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Optimization of Maching Parameters for Lathe Operation Using Genetic Alogrithm and Particle Swarm Optimization

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***Abstract*— It is unavoidable to determine the scientificlly optimal machining parameters of a unique material using preferred machine tools. This investigates the optimization of the desired response. The goal of this work is to optimise lathe machining parameters such as cutting speed, depth of cut, and feed rate using genetic algorithms and particle swarm techniques on surface roughness, MRR, and cutting forces.In this work, machining is done on OHNS steel with a Tungsten carbide cutting tool and a variety of machining parameters.**

Keywords—GA, PSO,feed rates,cutting speed,depth,MRR

I. INTRODUCTION

One of the most fundamental machining processes is turning. A single point cutting tool is moved parallel to the axis of rotation while the part is rotated.Turning can be done on both the external and internal surfaces of the part (boring). In most cases, the starting material is a work piece created by another process, such as casting, forging, extrusion, or drawing.

Turning can be done manually, on a traditional type of lathe that frequently requires constant supervision by the operator, or on a computer controlled and automated lathe that does not. In this work the optimization of machining parameters of the Centre lathe is carried out using Genetic Algorithm and Particle swarm optimization. The responses measured are MRR, machining time and surface roughness. The Centre lathe, PSG make was used for machining on OHNS steel using Tungsten Carbide cutting tool. The picture of the centre lathe is shown in the Figure1.

Fig 1-Centre lathe

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2. CUTTING TOOL

Tungsten Carbide is still primarily used in the production of various cutting tools such as drills, taps, milling cutters, tool bits, gear cutters, saw blades, planer and jointer blades, router bits, and so on, though usage for punches and dies is increasing. The tool insert is shown in the Figure 2.

Fig2 tungsten carbide tool Insert

Tungsten Carbide also found a market in fine hand tools, where its relatively good toughness at high hardness, combined with high abrasion resistance, made it suitable for low-speed applications requiring a long-lasting keen (sharp) edge, such as files, chisels, hand plane blades, kitchen knives, and pocketknives. The tool holing tungsten carbide insert is shown in the Figure 3.

Fig 3-tungsten carbide tool

3.Workpiece

The work materail taken for investigation is OHNS(Oil Hardening Non Shrinking Die Steel).It is commonly used in applications where alloy steel cannot provide adequate hardness, strength, or wear resistance.

Chemical composition of OHNS

Table 1 Chemical composition of OHNS

C	Mn	Cr	S	V
1.740%	0.570%	11.540%	0.028%	0.294%

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Moreover Rockwell Hardness of OHNS steel is 35.36HRC.OHNS steel is a popular material for the production of blocks, automobiles, components, and cutting tools.

4.Process parameters

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Cutting speed - The spindle and workpiece's rotational speed in RPM (revolutions per minute). The spindle speed is equal to the cutting speed divided by the circumference of the workpiece where the cut is being made; therefore, the spindle speed must vary depending on the diameter of the cut. The cutting speed will vary if the spindle speed is constant

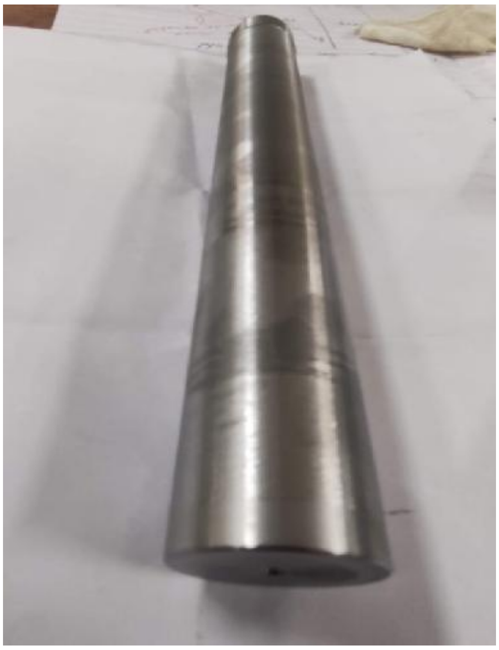

Fig 5-OHNS steel rod

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Feed rate - The rate at which the cutting tool moves relative to the workpiece as it makes a cut. The feed rate is expressed in millimeters per revolution (RPM).

Depth of cut - The depth of the tool as it makes a cut along the axis of the workpiece, as in a facing operation. A large radial depth of cut necessitates a low

5 Design of Experiment

Table 2 shows the selection of three factors at three levels during this process. A standard L9 orthogonal array was used for the fractional design. This orthogonal array was chosen because of its ability to examine factor interactions.

Table 2 Machining parameters and levels

Levels	Feed rate (mm/min)	DOC (mm)	Cutting Speed (m/min)
1	0.05	0.5	800
2	0.08	0.7	1150
3	0.1	1	1600

In an orthogonal array, the columns of the independent variables are orthogonal to one another and form a unique characteristic. By following this, enormous efforts are being redeemed and facilitates extensive analysis and inference are well-found the whole territory length and width of control factors and settings. The table 3 will has details of L9 orthogonal array values pertaining to this work.

6.EXPERIMENT CONDUCTED

External longitudinal turning was performed on centre lathe of excellent operational condition at Different Spindle speeds (S), Feed rates (f) and depth of cuts (d). Fig.1 shows the graphic view of the experimental set-up.

S.No	Feed rate (mm/min)	DOC (mm)	Cutting Speed (m/min)
1	0.1	1	800
2	0.08	1	1150
3	0.05	1	1600
4	0.08	0.7	800
5	0.05	0.7	1150
6	0.1	0.7	1600
7	0.05	0.5	800
8	0.1	0.5	1150
9	0.08	0.5	1600

TABLE3:ORTHOGONAL L9

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The work piece material was OHNS steel roll (Outer Diameter 25mm, and length 210mm). The cutting tool used was tungsten carbide tool. The insert has been clamped in a tool holder.

MRR=Wi-Wf/ρt

- =1.073-1.060/0.008*0.267
- =6.086CM^3/MIN
- SURFACE ROUGHNESS TESTER
- CUTTING FORCE=KISTLER DYNAMOMETER

7.Genetic algorithm

The regression analysis in Minitab 17 software is used to obtain the objective function equations. After thatthe optimization is then performed using MATLAB-R2018a for which aprogramme is required to run the optimization process based on the objective functions and constraints. The program's structure is shown below. Open the Genetic Algorithm solver in MATLAB's optimization toolbox and set the parameters based on the problem.

- Solver : Multi objective GA

  No. of variables : 3

  Lower bounds : 0.05, 0.5, 800

  Upper bounds : 0.1, 1, 1600

  Plot functions: Pareto front, Rank histogram.
- Run the solver and the till the termination is completed.
- The results will be obtained as Pareto front optimal values.

TABLE4-L9 TABLE AFTER EXPERIMENTATION

S. No	Federate (mm/min)	DOC mm	cutting speed (m/min)	time(min)	MRR	Ra
1	0.1	1	800	0.267	6.086	3.885
2	0.08	1	1150	0.237	6.329	4.4800
3	0.05	1	1600	0.267	5.149	3.7958
4	0.08	0.7	800	0.314	4.777	1.6678
5	0.05	0.7	1150	0.366	3.417	1.3683

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6	0.1	0.7	1600	0.152	8.223	0.4703
7	0.05	0.5	800	0.519	1.685	0.8753
8	0.1	0.5	1150	0.201	4.975	0.6451
9	0.08	0.5	1600	0.171	6.578	0.5492

Regression Equation

The Minitab 17 software was used to obtain the regression equation. Firstly,it needs to put all our experimental values in table and then select stat option and then analysis option after that we select our input values and the responses values and then we press 'ok'button.

%MRR

Y(1)=-9.899 + 177.0*X(1)+ 9.936*X(2)- 0.000173*X(3)- 1118 *X(1)*X(1) - 7.691*X(2)*X(2) + 0.000001 *X(3)*X(3)+ 60.09*X(1)*X(2) + 0.005887 *X(1)*X(3);

%TIME

Y(2) = 1.832 - 17.29*X(1) - 0.4329 *X(2) - 0.000892* X(3)+ 61.56 *X(1)*X(1) + 0.2988*X(2)*X(2) + 0.000000*X(3)*X(3)- 0.1847*X(1)*X(2)+ 0.003925* X(1)*X(3);

%RA

Y(3) = -0.3443 + 110.8 *X(1)- 13.74*X(2) + 0.002466 *X(3)- 711.5 *X(1)*X(1) + 14.50* X(2)*X(2) - 0.000001 *X(3)*X(3)- 16.38 *X(1)*X(2) + 0.000853 *X(1)*X(3);

Genetic code

```
function y = genetic(x)
%UNTITLED Summary of this function goes here
% It is a multi-objective function i.e., more than 1 function
% y (1) ---objective 1---equation for time minimize
% y (2) ---objective 2---equation for MRR maximize
% y (3) ---objective 3---equation for CF minimize
% y (4) ---objective 4---equation for Ra minimize
% x (1) ---feed rate
% x (2) ---DOC
% x (3) ---CS
%MRR
y (1) =-9.899 + 177.0*x(1)+ 9.936*x(2)- 0.000173*x(3)
- 1118 *x(1)*x(1) - 7.691*x(2)*x(2) + 0.000001 *x(3)*x(3)
+ 60.09*x(1)*x(2) + 0.005887 *x(1)*x(3);
%Time
y(2) = 1.832 - 17.29*x(1) - 0.4329 *x(2) - 0.000892* x(3)
+ 61.56 *x(1)*x(1) + 0.2988*x(2)*x(2) 0.000000*x(3)*x(3)
- 0.1847*x(1)*x(2)+ 0.003925* x(1)*x(3);
%ra
y(3) = -0.3443 + 110.8 *x(1)- 13.74*x(2) + 0.002466 *x(3)
- 711.5 *x(1)*x(1) + 14.50* x(2)*x(2) - 0.000001*x(3)*x(3)
- 16.38 *x(1)*x(2) + 0.000853 *x(1)*x(3);
end
```

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GA RESULT

From the above table optimal values of process parameters for the maximum MRR minimum time and surface roughness are given in the table 5.

8.PARTICLE SWARM OPTIMIZATION

- The PSO algorithm keeps track of multiple potential solutions at the same time.
- It is a population-based approach. An objective function evaluates a solution's fitness during each iteration of the algorithm.
- In PSO, the population of solutions is always referred to as a swarm, and the feasible solutions are referred to as particles.
- Each particle is made up of three vectors as well as two fitness values.
- The PSO algorithm is made up of three steps.

Step of PSO

- Each particle's fitness should be evaluated.
- Individual and global best practices should be updated.
- Each particle's velocity and position should be updated.
- This process is repeated until the desired conditions are met.

1.0	***12.617952374452374***	***-1.4439559058866327***	***6.998006972804508***	***0.09883541652320549***	***0.5316403910882953***	***1498.8166243254338***
2.0	6.398097981832314	-0.18810903181426208	-1.3965338098579245	0.054967599307889574	0.6761804781133952	871.0770300510792
3.0	3.8899220083392936	0.011855185881518016	0.2020323350722344	0.050009462317365555	0.5112355211343889	823.0575712468103
4.0	12.75928241034688	-1.4184160402169956	6.130377820521633	0.09704629970628216	0.5774539355644905	1482.6297192707502
5.0	9.567348128638569	-0.35163157731423045	-5.47017803079345	0.05570880989859081	0.982297981179368	891.4680023711289
6.0	17.206671434275414	-1.6553527158757995	0.8846344978344254	0.09944936530497464	0.9826393244002755	1505.0320921747857
7.0	15.136740891357313	-1.5038370001343238	3.2865194179376105	0.09851914799206182	0.789869215256524	1446.756219806083

8.0	12.210818958849142	-1.2440814580332127	1.409376634145131	0.08165687285951267	0.796342987549692	1479.2570033430236
9.0	5.179599083627548	-0.1022030222308854	-0.4587676503428839	0.05296069979564404	0.5890335141840848	855.964029679271
10.0	13.621111441567312	-1.521180532857076	5.797175314715526	0.09914704273370212	0.6276421447117619	1532.7599546475838
11.0	10.042518021992247	-0.36247103896097643	-4.770259331471862	0.05987155680979118	0.9550031497578672	836.1782042483255
12.0	7.8558122967895265	-0.47634660648506877	-3.936044608154382	0.0517131190952507	0.8858193770780031	1155.5555706178438
13.0	9.35076030736263	-0.26264879435453087	-5.787164153870023	0.054444454462687246	0.9817176414770367	816.500683519349
14.0	10.482385270371667	-0.7522619310835217	-2.555322923570882	0.06561425761518588	0.9030818306047773	1187.048534134697
15.0	15.05302182884644	-1.5566688690093964	3.7299696956617985	0.09908526163761269	0.7723468882208979	1503.5153894442224
16.0	13.825063511622979	-1.5512398846806907	4.400662443397511	0.09563076047000443	0.7118695507461428	1593.7395825519159
17.0	13.193532330798105	-1.1252922956074431	-2.062896613747095	0.0764941115324564	0.9850459357738088	1354.5770421690474
18.0	7.552372750596842	-0.781012964634977	1.992728066711309	0.06594301797132386	0.6053032368527462	1357.4242294587823
19.0	7.00785320740595	-0.2601869591631035	-1.0341031848992723	0.0582611243973457	0.6791481796727294	886.6018737137578
20.0	17.39292117962734	-1.7516202066049742	0.9466755471870809	0.09975485528591994	0.9975919123757976	1599.7771522914077
21.0	11.53644450986791	-1.3152180593577798	5.267554003559233	0.08972304487542818	0.5852304777983584	1505.1124883662753
22.0	**12.69037093209749**	**-1.549195219470443**	**7.534195049041244**	**0.09999142916273537**	**0.5200972895949076**	**1599.9924804720997**

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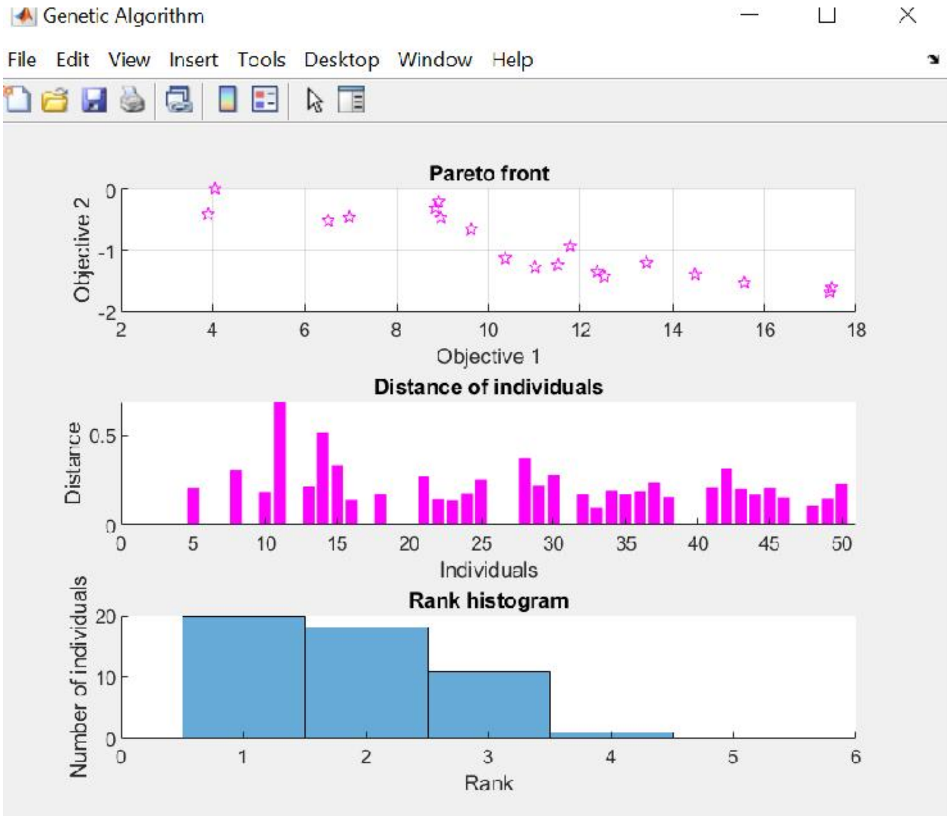

fig6-pareto, rank histogram of GA

TABLE6 – ITERATION OF GA

TABLE5-optimum values of GA

PARAMETERS	***OPTIMAL VALUES***
CUTTING SPEED (RPM)	1211
FEED RATE (MM/REV)	0.1
DOC(MM)	0.7

FORMULATION OF OBJECTIVE FUNCTION:

optimization of the machining process serves as the foundation for the entire development of machining process planning. Economic criteria are constrained by technical and managerial constraints. The economic criteria are the quality objectives of machining operations. This paper's objectives are as follows. Surface roughness is to be minimized, time is to be minimized, and MRR is to be maximized.

TABLE7- L9 PSO TABLE

SR NO	FEDERATE(MM/MIN)	DOC MM	CUTTING SPEED (M/MIN)	TIME(MIN)	MRR	RA
1	0.1	1	800	0.267	6.086	3.885
2	0.08	1	1150	0.237	6.329	4.4800
3	0.05	1	1600	0.267	5.149	3.7958
4	0.08	0.7	800	0.314	4.777	1.6678
5	0.05	0.7	1150	0.366	3.417	1.3683
6	0.1	0.7	1600	0.152	8.223	0.4703
7	0.05	0.5	800	0.519	1.685	0.8753
8	0.1	0.5	1150	0.201	4.975	0.6451
9	0.08	0.5	1600	0.171	6.578	0.5492

PSO CODE

```
clc;
clear all;
close all;

T = readtable('L9 TABLE.xlsx');

%MRR
MRR1 = T(:,4);
MRR2=table2array(MRR1);
Val_MRR = MRR2';

% TIME
CR1 = T(:,5);
CR2=table2array(CR1);
Val_CF = CR2';

%RA
```

```
RA1 = T(:,6);
RA2=table2array(RA1);
Val_RA = RA2';



T_MRR_S = tic;
[bParticles_MRR, gParticle_MRR,Final_MRR]= PSO_MRR(Val_MRR);
T_MRR =toc(T_MRR_S);


T_CR_S = tic;
[bParticles_CF, gParticle_CF,Final_CF]= PSO_CF(Val_CF);
T_CR =toc(T_CR_S);


T_RA_S = tic;
[bParticles_RA, gParticle_RA,Final_RA]= PSO_RA(Val_RA);
T_RA =toc(T_RA_S);



Final_Values = [Final_MRRFinal_CFFinal_RA];
time_cal = [T_MRR T_CR T_RA ];
X = categorical({'MRR','CR','RA'});
X = reordercats(X,{'MRR','CR','RA'});
figure(4);
bar(X,Final_Values,'FaceColor',[0 .5 .5],'EdgeColor',[0 .9
.9],'LineWidth',1.5)
ylabel('Values')
title('Final values - PSO');


figure(5);
bar(X,time_cal,'FaceColor',[0 .5 .5],'EdgeColor',[0 .9
.9],'LineWidth',1.5)
ylabel('Time (sec)');
```

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```
title('Exeution Time - PSO'
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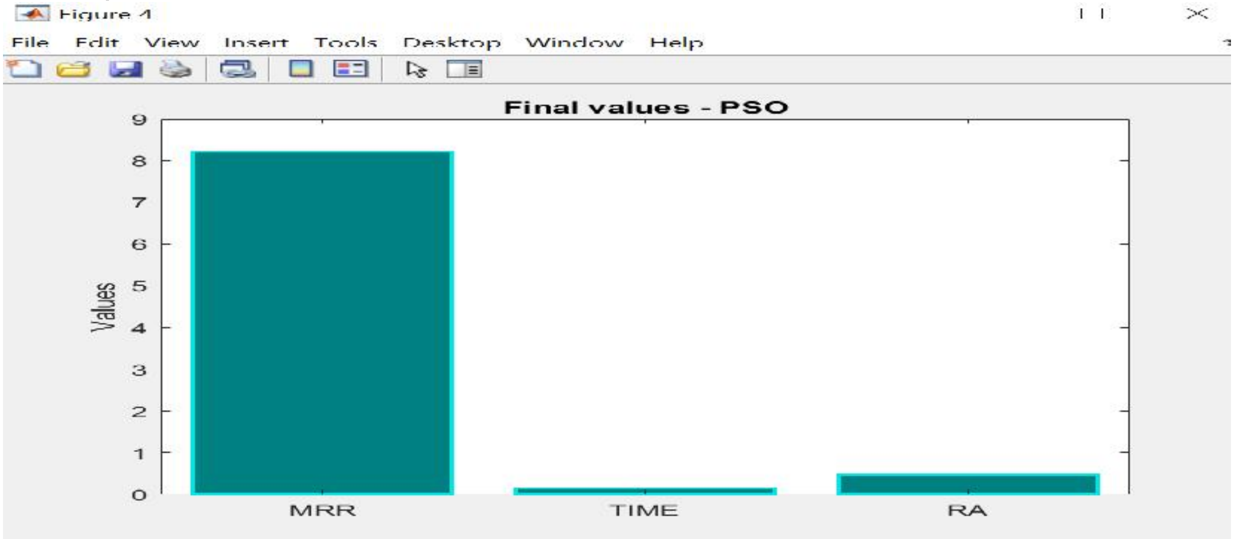

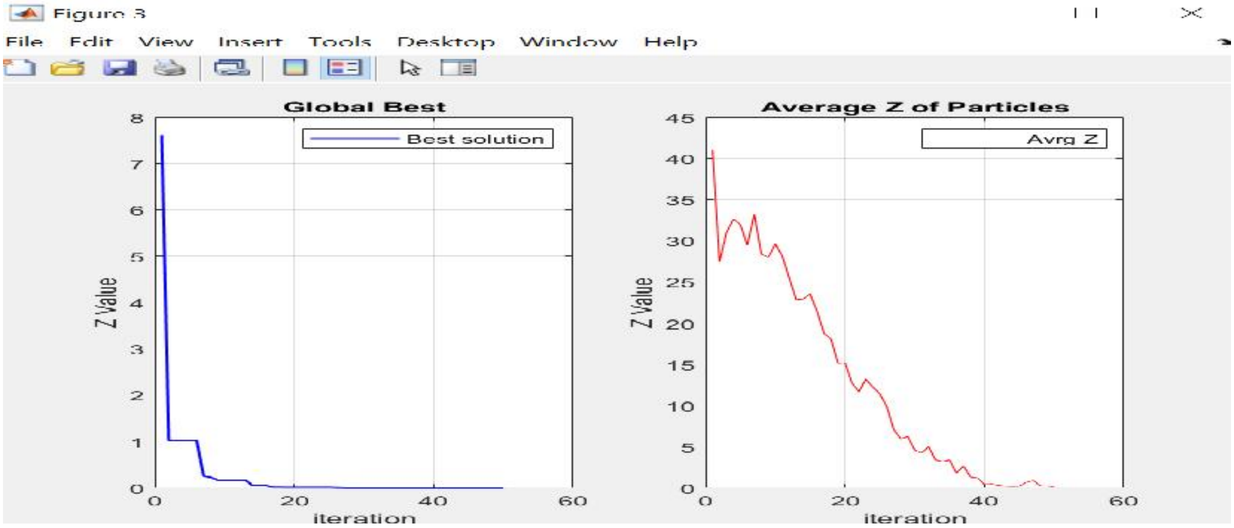

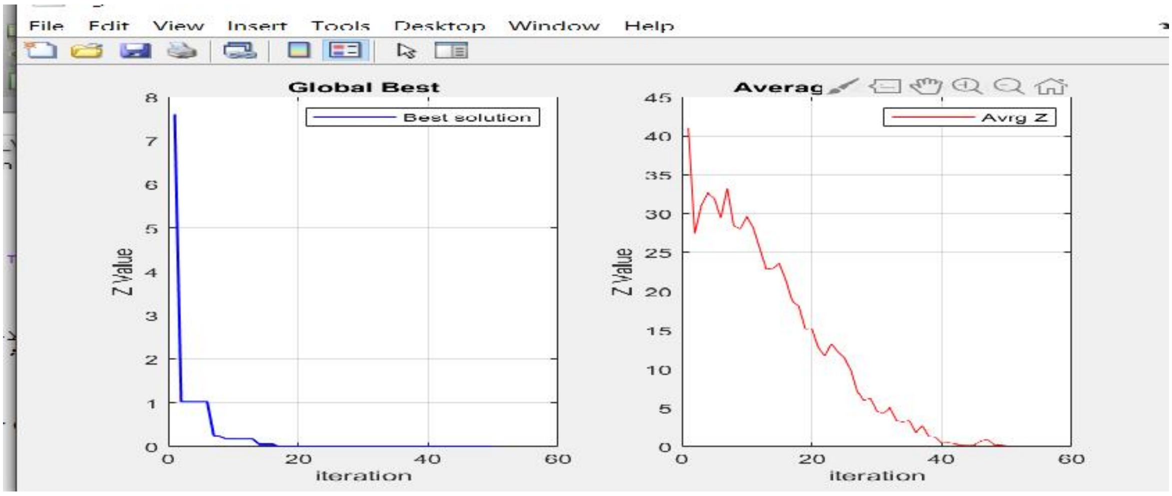

fig7 -graph of PSO

PSO RESULT

The optimal values of process parameters for maximum MRR, minimum time, and surface roughness are given in the table above.

Table8-optimum values of PSO

Parameter	*Optimal values*
Feed rate(mm/rev)	0.1
DOC (mm)	0.7
Cutting speed(m/min)	1600

CONCLUSION

1. By tutoring the network with a multi objective genetic algorithm, the optimum speed, feed, and depth of cut are determined, and the corresponding values of objective functions for the corresponding speed, feed, and depth of cut are discovered, with the following results.

By optimization of MRR machining time and surface Roughness
Optimum speed = 1211m/min
Optimum feed = 0.1mm/rev
Optimum depth = 0.7 mm

Maximized MRR=14.61Cm^3/min
Minimized surface roughness =0.4007µm
Minimized machining time=1.28sec

2. PARTICLE SWARM OPTIMIZATION
The corresponding value of the objective function for the corresponding cutting speed, feed, and depth of cut are found using the obtained equation from the particle swarm optimization programme, and the results are as follows.
By optimization of MRR, machining time, surface Roughness
Optimum speed = 1600 m/min
Optimum feed = 0.1mm/rev
Optimum depth =0.7 mm
Maximized MRR=8.223Cm^3/min
Minimized surface roughness =0.4703µm
Minimized machining time=0.152sec

3. The DOC and feed rates are same but slightly difference in cutting speed and the responses.

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