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Research Article

Experimental Analysis of 'V' Die Air Bending of Fe 410W-C Steel Plate

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Abstract

Sheet metal forming is one of the most common metals forming process. The production with accuracy is an important factor in forming process in sheet metal industries. In variety of sheet metal forming process, the bending of sheet metal is major area in the sheet metal industry. The major causes for inconsistent sheet metal part in bending process is spring back, die clearance, tool radius and load of press. Here we have taken the experimental study of The 8 mm thick plate bending process in Fe 410W-C material. The bending process in the plate is an important application because; it is used in various engineering applications. The bending analysis of 8mm thick plate bending has been one of the important issues in theory and engineering. Spring back is a common phenomenon caused by the elastic redistribution of internal stresses during unloading in the bending process and it directly affects the precision and quality of products. So there are strong demands from the manufacturing industry for evaluating the amount of spring back and predicting the final geometry of the work piece with accuracy after the process. There are many bending methods used widely, but the three point bending has been utilized extensively for the bending process due to its apparent simplicity and good flexibility. In this paper, three point bending method is used for 8mm thick plate bending process. Since the prediction of this phenomenon and the compensating of spring back, during process are still a formidable challenge today, few efforts have already been devoted to this objective as experimental studies and theoretical analysis. Here real time experiments conducted with 8mm thick plate for 3 different radiuses. Nearly 10 experiments conducted for each radius and every parameter of experiments noted down. Numerical simulations using finite element analysis are also performed for these three different radii to investigate the effect of spring back and all relevant parameters which are available through simulation also noted down. The finite element model is validated with experimental results of spring back. Then taking the account of three different type tests of three different radius which are formed by our experiments, a well formed pieces without any defect, due to formation is taken and bending radii are measured. Then the optimization of spring back, die clearances for different bending radius done using neural networks in later stage.

Keywords: *sheet metal forming; spring back; three point bending; finite element analysis; elastic redistribution of internal stresses, thick plate bending process.*

1. Introduction

1.1 Sheet Metal Working

As a fundamental and traditional metal working process in manufacturing, the sheet metal forming is widely being employed in almost all industrial fields. The choice of forming operation depends on the desired size, configuration, and production quantities of a part.

Bending is the common metal working operation to create localized deformation in sheets, plates, sections, tubes and wires. Bending is done in various types of operations and machines such as press brakes or four slide machines. Computer controlled air bending machine, wiping die machine, U bending machine and three roll benders are some types among them. This project mainly focuses on the bending of sheet metal or plate metal using the three point air bending method. If productions quantities are relatively small and work pieces are relatively large the air bending method is used as the cost effective method. The air bending method is considering its simple tool setup which can be used for bending any type of plate or sheet to various angle and forming various desired shape, instead of using heavy presses which can be used for only the single type of component. We can put the air bending method well above the today's conventional presses in cost effectiveness. The precision in dimension is a major concern in this type of bending process because of the considerable amount of elastic recovery during unloading leads to spring back. Hence the tool design (radius of tool) for given specific plate material should be based on elastic recovery amount (spring back).

And nowadays bending in thick plates (i.e. eight mm and above eight mm thick) finding its way faster in the industrial field for its need in structural components and it can be alternate for casting supporting components, this

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type of uses make the thick plate bending a most important one `nevertheless the problem we face in its bending. The spring-back is mainly case-dependent. Thus in sheet metals (i.e. below six mm thick) though the spring back is high the correcting stroke is easily accessible by technician itself and enough major study have been conducted on those. But in this thick plate bending though the spring back is less the problem we face in this bending is very high. Besides their difficulties in bending, their growing need as supporting components in heavy machine and all types of structure makes study of this type thick plate bending more inevitable, and needs more research work to be carried over in this area. And producing a result to these types of problems will be far more challengeable.

From song and yu (2012), it has been inferred that the advances in numerical simulation techniques, such as the finite element method and the numerical optimization like advanced Mat lab will be major use in this type of study and be very helpful to arriving at a solution to these types of problems. So that the accurate elastic recovery prediction and the systematic tool design are in a rapid development growth. But, plate metal bending belonging to these type bending is characterized by small spring back but a considerable deformation in its radius of curvature, as well the frictional contact boundary changes during the process. Which implies that the finite element analysis of plate metal bending process is quite difficult? Hence, remarkably intensive research efforts are still focused on its advancement. In addition, the effects of major process parameters on the elastic recovery phenomenon have not been sufficiently investigated. Now we introduce the effect of the material-hardening mode on the spring back simulation accuracy of V-free air bending, in which a linear- hardening model and an elastic–plastic power-exponent hardening model of the material are adopted and the change of the material's Young's modulus with plastic deformation is also considered.

Further, panthi et al (2006) carried out an investigation on the prediction of spring back in the sheet metal using the numerical experiment and expressed them in spring back ratio also to determine their influence on the numerical prediction of the spring back phenomenon. They used Finite element method software based on a total-elastic-incremental-plastic algorithm, for large deformation and large rotational problems, was employed. From these works, it can be concluded that the material-hardening mode directly affects the spring back simulation accuracy. But the classical elastic–plastic constitutive models and the isotropic hardening assumption are still successful in providing satisfactory predictions for traditional materials. And can be said FEM model well supports the real time model. Moreover, spring back can also be influenced by geometric parameters of the products. Most of the studies using the finite element methods are concentrated on large deformation problems such as sheet metal forming. But we try to implement the same in our "V" bending process of our 8mm thick plate bending.

1.2 Experiments

In the bending process, the plate will undergo spring back when the plate is bent and then unloaded, which leads to the change of bending deflection. There are many factors that affect the spring back stroke, such as material properties, geometric parameters of plate, etc., in which the two most important parameters in the process are identified to be initial deflection (∂x) and loading stroke ($\partial \varepsilon$). So the relationship between the bending and spring back can be written as.

$\partial f = \emptyset(\partial x, \partial \varepsilon)$ Equation 1.1

Where ∂f = Springback stroke.

The experiment was carried out on the self-made hydraulic bending machine. The 8mm thick plate test samples used in the tests were strictly selected from the same stock which is used to make the trolley bracket to ensure that the material remained as consistent as possible and the material considered for the 8mm thick plate air bending is Fe 410 W C.

1.3 Plate Configuration and Material Properties

1.3.1 Material Property

This grade is also commonly known as Fe 410 W C (IS 2062) and specifications of this grade as follows.

1.3.1.1 Chemical Composition

Table 1.1 Chemical Compositions

Carbon %	*Manganese Max %*	*Sulphur Max %*	*Phosphorous Max %*	*Silicon Max %*	*Carbon Equivalent*
0.20	1.50	0.045	0.045	0.40	0.42

1.3.1.2 Mechanical Properties

Table 1.2 Mechanical Properties

Tensile Strength Minimum, Mpa	*Yield Stress, Minimum, Mpa*
410	250

1.3.2 Plate Dimension

The experimental setup specimen dimensions are follows

Width = 30mm
Length = 100mm
Thickness = 8mm

1.4 Bending Theory

Bending is a common metalworking operation to create localized deformation in sheet (or blanks), plates, sections, tubes, and wires. Bending occurs from stressing a work piece in a localized area, and it results in non-uniform deformation (contradiction and elongation) within the cross-sectional area of bending. Because of these in-homogeneities, analyses of stress strain distributions are of utmost importance when evaluating bending conditions. Bending is done in various types of operations and machines such as press brakes or four-slide machines. Plates and sections are often bent in three-roll benders into complete circles. Roll forming is another type of bending operation that allows mass production of two-dimensional corrugated sheet, architectural sections, and lock-seam and welded tubes. This article focuses on the bending of sheet metal along with some coverage on flanging. Bending a sheet along a curved line is termed flanging. Circular or other close-shaped flanges (collars) are mass produced in preparation for joining tubes and fasteners to sheet, as in heat exchangers. Limits are set by fracture in a stretch flange and by buckling in a shrink flange. Related processes are flanging and necking of tubes and cans, as on beverage cans.

1.5 Finite Element Method

The Finite Element Method (FEM) is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously. The following figure shows CAD and its FEA model.

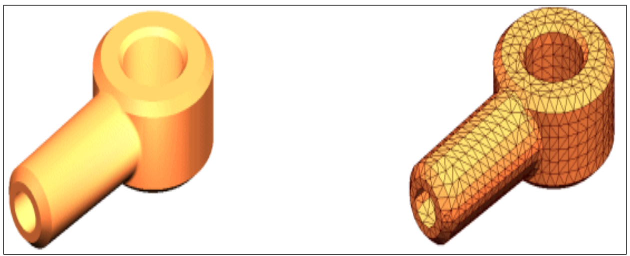

Figure1.10 CAD and FE Model

Elements share common points called nodes. The process of dividing the model into small pieces is called meshing. The behavior of each element is well-known under all possible support and load scenarios. The finite element method uses elements with different shapes. The response at any point in an element is interpolated from the response at the element nodes. Each node is fully described by a number of parameters depending on the analysis type and the element used.

For example, the temperature of a node fully describes its response in thermal analysis. For structural analyses, the response of a node is described, in general, by three translations and three rotations. These are called degrees of freedom (DOFs). Analysis using FEM is called Finite Element Analysis (FEA). Software programs formulate the equations governing the behavior of each element taking into consideration its connectivity to other elements. These equations relate the response to known material properties, restraints, and loads. Next, the program organizes the equations into a large set of simultaneous algebraic equations and solves for the unknowns.

2. Problem Description

2.1 Air Bending

Air bending of “V” shape for low thickness is achieved in higher accuracy with minimum spring back. Number of research had done on spring back and effect of bend with low thickness, low carbon steel sheets. When the bending required for plate like model, where thickness of the plate is >6.4 mm it is difficult to achieve the bend without side bulging and exact load to bend operation values.

And nowadays bending in thick plates (i.e. 8 mm and above 8 mm thick) finding its way faster in the industrial field for its need in structural components and it can be alternate for foundry casting supporting components, this type of uses make the thick plate bending a most important one nevertheless the problem we face in its bending. The spring-back is mainly case-dependent. Thus in sheet metals (i.e. below 6 mm thick) though the spring back is high the correcting stroke is easily accessible by technician itself and enough major study have been conducted on those. But in this thick plate bending though the spring back is less the problem we face in this bending is very high. Besides their difficulties in bending, their growing need as supporting components in heavy machine and all types of structure makes study of this type thick plate bending more inevitable, and needs more research work to be carried over in this area. And producing a result to these types of problems will be far more challengeable.

And making this thick plate material bending in air bending makes the process more versatile and can be done for any size of plate. The needs for the separate presses are avoided and this makes the process less expensive and more cost effective. So taking into account all these major care should be taken on this type of air bending of 8 mm thick plate material bending and main problem faced in these type of bending are

(1) After bending side wall bulging is the major problem in these type bending, so the correct loading stroke which avoids the side wall bulging and forms the radius should be found out.
(2) Though the spring back is less in these, the two or more correcting stroke needed, which forms the impression on the radius.

3. Methodology

3.1 Proposed Study

In this project work, FE410 sheet with 8 mm thickness is taken for research study with “V” bending. A standard hydraulic press is selected for the “V” bending experiment; a sample specimen of 100 x 30 x 8 mm is taken for the experiment. Three different radiuses were taken and tested and as follows R8, R12 and R16 mm.

3.2 Die and Punch

Die is made of tool steel with, 6T die opening, and the punch as prescribed as above in with three different radii.

Simply supporting is used for bending operation. The pressure of the three radiuses is as follows 50, 60 and 70 Kg/cm^{2}. These values are converted as force for finite element simulation, the hydraulic cylinder is having 97 mm diameter is used for applying pressure on the plate.

The experiment study is conducted on 30 pieces, for each radius with specified loading for the same. All these dimensions are taken for later interpretation for neural network model as well as for comparison with FE simulation.

3.4 Computation Strategy for FEA

Finite element method is the best and prescribed for large deformation non-linear simulation like this metal forming process. Autodyne is one of the best explicit solvers available in the market; ANSYS integrates this solver for all type of explicit solution.

3.5 Meshing Setup for FEA

Quad and Tetra elements were chosen for the meshing. Since ANSYS automatically selects the meshing algorithm and type of element required for the analysis model, it is easy to concentrate with the mesh density for accurate analysis.

3.6 Material Property for FEA

Proper explicit model of the low carbon steel is selected for sheet model and tool steel is applied for die and punch. The material library in the Autodyne software allows us to select the required material model. Proper hardening law is used for the material model; all the models are collected by the software from different research work of different scholars all around the globe. The hardening of the materials after the yield is an important factor for any forming process and not limited to this only for any plastic flow models. Different research works have been conducted to explore the material property after the yield limit and algorithm are formulated for identifying the hardening factors of the material.

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3.7 Loading details for FEA

Table 3.1 Load Vs Punch Radius

Load (N)	Punch Radius (mm)
36949	8
44338	12
51728	16

The loads for the model with respect to the radius of the punch are calculated as force as are given in table 3.1

Based on the pressure applying on the piston of the hydraulic cylinder, the pressure is converted to force for easier application in to finite element solution.

3.8 Solution Accuracy of FEA

The accuracy of the simulation is decided by the kinetic energy (KE) and hourglass energy (HE) values, after the simulation the values of the both is verified and it is checked the KE > HE, so that the simulation is in right way and predict a good result for the simulation. The quality of the solution can be monitored by reviewing momentum and energy conservation graphs in the solution output. Low energy errors (<10% of initial energy) are indicative of good quality solutions

4. Results and Discussions

4.1 Model and Parameters

The air "V" bending is performed for a low carbon steel sheet for a given dimension; thedie is to gives 90° "V" bend for a three different force with different punching radius.

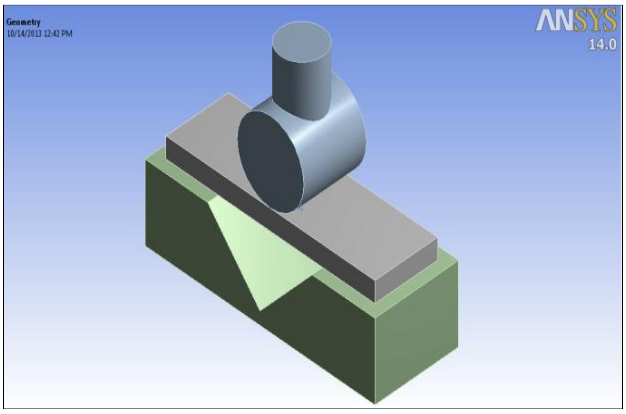

Figure 4.1 Die-Punch and Sheet

4.2 Analysis Setup

- Length = 100 mm
- Width = 30mm
- Thickness = 8mm
- Material = Fe 410 W C
- Boundary = Simply supported
- Punch = Force of 35K (R8),40K(R12) & 45K(R16) N

The load on the punch is converted to Newton's by means of pressure applied on the punch and the diameter of the hydraulic cylinder piston. Three types of punch is used for experimental and the same is used for simulation with calculated loads

Table 4.1 Load Calculation

Punch Radius(mm)	Pressure (Kg/Cm^2)	Load (N)
8	50	36948
12	60	44338
16	70	51728

4.3 Mesh Details

The model is meshed with tetra and quad combination, by default the solver selects meshing with respect to physics nature. In this case explicit is selected for the meshing and solving.

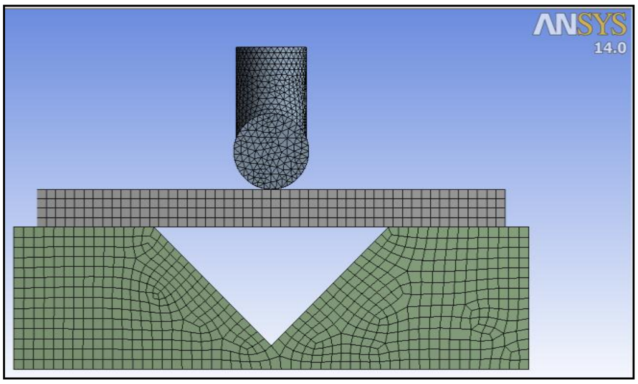

Figure 4.2 Meshing

Table 4.2 Meshing Details

Component	Mesh Type	Node / Elements
Sheet	Hexa	4080/3000
Die	Hexa	14020/11951
Punch	Tetra	4616/22309

4.4 Load Vs Deformation

The following table shows the deformation or the bend in the bend axis (Y) of the three different radius punches with their respective loads.

Table 4.3 Load Vs Deformation

Punch Radius	Load (N)	Max. Deformation (mm)
8	36948	21.363
12	44338	20.246
16	51728	19.216

4.5 Load Vs Von-Mises Stress

The following table shows the stress (Plastic) with respect to their punch radius and their loads. When the radius increases the stress increases, and after a stage it decreases due to die opening limitation.

Table 4.4 Load Vs Plastic Stress

Punch	Load (N)	Plastic Stress (N/mm^2)
R8	36948	507.1
R12	44338	588.0
R16	51728	590.5

4.6 Load Vs Shear Stress

The following table shows the shear in the sheet vs load of the punch. The stress decreases after 12 radius punching. The magnitudes of the stress level are in the range of 1.5 to 2 times of the von-mises stress.

Table 4.5 Load Vs Shear Stress

Punch	Load (N)	Shear Stress (N/mm^2)
R8	36948	292.3
R12	44338	329.0
R16	51728	326.3

4.7 Experimental Setup

Hydraulic Press : 10 T
Die : "V" Type
Punch : R8, R12 & R16
Sheet Size : 100 x 30 x 8 mm
Die/Punch Material : Tool Steel
Sheet Material : FE 410
No. of Test Specimens : 30 specimens

4.8 Experimental Findings

The following table shows the experimental results obtained from the air bending of "V" die with R8 punch.

Table 4.6 Experimental Results of R8 Punch

Serial No.	Radius (mm)	Load for first stroke Kg/cm^2)	Angle after spring back (°)	Load for correcting stroke (Kg/cm^2)	Angle after Correcting Stroke (°)	Time taken for process (sec)
1	8	45	88	49	89	18
2	8	44	87	50	90	19
3	8	46	87	51	90	18
4	8	44	86	50	90	20
5	8	45	87	51	90	21
6	8	44	86	49	90	18
7	8	44	87	50	91	20
8	8	46	86	49	90	19
9	8	42	85	50	91	18
10	8	46	88	50	89	18

The following table shows the experimental results obtained from the air bending of "V" die with R12 punch.

Table 4.7 Experimental Results of R12 Punch

Serial No.	Radius (mm)	Load for first stroke (Kg/cm^2)	Angle after spring back (°)	Load for correcting stroke (Kg/cm^2)	Angle after Correcting Stroke (°)	Time taken for process (sec)
1	12	56	87	58	89	21
2	12	58	86	62	90	18
3	12	57	87	60	90	19
4	12	56	88	60	90	20
5	12	54	86	58	90	21
6	12	57	87	61	89	18
7	12	55	86	59	90	19
8	12	54	88	58	90	20
9	12	55	87	59	90	21
10	12	57	88	61	91	20

The following table shows the experimental results obtained from the air bending of "V" die with R16 punch.

Table 4.8 Experimental Results of R16 Punch

Serial No.	Radius (mm)	Load for first stroke (Kg/cm^2)	Angle after spring back (°)	Load for correcting stroke (Kg/cm^2)	Angle after Correcting Stroke (°)	Time taken for process (sec)
1	16	65	87	69	89	14
2	16	64	85	68	90	16
3	16	68	86	72	90	15
4	16	65	87	69	90	17
5	16	67	88	71	90	15
6	16	66	87	70	89	15

R8 “V” Test Specimen

R12 V” Test Specimen

R16 V” Test Specimen

5. Conclusion

The experiential study of “V” die air bending with three different radius punches was conducted successfully. Single die setup is used for experiment, it has been inferred that for this single die setup which has no clearance, the load increases to bend the specimen as the punch radius increases, also it has noted that spring back angle is less for R8 punch and considerably more for R16 punch. Also it has been noticed that for the given die setup the simulation result (load) which is obtained through ANSYS well supports the experimental findings (load) for all the three radius. Each test specimen has been studied and it has been observed that though spring back is considerably less, the more side bulging in the test piece makes to conclude that R8 punch radius can’t be used for forming this 8 mm thick plate. Though the spring back is considerably high, and also the load given to bend the specimen is also high in other two radius. A study can be done on this to overcoming this spring back, and to reduce the load to bend the specimen by using ‘v’ die with greater clearences. So the punch radius R12 and R16 can be taken for further studies.

The experimental results were compared with finite element analysis results and the material property of the sheet is also studied. These results will be taken for further work.

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