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Wrinkling optimization in deep drawing using flower pollination algorithm

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ABSTRACT

In sheet metal-forming operations the finished part is stretched or squeezed into a desired shape. Deep drawing process is one of the most complex metal-forming operations. Deep drawing can be defined as a metal forming process in which a part is produced from a flat sheet-metal blank by the action of a punch force onto the blank. Wrinkling in sheet metal forming is one of the most important instabilities that occur in parts formed using deep drawing process. Wrinkles that form during the sheet forming are due to internal compressive instabilities. Wrinkling defect generally occurs at the flange and is generated by excessive compressive stress that causes the sheet to buckle. Nature-inspired algorithms have shown their promising performance and have thus become popular. Flower pollination algorithm is a new nature-inspired algorithm developed by Dr. Xin-She Yang in 2012. It is based on the characteristics of flowering plants. Pollination process constitutes a set of complex mechanisms crucial to the success of plants reproductive strategies. The paper aims to optimize various parameters that cause wrinkling using flower pollination algorithm.

Keywords— **Deep Drawing, Optimization, Wrinkling, Flower Pollination Algorithm.**

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I. INTRODUCTION

Deep drawing is one of the most important processes for forming sheets metal parts. It is used widely for mass production of hollow shapes in the packing industry, automotive industry as well as aerospace parts. Deep drawing process is capable of forming circular shapes such as circular cups or even rectangular shapes or shell-like containers. The term Deep Drawing simply implies that the formed parts are deeper than could be obtained by other metal forming processes. Deep Drawing is more an art rather than science.[1, 2]

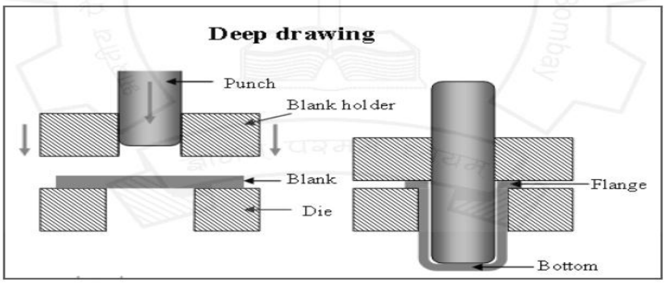

Figure 1. Deep Drawing Process

The effectiveness of deep drawing operation and the quality of the formed parts strongly depends on the proper selection of a wide range of operating parameters. Among them the blank shape, the blank-holder force (or the blank-holder force history), the position and the penetration of draw-beads, the geometry of the punch and the die, the lubrication at the interfaces among the blank, the punch, the die and the blank-holder are probably the most relevant; for this reason they attracted in the last decades the attention of a large number of researchers all over the world. Excessive metal flow will cause wrinkles in the part, while insufficient metal flow will result in tears or splits. Thus, the failure of deep drawing parts during deep drawing processes usually takes place in the form of wrinkling, tearing, fracture or excessive spring-back. Hence, any of these defects need to be avoided by selecting optimized process parameters. [3, 4].

I. WRINKLING IN DEEP DRAWING

Wrinkling is usually undesired in final sheet metal parts as it is aesthetically unpleasant and also affects the functionality of the parts. In addition, severe wrinkles may even damage dies. Hence, prevention of wrinkling is most vital in sheet forming process. Wrinkling generally occurs in the wall or flange of the part which are subjected to compressive stresses causing the sheet to buckle. The major parameters that can cause wrinkling and need to be optimized are Blank Holder Force, Coefficient of friction, Radius on Die and Radius on Punch.Usually, the blank holding force has to increase along with the increase of the deep drawing depth, but we must take into consideration the fact that if its value is too big it can lead to cracks and even a break or tearing of the material. Wrinkling and tearing or rupture thus defines the deep drawing process limits. For this problem, various parameters that affect the wrinkling in deep drawing process are considered viz. Blank Holder Force, Coefficient of friction, Radius on Die and Radius on Punch.

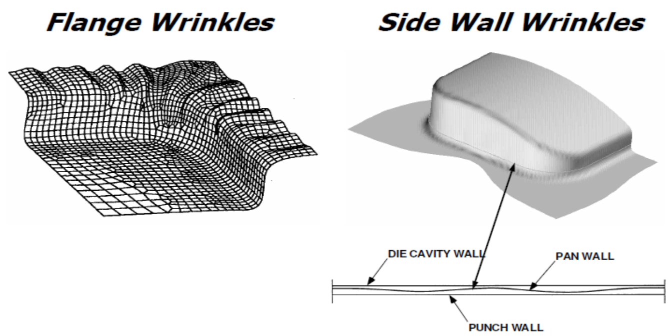

Figure 2. Wrinkle Occurrence in Deep Drawing

A. Blank Holder Force[5]:

The Blank Holder Force is the force exerted by blank holder which controls the metal flow inside the die. If this force is not properly maintained, it may cause excessive material flow resulting in wrinkles within the formed part. A thin blank is always prone to wrinkles while a large blank holder force causes the part to fracture. Hence selection of proper BHF is extremely important in order to avoid wrinkling.

Today, in the vehicle industry, many deep drawing types of equipment provide constant BHF over the whole punch stroke. So, it is very necessary and vital that these equipments be rebuilt in time to satisfy increasing demands for improving vehicles and their components' quality standards. However, there is increasing demand of alternating BHF or variable BHF as it can lead to high quality components. Hence, providing a suitable BHF is very important for very high surface finish of deep drawn component.

B. Coefficient of Friction[6]:

The main course of friction in a deep draw operation is in the blank holder. Large friction forces there will increase the punch force and consequently the load on the wall of the product. Excessive friction forces in the blank holder may cause failure of the product, so the friction in the blank holder must be limited. During the deep draw operation, material is pulled out of the blank holder area. Material flow in the die cavity is influenced by frictional conditions at the die/work piece interface. Hence, a good understanding of the friction parameters is essential to avoid excessive wrinkling on the formed parts. By analysing the conditions which control the friction in deep drawing, wrinkling can be easily avoided. Too low friction involves excessive material flow causing wrinkling while too high friction may result in crack formation.

C. Die and Punch Radius[7]:

The radius on die and punch too has an effect on wrinkling. Selection of optimal Die and Punch Radius is very important to avoid wrinkle-free component. Hence properly designing of the punch and die is very important in avoiding wrinkling.

II. PROBLEM FORMULATION:

The optimization problem was formulated by linear regression analysis and the linear equations obtained were as follows:

$$Wrinkling = 349 - 157BHF + 283\mu + 337R_D + 61R$$

Subject to

$2<R_D<4$

$3R_D > R_P > 6R_D$

where

$$BHF = \frac{\pi}{4}(d_o{}^2 + 2r)^2) * , \text{ Where P=2.5 N/mm}^2.$$

And

$$R_D = 0.035[50 + (d_0 - d_1)\sqrt{S_0}$$

Where is the sheet thickness.

$$R_p = (3\ to\ 6)R_D$$

The problem was solved using Flower Pollination Algorithm and the results were obtained.

III. COMPONENT DESCRIPTION:

The component selected for wrinkling optimization was connector. The thickness of the sheet was selected as 1 mm. The material used was SS 4010.

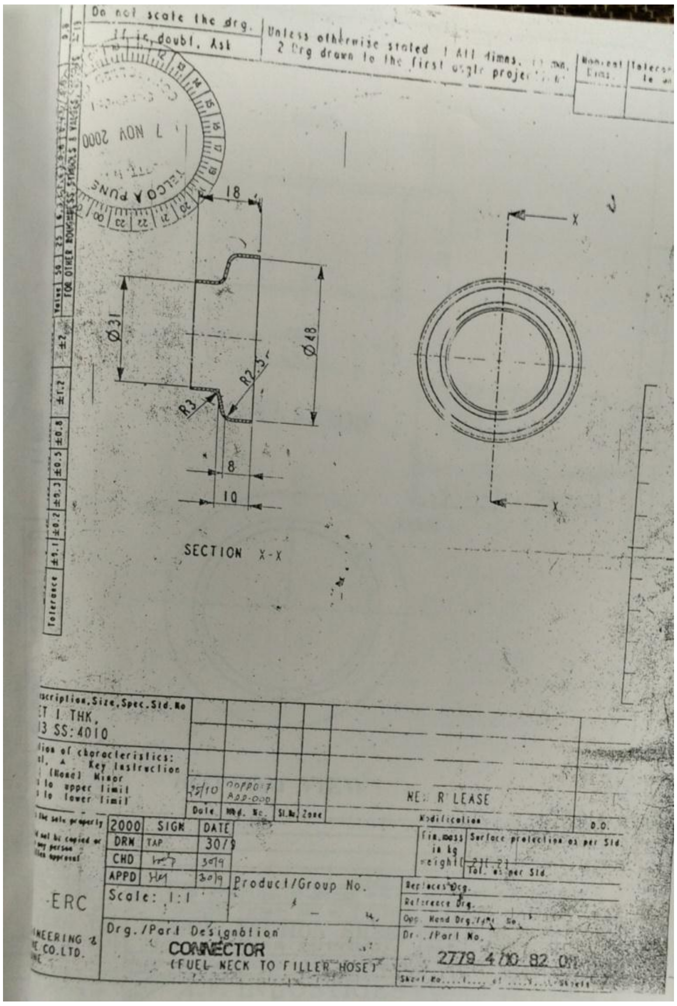

Figure 3. Drawings of the original component

IV. FLOWER POLLINATION ALGORITHM:

Flower pollen localization algorithm is a nature inspired algorithm which is inspired from the pollination of flowering plants. Pollination means transfer of pollens from one flower to another flower in the same plant or another plant.[8] This transfer of pollens can happen through pollinators such as birds, insects, bats and other animals. Pollination by birds, animals, bats and insects are termed as biotic pollination. Pollination by wind and diffusion is called as abiotic pollination. Further, pollination can be classified as cross pollination and self pollination. If pollination or fertilization happens between flowers from different flower plants then it is called as cross pollination. If pollination happens between flowers in the same flowering plant then it is called as self pollination. Pollination of flowers is a process of reproduction and survival of the fittest of a particular plant species. This fitness characteristic is used to define the optimization of the problem. [9]Some insects and bees can have levy weight behavior, means the jumps or fly distance steps obey Levy distribution. Some pollinators have developed flower constancy, means some flowers are related to some birds and insects. They are interdependent. That birds and insects jump or fly to only certain species flower plants. And the flower also provides food required by the certain birds and insects. This flower constancy increases the pollination process in certain specific flower species and so maximizing the reproduction.[10]Flower pollen localization algorithm uses the following rules:

Rule 1: Biotic and cross-pollination can be considered as a process of global pollination process, and pollen-carrying pollinators move in a way that obeys Le'vy flights.

Rule 2: For local pollination, a biotic and self-pollination are used.

Rule 3: Pollinators such as insects can develop flower constancy, which is equivalent to a reproduction probability that is proportional to the similarity of two flowers involved.

Rule 4: The interaction or switching of local pollination and global pollination can be controlled by a switch probability p € (1, 0).with a slight bias toward local pollination.

The rules can be formulated into updating equations as

$$x_i^{t+1} = x_i^t + \gamma L(\lambda)(x_i^t - B)$$

Where x_i^t is the pollen i or solution vectorx_i at iteration t, and B is the current best solution found among all solutions at the current generation/iteration. γ is the scaling factor to control the step size. Also $L(\lambda)$ is the parameter that corresponds to the strength of the pollination. Since insects may move over a long distance with various distance steps, we can use a Le'vy flight to imitate this characteristic efficiently. To model the local pollination, both Rule 2 and Rule 3 can be represented as:

$$x_i^{t+1} = x_i^t + U\left(x_j^t - x_k^t\right)$$

Where x_j^t and x_k^t are pollen from different flowers of the same plant species. This essentially imitates the flower constancy in a limited neighborhood. For rule 4, a switch probability value can be set (usually 0.8) to switch between common global pollination to intensive local pollination.

The selection of flower Pollination algorithm was based on its capability to converge fast as compared to other nature-inspired algorithms as well as its compatibility to be hybridized with other algorithms such as Particle Swarm Optimization Algorithm, Cuckoo Search Algorithm, Firefly Algorithm and Grey Wolf Algorithm. This capability of FPA was important as the optimization problem is rather complex and selection of improper algorithm may lead to faulty design.The parameters that were considered during coding session of algorithm were the population size of 25 and the probability switch of 0.1. In addition, the penalty applied was static penalty which was taken as 20. These parameters for flower Pollination algorithm were properly selected by testing them on various benchmark functions (constrained and unconstrained) like Ackley, Michalewicz function and Pressure vessel design constrained problem. The results obtained to these functions by FPA gave satisfactory results as compared to other evolutionary algorithms.

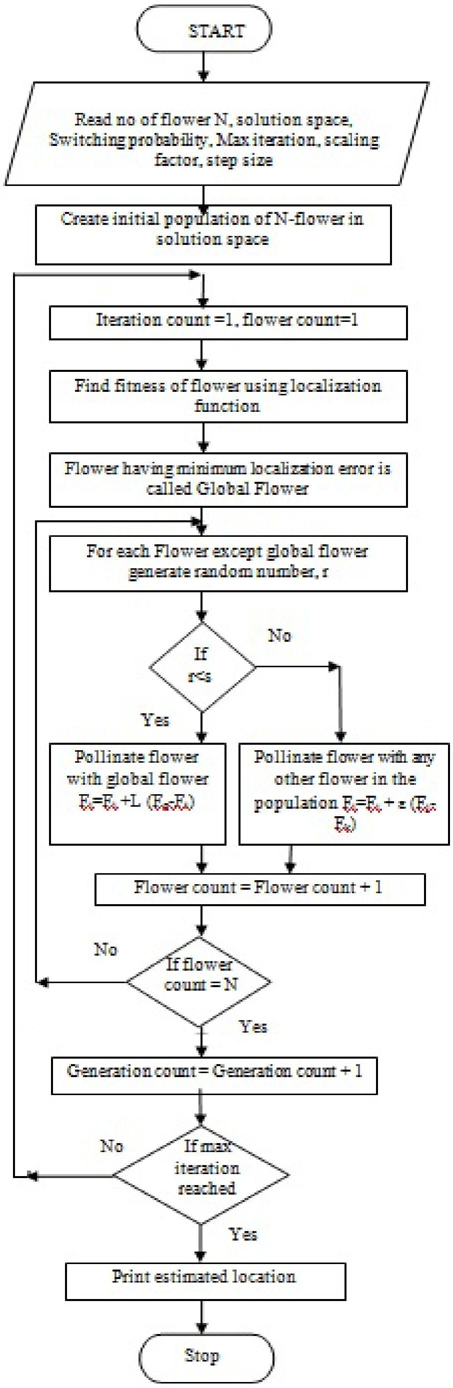

Figure 4. Flower Pollination Algorithm Flowchart

PSEUDOCODE [11]:

Define Objective function $f(x)$, $x = (x_1, x_2, ..., x_d)$
Initialize a population of n flowers/pollen gametes with random solutions
Find the best solution B in the initial population
Define a switch probability $p \in [0, 1]$
Define a stopping criterion (either a fixed number of generations/iterations or accuracy)
While *(t <MaxGeneration)*
for $i = 1 : n$ *(all n flowers in the population)*
if rand <p,
Draw a (d-dimensional) step vector L which obeys a L´evy distribution
Global pollination via $x_i^{t+1} = x_i^t + L(B - x_i^t)$
else
Draw U from a uniform distribution in [0,1]
Do local pollination via $x_i^{t+1} = x_i^t + U(x_j^t - x_k^t)$
end if
Evaluate new solutions
If new solutions are better, update them in the population
end for
Find the current best solution B
end while
Output the best solution found

VI. OPTIMIZATION RESULTS

The formulated optimization problem was solved in flower pollination algorithm and the results were obtained as follows

Wrinkling Factor	1096.2323 mm^2
Radius on Die	2.2750 mm
Blank Holder Force	2.7862 KN
Radius on Punch	8.3595 mm
Coefficient of Friction	0.005

The formability analysis was done on the original component and the forming limit diagrams were plotted. FTI_Forming_Suite_2014_SP1_build_1956_SSQ software is used for formability analysis and analysis results of original component are displayed below along with the FLD.

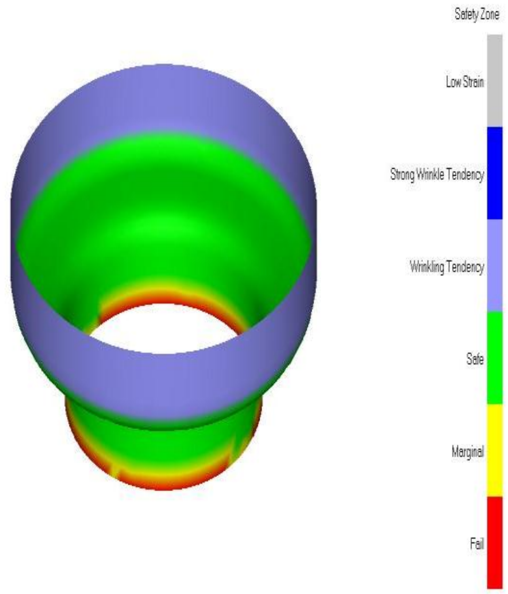

Figure 5. Safety Zone of Original Component

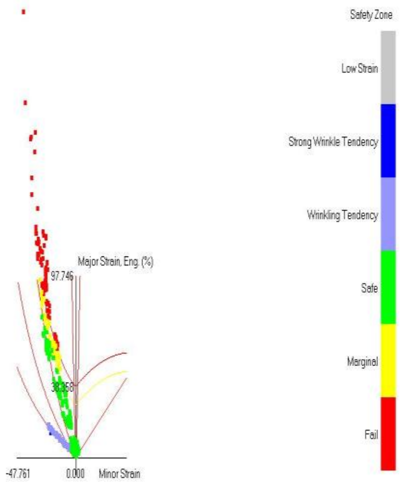

Figure 6. Forming Limit Diagram of original component

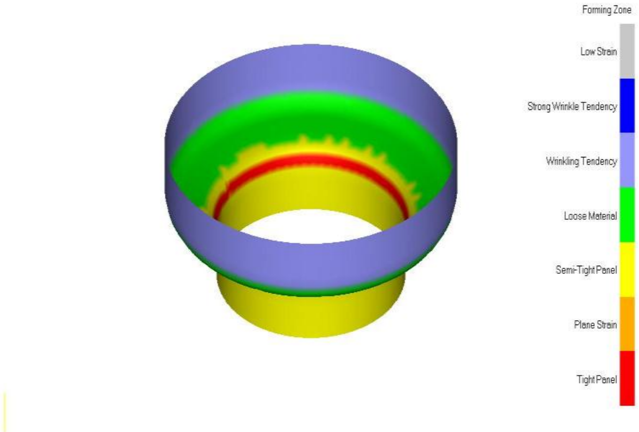

Figure 7. Forming Zone of original Component

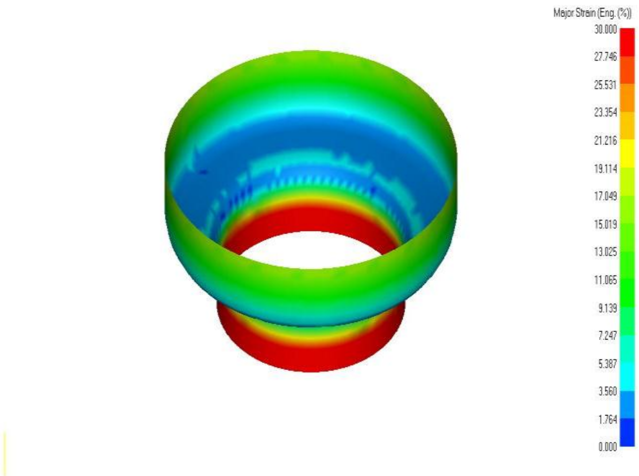

Figure 8. Major Strain of original component

V. CONCLUSIONS

Wrinkling of Deep Drawing is an important criteria which needs to be optimized in order to contain the aesthetic and functional requirements in the component. The wrinkling is dependent on various parameters like BHF, coefficient of friction, Die radius and punch radius. These four parameters need to be optimized in order to reduce wrinkling and enhance the quality of the finished part. Flower Pollination algorithm is a very efficient and fast algorithm inspired by the pollination characteristics of flowering parts. The formability analysis of the original component is also performed.

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REFERENCES

[1] Peter Ulintz, "Tooling by Design", Metal Forming Magazine, February 2007, pp.52-53.

[2] D. Ravi Kumar, "Formability Analysis of extra-deep drawing steel", Journal of Materials Processing Technology 130–131 (2002) 31–41.

[3] T.J. Kim, D.Y. Yang, "Improvement of formability for the incremental sheet metal forming process," IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.

[4] M.T. Browne*, M.T. Hillery, "High resolution fiber distributed measurements with coherent OFDR," Journal of Materials Processing Technology 136 (2003) 64–71

[5] H. Gharib*, A.S. Wifi, M. Younan, A. Nassef, "Optimization of the Blank Holder Force in cup drawing," Journal of Achievements in Materials and Manufacturing Engineering, Vol.18,No.1-2, 2006, pp. 291-294.

[6] Prof. dr. Milan Jurković, Muslić Merima,"Mathematical Modelling of Friction Force and Friction Coefficient at Deep Drawing Process", 15th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology"TMT 2011, Prague, Czech Republic, 12-18 September 2011.

[7] S. RAJU1, G. GANESAN, R. KARTHIKEYAN, "Influence of variables in deep drawing of AA 6061 sheet" Transactions of Non-ferrous Metals Society of China, Vol.20, 2010, pp.1856-1862.

[8] P.Sabarinath1, R.Karthick1 M.R.Thansekhar1, R.Saravanan2, "Energy Conservation by Design Optimization of Flywhel using Flower Pollination Algorithm," National Conference On Recent Trends And Developments In Sustainable Green Technologies, issue.7, 2015,pp.166-171.

[9] Osman Hegazy1*, Omar S. Soliman1 and Mustafa Abdul Salam2," Comparative Study between FPA, BA, MCS, ABC, and PSO Algorithms in Training and Optimizing of LS-SVM for Stock Market Prediction", International Journal of Advanced Computer Research ISSN (Print): 2249-7277 ISSN (Online): 2277-7970 Volume-5 Issue-18 March-2015.

[10] O. Abdel-Raouf*, M. Abdel-Baset, I. El-henawy, "A New Hybrid Flower Pollination Algorithm for Solving Constrained Global

Optimization Problems" International Journal of Applied Operational Research Vol. 4, No. 2, pp. 1-13, Spring 2014.

[11] Mohamed Abdel-Baset 1,* and Ibrahim M. Hezam 2., " An Improved Flower Pollination Algorithm for Ratios Optimization Problems ", Appl. Math. Inf. Sci. Lett. 3, No. 2, 83-91 (2015).

