Optimization of Extrusion Pressure Using Genetic Algorithm

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Abstract - Extrusion is the process by which a block of metal is reduced in cross section by forcing it to flow through a die orifice under high pressure. Die with conical entrance angles are used in extrusion with good lubrication. Decreasing the die angle increases the homogeneity of deformation and lowers the extrusion pressure, but beyond a point the friction in the disc surfaces become too large. Presently the die design is made by trial and error methods. But these methods are approximate and time-consuming. In order to avoid the above problems a new approach called genetic Algorithm is used for optimizing the die profile. In this paper an attempt is made to use of Genetic Algorithm to optimize the extrusion die cone angle and friction factor.

Keywords: Extrusion pressure minimization, Genetic algorithm, Optimization

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, Xuemei et al [1] have used genetic algorithm method for optimal extrusion die shape design in extrusion process. Avitzur [2] derived the equations for computing upper bound for the extrusion stress. Hong et al [3] have designed different corner angles with and without inner round fillet with the finite element technique and DEFORM. Venkatesan R and Venkatesan C [4] presented a upper bound technique, area mapping technique and finite element based approaches for streamlined extrusion die for round to hexagon. Bhattacharyya, Majumdar, and Basu [5] described a calculation procedure for the detailed prediction of flow during the process of metal extrusion. Ali and Ardeshir [6] analyzed with different optimization methods to find optimal extrusion parameters with minimum tool loading obtained by cold forward extrusion. Chung and Hwang [7] have applied genetic algorithm and finite element method for optimizing the extrusion die shape. Subsequently Zhao et al [8] have used a Pareto-based genetic algorithm for optimization design of extrusion die to gain even velocity distribution in extrusion die and decrease the deflection of the mandrel and stress on the die. Genetic algorithm 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 friction factor.

II. GENETIC ALGORITHM PROCEDURE

The objective is to minimize the extrusion pressure. This can be obtained by keeping the extrusion ratio as constant and varying the die cone angle and friction factor.

Step 1: In order to solve this problem using genetic algorithms, choose binary coding to represent variables extrusion die cone angle (α) and friction factor (μ). In the calculations here, 10 bits are chosen for each variable, thereby making the total string length equal to 20.Choose population size, n, crossover probability=0.8,and mutation probability=0.01. Choose a maximum allowable generation number tmax=25 and initialize the generation counter t=0.
Step 2: Evaluate each string in the population.
Step 3: If $t > tmax$ 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 $t = t + 1$ and go to step 3.

The algorithm is straight forward with repeated application of three operators (Steps 4 to 7) to a population of points.

2.1 *Objective function*

The objective function is minimization of extrusion pressure by optimizing the die cone angle and coefficient of friction factor shown in Figs.1 and 2. The extrusion pressure can be calculated by using the formula

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

Where

P = extrusion pressure
σo = flow stress=250 MPa (for Aluminum alloy)
R = extrusion ratio=1.67
$B = \mu \cot \alpha$

The eqn (1) can be modified as

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

Where
μ = friction factor
α= die cone angle

In the interval
$\mu = 0.1$ to 0.5
$\alpha = 0$ to $\pi / 2$ or
0 to 1.571

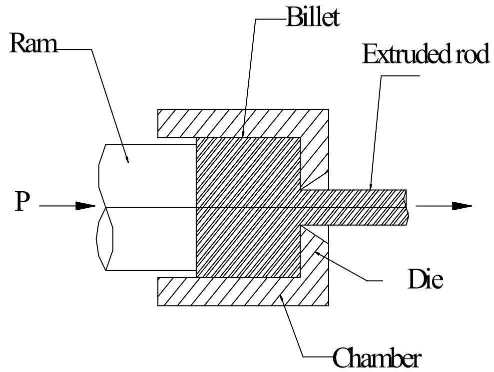


Fig.1. Forward extrusion

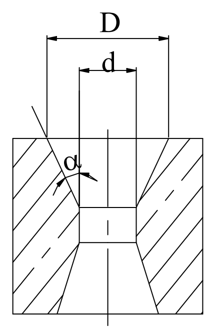
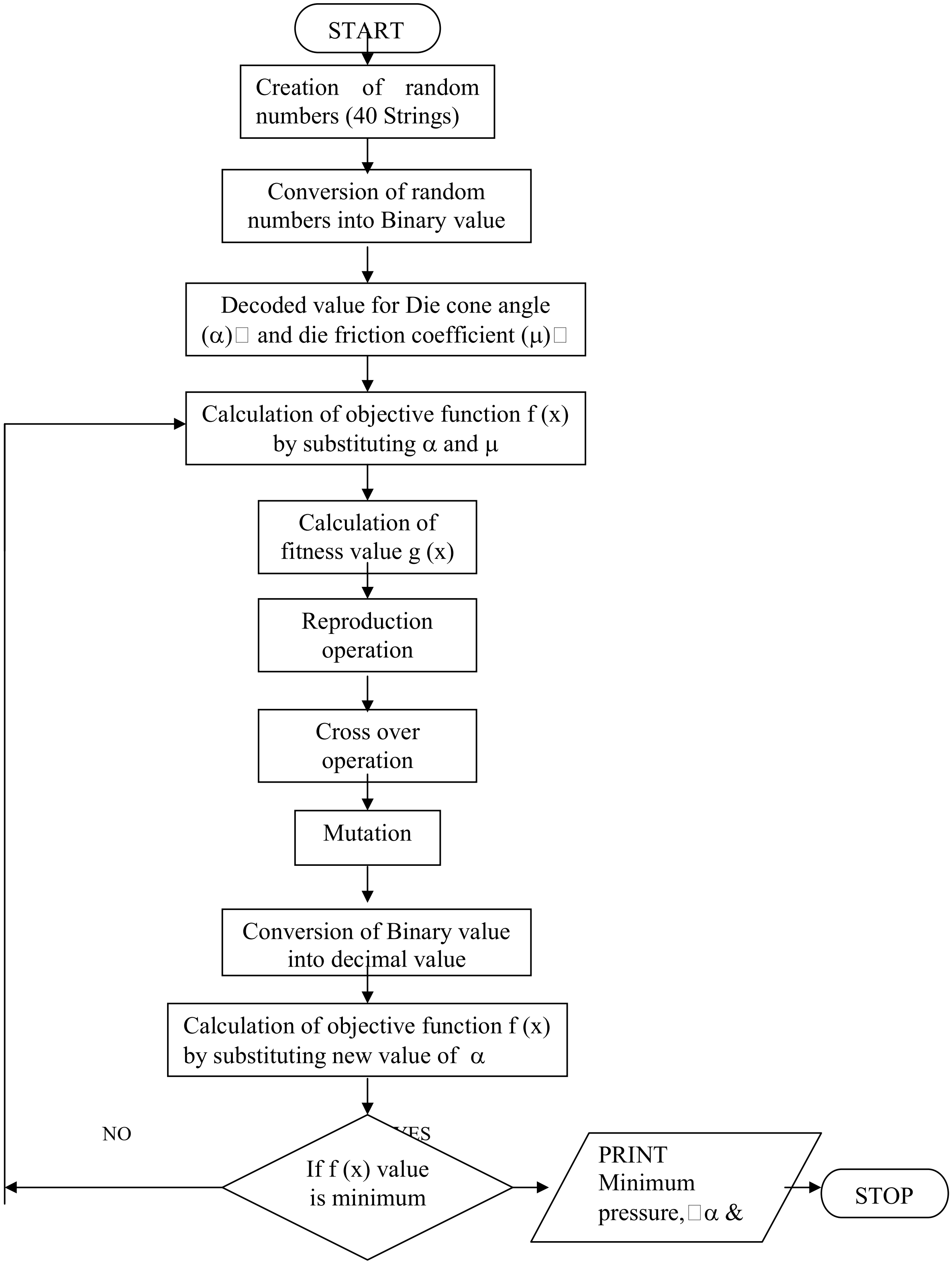


Fig.2. Extrusion Die

The flow chart for the Genetic Algorithm computer program is given below.



2.2 Implementation of GA binary coding

Representation for die cone Angle

In order to solve this problem using genetic algorithm, we choose binary coding to represent the variables die cone angle and friction factor. The length of the string is usually determined according to the desired solution accuracy. Here 10 bits are chosen.
For example for a two step process two set of 10 bits of strings are selected.

No	Code	Decode	Die cone angle
1	0000000000	0	0
2	1111111111	1023	1.571

Representation for friction factor

No	Code	Decode	Friction factor
1	0000000000	0	0.1
2	1111111111	1023	0.5

III. INITIALIZATION

During initialization, a solution space of population size solution string is generated randomly between the limits.The actual decoded die cone angle and friction factor are calculated by using the below formula,

$$X_i = X_i^{(U)} + \frac{X_i^{(U)} - X_i^L}{2^n - 1}(Decoded\ value)$$

or

$$= \text{Maximum} + \left(\frac{\text{Maximum} - \text{Minimum}}{2^n - 1}\right)_{\text{(Decoded value)}}$$

Table-1

1	2	3	4	5	6
String1	De Value	Act value	String2	De Value	Act Value
0011011010	218	0.185	1011011001	729	1.119
0011000000	192	0.17500	0111111100	508	0.780
0011101111	239	.193	1101011001	857	1.316
1001101100	620	0.342	1111100011	995	1.528

3.1 Fitness function

As pointed out earlier, GAs mimics the survival of fittest principle of nature to make a search process. Therefore, G3As are naturally suitable for solving maximization problems. In this work, the objective is the minimization of extrusion pressure, which is the function of extrusion die cone angle and friction coefficient. After getting the expected count of all strings, the string having the highest expected count is given a highest rank. And the string having low value of expected count value is given a low rank. The strings of highest ranks replace the strings having lowest ranks.

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

3.2 Genetic algorithm parameters

Sample Size	10
Crossover probability	0.6
Mutation probability	0.05
Number of generation	25

IV. GENETIC ALGORITHM OPERATORS

4.1 Reproduction

Reproduction is usually the first operator on a population. Reproduction select good string in a population and forms a mating pool. There exist a number of reproduction operator in GA, but the essential idea in all of them is that the above average are picked from the current population and their multiple copies are inserted in the mating pool in a probabilistic manner.

The following table 2 shows the strings after reproduction operation

Table 2

After Reproduction	
String1	String2
1101010000 0011011010 1001101100 1101000101	1000001111 1011011001 1111100011 1000000101

4.2 Crossover

The strings in the mating pool formed after reproductions are used in the crossover operation. Single-point crossover is used in this work. Crossover is first performed for the ten digits and is repeated for the remaining angles. Two strings are selected at random and crossed at random site. When two strings are chosen for crossover, a random number is generated between 0 and 1 with the probability of 0.6 to check weather a crossover is desired or not. The next step is found the cross-site at random. Creating a random number between 1 and 10 for the crossover site. Table 3 shows the strings for parent1 and parent2 before crossover and the sites of crossover in the last column.

Before crossover		
Parent1		Crossover Sites
1101010000	1000001111	9
0011011010	1011011001	9
1001101100	1111100011	12
1101000101	1000000101	12

Table 3

Crossover is performed as follows, consider the first two strings

Before crossover

110101000 0 | 1000001111
001101101 0 | 1011011001

After crossover

110101000 0 | 1011011001
001101101 0 | 1000001111

This means crossover-taking place at 9th site.
The table 4 shows the computer generated result for crossover operation.

After crossover	
String1	String2
1101010000	1011011001
0011011010	1000001111
1001101100	1100000101
1101000101	1011100011

Table 4

4.3 *Mutation*

Mutation is a random modification of randomly selected string. Mutation is done with a mutation probability of 0.01

Before mutation
11 1 1001111
8 -> 2 means mutation taking place at 8th chromosome at second site.

After mutation
11 0 1001111

The following table 5 shows the mutation resulting population.

Mutation resulting population	
String1	String2
1100001000	1101111100
1100111111	1000111011
1111001000	1010111100
1101010110	1010001110

Table 5

After adjustment the good strings in the previous iteration are used in the next iteration.
Table 6 shows the initial population for the next generation.

1	2	3	4	5	6
String1	De Val.	Act value	String2	De Val.	Act Value
1101011010	858	0.985	1011100110	742	0.317
1100111110	830	0.875	1000111011	571	0.267
1110110110	950	1.256	1010101000	680	0.299
1101010101	853	0.886	1010001110	654	0.291

Table 6

The best string in the list of one iteration of GA, which is having the minimum extrusion pressure, is stored. And all the strings available at the end of first iteration will be treated as parent for the 2nd iteration. This procedure is repeated for the number of iterations as given by the user.

V. RESULT AND DISCUSSION

The present problem is an optimization problem with constraints. The objective function is the minimization of die cone angle and minimization of friction coefficient. In this work involving at the die profile, the optimum die cone angle could be obtained at the 19th generation in GA. In this work, the parameter values ie., Diameter of the billet, length of the die, exit billet diameter are changed.

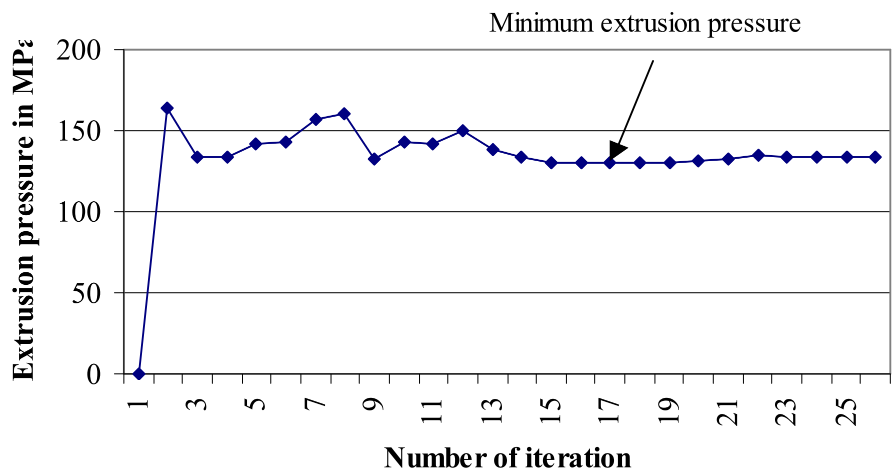


Fig.2. Genetic algorithm results

VI. CONCLUSION

A genetic algorithm 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 friction coefficient 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.

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NOMENCLATURE

α - Die cone angle
μ - friction coefficient
L – Length of the die
D – diameter of the die
d1 – entry diameter of the billet
d2 – exit diameter of the billet