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Optimization of Cutting Parameters for Milling Operation using Genetic Algorithm technique through MATLAB

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ABSTRACT

In any manufacturing operation, machining is the critical operation involves maintenance, cost and tool replacement. Change of tool cutting is generally time consuming operation in any automated machining process. So, one of the nontraditional technique called Genetic Algorithm (GA) based on MATLAB- Ga tool has been used for optimizing machining parameters and to reduce unit cost of a component during milling operation. The main objective of the project work is to check whether MATLAB – Ga tool will help production and design operations as well as to optimize machining parameters and also to reduce the unit cost. The work has been carried out to optimize the machining parameters during milling and to reduce the unit cost of product. For this, initially a known problem is checked with MATLAB. A known problem whose sum of squares is 100 and designed optimized for 3 variables. Next, in a similar way, standard equation is coded with MATLAB function considering three constraint functions like force, power and surface finish. Finally, first experiment carried out by considering two variables speed and feed and second experiment is done with three variables considering speed, feed and depth of cut.

Ga tool also shows the convergence in the graph along with listing of the variables as execution proceeds further. The objective values are found to be Rs 443 by considering speed and feed whose optimized values are 120rpm and 0.28mm/min respectively. Similarly in second experiment objective values is found to be Rs 448.36 and optimum parameters value such as speed, feed and depth of cut as 120rpm, 0.304mm/min and 10mm respectively. The obtained results from the GA method are compared with Particle Swarm Optimization method which is popularly known as PSO where, GA gives superior result than PSO method.

Keywords - *Optimization, Machining parameters, MATLAB, Genetic Algorithm.*

1. INTRODUCTION

Optimization is a process where minimizing or maximizing certain functions with respect to few element or variables. This function compares with the choices made for obtaining which might be best. Now a day's optimization based algorithm techniques are fetching extremely poyakepular in the field of engineering activities and this is mainly because of the accessibility and availability of high-speed digital systems. These optimized processes are exclusively utilized or opted in engineering obstacles where focus is on increasing or reducing a firm aims.

Optimization techniques are regularly opted in aeronautical field to decrease the overall mass of aircraft components, because on the whole each component adds its weight to the system. Both chemical and mechanical engineers focused on several techniques to optimize various variables or parameter associated during planning of process plant and in design of production rate on machine shop. On the other hand civil engineers are also interested in reducing cost and to increase factor of safety during building of various bridges; construction of dams and other geometrical structures. Electronic engineers also involved in design of communication systems where time for communication from one knot to another should be minimized.

Optimization algorithms are becoming increasingly popular in engineering activities, primarily because of the availability and affordability of high-speed computers. They are extensively used in those engineering problems where the emphasis is on maximizing or minimizing of a certain goal.

For example, optimization algorithms are routinely used in aerospace design activities to minimize the overall weight, simply because every element or component adds to the overall weight of the aircraft. Chemical engineers on the other hand are interested in designing or operating a process plant for an optimum rate of production. Mechanical engineers design mechanical components for the purpose of achieving either a minimum manufacturing cost or maximum rate of production.

Production engineers are interested in designing optimum schedules of various machining operations to minimize the idle time of machines and the overall completion time. Civil engineers are involved in designing buildings, dams and other structures in order to achieve a minimum overall cost or maximum safety or both. Electronics engineers are interested in designing communication networks so as to achieve minimum time for communication from one node to another.

Thus, the ultimate aim of the optimization is to improve an existing process that meets the given requirements and satisfies all the restrictions/constraints placed on it. This process is known as optimum process. MATLAB code is executed selecting the suitable supportive algorithms like cross over, mutation, selection, feasible population etc. The Ga tool shows optimized values of 120 and 0.28 for speed and feed. The objective function value is found to be Rs 443 per component. The value is near to the standard value available in the literature. Here also system has taken 58 iterations for convergence of the values. Here also convergence or slope is almost optimized in the beginning 10 iterations indicating the strength of the Ga tool.

2. OBJECTIVES OF THE STUDY

The objective of this project work is to minimize the unit cost of a component which is to be produced by CNC milling operation and optimize the cutting parameters such as speed, feed, and depth of cut using nontraditional method called genetic algorithm with the help of MATLAB software. MATLAB validation and function development for machining parameters optimization using Ga tool is the main definition of the problem. Here the main objectives includes,

- Validation to check whether MATLAB code works for optimization problems.
- Function development for objective and constraint functions.
- Check through standard references.

3. EQUATIONS

In manufacturing any component production time, tool life, production rate are three major economic constraints and in this study, maximization of tool life and minimization of production cost is taken as objectives for the optimization problem.

Further code is optimized with three design variables (speed, feed and depth of cut). The results shows optimized value is Rs448 per component. The cost is increased due to the increase in the feed from 0.28mm/min to 0.30mm/min.

The unit production cost is represented by the below equation (1) [1]

$$C_u = C_{mat} + (C_l + C_o)\, t_s + \sum_{i=1} (C_l + C_o)\, K_{li}\, V_i^{-1} f_i^{-1} + \sum_{i=1}^{m} C_{ti} K_{2i} V_i^{\left(\frac{1}{n}\right)-1} f_i^{\left[\frac{w+g}{n}\right]-1} + \sum_{i=1}^{m} (C_l + C_0) \qquad (1)$$

Where $K_1 = \frac{\pi d k}{1000 z}$ and $K_2 = \frac{\pi d K Q 5^{g/n}}{60000 z C^{1/n}} \frac{1}{a^{g-w/n}}$ [1]

The machining power is represented by equation (2) $P = \frac{0.78\, K_p}{60 \pi d e} w z a_{rad} * a * v * f^{0.8}$ (2)

And for face milling is represented by equation (3)

$$R_{a1} = 318 * \frac{f}{\tan(y) + \cot(z)} \quad [1] \qquad (3)$$

Where, y=la and ca=z.

4. CONSTRAINTS

Machining parameters such as feed rate and cutting speed are restricted by the following constraints:

- Maximum cutting force permitted by the rigidity of the tool.
- Surface finish.
- Machine power.

a) Speed limits [1]

1) Face milling : 60-120 m/min
2) Corner milling : 40-70 m/min
3) Pocket milling : 40-70 m/min
4) Slot milling 1 : 30-50 m/min
5) Slot milling 2 : 30-50 m/min

b) Feed rate limits [1]

1) Face milling : 0.05mm/tooth
2) Corner milling : 0.05- /tooth
3) Pocket milling : 0.05mm/tooth
4) Slot milling 1 : 0.05mm/tooth
5) Slot milling 2 : 0.0mm/tooth.

5. RESULTS AND DISCUSSION

Constants [1]

C_{mat} = Rs 22.2176
C_o = Rs 64.4311 per min
C_1 = Rs 19.9958 per min
t_s = 2min
t_{ct} = 0.5 min
C = 33.98 for HSS tools
C = 100.05 for carbide tool
K_p = 2.24
W = 1.1
n = 0.15 for HSS tools.

n = 0.3 for carbide tool
g = 0.14
w = 0.28

5.1 Problem Description

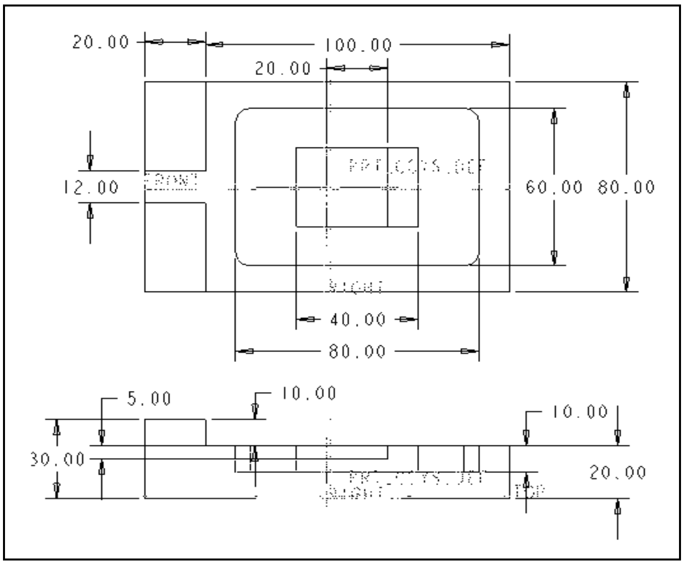

Fig 1: Top view of the Component (mm) [1].

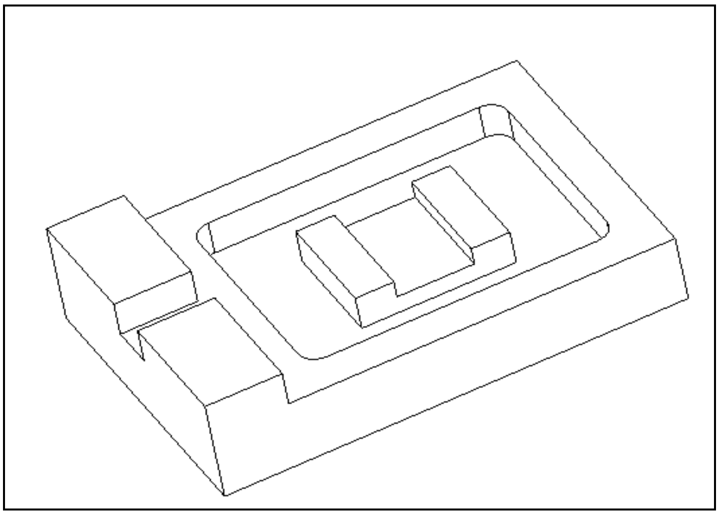

Fig 2: Isometric view of the Component [1].

5.2 Results:

In this project, a non-traditional technique called genetic algorithm is employed to solve optimization problems. Here, two experiments are carried considering two variables in experiment number one and three variables in experiment number 2 respectively.

Two experiments are carried out by considering 2 variables initially and 3 variables in next experiment and results obtained from it are tabulated and discussed below.

Validation Program:

A known problem is considered for MATLAB validation for engineering applications. Here idea is to select 3 variables whose optimum square value is 100. The nearness of values goes by constraint function defined in the problem. Three variables (y1, y2 and y3) are considered whose sum of square value should be equal to 100. But optimum value needs to be find whose value will satisfy the nonlinear constraint function. For simple sense, if one value equal to 10 and other values equal to zero's maximum objective function value should be 10. But we need to optimize the variables whose sum needs to be maximized.

The objective of this is obtained as follows.

Let sum =y1+y2+y3

Constraint for this $y1^2+y2^2+y3^2=100$

And let y1, y2, y3 are varying from 1 to 10.

What is the optimum valued for sum satisfying the constraint?

Validation through MATLAB:

Optimizing function by theoretical calculation:

```
function t1= obj1(x)
t1= x(1)+x(2)+x(3)
```

Constraint Functions:

```
function [c ceq] =con1(x)
ceq(1)=y(1)^2+y(2)^2+y(3)^2-100;
c= []
```

Generation	f(x)	Constraint	Generation	f(x)	Constraint
1	17.2746	0.00740079	16	17.1545	2.84507e-006
2	17.2762	0.00132379	17	17.1545	2.84507e-006
3	17.2749	0.00301591	18	17.1544	1.27e-005
4	17.2597	0.00239008	19	17.1543	3.61152e-006
5	17.2596	0.000299962	20	17.1543	5.6449e-006
6	17.2534	0.00169423	21	17.1543	5.6449e-006
7	17.2472	0.00168941	22	17.1542	5.6449e-006
8	17.1751	0.00100528	23	17.1544	5.6449e-006
9	17.1736	0.00118107	24	17.1543	5.6449e-006
10	17.1626	0.000687743	25	17.1543	5.6449e-006
11	17.1577	0.00461789	26	17.1543	3.19253e-006
12	17.1597	0.000218961	27	17.1543	3.19253e-006
13	17.1591	0.000370986	28	17.1543	3.19253e-006
14	17.159	0.000177661	29	17.1543	3.19253e-006
15	17.1545	5.87224e-005	30	17.1543	6.25485e-007

Table 1: Optimization Cycle for Validation Program.

Once the variables and constraints boundaries are entered on Ga tool box, optimization cycle takes place and number of iterations i.e. generation (30) emerges where at one point value of constraints converges as tabulated in above table which represents value is going to be constant and intern produces objective function value as 17.1543.

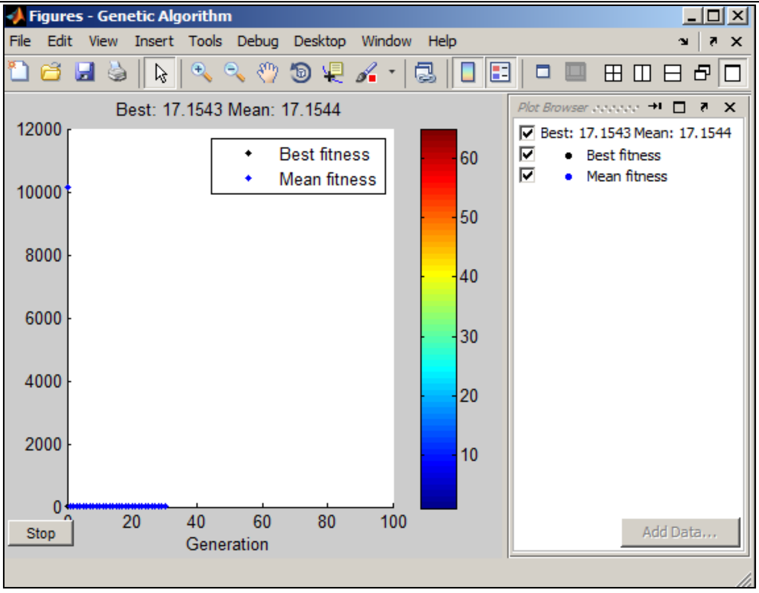

Fig 3: Optimization Loop of Validation.

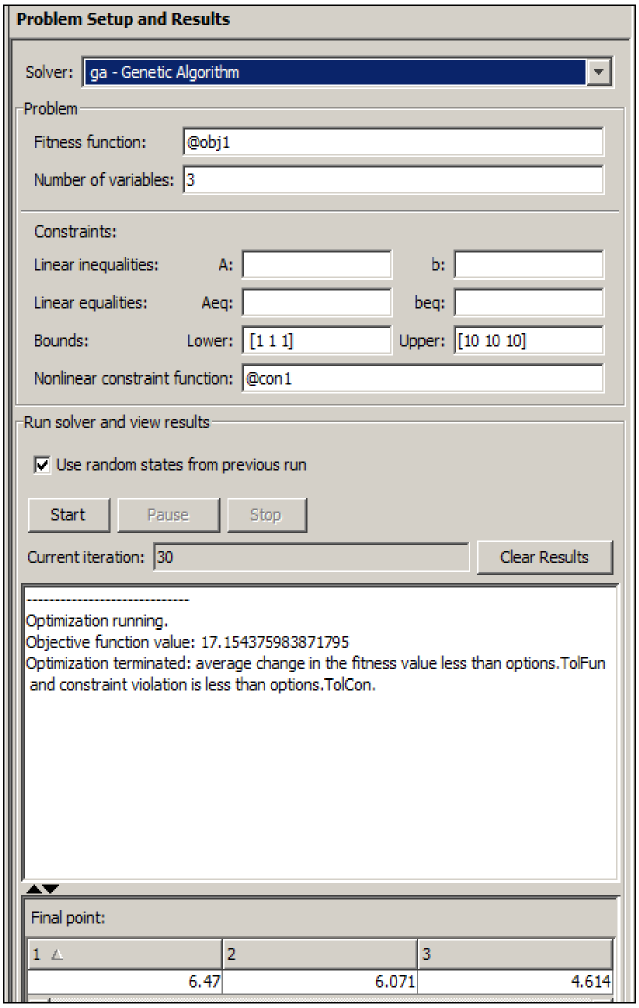

Fig 4: GA Tool Optimum List of Validation.

Squaring the values of $6.47^2 + 6.071^2 + 4.614^2 = 100$

Hence, MATLAB can be used for optimization problems.

5.3 Experiment

Initially, in order to determine objective function that is cost, considered 2 variables that is feed and speeds and experiment is carried out as follows:

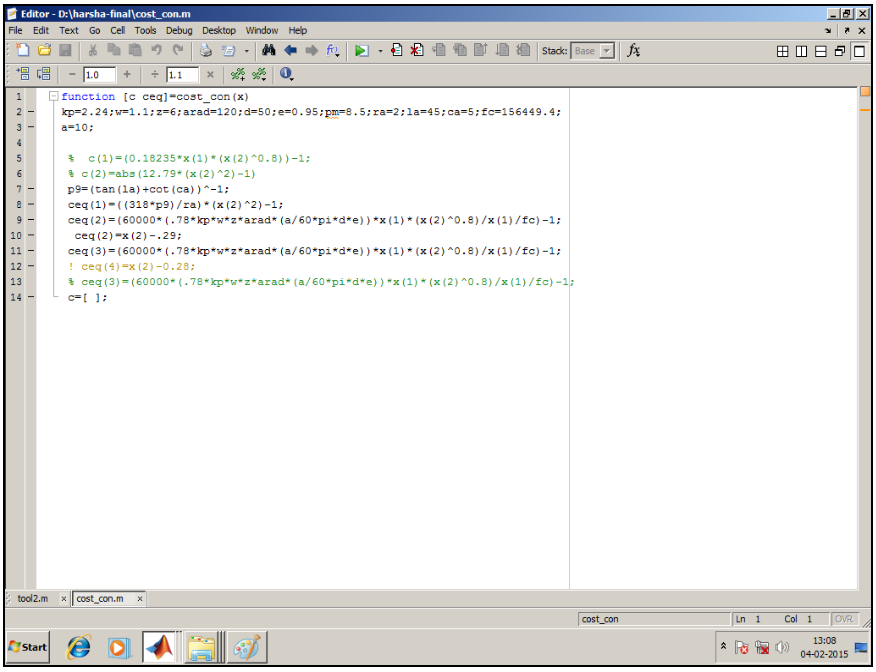

Fig 5: Constraint Function Program Dial Box for 2 Variables.

Optimization cycle: for 2 variables

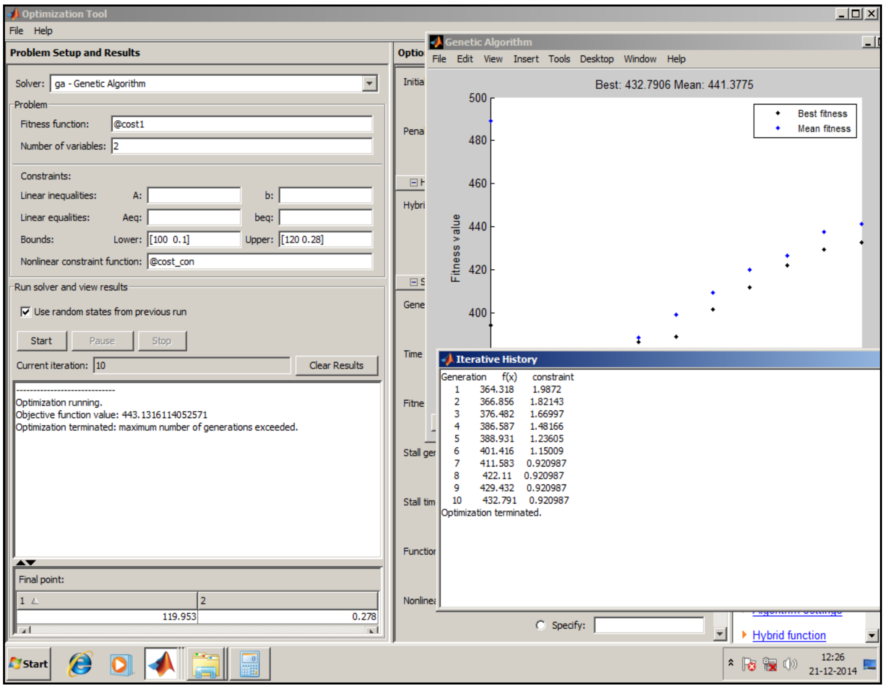

Fig 6: Ga Tool Box for 2 Variables.

Generation	f(x)	Constraint	Generation	f(x)	Constraint
1	364.382	1.91384	29	443.68	0.920547
2	382.041	1.58264	30	443.681	0.920547
3	435.563	0.920547	31	443.697	0.920547
4	443.522	0.920547	32	443.681	0.920547
5	443.681	0.920547	33	443.681	0.920547
6	443.703	0.920547	34	443.681	0.920547
7	443.68	0.920547	35	443.681	0.920547
8	443.703	0.920547	36	443.703	0.920547
9	443.681	0.920547	37	443.69	0.920547
10	443.681	0.920547	38	443.681	0.920547
11	443.681	0.920547	39	443.681	0.920547
12	443.68	0.920547	40	443.681	0.920547
13	443.68	0.920547	41	443.68	0.920547
14	443.68	0.920547	42	443.68	0.920547
15	443.665	0.920547	43	443.703	0.920547
16	443.681	0.920547	44	443.68	0.920547
17	443.66	0.920547	45	443.68	0.920547
18	443.635	0.920547	46	443.681	0.920547
19	443.68	0.920547	47	443.681	0.920547
20	443.635	0.920547	48	443.658	0.920547
21	443.681	0.920547	49	443.692	0.920547
22	443.681	0.920547	50	443.681	0.920547
23	443.681	0.920547	51	443.681	0.920547
24	443.681	0.920547	52	443.681	0.920547
25	443.681	0.920547	53	443.681	0.920547
26	443.681	0.920547	54	443.681	0.920547
27	443.681	0.920547	55	443.68	0.920547
28	443.68	0.920547			

Table 2: Iteration Values for 2 Variables.

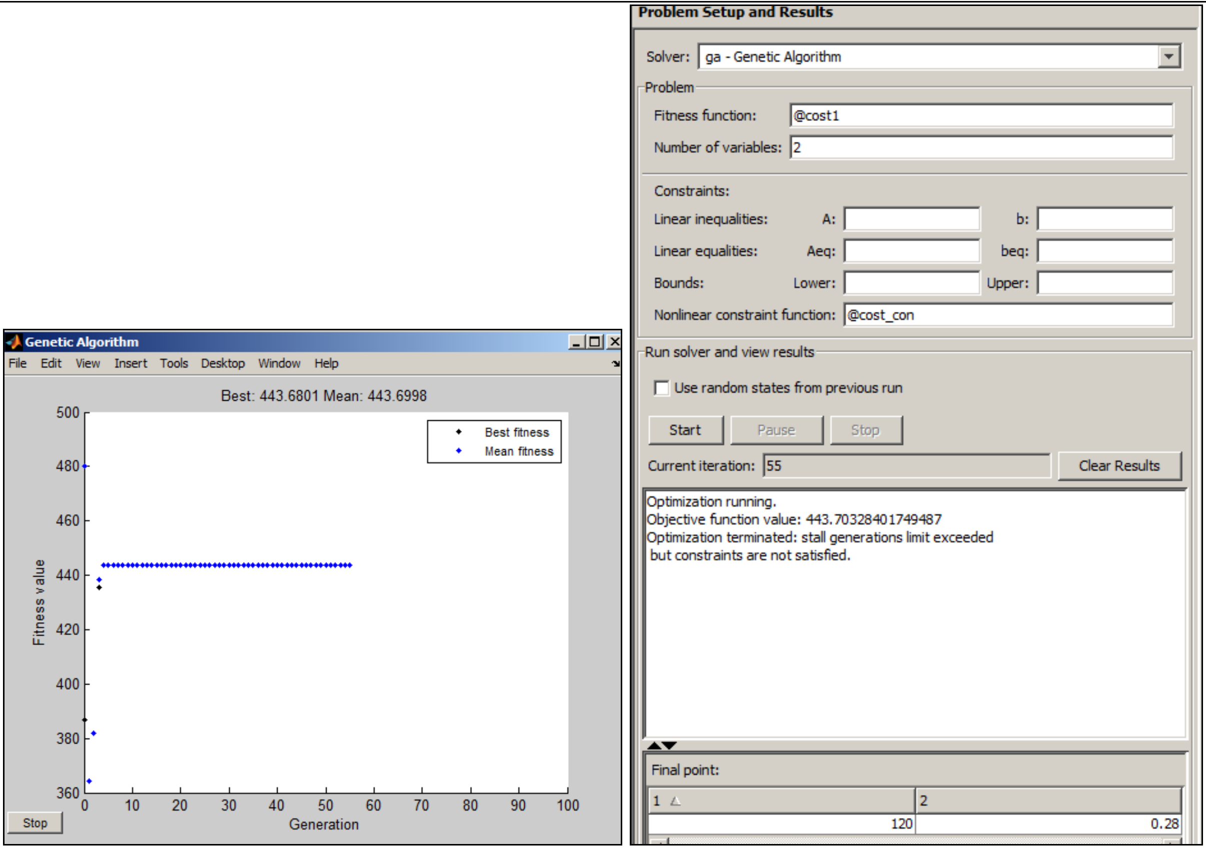

Fig 7: Optimization Looping of 2 Variables.

At the end of the process we get value of objective function that is cost as Rs 443.70and optimum parameters value such as speed and feed as 120rpm and .28mm/min respectively as shown in above tool box

Similarly, for 3 variables i.e. speed, feed and depth of cut, minimum unit cost and optimum values of 3 variables are shown in fig 8.

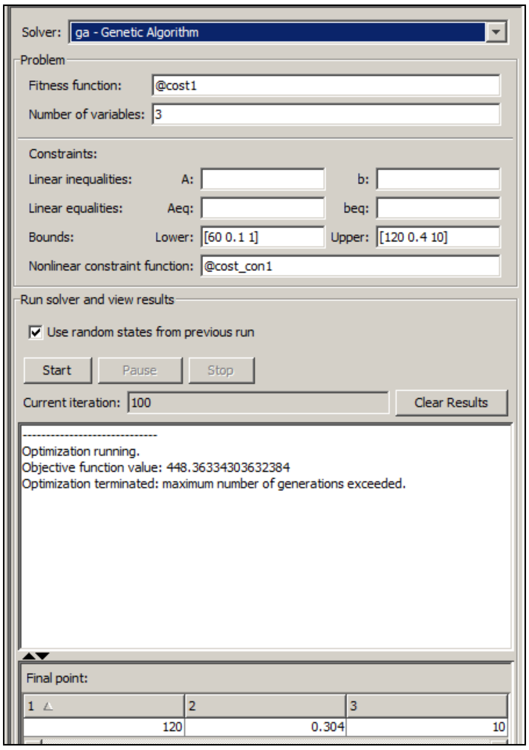

Fig 8: Maximum Optimum Value Box.

At the end of the process we get value of objective function as Rs 448.36 and optimum parameters value as 120rpm for speed, 0.304mm/min for feed and 10mm for depth of cut respectively as shown in above tool box.

5.4 Result Comparison:

Table 3, shows the result obtained from the methodology proposed in this project work i.e. genetic algorithm technique. This result is compared with Particle swarm optimization method (PSO) [1].

Methodology	Unit cost (Rs)	Improvement (%)
Particle swarm optimization (PSO) considering two variables	490	---
Genetic Algorithm (GA) considering two variables	443.70	9.449
Genetic Algorithm (GA) considering three variables	448.36	8.497

Table 3: Result Comparison.

6. CONCLUSION

MATLAB use in the Mechanical engineering is explored to find the use in the design parameter optimization. The results are as follows.

- Initially a MATLAB code is written to check the validity of the results. A problem with known solution is optimized for parameter optimization. Two function files are written and tested through genetic algorithm based Ga tool in the MATLAB.
- The results show complete convergence and best optimum values for the three variables considered. Also it shows faster convergence for finding accurate solution. The constraints are minimized within 10 iterations. Ga tool also shows convergence in the graph along with listing of the variables as execution proceeds. MATLAB is supported by many algorithms for minimization or maximization of the variables. Totally 55 iterations are considered and for each iteration, results are presented for objective function and constraint value.
- Further functions are coded for optimizing the machining parameters like speed and feed. Standard formulae's from literature are considered for coding the functions. Two function files are coded. One for objective and the other for constraint function. Three constraint variables are considered based on power, surface finish and cutting force. Initially two variables are considered for optimization.
- MATLAB code is executed selecting the suitable supportive algorithms like crossover, mutation, selection, feasible population etc. The Ga tool shows optimized values of 120 and 0.28 for speed and feed. The objective function value is Rs 443 per component. The value is near to the standard value available in the literature. Here also system has taken 58 iterations for convergence of the values. Here also convergence or slope is almost optimized in the beginning 10 iterations indicating the strength of the Ga tool.
- Further code is optimized with three design variables (speed, feed and depth of cut). The results shows optimized value is Rs448 per component. The cost is increased due to the increase in the feed from 0.28 to 0.304.

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