EXTRUSION DIE LOAD MINIMIZATION USING GENETIC ALGORITHM AND SIMULATED ANNEALING ALGORITHM

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ABSTRACT

Metal forming extrusion processes are widely used in industry for higher production rate. Extrusion is one of the metals forming process. In this process a block of metal is forced through a die orifice and its cross section is reduced. Extrusion die are presently designed by trial and error method. But these methods are approximate and time consuming. Methods like upper bound solution, Area mapping technique, slab method are widely used for analyzing the die profile. In this paper a new approach called Genetic Algorithm and Simulated Annealing are used to minimize the extrusion pressure by optimizing the extrusion ratio and die cone angle.

Keywords: Extrusion, Genetic algorithm, Simulated Annealing

I. INTRODUCTION

Extrusion dies are used in the industries for high production rate and accuracy in the metal forming process. There are many factors that affecting the extrusion process are die cone angle or die profile, friction factor, extrusion pressure and temperature. Presently extrusion die profile design is made trial and error methods but these methods are very time consuming methods and also approximate. To avoid the problems a new approach called genetic algorithm is used for optimizing the extrusion pressure and die cone angle. In earlier work, Richmond and Devenpeck [1] have used slip-line method for optimal die shape design in extrusion process.

Avitzur [2] derived the equations for computing upper bound for the extrusion stress. Aravamadhu Balaji, Sundararajan, and Lal [3] have developed a generalized methodology for optimal die design using the viscoplastic formulation coupled with the finite element technique. Joun and Hwang [4] presented a finite element based approach for pass schedule optimal design in multi-pass extrusion and drawing. Bhattacharyya, Majumdar, and Basu [5] described a calculation procedure for the detailed prediction of flow during the process of metal extrusion. Yang, Kim, and Lee [6] analyzed the forward extrusion of composite rods through curved dies using flow function concept. Chung and Hwang [7] have applied genetic algorithm and finite element method for optimizing the extrusion die shape. Subsequently Wu and Hsu [8] have developed a polynomial networks and genetic algorithm for optimize the die shape with minimum force and strain.

1.1 Genetic Algorithm

Genetic algorithm [9,10] is an adaptive search and optimization algorithm that mimics the principles of natural genetics. GA's are very different from traditional search and optimization methods used in engineering design problems. Because of their simplicity, easy of operations minimum requirements and global perspective, GA's has been successfully used in a wide variety of problem domains. GA work through three operators, namely reproduction, cross over and mutation. In this paper an attempt is made to use of genetic algorithm to minimize the extrusion pressure by optimizing the extrusion die cone angle and extrusion ratio and the results are compared with simulated annealing algorithm.

1.2 Working Principle

1. The decision variables X^i are coded in some string structure, binary coded string having zeros and one's are mostly used.

2. The length of the string is usually determined according to the desired solution accuracy. For example, the strings (0000) and (1111) represent the point ($X_1^{(L)}$, $X_2^{(L)}$) and ($X_1^{(u)}$, $X_2^{(u)}$) .The sub string has the minimum and maximum decoded values.

3. The parameter values are calculated by using the following formula

$$X = X_i^{(L)} + \frac{X_i^{(U)} - X_i^{(L)}}{2^n - 1} \ (Deocoded\ value)$$ **or**

$$= Min + \left(\frac{Max - Min}{2^n - 1} \right) \ \boldsymbol{*\ (Decoded\ value)}$$

1.3 Fitness Function

1. Genetic Algorithm mimics the survival of the fittest principle of nature to make search procedure

2. The fitness function F (x) is first derived from the objective function and used in successive genetic operation

3.For minimization problems, the fitness function is an equivalent maximization problem such that the optimum point remains unchanged.

$$f(x) = \frac{1}{1 + f(x)}$$

1.4 Operation of genetic Algorithm

1. Genetic Algorithm begins with population of random strings representing design and decision variables thereafter each string is evaluated to find the fitness value.

2. The population is operated by three main operators

Reproduction

Crossover

Mutation

3. The population formed is further evaluated and tested for termination. If the termination criteria is not met, the population is iteratively operated by the above three operators and evaluated.

4. This procedure is continued until the termination criteria are met.

1.5 Genetic Algorithm operators

Reproduction

1.It is the first operator applied on a population. It selects good strings in a population and form mating pool.

2The average strings are picked from the current population and the multiple copies are inserted in the mating hole in a probabilistic manner.

3.The commonly used reproduction operator is proportionate reproduction operator where the string is selected for the mating hole with a proportional to its fitness. The probability for selecting i th string is

$$P_i = \frac{F_i}{\sum_{j=1}^{n} Fj}$$

Crossover

1.In the crossover operator, exchanging information among strings of the mating pool creates new strings.

2.In most crossover operators, two strings picked from the mating pool at random and some portion of the strings are exchanged between the strings.

Before crossover After crossover

00 | 11 |00 00

11 11 11 00

Mutation

i. Mutation operator changes one’s to zeros and zeros to one’s with a mutation probability Pm.
ii. The widthwise mutation is performed bit by bit by flipping a point with a probability Pm
iii. If at any width the outcome is true then the bit is altered otherwise the bit is kept unchanged.
iv. Mutation probability Pm=0.05
v. The need for mutation is to create a point in the neighborhood of the current point thereby achieving the local search around the current solution

For example,

0110 $\Rightarrow$ 0111

1001 1011

II. OPTIMIZATION PROCEDURE

Step1: Choose a coding to represent problem parameter, a selection operator, a crossover operator and a mutation operator. Choose population size N, crossover probability p_c, and mutation probability p_m. Initialize a random population of strings of size 10. Set iteration t=0.

Step 2: Evaluate each string in the population.

Step 3: If it > it_{max} (or) other termination criteria is satisfied, terminate.

Step 4: Perform reproduction on the population.

Step 5:Perform crossover on the random pairs of strings.

Step 6:Perform bit wise mutation.

Step 7:Evaluate strings in the new population. Set

it = it +1 and go to step 3.

2.1 Objective function

The objective function is minimization of extrusion pressure [11] by optimizing the die cone angle and extrusion ratio. The extrusion pressure can be calculated by using the formula

$$P = \sigma_O \left[\frac{1+B}{B}\right]\left(1 - R^B\right) \qquad \text{--------- } \mathbf{(1)}$$

Where

P = extrusion pressure

σ_O = flow stress

R = extrusion ratio

B = μ cot α

Where

μ = Friction coefficient

α= Die cone angle

The eqn (1) can be modified as

$$f(R,\alpha) = \sigma_O \left[\frac{1+B}{B}\right]\left(1 - R^B\right) \qquad \text{--------- (2)}$$

In the interval

R = 1 to 5

α = 0 to π / 2 or

0 to 1.571

III. SIMULATED ANNEALING

1) Simulated Annealing method [10] resembles the cooling process of molten metals through annealing.
2) At high temperature, the atoms in the molten metal can move freely with respect to each other but as the temperature is reduced, the movement of atoms gets restricted.

3) The atoms start to get ordered and finally form crystals having the minimum possible energy.
4) The formation of crystal mainly depends on the cooling rate.
5) If the temperature is reduced at very fast rate, the crystalline state may not be achieved at all; instead the system may end up in a polycrystalline state, which has high-energy state than the crystalline state.
6) Therefore, in order to achieve the absolute minimum energy state the temperature needs to be reduced at a slow rate.

3.1 General Procedure

1) Simulated Annealing procedure [10] simulates the process of slow cooling of molten metal to achieve the minimum function value in a minimization problem.
2) The cooling phenomenon is simulated by controlling temperature like parameter introduced the concept of Boltzmann probability ditribution. According to the boltzmann probability distribution, a system in thermal equilibrium at temperature 'T' has its energy distributed probabilistically according to

$$\mathbf{P\ (E)=e}^{-(E/KT)}$$

Where K is Boltzmann constant

3) At any instant current point at the X (t), the functional value at that point

$$\mathbf{E\ (t)=f\ (x\ (t))}$$

4) Using the metropolis algorithm we can say that probability of the next point being at X $^{(t+1)}$, depend on the value at two points ΔE=E (t+1)-E (t) and is calculated using the boltzmann probability distribution

$$\mathbf{P\ (E\ (t+!)=Min\ ([1,e}^{-E/KT}\ \mathbf{]}$$

If the function value at X $^{(t+1)}$ is better than X $^{(t)}$, then the point X $^{(t+1)}$ must be accepted.

IV. RESULT AND DISCUSSION

The present problem is an optimization problem with constraints. The objective function is the minimization of extrusion pressure by varying die cone angle and extrusion ratio. In this work, the optimum extrusion pressure is obtained by using genetic algorithm at the 16th generation. The optimum value of extrusion pressure is 125.72 Mpa, the corresponding die cone angle is 32.35^{o} and extrusion ratio is 1.477, as shown in Fig.4.The graph shows that varying fitness in the initial iteration and smooth fitness at the subsequent iteration. The Maximum fitness value is 0.0075.The optimum extrusion pressure is obtained by using simulated annealing algorithm at the 46th generation. The optimum value of extrusion pressure is 143.14 Mpa, as shown in Fig.5.The corresponding die cone angle is 25.46^{o} and extrusion ratio is 1.6.The graph shows that varying fitness in the initial iteration and smooth fitness at the subsequent iteration. The extrusion pressure obtained in the genetic algorithm is a minimum value when compared with the simulated annealing algorithm.

V. CONCLUSION

A genetic algorithm and simulated annealing approach was proposed for optimizing the die shape in extrusion. The main advantage of this approach is that it can be used for any objective function, which was most clearly demonstrated in this example, where the objective function was the minimization of extrusion pressure. In this approach two constraints namely die cone angle and extrusion ratio are considered for minimizing the extrusion pressure. There are many other constraints that affect extrusion pressure, which can be solved by using multi objective genetic algorithm in the future. The result obtained in the genetic algorithm is compared with the simulated annealing algorithm for verification. It is found that the result obtained by genetic algorithm is better than simulated annealing algorithm.

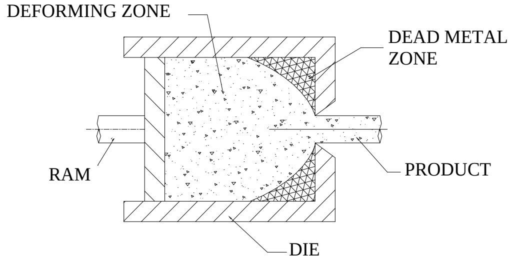

Fig.1 SHEAR DIE

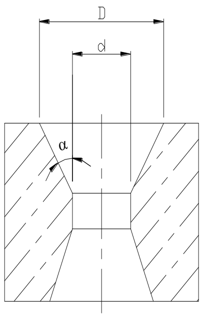

Fig.2. Extrusion Die

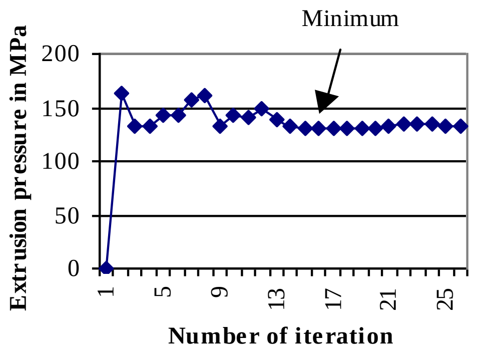

Fig.4. Genetic algorithm results

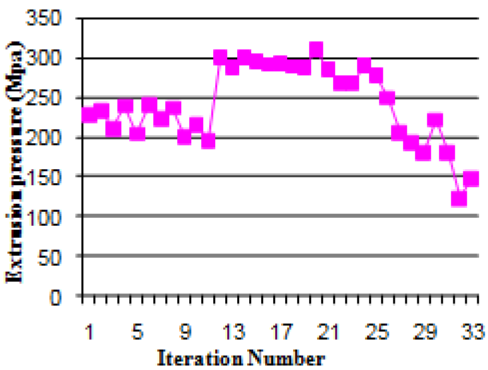

Fig.5.Simulated annealing results

Nomenclature

α - die cone angle

μ - friction factor

D- entry diameter of the billet

d - exit diameter of the billet

P- extrusion pressure

σ_o -flow stress

f(x) – objective function

g(x) – fitness number

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