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Optimization of Thinning In Deep Drawing Process Using Ant-Lion Optimization Algorithm (May 2016)

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***Abstract* —Deep drawing is a manufacturing process which is used extensively in the forming of sheet metal into cup as well as box like structures. In deep drawing process the depth of the part being made is more than half its diameter. The geometry of die which influences the thickness distribution and thinning of sheet metal blank in the deep drawing processes. Excess thinning in deep drawing process is caused by incorrect die and punch clearance and radii. Thinning will usually be greatest near the base of part. Thinning effect created by tension forces. Determination of the thickness distribution and of the thinning of the sheet metal blank results into reduction of production cost of the material and time too. In general the final objective of deep drawing process in particular or of any sheet metal forming process is to produce good quality product, hence uniform thickness should be obtained throughout. Ant Lion optimization algorithm which is used here which is developed by Seyedali Mirjalili in Jan.2015. Ant Lion optimization algorithm is used to obtain optimal effect of blank holding force on the thinning of deep drawing parts.**

Keywords: **Deep Drawing Process , Thinning , Ant lion Optimization**

I. Nomenclature

BHF Blank holding force(N)
F_{max} Forming load(N)
R_D Radius on Die(mm)
R_p Radius on Punch(mm)
μ Coefficient of Friction
d_1 and d_2 Diameters of component at bottom and at the top respectively (mm)
d_0 Blank diameter (mm)
r Corner radius (mm)
S_0 Material thickness (mm)
S_u Ultimate tensile strength (495 N/mm^2)
P Pressure applied (2.5 N/mm^2)

II. Introduction

Deep drawing is a mostly used metal forming process in which a sheet metal blank is drawn into a forming die by the mechanical action of a punch. Deep drawing has been classified into conventional and unconventional deep drawing. The sheet metal work piece i.e. blank is placed over the die opening. A blank holder applies pressure to the entire surface of the blank except the area which comes under the punch, holding the sheet metal work flat against the die [1, 2]. The punch travels towards the blank. After contacting the blank, 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 as "deep" drawing process when the depth of the drawn part exceeds its diameter.

Deep drawing process is capable of forming circular shapes such as circular cups or even rectangular shapes or shell-like containers. The deep drawing process which occurs under a combination of both tensile and compressive forces is a forming process. Wall thinning is prominent due to tensile forces and results in an uneven part wall thickness. The material starts to flow in the die when the stress exceeds. Determination of the thickness distribution 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.

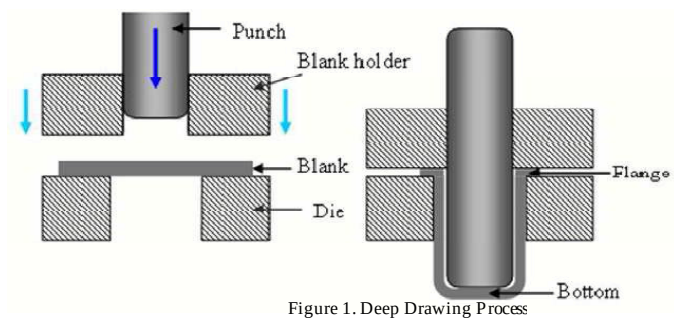

Figure 1. Deep Drawing Process

III. LITERATURE REVIEW

H. Zein, M. El Sherbiny, M. Abd-Rabou, M. El Shazly [4] studied on thinning and spring back prediction Prediction of the forming results as spring back, determination of the thickness distribution and of the thinning of the sheet metal blank reduces the production cost of the material and time.

Y. Marumo, H. Saiki, L Ruan [5] studied the influence of sheet thickness on blank holding force and limiting drawing ratio. Variation in blank holding force and limiting drawing ratio in deep drawing of metal foils were evaluated by calculation. The paper shows variation in the blank holding force required for the elimination of wrinkling and the limiting drawing ratio with sheet thickness. Menakshi Mahendru

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Nischal,Shivani Mehta[11]solved optimal load dispatch problemby using ALO. Petrovi , M., Petronijevi , J.etc[12] used ALO for flexible process planning. S. Talatahari[13]worked on optimal design of skeletal structure to design three truss and frame design optimization. Shivani Mehta, Meenakshi Mahendru Nischal[14]used ALO for optimum power generation so that operation of power is most efficient and at low cost. Seyedali Mirjalili[15] had done very much work on development of Ant Lion Optimizer, its behavior, pseudo code and solved constrained optimization problemby applying ALO.

IV.TH INNING IN DEEP DRAWING

The original blank thickness has some effect on the thinning and thickness distribution of sheet metal blank in the deep drawing processes. The average distribution of the wall thickness is increasing with increasing the blank thickness. As blank thickness increases % of thinning also increases with respect to it. Taking into account, the punch diameter and blank thickness effects the limiting drawing ratio (LDR) decreases as the relative punch diameter increases. During the deep drawing process slightly thicker materials can be gripped in better way. With increasing in thinning sheets stretched to a greater extend because of its more volume.[3]

A. Blank Holder Force (BHF)

Blank holder force (BHF) is a very important parameter in thedeep drawing process. It is used to suppress the formation of wrinkles which appear on the flange of the drawn part. Also when we increases 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 maximumpunch force must be reduced and this can be achieved by controlling the value of the BHF throughout the process.[4]

B. Radius on Die (R_D)

Theoretically, the radius on the draw die also called as draw ring should be as large as possible to permit full freedom of metal flow as it passes over the entire radius. Draw ring causes the metal to begin flowing plastically and side near compressing and thickening of outer portion of the blank. However, if the draw radius is too large, the metal will be release through the blank holder too soon and results into wrinkling . Too sharp radius will hinder the normal flow of the metal and causes uneven thinning of a cup wall, with resultant erring.[5]

C. Radius on Punch (R_P)

There is no such a set rule for the size of the radius on the punch. Sharper radius will require higher forces when the metal is folded around the nose of punch and may result in excessive thinning and some times tearing at the bottom of the cup. A general rule to make reduction in the thinning is to design the punch with a radius of from 4-10 times the metal thickness.

D. Coefficient of Friction (μ)

The force of static friction between the work piece, blank and draw die surface must overcome in a drawing operation and the force of the blank holder adds significantly to the force of static friction.[6]

V.CO MPONENT DESCRIPTION

The component selected for thinning optimization is sealing cover. The thickness of sheet is 2 mm.

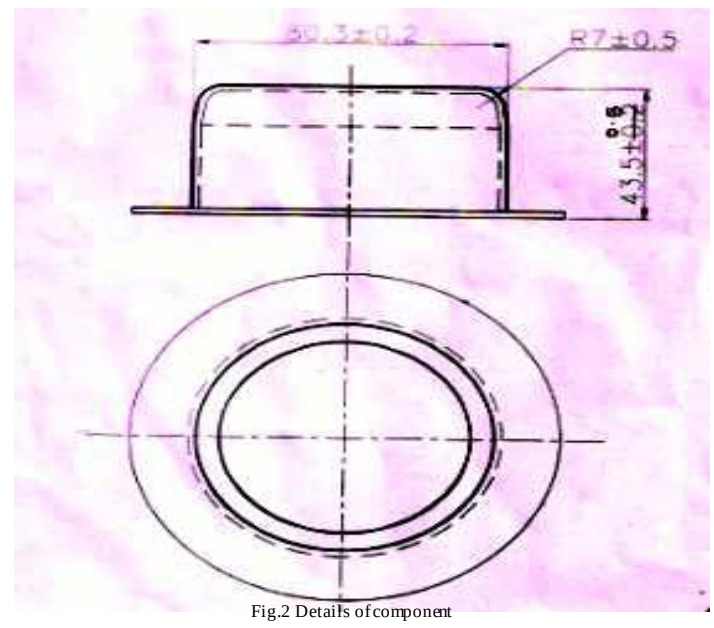

Fig.2 Details of component

VI. PROBLEM FORMULATION

From component description diagram, we get values of d_1,d_2,d_3,r,h.Using these values equations explained below are solved.

Forming load,

F_{dmax} =1.2 (d1+S_0).S_0.Su . .....(1)

Blank holder force,

FBH= (d_o^2-(d_1+2r)^2).P .....(2)

Blank diameter,d_0

.....(3)

Radius of Die,

R_D =0.035[50+(d_0-d_1)] .....(4)

Radius of Punch,

Rp=3 to 6 R_D . .....(5)

The above values are calculated by numerically and by using software (Forming Suit) also, the values came by these both methods are nearby same. Values are tabulated below.

TABLE NO.1

EXPERIMENTAL RESULTS

Exp.no.	Blank holder force	Coe.of friction, μ	Radius of Punch,R_p
1	600	0.05	7
2	600	0.10	8
3	600	0.15	9
4	700	0.05	8
5	700	0.10	9
6	700	0.15	7
7	800	0.05	9

8 800 0.10 7

9 800 0.15 8

By using above exp. results we had done regression analysis of above values, then we get equation for thinning.

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

Thinning=0.113+0.000314BHF-0.0366 μ-0.00016R_D+0.00025r .....(6)

Subjected to:

4.2<R_D< 8.5

3 R_D > R_P > 6R_D

The problem was solved using by Ant-Lion optimization algorithm and results were obtained.

VII. ANT LION OPTIMIZATION ALGORITHM

The names of ant lions originate from their unique huntingbehavior and their favorite prey.Ant lion larvae digs acone-shaped pit in to sand by moving along a circular path andthrowing out sands outside with its massive jaw [11,12]. Aftertrap digging, the larvae hides underneath the bottom of the cone and waits for insects(preferably ant) to come to be trapped in to the pit [13]. The edge of the cone issharpso insectsfall to the bottom of the trapeasily. When the ant lion realizes ,a prey is in the trap, ittries to catch it with its massive jaw. When a prey is caught into the jaw, it ispulled under the soil easily and consumed. After consuming theprey, ant lions throw the leftovers outside the pit and digsthe pit for the next hunt. Also another interesting behavior thathas been observed in life style of ant lions is that they tendto dig out larger traps as they become more hungry and/orwhen the moon is full [9]. They have been evolved andadapted by this way to improve their chances of survival. Themain inspiration of the ALO algorithm comes from theforaging behavior of ant lion's larvae.The ALO algorithm mimics interaction between ant lionsand ants in the trap. To model such interactions systematically, ants are required to move over the search space, and ant lions areallowed to hunt them and become fitter using traps.[15]

Fig.3 Cone-shaped traps and hunting behaviour of ant lions

Since ants move randomly in nature when searching for food, a random walk is chosen for modeling ants' movement as follows:

X(iter)=[0,cumsum(2r(1)1),cumsum(2r(2)1),...,cumsum(2r(n)-1)]

Where *cumsum* calculates the cumulative sum, nis the max. no. of iteration, *iter* shows the iteration of random walk, and r(t) is a stochastic function defined as follows:

r(t) i= 1 if rand>0.5

r(t)=0 if rand 0.5 .....(8)

The position of ants and their related objective functions are saved in thematrices *MAnt* and M *OA*, respectively. In addition to ants, it is assumed that the ant lions are hides somewhere in a search space,in order to save their positions and fitness values, the *MAntlion* and M *OAl* matrices are used. The pseudo codes the ALO algorithm is defined as, [1]:

Step 1: Initialize the first population of ants and antlions randomly in search space and calculate the fitness of ants and antlions.

Step 2: Find the best antlions and assume it as the elite. In this study the best ant lion obtained so far in each iteration is saved and considered as an elite.

Step 3: For each ant, select an ant lion using Roulette wheel and

3.1 Create a random walk

3.2 Normalize this in order to keep the random walks inside the search space

$X_i^{iter+1} = \{[(X_i^{iter} - a_i)\times(d_i - a_i)]\div(b_i - a_i)\} + c_i$ ….(9)

where a_i is the min.of random walk of *i*-th variable, b_i is the maximum of random walk in *i*-th variable, c_i and d_i are the min. and max.of *i*-th variable at the current iteration.

3.3 Update the position of ant

$Ant_i^{iter+1} = (R_A^{iter} + R_E^{iter})\div 2$ …(10)

where R_A^{iter} is the random walk around the ant lion selected by the roulette wheel; R_E^{iter} is the random walk around the elite and Ant_i^{iter+1} indicates the position of *i*-th ant at the iteration *iter*+1.

3.4 Update c and d using the following

$C^{iter+1} = C^{iter}\div I$ .....(11)

$d^{iter+1} = d^{iter}\div I$ …..(12)

Where

$I = 10^{w\, iter/n}$ …..(13)

And *w* is a constant based on the current iteration (*w* = 2 when *iter* > 0.1 *n*, *w* = 3 when *iter* > 0.5 *n*, *w* = 4 when *iter* > 0.75 *n*, *w* = 5 when *iter* > 0.9n, and w = 6 when *iter* > 0.95 *n*

Step 4: Calculate the fitness of all ants.

Step 5: Replace an ant lion with its corresponding ant it if becomes fitter.

Step 6: Update elite if an ant lion becomes fitter than the elite.

Step7: Repeat procedure from step 3 until a stopping criteria is get satisfied

The pseudo code of the ALO algorithm-

1) Initialize the first population of ants and ant lions randomly

2) Calculate the fitness of ants and ant lions

3) Find the best ant lions and assume it as the elite(determined optimum)

4) **While** the end criterion is not satisfied

5) **For**

Every ant

(i) Select an ant lion using Roulette wheel

(ii) Update c and d(max & min. variable) using equations

(iii) Create a random walk and normalize it using equation. .....(7)

(iv) Update the position of ant

6) **End for**

(i) Calculate the fitness of all ants

(ii) Replace an ant lion with its corresponding ant if

antbecomes fitter
(iii) Update elite if an ant lion becomes fitter than the elite
End w hile
Return elite

VIII .OPTIMIZATION RESULTS

The formulated optimization problem w as solved by Ant Lion Optimization algorithm.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.

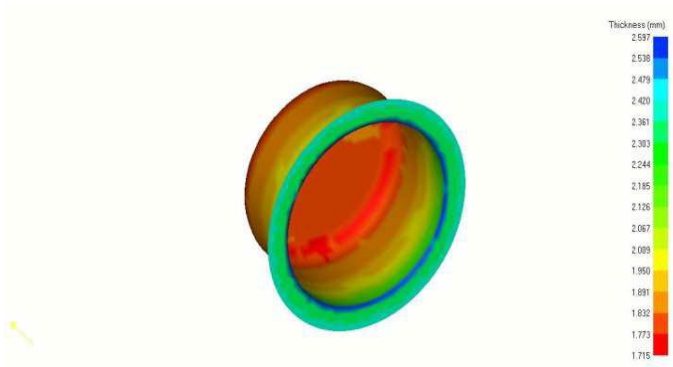

Figure 4. Thickness distribution of Original Component

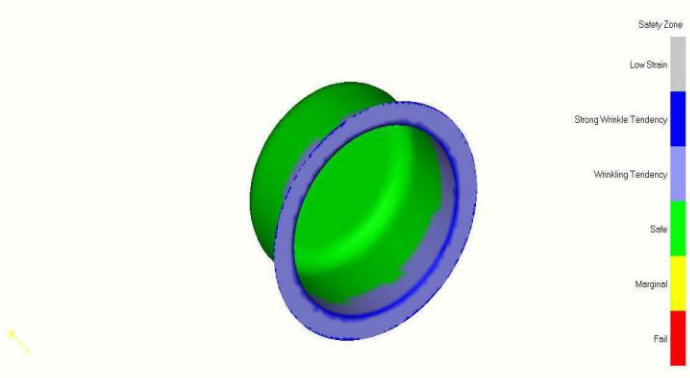

Figure 5. Safety Zone of Original Component

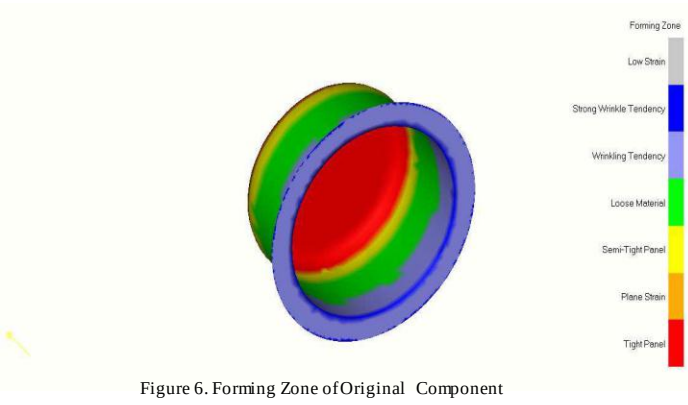

Figure 6. Forming Zone of Original Component

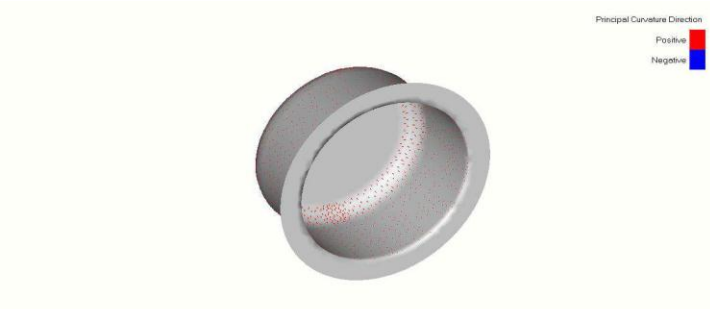

Figure 7.Principal curvature direction of Original component

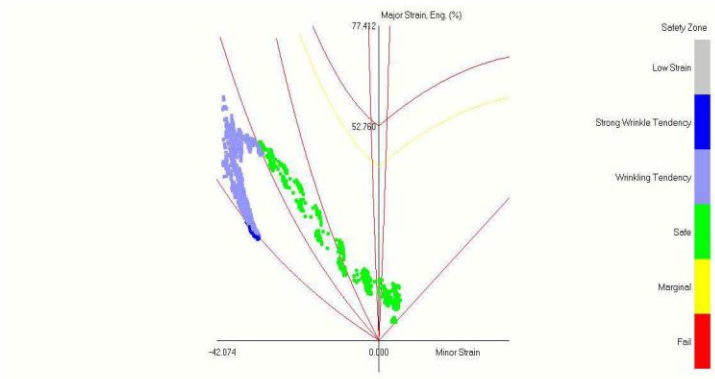

Figure 8.Forming limit diagram of Original component

The further work in ongoing on thinning optimization.

IX. CONCLUSIONS

Excessive thinning in areas of the sheet metal is mostly an unwanted defect.Maximum thinning will most likely occur at the side wall, near by the base of the part. 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 Ant Lion optimization algorithm is used to optimize the thinning in deep drawing. Here four input parameters are blank holder force, radius on die, radius on punch and coefficient of friction. The results shows the thickness distribution of original component, safety zone of original component and forming zone of original component. And from this analysis it comes to know that this algorithm gives optimized results of thinning.

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