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MODELLING AND ANALYSIS OF SPRINGBACK EFFECT ON ROTAVATOR BLADE USING DEFORM 3D

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Abstract – *The rotavator blade is a critical part of tiller machine that directly engages in soil bed preparation. Moreover, it is required to cut costs of die production with high quality. Blades are produced from materials which belong to High Strength Steel. Nevertheless, it results in appearance of springback effect. Springback value depends mainly on type of material as well as part geometry and processing condition. Die design requires using of appropriate Finite Element Method software to make them more economic and less time consuming. This paper is basically an investigation of springback behavior during sheet metal forming process by DOE using different parameters like die design, temperature and holding force. The spring back effect performed by numerical analysis in DEFORM considering temperature (850, 900 and 950 0C), blank holding force (0, 150 and 300 N) and different punch and die combinations (v-bend, air bend & partial punch) parameters were taken. Design of experiment using Taguchi L9 array was formulated to understand the influence of parameters on the blade.*

***Key Words*:** Springback, DEFORM 3D, Rotavator blade

1. INTRODUCTION

Rotavator tiller shown in the Fig-1 is a machine designed for making the land suitable for sowing seeds, for removing weeds, mixing manure and fertilizing into soil, to break up and cleaning grasses for breaking clods. It offers an advantage of speedy seedbed preparation and decreased draft compared to conventional tillage. The rotary tiller saves 30-35 % of time and 20-25 % in the cost of operation as compared to conventional tillage. It gave higher quality of work (25-30 %) than tillage by cultivator [1].

Fig-1: Rotavator and its main elements

1. Independent Top Mast
2. Single/Multiple Speed Gear Box
3. Chain drive
4. 6 Blades per Flange
5. Adjustable depth skids
6. Central with offset positions

Blades are the main parts of rotavator tiller which directly engaged with the soil to prepare the seed bed for cultivation land [2]. Many types of rotavator blades as shown in the Fig-2 are available in market. Rotavator are usually supplied with L blades for general work [3].

L - blade C – blade J - blade

Fig-2: Types of Blades

1.1 Springback

The major problem in bending process is the spring back. It is a complex phenomenon and depends on process and material parameters. Spring back is the amount of elastic distortion a material has to go through before it becomes permanently deformed, or formed [4]. Bauschigner effect is the main cause of this spring back phenomenon [5]. The die width reduction can significantly reduce spring back and avoid unwanted sheet slip over the die radius thus allowing spring back compensation by over bending [6]. As the thickness of the sheet metal increases there will be a decrease in the spring back effect [7].

The complete amount of deformation is therefore equal to the sum of the elastic deformation and the plastic deformation of the operation [8] as shown in Fig-3, i.e.

$$E_{TOTAL} = E_{EL} + E_{PL}$$

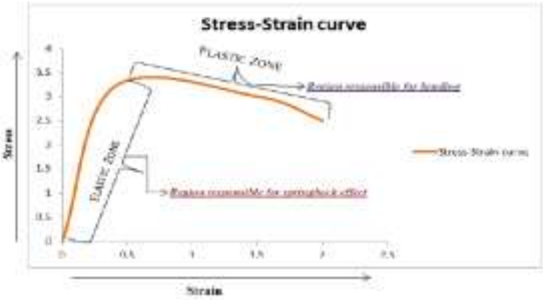

Fig-3: Graph Showing Elastic and Plastic Zone

2. MATERIALS AND METHODS

There are many materials that can be used for the manufacturing of blades, some of the materials used for the manufacture of blades are high carbon and spring steel grade AISI 1070, AISI 1080, EN 45, SUP 9, Boron steel and equivalent material. But for the present study the material used was AISI 9260 steel. AISI 9260 is high silicon especially designed for its spring properties [9].

Table -1: Mechanical Properties of AISI 9260

Density	7.85 g/cc
Tensile strength	770 MPa
Ultimate tensile strength	1525 MPa
Poission's ratio	0.29
Modulus of Elasticity	200 Gpa

Table -2: Chemical composition of AISI 9260

Carbon	0.56 – 0.64
Iron	96.085 – 96.89
Manganese	0.75 – 1.0
Phosphorus	<= 0.035
Sulphur	<= 0.04
Silicon	1.8 – 2.2

3. BENDING FORCE CALCULATION

Bend force is the force required to cause a sheet metal to bend at an angle and form the desired shape. Bend force is influenced by sheet metal properties

Bending force $F = (k \times L \times TS \times t^2)/W$..... [8]

Where

F: Bending force (kgf)
L: Bending line length (mm)
t: Plate thickness (mm)
W: die shoulder width (mm)
TS: Tensile strength (kgf/mm^2)
Die shoulder width (W)
Bending Coefficient (k)

- 1.33 [when the die shoulder width (W) is 8 times the material plate thickness (t)]
- 1.5 [when the die shoulder width is about 5 times the plate thickness (t)] and
- 1.2 [when it is about 16 times the plate thickness (t)]

4. DESIGN OF EXPERIMENTS (DOE)

Taguchi method is one of the designs of experiment technique to find the optimum number of experiments based upon the factors relating the experiments. In below Table 3 shows the Taguchi model used for design of experiment technique to fit experiments for three factors each of three levels is given. The factors influencing the experiments are work piece temperature (°C), Different combination of punch and die and Blank Holding force (BHF).

Table -3: Taguchi design model

Exp. no.	Die combinations	T (°C)	BHF (N)
1	1	850	0
2	1	900	150
3	1	950	300
4	2	850	150
5	2	900	300
6	2	950	0
7	3	850	300
8	3	900	0
9	3	950	150

4.1 Die Combination used for the DOE

The combination 1 consists of a normal V type punch and bottom die with 900 angle. The die has a height of 150 mm and width 85 mm.

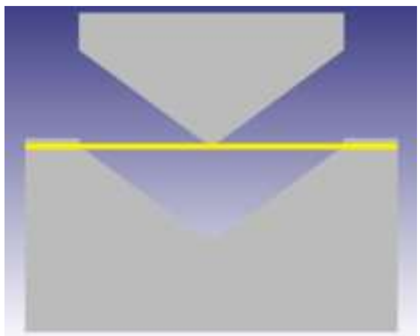

Fig-4: Combination 1

The die combination 2 consist of a normal V-punch with 900 angles and an air bending die which has a height of 200 mm and width 85 mm.

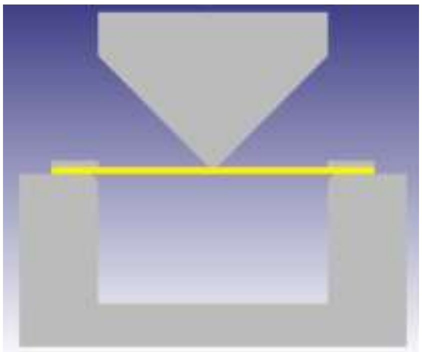

Fig-5: Combination 2

The combination 3 consists of a partial v-type punch or punch with side relief and bottom stationary die which has a height of 200 mm and width 85 mm.

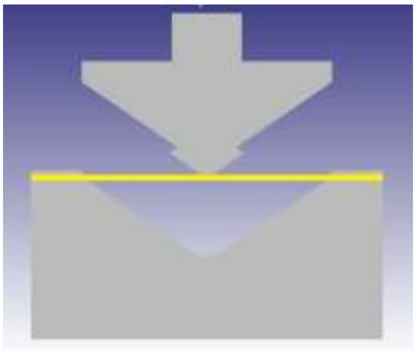

Fig-6: Combination 3

5. NUMERICAL ANALYSIS IN DEFORM 3D

Simulation of the hot forging of AISI 9260 is carried using Punch and Dies, where the deformation and spring back behavior of the material can be studied. It consists of a punch of required dimension which moves continuously deforming the work piece until it reaches the required depth as shown in Fig-7.

5.1 Import of Models

The blade, punch and die are loaded into the Deform software separately in STL format. The blade is considered as elasto-plastic in nature shown in figure Fig-8. Then required material is assigned to the blade from the material library.

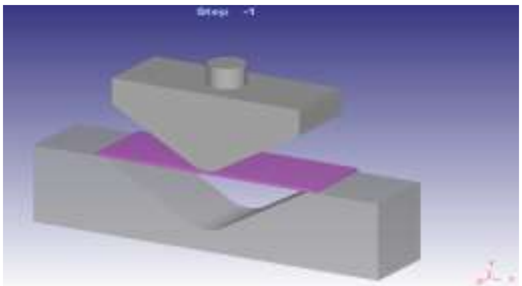

Fig-7: Geometric model in Deform

Fig-8: Input of Boundary conditions

5.2 Mesh Size and Density

Fig-9 shows the meshing of the component in Deform 3D. Tetrahedral mesh was maintained, 32000 elements were used in the mesh and majority of the elements are concentrated where the die makes contact with the work piece. Fig-10 is the mesh model during the process.

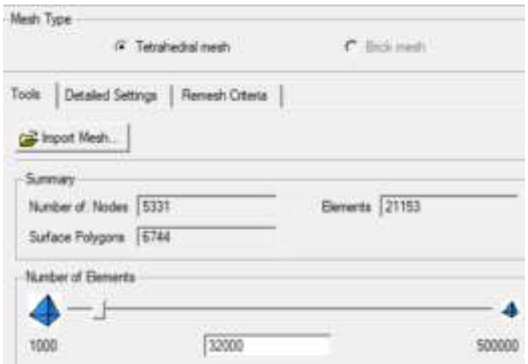

Fig-9: Geometric model in Deform

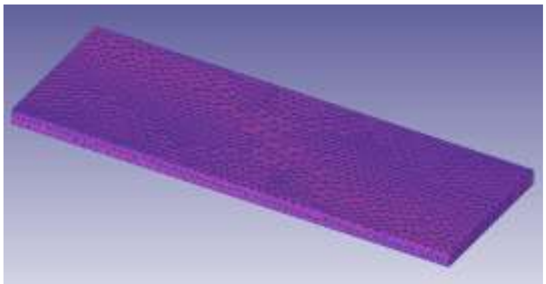

Fig-10: Mesh Model

5.3 Contact Generation of the FE Model

Fig-11 shows the work piece and dies are assembled together and the contact generation is made between the surface contacts by selecting co-efficient of friction value for the simulations and heat transfer.

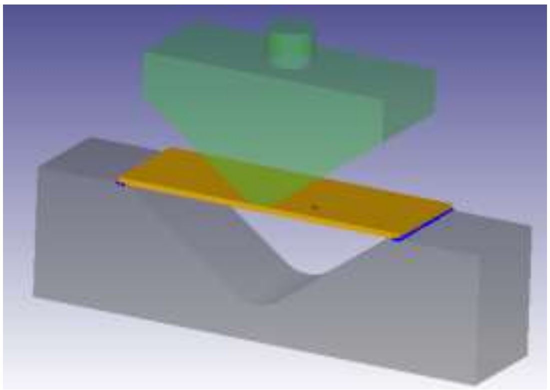

Fig-11: Contact Point Generation

6. RESULTS AND DISCUSSION

The Fig-12 shows the maximum displacement graph. For experiment 1 max. Displacement 0.6 mm was observed i.e. 0.2980.

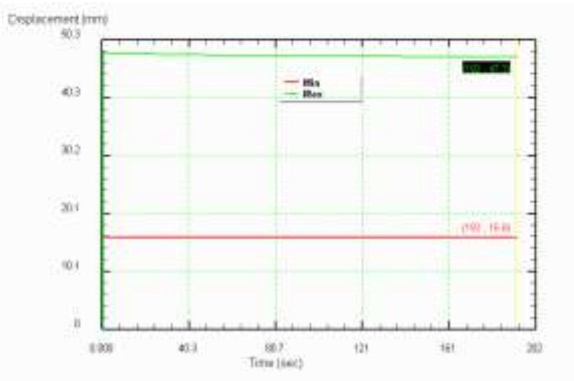

Fig-12: Displacement v/s graph for experiment 1

The Fig-13 shows the maximum displacement graph. For experiment 1 max. Displacement 0.7 mm was observed i.e. 0.660.

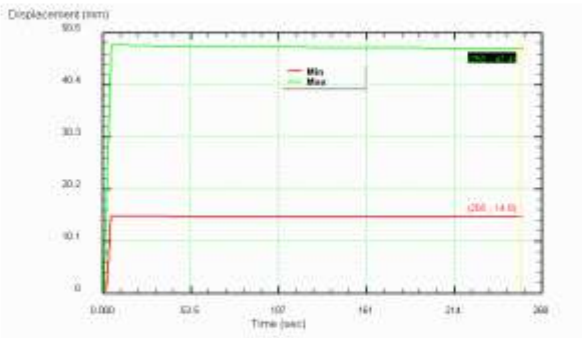

Fig-13: Displacement v/s graph for experiment 2

The Fig-14 shows the maximum displacement graph. For experiment 1 max. Displacement 1.4 mm was observed i.e. 1.580.

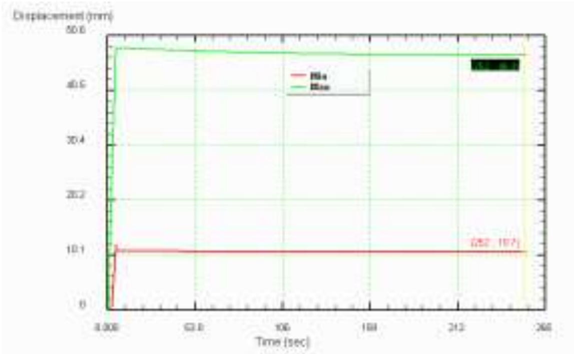

Fig-14: Displacement v/s graph for experiment 3

The Fig-15 shows the maximum displacement graph. For experiment 1 max. Displacement 1.7 mm was observed i.e. 3.60.

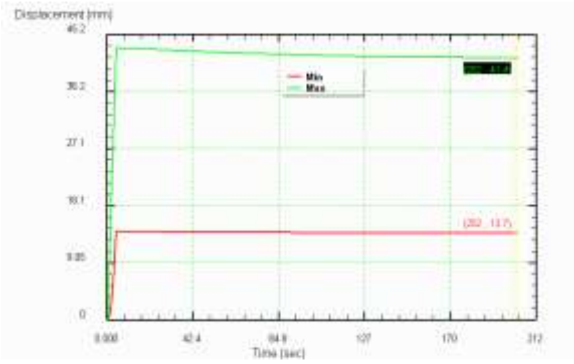

Fig-15: Displacement v/s graph for experiment 4

The Fig-16 shows the maximum displacement graph. For experiment 1 max. Displacement 1.9 mm was observed i.e. 7.040.

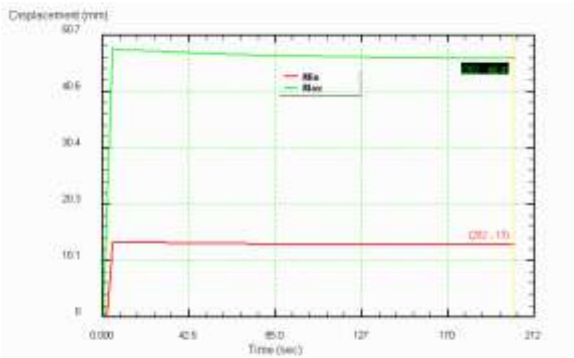

Fig-16: Displacement v/s graph for experiment 5

The Fig-17 shows the maximum displacement graph. For experiment 1 max. Displacement 0.8 mm was observed i.e. 2.580.

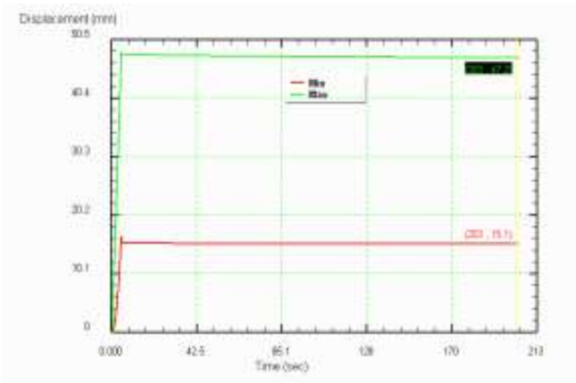

Fig-17: Displacement v/s graph for experiment 6

The Fig-18 shows the maximum displacement graph. For experiment 1 max. Displacement 1.1 mm was observed i.e. 1.50

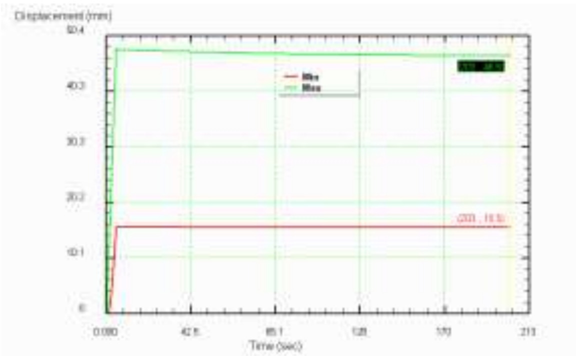

Fig-18: Displacement v/s graph for experiment 7

The Fig-19 shows the maximum displacement graph. For experiment 1 max. Displacement 0.7 mm was observed i.e. 2.40

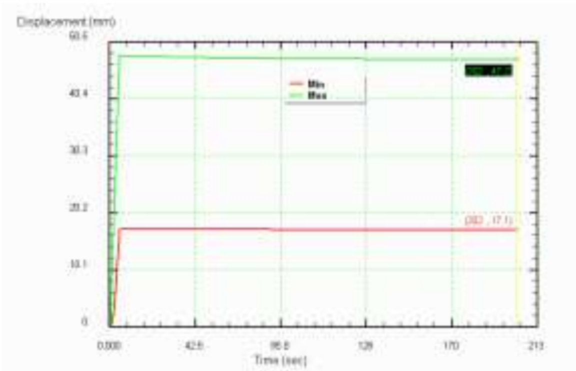

Fig-19: Displacement v/s graph for experiment 8

The Fig-20 shows the maximum displacement graph. For experiment 1 max. Displacement 1.3 mm was observed i.e. 0.9670.

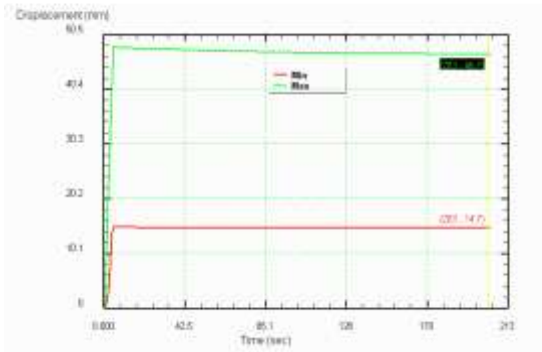

Fig-20: Displacement v/s graph for experiment 9

7. CONCLUSIONS

The study was carried out for metal forming process using finite element analysis for elasto-plastic deformation of the blade material AISI 9260. Blade bending process is simulated using finite element analysis (FEA) software DEFORM 3D. The spring back is examined in great details. The significance of process parameter for the response parameters (spring back) was studied during the bending simulation. Taguchi method was applied to investigate the effect of Temperature (°C), blank holding force and different punch & die combination. The below mentioned conclusions were made from the study.

a) Experiments were conducted using L9 orthogonal array. Taguchi method can predict an accurate relationship between temperatures of material, blade holding force, different combination of dies and spring back, effective stress and effective strain of the material.

b) From the numerical analysis it was found that for experiment 1 (V-bend combination, 850 0C Temperature and Zero holding force) the spring back was found to be 0.6 mm maximum displacement (0.298° angle) compared to other experiments. This shows that this combination of experiment will give the lowest spring back effect. For experiment 5 (Air bend, 900 Temperature and 300 N Holding force) the spring back was found to be 1.7 mm maximum displacement (7.04° angle).

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