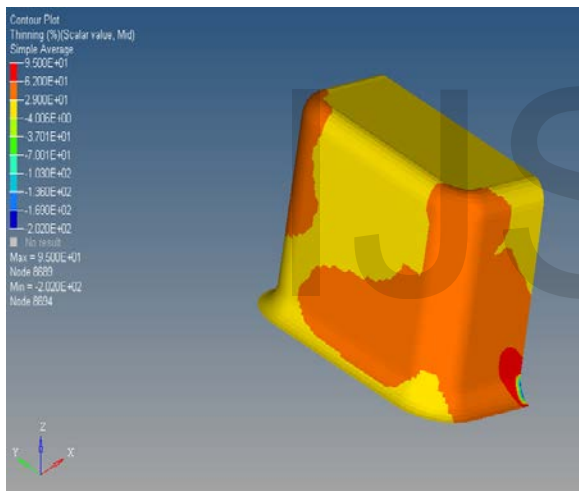


Figure 3:- The forming thinning ratio at load 10kN at Coefficient of friction is 0.125

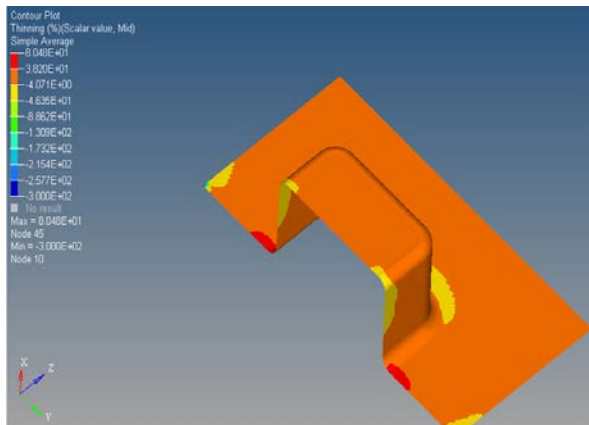


Figure 4:- The forming thinning ratio at load 12kN at Coefficient of friction is 0.152

From Table.3 and Figure.3, when blank holder force kept to 10 kN and friction as 0.125, It has been observed that the cup sidewall and the bottom surface thin most seriously and the maximum thinning ratio is 9.5%, where as flange area thickens and minimum thinning ratio is -2.0%, this region has wrinkles. Results show that the blank holding force increases with the growth of the maximum thinning ratio and the reduction of the minimum thinning ratio. When the blank holding force is kept to 12kN in next set, the maximum thinning ratio is 8.0% but minimum thinning is -3.0% , this shows that thinning at side walls has been reduced and drawing depth increased but still there will be thickening at flange area that results in formation of wrinkles. As the blank holding force kept to 15 kN , it has been observed that maximum thinning is 8.7% and maximum thinning is 1.3%. The limit thinning ratio decreases and the maximum drawing height increases with the increasing of the coefficient of normal anisotropy. The dangerous area of breakage disappears and wrinkling still exists. But the area of wrinkling reduces greatly. It means that smaller the coefficient of normal anisotropy, more easily the sheet changes in thickness.

4 CONCLUSION

Successful deep drawing depends on many parameters such as geometrical parameters and physical parameters. The finite element analysis simulation is a powerful tool in the sheet metal die design, reducing time and trial and error efforts. A Finite Element Model is developed to reach the optimum solution without many costly trials of production which is a common practice in the traditional production approaches. In this research work; simulation of the deep drawing process of the square cup has been carried out to discuss the influence of the blank holding force and the coefficient of normal anisotropy on the forming limit. The results show that: The limit thinning ratio decreases gradually and the deformation area tend to be scattered with the increase of blank holder load value and the coefficient of normal anisotropy. Also the trend of wrinkles in the local deformation area reduces and the maximum height increases, which is favorable to formation of sheet metal. The current model better describes the friction conditions related to sliding contacts surfaces in the deep drawing processes under lubricated conditions. In the present research work it has been observed that the optimum blank holding force should be kept upto 15 kN with increased friction coefficient as 0.205.

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