Optimization of Blank Holding Force in Deep Drawing Process by Fuzzy Logic

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ABSTRACT

In deep drawing process, if the blank holding force (BHF) is too low, the draw depth is restricted by the limits of wrinkling and if the blank holding force is too high, the draw depth is limited by fracture. In this paper an optimization technique by fuzzy logic is proposed to optimize the blank holding force so that the maximum draw depth can be achieved. In this technique, at first blank holding force and draw depth are inter-related by fuzzy rules (patches) and from there optimum blank holding force is computed by standard mathematical curve fitting procedure.

Keywords: *Blank holding force, optimization, fuzzy logic.*

NOMENCLATURE

F	punch force
P_H	blank holder pressure
c	an empirical factor ranging from 2 to 3
DR	draw ratio (draw depth/punch diameter)
d_0	blank diameter
S_u	ultimate tensile strength
σ_r	radial stress
R_d	radius of the die
β	empirical factor ranging from .02 - .08
K	shear yield stress
μ	friction co-efficient (lets take 0.1)
R_P	radius of the punch
t	thickness of the sheet
r_j	radius of job
r_p	punch corner radius,
r_d	die corner radius,
r_o	is blank radius,
C	clearance

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1 INTRODUCTION

In forming processes the desired shape and size of an object are obtained through plastic deformation of materials. The stresses induced during the processes are greater than the yield strength but less than fracture strength. This is a very economical process as the desired shape, size and finish can be obtained without any significant loss of materials. Moreover, a part of the input energy is fruitfully utilized in improving the strength of the product through work hardening [1]. Metal forming processes can be grouped into many categories. Deep drawing process is one of the drawing processes in metal forming processes. Deep drawing primarily uses the principle of stretching the materials beyond the elastic limit without compression, but may have a combination of compressive and tensile stresses locked in the part [2]. The parameters for deep drawing using mechanical dies include materials, blank diameter, material thickness and the flange overhang. It is not difficult to realize that without proper precautions the products of deep drawing drawingoperations onsheet metals. An insufficient blank holder pressure causes wrinkles to develop on the flange, which may also extend to the wall of the cup. Further,too much of a blank holder pressure may cause a thinning of the walls and a fracture at the flange, bottom and the corners. These types of defects may be removed by considering the optimum values of blank holding force [3].

Logic based on the two truth values true and false is sometimes inadequate when describing human reasoning. Fuzzy logic uses the whole interval between 0 (False) and 1 (True) to describe human reasoning [4]. A system of logic developed for representing conditions that deal with degrees of membership and degrees of truth (cannot be easily described by the binary terms true and false). Fuzzy logic is determined as a set of mathematical principles for knowledge representation based on degree of membership. Thus, fuzzy logic is a very suitable solution to optimize the blank holding force in order to obtain the desired product geometry.

Technique of building a fuzzy logic system involves three steps [5]. The first step is to convert the measured parameter into a set of fuzzy variables. This is called fuzzy classification or fuzzification. It is done by giving values to each of a set of membership functions. Next step of fuzzy logic is known as inference rules. In this step fuzzy control uses fuzzy equivalents of logical AND, OR and NOT operations to build up fuzzy logic rules. The last step in building a fuzzy logic system is turning the fuzzy variables generated by the fuzzy logic rules into real parameter again. The fuzzy logic process which does this is called defuzzification because it combines the fuzzy variables to give a corresponding real (crisp ornon-fuzzy) parameter which can then be used to perform some action.

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2 FEM SIMULATION

To complete the scheme for the development of finite element simulation, a preprocessor and a post processor development work is going on. A post processor for metal forming process has been developed. A typical post processor developed is shown in Fig.1.

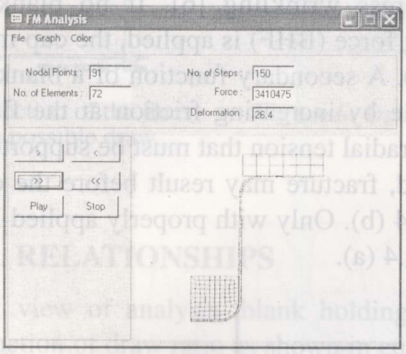

Figure 1: Development of a post processor for metal rming processes.

The post-processor simulates the simulation result by taking data from out put data file which is generated by the pre-processor. The postprocessor is interfaced with the numerical model in such a way that as the model runs, the simulated dies, blank, blank holder are displayed for each time step, thus creating an animation of model results. The post-processor can also run in a standalone mode to play back a saved simulation.

3 DEEP DRAWING PROCESS

Deep drawing (shown in Fig.2) is a process [2] in which a blank is forced into or through a die by a punch to form a hollow component that has essentially the

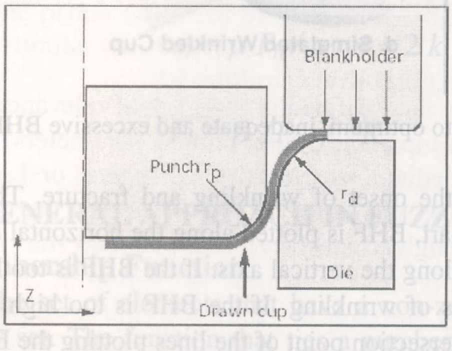

Figure 2: Die blank-holders and punch geometry.

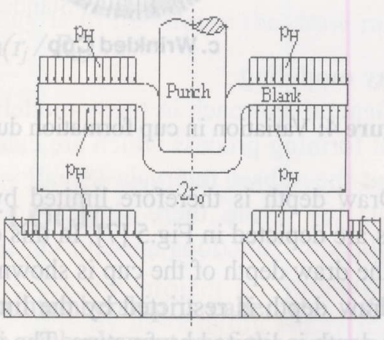

Figure 3: Free body diagram Showing forces on the blank holder and the die

same thickness as the original material. The most critical region of a deep drawn cup is the flange because of the circumferential stresses involved. The details mechanique of deep drawing process is shown in Fig.3.

Significance of blank holder in deep drawing process

The main function of blank holder is to apply blank holder pressure (BHP) to the cup flange to suppress wrinkling [6]. If no blank holder is used or insufficient blank holding force (BHF) is applied, the cup may wrinkle as shown in Fig.4 (c) and Fig.4 (d). A secondary function of a blank holder is to restrain material flow into the die by increasing friction at the flange. This increased friction causes increased radial tension that must be supported by the cup wall. If too much BHF is applied, fracture may result before the desired cup height is attained as shown in Fig.4 (b). Only with properly applied BHF, a good cup can be drawn as shown in Fig.4 (a).

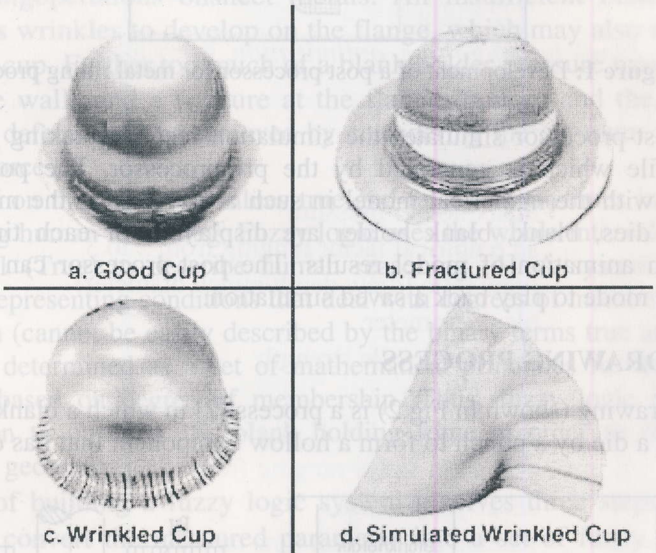

Figure 4: Variation in cup formation due to optimum, inadequate and excessive BHF.

Draw depth is therefore limited by the onset of wrinkling and fracture. These limits are depicted in Fig.5 [7]. In this chart, BHF is plotted along the horizontal axis and the draw depth of the cup is shown along the vertical axis. If the BHF is too low, the draw depth is restricted by the limits of wrinkling. If the BHF is too high, the draw depth is limited by fracture. The intersection point of the lines plotting the BHF and the draw depth of a cup reveals the maximum possible draw depth for a given cup. The optimum BHF time profile for different draw depths as shown in Fig.6.

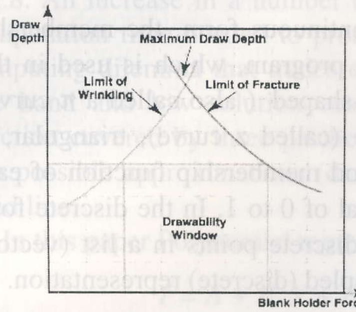

Figure 5: The intersection of the lines reveal the maximum possible draw depth for a cup.

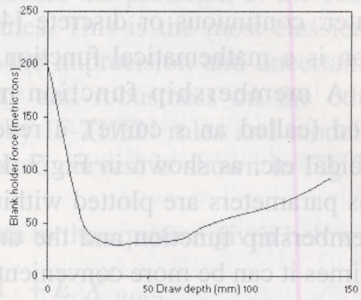

Figure 6: Optimum BHF time profile

MATHEMATICAL RELATIONSHIPS

From the point of view of analysis, blank holding force is considered as variable which is a function of draw ratio as shown in eqn. 1. Draw ratio changes in each simulation time step. Though in deep drawing operation varying amount of thickening and thinning of the work piece is unavoidable, but in this analysis it is not taken into consideration. Thus in eqn.2 thickness of the work piece is always considered as constant. The annular portion of the sheet metal work piece between the blank holder and the die is subjected to a pure radial load which is also a function of blank holding force as shown in eqn.3. Eqn.4 represents blank holding force in terms of shear yield stress.

$$P_H = 10^{-3} c[(DR-1)^3 + \frac{0.005 d_0}{t}] \tag{1}$$

$$F = \sigma_r \,(e^{\mu\pi/2})\, 2\pi R_p\, t \tag{2}$$

$$\sigma_r = \mu\, P_H / \pi\, r_j\, t + 2\, k \ln(r_j / R_d) \tag{3}$$

$$P_H = \beta\; \Pi\; r_j^2\;\; K \tag{4}$$

4 GENERAL APPROACH IN FUZZY LOGIC

Membership Function

The set of elements that have a non-zero membership is called the of the fuzzy set. The function that ties a number to each element x of the universe is called the membership function $\mu(x)$.

There are two alternative ways to represent a membership function in a computer: continuous or discrete [4]. In the continuous form, the membership function is a mathematical function, possibly a program, which is used in this study. A membership function may be bell-shaped (also called a π curve), s-shaped (called an s curve), a reverse s-curve (called z curve), triangular, or trapezoidal etc. as shown in Fig.7. In this method membership function of each process parameters are plotted within the interval of 0 to 1. In the discrete form the membership function and the universe are discrete points in a list (vector). Sometimes it can be more convenient with a sampled (discrete) representation.

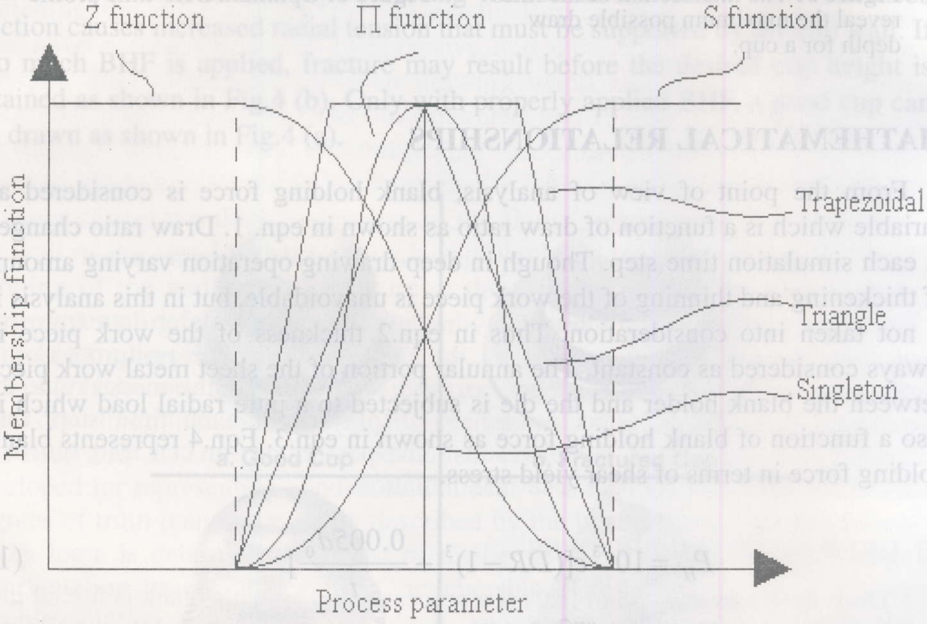

Figure 7: Standard Membership functions

Fuzzy modeling

General approach in fuzzy modeling is to define the variables of relevance (in metal forming process which are called input and output process parameters) and define the subset intervals (Small - Medium, or Negative - Positive, or Left – Right) [8]. From there shapes and the positions of fuzzy subsets therefore membership functions are chosen, through which fuzzy rules (If-then rules) are implemented.

Curve fitting procedure

Standard mathematical procedure of curve fitting results in a more or less acceptable solution. It is usually done by using fuzzy rules (patches) as shown in

Fig.8. An increase in a number of rules increases the precision at the cost of a computation time needed to process more rules. This is the most classical soft computing dilemma that trades off between the imprecision and uncertainty on one hand and low solution cost, tractability and robustness on the other. A function covered by three patches produced by IF-THEN rules and modeled by two possible approximations (dashed and dotted curves) is shown in Fig.9 by a solid line.

In this paper Polynomial regression fits data to the equation given below:

$$Y = A + B.X + C.X^2 + D.X^3 + E.X^4 \ldots\ldots \quad (5)$$

Here Y is membership function, X is process parameter and A, B, C... are constants.

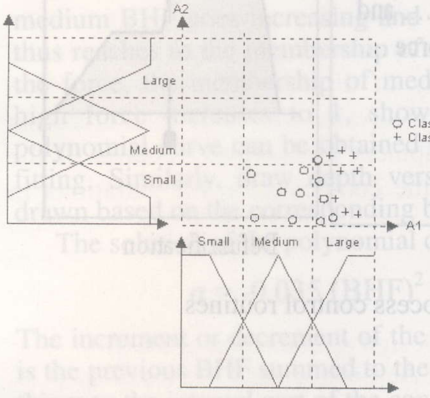

Figure 8: Pattern recognition and classification of the fuzzy patches.

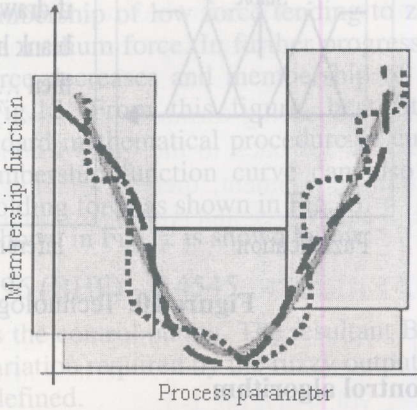

Figure 9: Standard mathematical curve fitting

5 CONTROL STRATEGEY

The prime objective of the control strategy is to maximize the draw ratio. In particular the objectives are

- To minimize wrinkling,
- To minimize fracture,
- To maximize the draw depth

Fuzzy logic may be considered as an assortment of these decision-makings. The algorithm's outcome is ruled by a number of key decisions which are made in the algorithm. An extensive knowledge of the system is required to define the best decision. For the present project the problem is decomposed into a number of possible decisions by associating fuzzy logic functions with predefined input and output. The accuracy of the system depends on how many functions and how many rules are implemented. For the same manner. This computation proceeds until the maximum draw depth is achieved. The governing equations regarding the decision criteria are as follows,

$$P_H = P_H + 10^{-3} c[((DR_{\max} - DR) - 1)^3 + \frac{0.005 d_0}{t}] \quad (7)$$

$$P_H = P_H - 10^{-3} c[((DR - DR_{\max}) - 1)^3 + \frac{0.005 d_0}{t}] \quad (8)$$

6 CONCLUSIONS

The optimization technique is integrated with the FEM method of deep drawing process for precise driving of the blank holding force that has very hard dependence of nonlinearity of controlled variables. This solution allows monitoring and control of the deviation of physical parameters. Using fuzzy method of programming, the user makes the system adaptive and increases the stability of the results. With the possibility of directly sensing work piece conditions during forming operations, it is conceivable that these measurements could be fed back to the metal-forming equipment for computer control of the forming equipment, thereby enabling real-time compensation for variations in initial work piece and equipment conditions.

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