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Optimization of Thinning In Deep Drawing Process Using Grey Wolf Optimizer Algorithm

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ABSTRACT

Deep drawing is a manufacturing process that is used extensively in the forming of sheet metal into cup or box like structures. In deep drawing the depth of the part being made is more than half its diameter. The geometry of die influences the thickness distribution and thinning of sheet metal blank in the deep drawing processes. Excess thinning in deep drawing is caused by incorrect die and punch clearance and radii. Thinning will usually be greatest near the part's base. The tension forces will tend to create a thinning effect. Determination of the thickness distribution and of the thinning of the sheet metal blank reduces the production cost of the material and time. The final objective of deep drawing process in particular or of any sheet metal forming process in general is to produce good quality product, hence uniform thickness should be obtained throughout.Grey Wolf Optimizer (GWO) inspired by grey wolves. The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature.

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I. INTRODUCTION

Deep drawing of sheet metal is performed with a punch and die. The punch is the desired shape of the base of the part, once drawn. The die cavity matches the punch and is a little wider to allow for its passage, as well as clearance. The sheet metal work piece, called a blank, is placed over the die opening.[1] A blank holder, that surrounds the punch, applies pressure to the entire surface of the blank except the area under the punch, holding the sheet metal work flat against the die. The punch travels towards the blank. After contacting the work, the punch forces the sheet metal into the die cavity, forming its shape. It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. The deep drawing process is a forming process which occurs under a combination of tensile and compressive conditions. A flat sheet metal blank is formed into a hollow body open on one side or a hollow body is formed into a hollow body with a smaller cross-section.[2]Deep drawing presents a number of challenges regarding materials and their malleability and the level of work hardening resulting from the draw process; heat treatment (annealing) is used to restore elasticity for any further draw operations. Other factors to be considered are lubrication, dies and material which is used to aid the drawing process and can be used to leave a fine surface finish.Defects that occur during deep drawing of sheet metal can be controlled by careful regulation of process factors. Tearing is one of the most common defects. Excessive thinning in areas of the sheet metal is also an unwanted defect. Causes of these are mostly too high or improper force distribution and material considerations. Wrinkling is another common defect.Wrinkling may often occur if the blankholder force is too low. Therefore optimization of blankholder force is necessary, since too high a force will cause excess friction. Sheet metal thickness is an essential parameter.

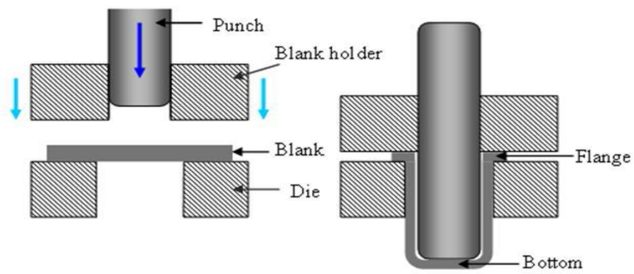


Figure 1: Deep Drawing Process

I. THINNING IN DEEP DRAWING

The original blank thickness has some effect on the thickness distribution and thinning of sheet metal blank in the deep drawing processes. The average distribution of the wall thickness is increasing with increasing the blank thickness. Also, the % of thinning is increasing with increasing of the blank thickness. Taking into account, the blank thickness and the punch diameter effects, the limiting drawing ratio (LDR) decreases as the relative punch diameter increases. Slightly thicker materials can be gripped better during the deep drawing process. Also, thicker sheets have more volume and hence can be stretched to a greater extent with increasing in thinning.[3] Sheet metal thickness is an important aspect of deep drawing process design. Thickness to diameter ratio is a main factor used to quantify the geometry of a blank and can be calculated by t/D_b. Thickness is represented by t, and D_b is the diameter of the blank.

A. Blank Holder Force (BHF)

Blank holder force (BHF) is an important parameter in the deep drawing process. Control of the blank holding force enables control of friction on the flange during deep drawing process. It is used to suppress the formation of wrinkles that can appear in the flange of the drawn part. When increasing the BHF, stress normal to the thickness increases which restrains any formation of wrinkles.in order to have less thinning in the drawn part, the maximum punch force must be reduced. This can be achieved by controlling the value of the BHF throughout the process. Blank holding force is small at beginning, which is good for the flow of material towards die cavity. increase in blank holder force reduces sliding of the sheet between the die and the blank holder and reduces spring back by increasing the tension [4]

B. Radius on Die (R_D)

Theoretically, the radius on the draw die (draw ring) should be as large as possible to permit full freedom of metal flow as it passes over the radius. The draw ring causes the metal to begin flowing plastically and side in compressing and thickening the outer portion of the blank. However, if the draw radius is too large, the metal will be release by the blank holder too soon and wrinkling will result. Too sharp a radius will hinder the normal flow of the metal and cause uneven thinning of the cup wall, with resultant erring.[5]

C. Radius on Punch (R_P)

There is no set rule for the size of the radius on the punch. A sharper radius will require higher forces when the metal is folded around the punch nose and may result in excessive thinning or tearing at the bottom of the cup. A general rule to reduce the thinning is to design the punch with a radius of from 4-10 times the metal thickness. It has been observe that the punch/die radii have the greatest effect on the thickness of the deformed mild steel cups compared to blank -holder force or friction.

D. Coefficient of Friction (μ)

In metal forming processes friction influences the strain distribution at tool blank interface and drawability of metal sheet. The force of static friction between the work piece blank and draw die surfaces must be overcome in a drawing operation. The force of the blank holder adds significantly to the force of static friction.[6]

II. Problem Formulation

The optimization problem for thinning in deep drawing is formulated as follows:

$$Thinning = 0.782+0.000778\, BHF - 0.0433\mu - 0.00039\, R_D + 0.00069\, R_P$$

Subjected to:

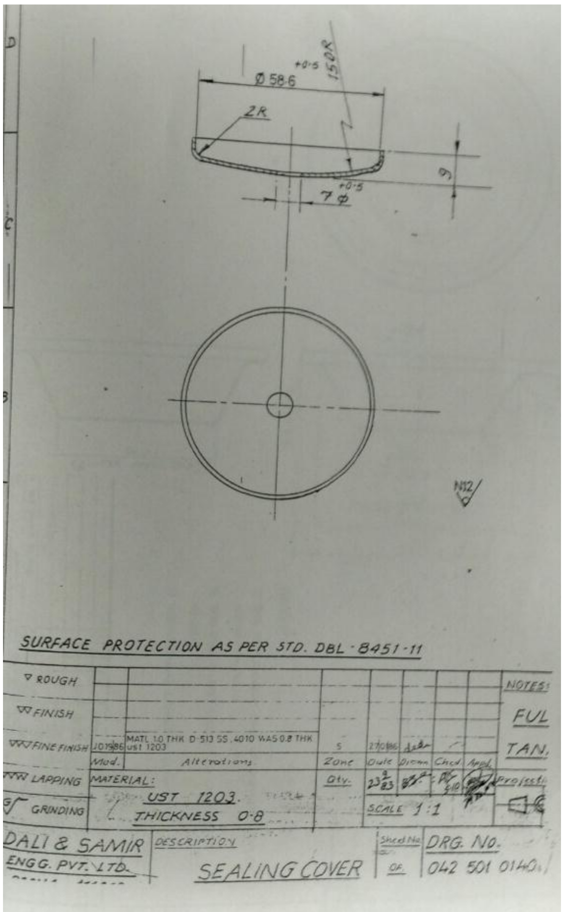
$$1.6 < R_D < 4.8$$

$$3\, R_D > R_P > 6R_D$$

The problem was solved using by Grey Wolf Optimizer algorithm and results were obtained.

III. COMPONENT DESCRIPTION

The component selected for thinning optimization is sealing cover. The thickness of sheet is 0.8mm.



IV. GREY WOLF OPTIMIZER ALGORITHM

Grey Wolf Optimizer (GWO) inspired by grey wolves (Canis lupus). The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types of grey wolves such as alpha, beta, delta, and omega are employed for simulating the leadership hierarchy. In addition, the three main steps of hunting, searching for prey, encircling prey, and attacking prey, are implemented.[7]

1. Inspiration

The leaders are a male and female, called alphas. The alpha is mostly responsible for making decisions about hunting, sleeping place, time to wake, and so on. The alpha's decisions are dictated to the pack. The alpha wolf is also called the dominant wolf since his/her orders should be followed by the pack.

The second level in the hierarchy of grey wolves is beta. The betas are subordinate wolves that help the alpha in decision-making or other pack activities. The beta wolf can be either male or female, and he/she is probably the best candidate to be the alpha in case one of the alpha wolves passes away or becomes very old. The beta wolf should respect the alpha, but commands the other lower-level wolves as well. It plays the role of an advisor to the alpha and discipliner for the pack.

The lowest ranking grey wolf is omega. The omega plays the role of scapegoat. Omega wolves always have to submit to all the other dominant wolves. In some cases the omega is also the babysitters in the pack.

If a wolf is not an alpha, beta, or omega, he/she is called subordinate (or delta in some references). Delta wolves have to submit to alphas and betas, but they dominate the omega. Scouts, sentinels, elders, hunters, and caretakers belong to this category.[8]In addition to the social hierarchy of wolves, group hunting is another interesting social behavior of grey wolves.

The main phases of grey wolf hunting are as follows:

- Tracking, chasing, and approaching the prey
- Pursuing, encircling, and harassing the prey until it stops moving
- Attack towards the prey

Figure 2Hunting behavior of grey wolves:

(A) chasing, approaching, and tracking prey (B-D) pursuing, harassing, and encircling (E) stationary situation and attack

1. Mathematical model and algorithm

1.1 Social hierarchy:

In order to mathematically model the social hierarchy of wolves when designing GWO, we consider the fittest solution as the alpha (α). Consequently, the second and third best solutions are named beta (β) and delta (δ) respectively. The rest of the candidate solutions are assumed to be omega (ω). In the GWO algorithm the hunting (optimization) is guided by α,β ,δ and ω.

1.2 Encircling prey:

As mentioned above, grey wolves encircle prey during the hunt. In order to mathematically model encircling behavior the following equations are proposed:

$$\vec{D} = |\vec{C} * \overrightarrow{X_p}(t) - \vec{X}(t \qquad (1)$$

$$\vec{X}(t+1) = \overrightarrow{X_p}(t) - \vec{A} * \qquad (2)$$

wheret indicates the current iteration, and are

coefficient vectors , is the position vector of the prey, and indicates the position vector of a grey wolf.

The vectors and are calculated as follows:

$$\vec{A} = |2 * \vec{a} * \overrightarrow{r_1} - \qquad (3)$$

$$\vec{C} = 2 * \qquad (4)$$

where components of are linearly decreased from 2 to 0

over the course of iterations and , are random vectors in [0,1].

1.3 Hunting:

Grey wolves have the ability to recognize the location of prey and encircle them. The hunt is usually guided by the alpha. The beta and delta might also participate in hunting occasionally.In order to mathematically simulate the hunting behavior of grey wolves, we suppose that the alpha (best candidate solution) beta, and delta have betterknowledge about the potential location of prey. Therefore, we save the first three best solutions obtained so farand oblige the other search agents (including the omegas) to update their positions according to the position ofthe best search agent. The following formulas are proposed in this regard.[9]

$$\overrightarrow{D_\alpha} = |\overrightarrow{C_1} * \overrightarrow{X_\alpha} - |, \quad \overrightarrow{D_\beta} = |\overrightarrow{C_2} * \overrightarrow{X_\beta} - , \quad \overrightarrow{D_\delta} = |\overrightarrow{C_3} * \overrightarrow{X_\delta} - . \qquad (5)$$

$$\overrightarrow{X_1} = \overrightarrow{X_\alpha} - \overrightarrow{A_1} * (\overline{D}, \quad \overrightarrow{X_2} = \overrightarrow{X_\beta} - \overrightarrow{A_2} * (\overline{D}, \quad \overrightarrow{X_3} = \overrightarrow{X_\delta} - \overrightarrow{A_3} * (\overline{D} \qquad (6)$$

$$\vec{X}(t+1) = \frac{\overrightarrow{X_1} + \overrightarrow{X_2} +}{3} \qquad (7)$$

2.4 Attacking Prey

The grey wolves finish the hunt by attacking the prey when it stops moving. In order to mathematically model approaching the prey we decrease the value of With the operators proposed so far, the GWO algorithm allows its search agents to update their positionbased on the location of the alpha, beta, and delta; and attack towards the prey.

1.4 Search for prey (exploration):

Grey wolves mostly search according to the position of the alpha, beta, and delta. They diverge from each other to search for prey and converge to attack prey.[10]

2.5 The pseudo code of the GWO algorithm

Initialize the grey wolf population Xi (i = 1, 2, ..., n)
Initialize a, A, and C
Calculate the fitness of each search agent
Xα=the best search agent
Xβ=the second best search agent
Xδ=the third best search agent
while(*t < Max number of iterations)*
for*each search agent*
Update the position of the current search agent by equation (3.7)
end for
Update a, A, and C
Calculate the fitness of all search agents
Update Xα, Xβ, and Xδ
t=t+1
end while
return Xα

VI OPTIMIZATION RESULTS

The formulated optimization problem was solved by Grey Wolf Optimizer algorithm and the results were obtained as follows

Thinning Factor	0.77922 mm
Radius on Die	1.8782 mm
Blank Holder Force	1.5315 KN
Radius on Punch	10.1680 mm
Coefficient of Friction	0.10

The formability analysis was done on the original component and the forming limit diagrams were showing the results of thickness distribution, safety zone and forming zone of original component.

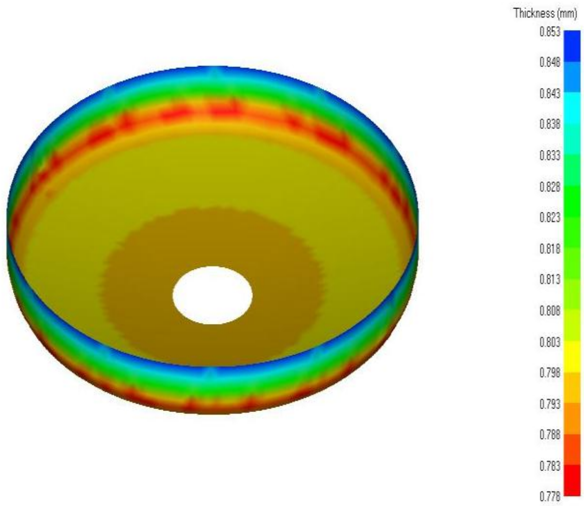


Figure 2. Thickness distribution of Original Component

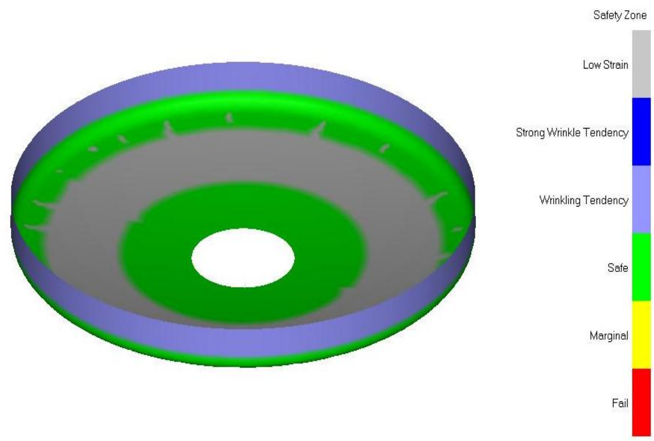


Figure 4. Safety Zone of Original Component

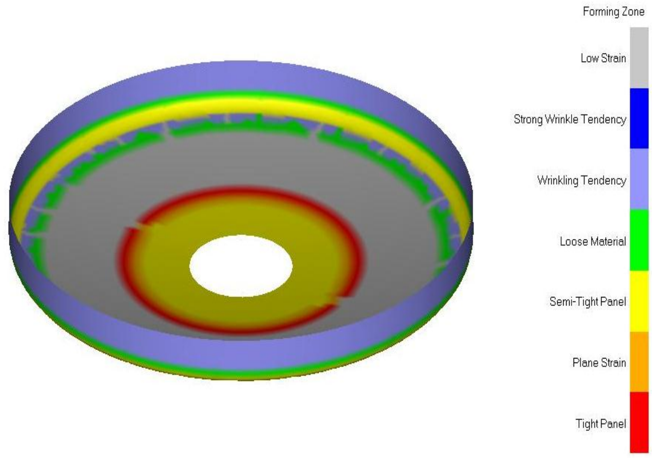


Figure 5. Forming Zone of Original Component

The further work in ongoing on thinning optimization.

I. VII. CONCLUSIONS

Excessive thinning in areas of the sheet metal is an unwanted defect.Maximum thinning will most likely occur on the side wall, near the base of the part. So minimization of thinning is important in deep drawing process. The parameters affecting on thinning in deep drawing are blank holder force, radius on die, radius on punch and coefficient of friction. By controlling all these parameters minimization of thinning occurs. Here, in this paper grey wolf optimizer algorithm is used to optimize the thinning in deep drawing. And from the formability analysis it comes to know that this algorithm gives optimized results of thinning.

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