न हि ज्ञानेन सदृशं पवित्रमिह विद्यते।
Smt. S. R. PATEL
ENGINEERING COLLEGE

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Optimization of process parameters in laser cutting of s.s using genetic algorithm

Under the Valuable Guidance of
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Group No : 14

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INTRODUCTION

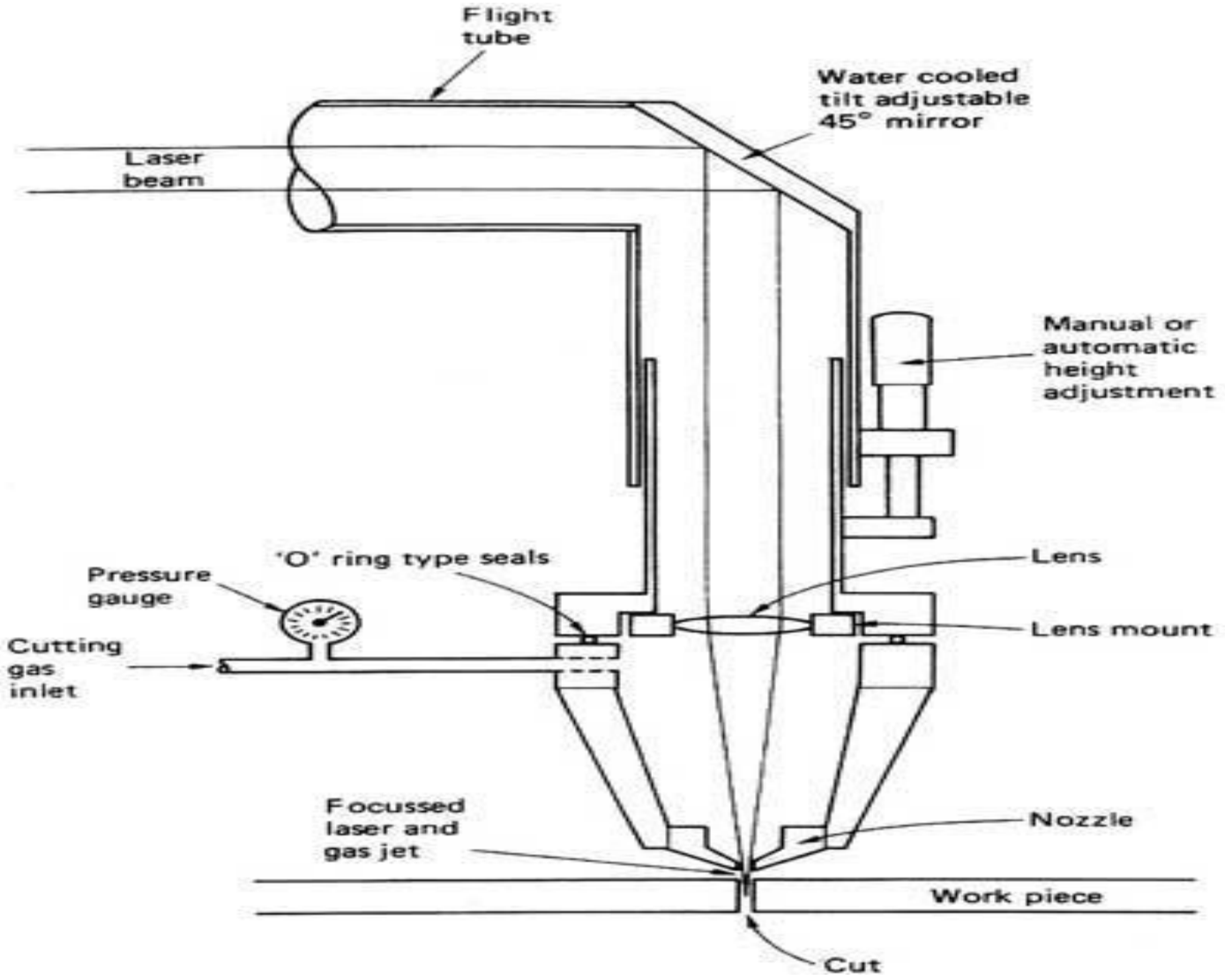
Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications.

Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated.

Cont.

The focused laser beam is directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

WORKING PRINCIPLE



WORKING PRINCIPLE

The laser beam is a column of very high intensity light, of a single wavelength, or colour. In the case of a typical CO2 laser, that wavelength is in the Infra-Red part of the light spectrum, so it is invisible to the human eye.

The beam is only about 0.32 mm in diameter as it travels from the laser resonator, which creates the beam, through the machine’s beam path.

Cont.

It may be bounced in different directions by a number of mirrors, or “beam benders”, before it is finally focused onto the plate. The focused laser beam goes through the bore of a nozzle right before it hits the plate. Also flowing through that nozzle bore is a compressed gas, such as Oxygen or Nitrogen.

PROJECT DEFINITION

- It is therefore required to minimize surface roughness to improve product quality simultaneously by selecting an appropriate (optimal) process environment and selecting best input parameters like cutting speed, laser power and gas pressure. Hence, we are planning multi-objective optimization philosophy based on Taguchi method applied in laser cutting operation.

OBJECTIVES

Based on above guiding principles, the objective of present research are as follows:

- Study on effect of process parameters on laser cutting performance which is measured in terms of surface roughness.

- Analysis of experimental results using statistical methods and developing mathematical models either first or second order response surfaces with best fittings.

Cont.

- To conduct experiments in laser cutting process using Taguchi L_9 single level orthogonal array design.

- Design of experiment and statistical methods have been performed for analysis, prediction and optimization.

SCOPE OF PROJECT

•The world is advancing technically in the field of space research, missile and nuclear industry. These industries demand very complicated and precise components having some special requirements. The challenges are taken by the new development taking place in manufacturing field.

•One of the current challenges faced by manufacturing industries is the reduction of process time and improvement of performance through optimization of controllable process parameter using different optimization technique.

Cont.

- This can be obtained by experimentation or using any model developed from experiment. Although performance improvement in laser cutting operation has been studied extensively, proper selection of machining parameters for the best process performance is still a challenging job.

TAGUCHI METHOD

- Taguchi's philosophy, developed by Dr. Genichi Taguchi, is an efficient tool for the design of high quality manufacturing system which gives minimum no. Of experiments to be performed.

- Taguchi's Orthogonal Array (OA) provides a set of well-balanced experiments (with less number of experimental runs), and Taguchi's signal-to-noise ratios (S/N), which are logarithmic functions of desired output; serve as objective functions in the optimization process.

- The Taguchi Method is applied in four steps.

1. Brainstorm the quality characteristics and design parameters important to the product/process
2. Design and conduct the experiments.
3. Analyse the results to determine the optimum conditions.
4. Run a confirmatory test using the optimum conditions.

ADVANTAGES

1. The main advantage of using Taguchi method is that it gives more importance to the mean performance characteristic value which is very close to the target value than the value within a definite specification limits, thus improves the quality of the product.
2. Taguchi's method is a powerful simple tool and easy to apply to many engineering processes for experimental design.
3. The Taguchi method is used to narrow down the scope of a research project or to know the problems in a manufacturing process from existence data.

LITERATURE REVIEW

Sr. No.	Authors	Study	Results
1.	Erica Librera*a, Giovanni Rivaa, (2014)	On the use of Areal Roughness Parameters to Assess Surface Quality in Laser Cutting of Stainless Steel with CO2 and Fiber Sources	The protocol is capable of representing the cut kerf visually and maintains the most important quality aspect, surface striations in the measurement data.
2.	R. Adalarasan, M. Santhanakumar, M. Rajmohan (June 2014)	Optimization of laser cutting parameters for Al6061/SiCp/Al2O3 composite using grey based response surface methodology (GRSM)	The GRA was applied to form the single representative (GRG) for the three quality characteristics studied in laser cutting and RSM approach was used to create a model for GRG.

LITERATURE REVIEW

Sr. No.	Authors	Study	Results
3.	M. Hashemzadeha, W. Suderb, S. Williamsb, (2014)	The application of specific point energy analysis to laser cutting with 1 μm laser radiation	Here energy efficiency can be maximized by selecting the largest beam diameter available and then minimising Surface roughness.
4.	R.M. Colombo, G. Guerra , M. Herty, F. Marcellini (2012)	A hyperbolic model for the laser cutting process	From the engineering point of view, this stability suggests that imperfections in the laser cuts might be due to small variations in the various parameters governing the process, in particular to the speed of the cutting gas.

LITERATURE REVIEW

Sr. No.	Authors	Study	Results
5.	B. Adelmann, R. Hellmann (2011)	Fast Laser Cutting Optimization Algorithm	Specifically, we have optimized the laser fusion cutting of 1 mm aluminium sheets with a single mode fiber laser demonstrating free contour cuts.
6.	Chen-Hao Li, Ming-Jong Tsai, Ciann-Dong Yang (2006)	Study of optimal laser parameters for cutting QFN (Quad Flat No-lead) packages by Taguchi's matrix method	The variance analysis using data obtained from matrix experiments for cutting a QFN package also shows that the optimal cutting parameters are 29A for the current, 2 kHz for the laser frequency and 2 mm/s for the cutting speed.

LITERATURE REVIEW

Sr. No.	Authors	Study	Results
7.	Ahmet Cekic*, Derzija Begic-Hajdarevic (2014)	Definition of Mathematical Models of High-Alloyed Steel 1.4828 in CO2 Laser Cutting	Systematic experimental measurements of the parameters controlling the quality of the cut surface condition.
8.	Thombansen, Ulrich, Hermanns, Torsten (2014)	Measurement of cut front properties in laser cutting	In the experiment, the focal planes could only be set to discrete steps at millimeter resolution. This might cater for some differences in absolute values.

LITERATURE REVIEW

Sr. No.	Authors	Study	Results
9.	Natasa Naprstkova, Stanislav Dubsky (2012)	Optimization Of Setting Parameters Of Laser Cutting Machine	Series of experiments were performed in which the cutting parameters have been optimized for most grades of the processed materials and thicknesses.
10.	Vipul K Shah, Mr. Hardik J Patel, Dr. Dhaval M Patel (2014)	Optimization Of Input Parameters On Surface Roughness During Laser Cutting	The main objective was to cutting condition for studying the cut quality.

LITERATURE REVIEW CONCLUSION

- The surface roughness is mainly affected by power and cutting speed.
- Taguchi method and surface response method is best suited for all alloy.
- Taguchi method give lowest cost, minimum number of experiments and Industrial Engineers can use this method compare with other.

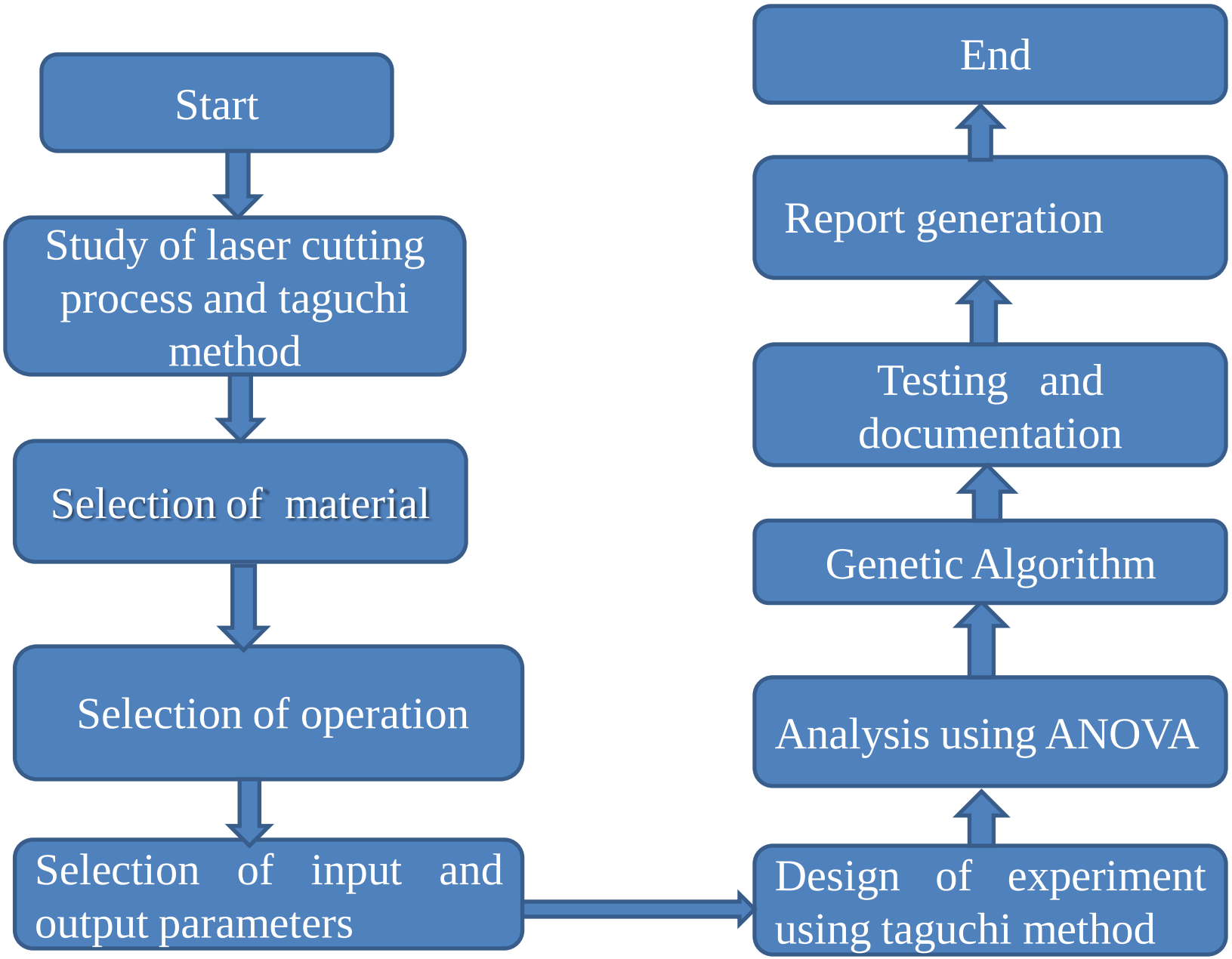
RESEARCH GAP

- Many researchers have on optimization of laser cutting parameters using different techniques like ANN, GRA But haven't used genetic algorithm.

- optimization of laser cutting parameters using TAGUCHI method coupled with genetic algorithm has not been performed.

- The levels and their parameters used in this project has not been used by any other researchers.

WORK FLOW


Start
Study of laser cutting process and taguchi method
Selection of material
Selection of operation
Selection of input and output parameters
Design of experiment using taguchi method
Analysis using ANOVA
Genetic Algorithm
Testing and documentation
Report generation
End

WORK PLAN FOR PROJECT WORK

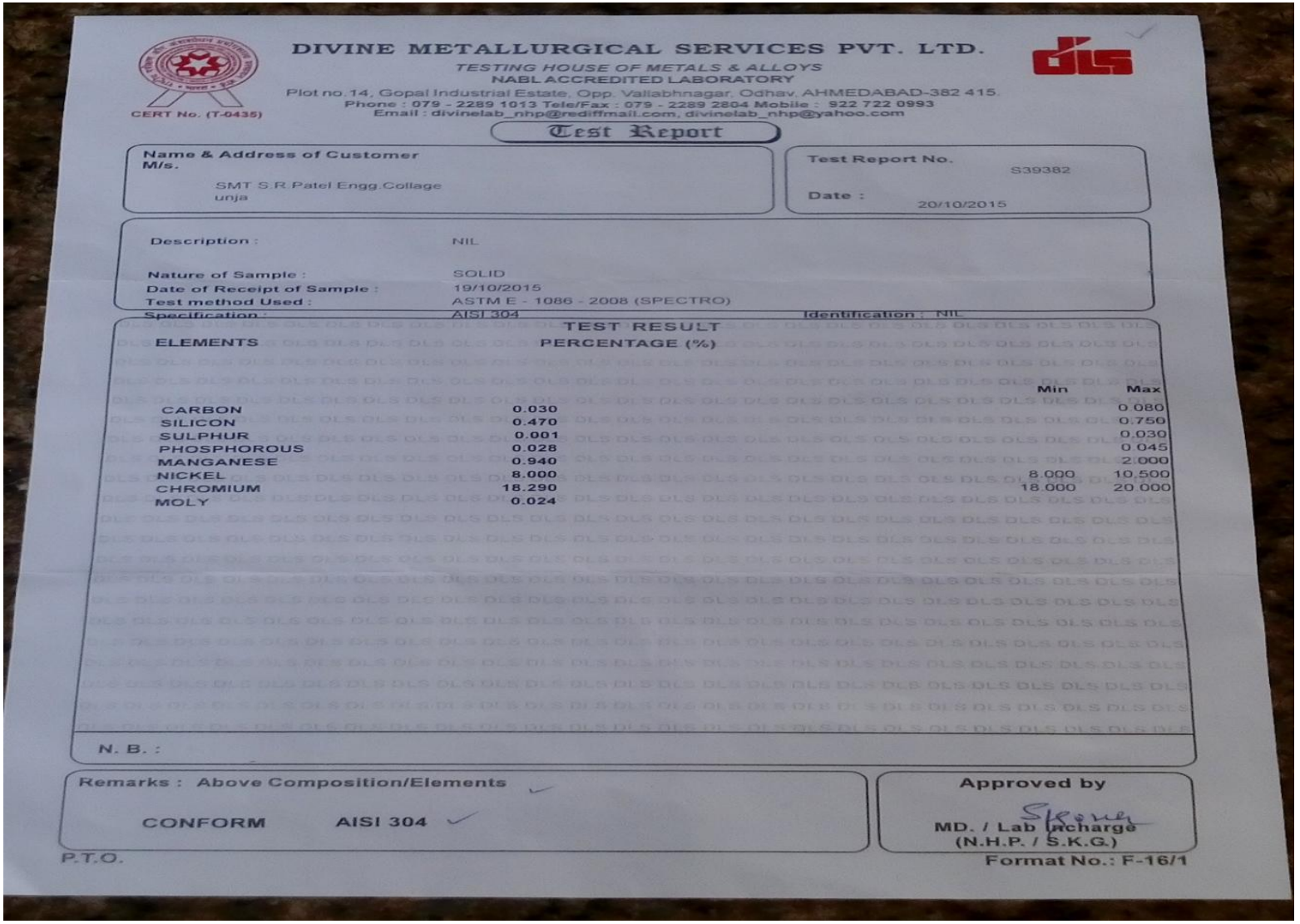
	July	August	Sept.	October	November	January	Feb.	March
1.Definition of project								
2.Literature review								
3.Selection of material								
4.selection of Input Parameters and output parameters								
5. Experimentation on laser machine								
6. Design of experiment using taguchi method								
7. Analysis using ANOVA								
8. report generation								

SELECTION OF MATERIAL AND PROPERTIES

- Stainless Steel 304 -

Density	8 g/cm^3
Melting Point	1400-1420°C
Specific heat capacity	0.5 J/g-°C
Modulus of Elasticity	193 Gpa
Thermal Conductivity	16.2 W/m-K
Poisson's Ratio	0.25
Tensile Strength	415 MPa
Elongation at Break	40%
Shear Modulus	77.2 GPa
Hardness, Vickers	240

TESTING REPORT



DIVINE METALLURGICAL SERVICES PVT. LTD.

TESTING HOUSE OF METALS & ALLOYS
NABL ACCREDITED LABORATORY

Plot no.14, Gopal Industrial Estate, Opp. Vallabhnagar, Odhav, AHMEDABAD-382 415.
Phone : 079 - 2289 1013 Tele/Fax : 079 - 2289 2804 Mobile : 922 722 0993
Email : divinelab_nhp@rediffmail.com, divinelab_nhp@yahoo.com

CERT No. (T-0435)

Test Report

Name & Address of Customer
M/s.
SMT.S.R.Patel Engg.Collage
unja

Test Report No. S39382
Date : 20/10/2015

Description : NIL
Nature of Sample : SOLID
Date of Receipt of Sample : 19/10/2015
Test method Used : ASTM E - 1086 - 2008 (SPECTRO)
Specification : AISI 304 Identification : NIL

TEST RESULT

ELEMENTS	PERCENTAGE (%)	Min	Max
CARBON	0.030		0.080
SILICON	0.470		0.750
SULPHUR	0.001		0.030
PHOSPHOROUS	0.028		0.045
MANGANESE	0.940		2.000
NICKEL	8.000	8.000	10.500
CHROMIUM	18.290	18.000	20.000
MOLY	0.024		

N. B. :

Remarks : Above Composition/Elements
CONFORM AISI 304

Approved by
MD. / Lab Incharge
(N.H.P. / S.K.G.)

P.T.O.

Format No.: F-16/1

EXPERIMENTAL SETUP

- AMADA FO M2 3015NT, laser machine with 2.0 kW in continuous mode is used for experiment work.
- Lens of 7.5|| in. used with Nitrogen as assist gas for cutting of selected material with 85% duty cycle and 2.5 mm nozzle diameter.
- The size of the work piece was 40 mm x 40 mm x 5 mm slot cut down from the plate for surface measurement.
- Surface roughness measured using surface roughness tester.

FOM2 3015NT

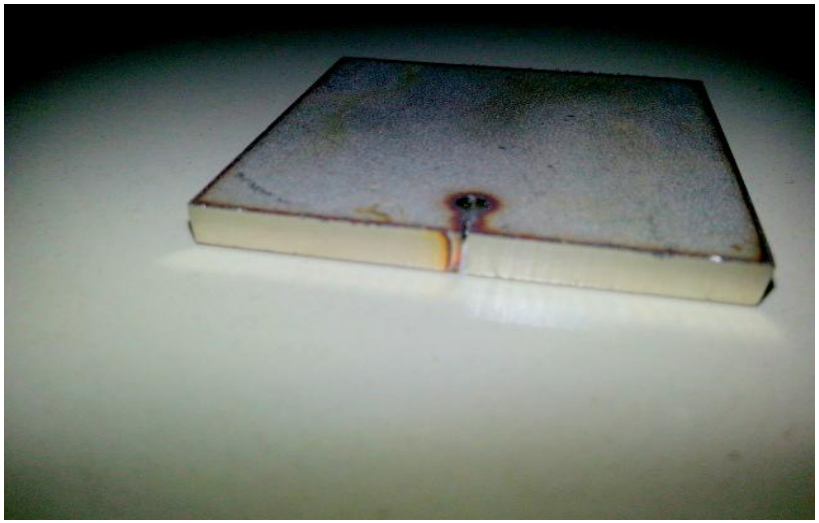
SPECIFICATIONS

Model		FOM2 3015NT
Travel Method		X & Y – Axis Beam Move
Drive Method		X Rack & Pinion – Y & Z Ball Screw
Work Area	X	121″ (3070mm)
	Y	61″ (1550mm)
	Z	7.87″ (200mm)
Maximum Thickness		⅞″ Mild steel, ½″ Stainless Steel, ⅜″ Aluminum
Maximum Work Weight		2,000 lbs.
Rapid Traverse	X & Y	X,Y = 3,150″/min. Simultaneous = 4,455″/min.
	Z	Z = 2,362″/min.
Repeatability		+0.0002″
Z-Axis Sensor		HS-2007
CNC		AMNC-PC – OS: WINDOWS EMBEDDED
Assist Gas Control		Automatic Select
Oscillator		AF4000iB – 4000 watt
Approximate Machine Weight		34,216 lbs. (includes shuttle table)
Power Requirements		200/220V ±10% 50/60Hz

LASER CUTTING PARAMETERS AND THEIR LEVELS

Laser cutting parameters	**Unit**	**Level**		
		1	2	3
Cutting speed, v	m/min	3	4	5
Laser power, P	kW	0.7	0.9	1.1
Assist gas pressure, p	bar	3	4	5

S.S SHEET AFTER EXPERIMENT



INPUT & OUTPUT PARAMETERS

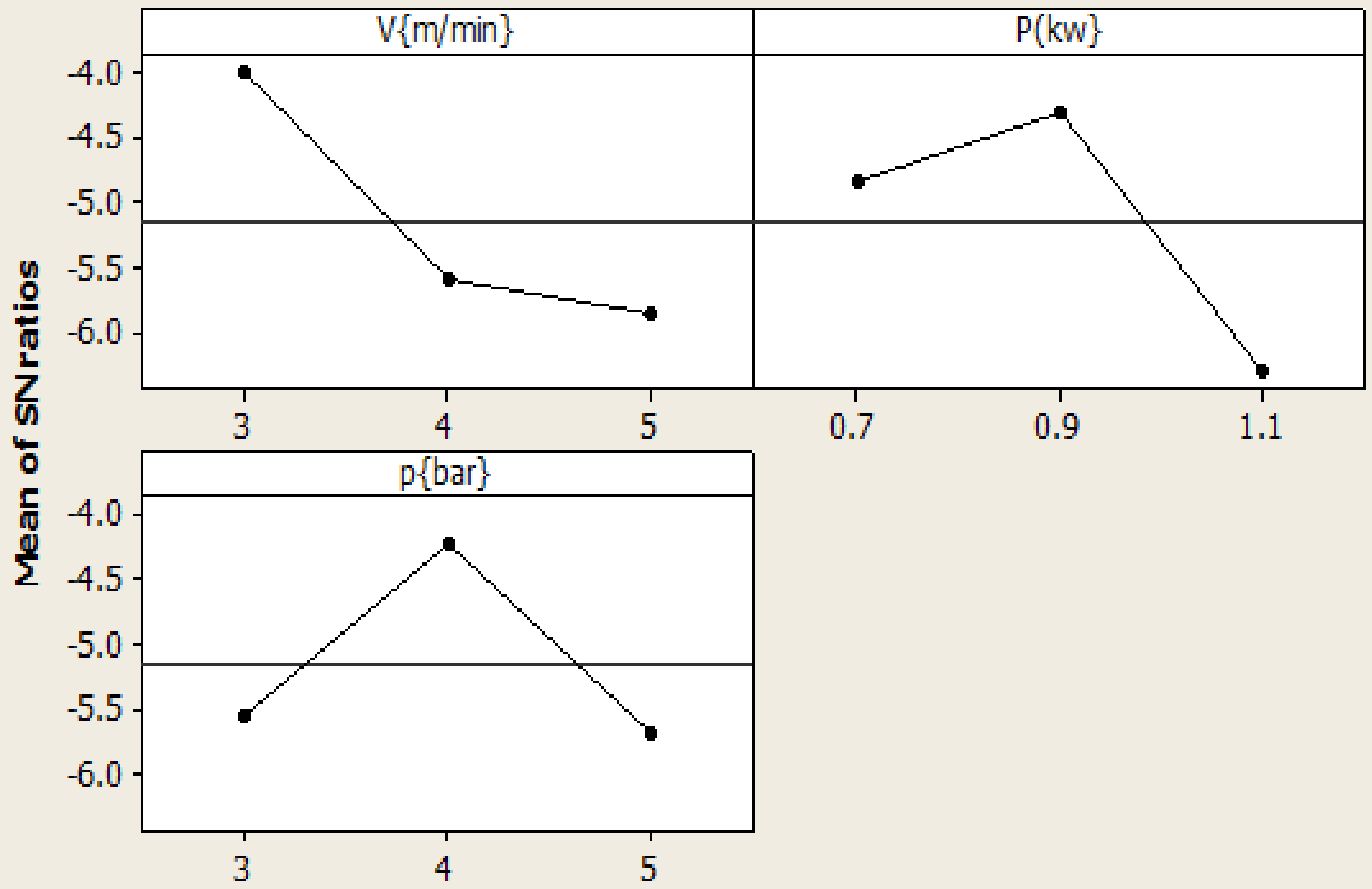
SR. No.	V (m/min)	P (kw)	p (bar)	Ra	S/N RATIO
1	3	0.7	3	1.487	-3.44622
2	3	0.9	4	1.290	-2.21179
3	3	1.1	5	2.073	-6.33199
4	4	0.7	4	1.780	-5.00840
5	4	0.9	5	1.707	-4.64467
6	4	1.1	3	2.270	-7.12052
7	5	0.7	5	2.013	-6.07688
8	5	0.9	3	2.017	-6.09412
9	5	1.1	4	1.873	-5.45076

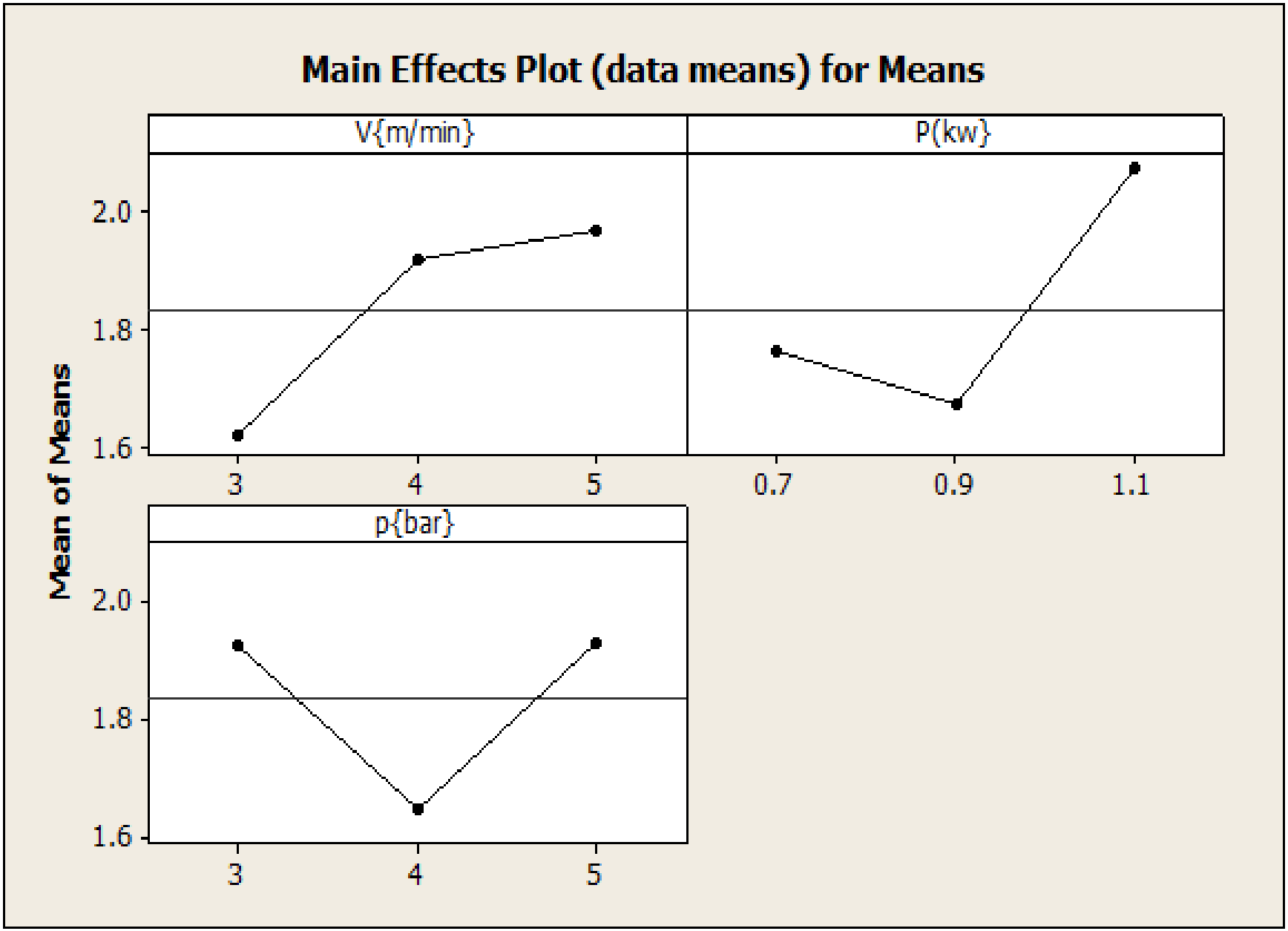
ANOVA ANALYSIS

ANOVA is a particular form of statistical hypothesis testing heavily used in the analysis of experimental data.

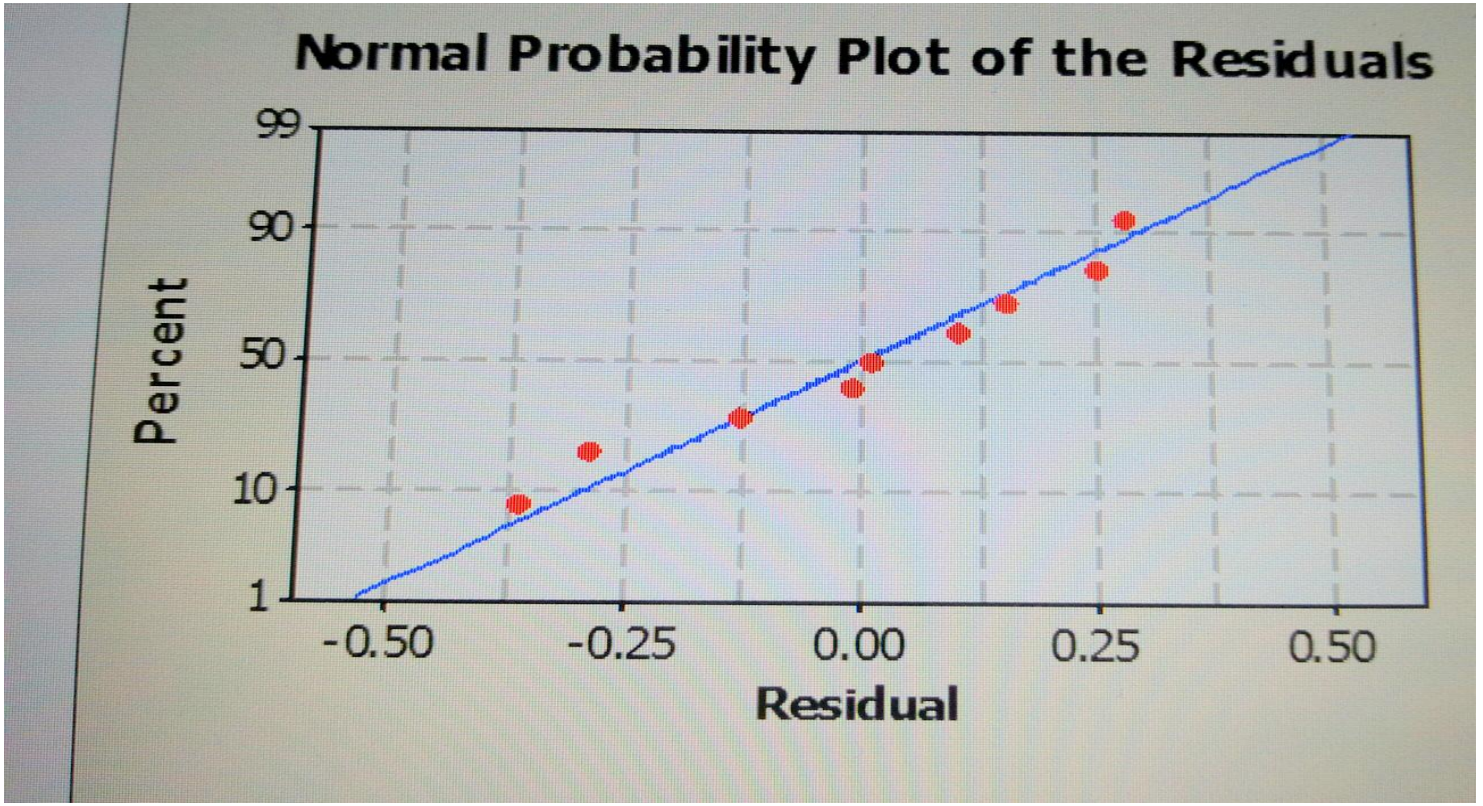
The terminology of ANOVA is largely from the statistical design of experiments. The experimenter adjusts factors and measures responses in an attempt to determine an effect.

Responses show a variability that is partially the result of the effect and is partially random error.


Main Effects Plot (data means) for SN ratios
V{m/min}
P(kw)
p{bar}
Mean of SN ratios
-4.0
-4.5
-5.0
-5.5
-6.0
3
4
5
0.7
0.9
1.1
Signal-to-noise: Smaller is better


Main Effects Plot (data means) for Means
V{m/min}
P(kw)
p{bar}
Mean of Means
2.0
1.8
1.6
3
4
5
0.7
0.9
1.1

RESIDUALS



Residual = Observed value - Predicted value

CALCULATION

- S/N = $-10 \log \left(\frac{1}{n} \sum_{j=1}^{n} y_{ij}^{2} \right)$
- Ra = 0.418+0.175V+0.780P+0.003p

Predictor	T	P
Constant	0.49	0.647
V{m/min}	1.49	0.198
P(kw}	1.32	0.244
p{bar}	0.03	0.980

Anova analysis of variance

Source	DF	F	P
Regression	3	5.32	0.036
Residual error	5		
Total	8		

GENETIC ALGORITHM

- Mathematical modeling for Ra

On the basis of Anova analysis, the mathematical relationship for correlating the surface roughness Ra for analyzing the influences of various parameters on Ra is given by

Ra = 0.418+0.175*(cutting speed)
+0.780*(power)+0.003(gas pressure)

Cutting speed: $3<V<5$

Power: $0.7< P<1.1$

Gas pressure: $3<p<5$

Step 1: Coding

y = 0.418+ 0.175*x(1)+ 0.780*x(2)+ 0.003*x(3);

Where, y= Surface Roughness

x(1)= Cutting Speed

x(2)= Power

x(3)= Gas pressure

Step2: Open Matlab window

Step3: Open Matlab Editor

Step4: Write a small program for the Objective function as follows

```
function y =three_laser(x)
y = 0.418+ 0.175*x(1)+ 0.780*x(2)+ 0.003*x(3);
end
```

Step 5: Save and Run

The file will be saved as three_laser.m

Step 6: In the command window, write the command gatool and press Enter

Step 7: In fitness function, recall the fitness function using @three_laser

Step 8: Define the upper bounds and lower bounds for each parameters

Step 9: Start the GA tool

Step 10: Obtain the optimized Value of the function and Optimal prameters Value

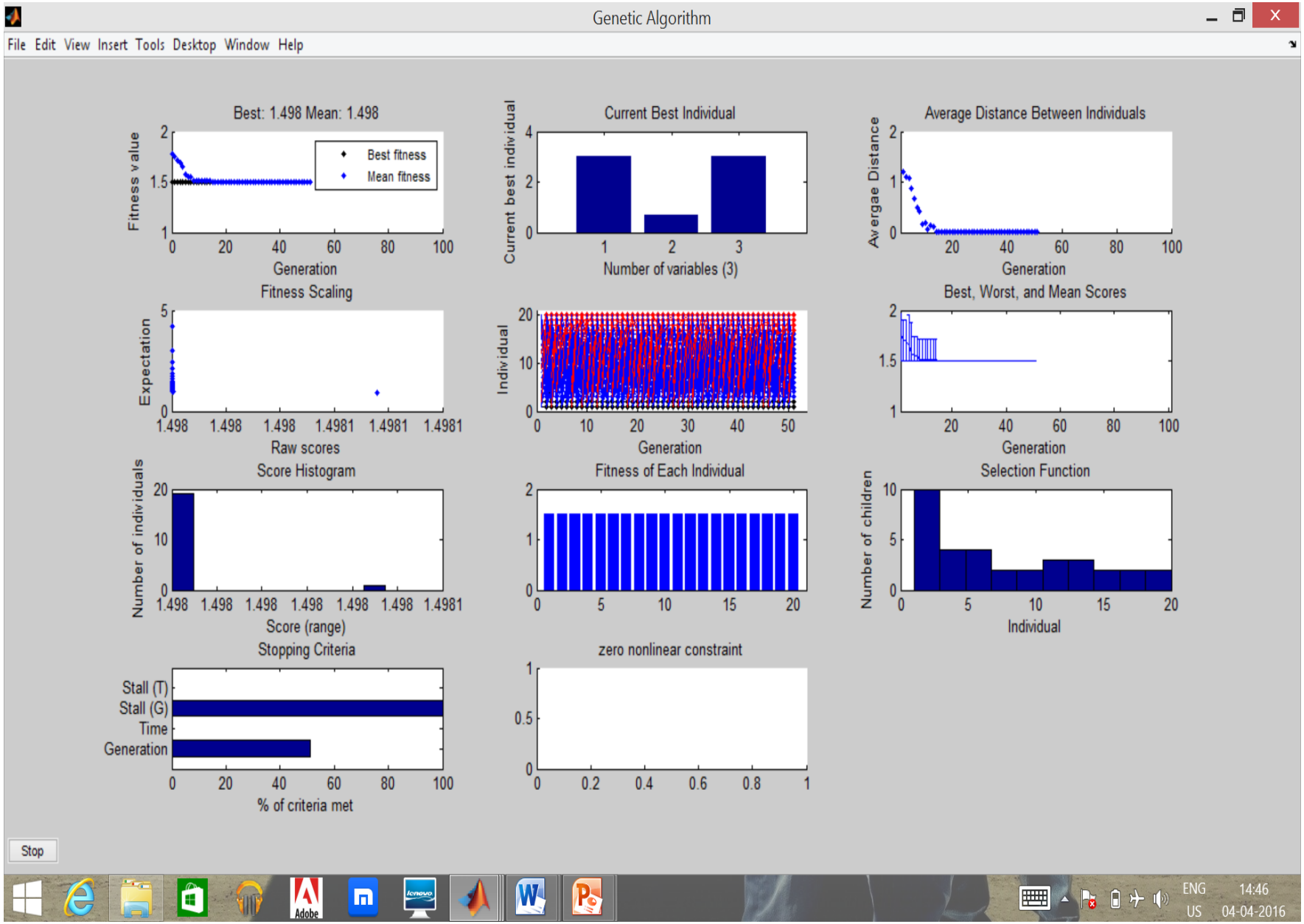
➢ Objective function

Number of variables = 3

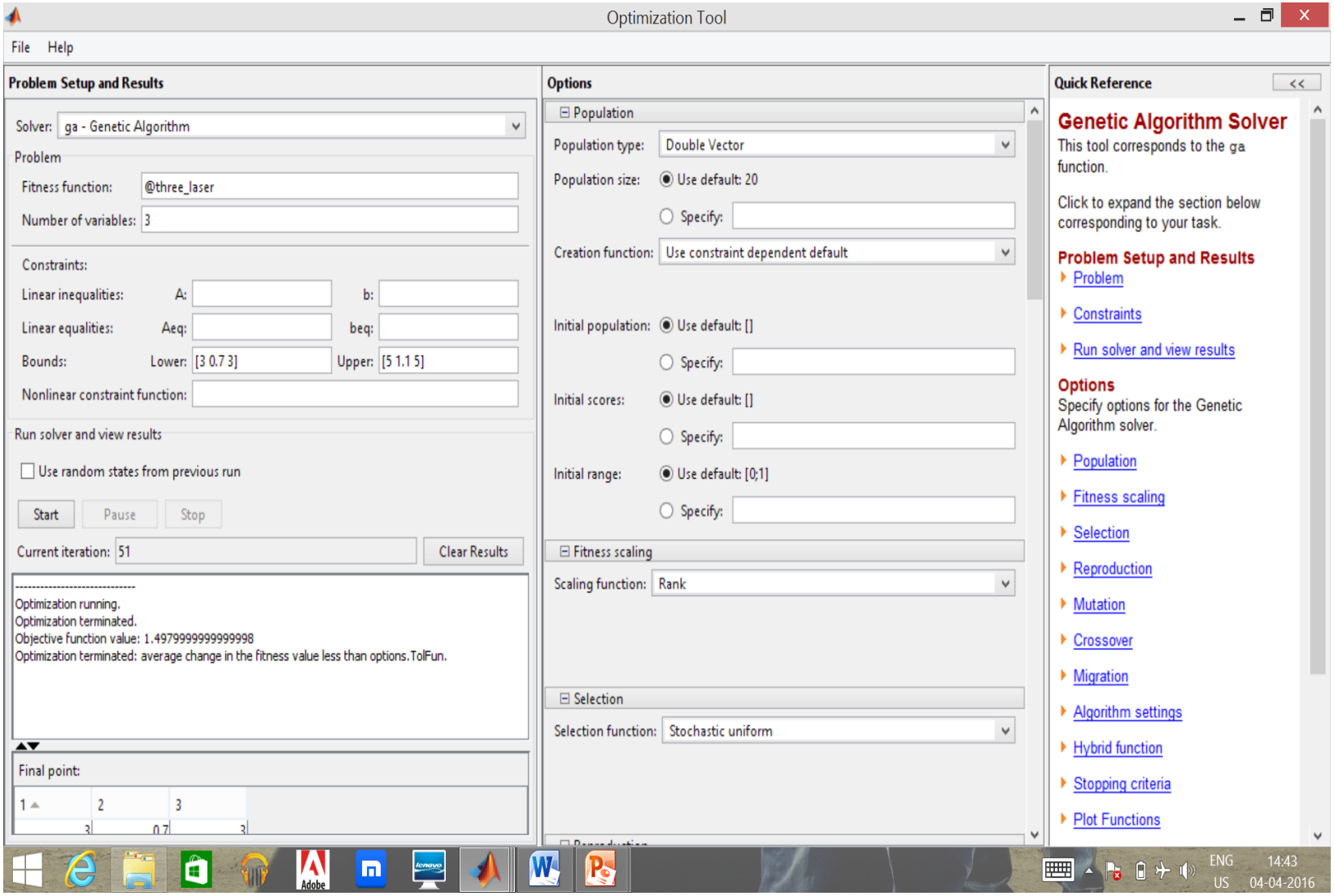
Bounds: lower: [3 0.7 3] upper: [5 1.1 5]

Objective function value: 1.4979999999999998

Number of iteration = 51


Genetic Algorithm
File Edit View Insert Tools Desktop Window Help
Best: 1.498 Mean: 1.498
Best fitness
Mean fitness
Fitness value
Generation
Current Best Individual
Current best individual
Number of variables (3)
Average Distance Between Individuals
Avergae Distance
Generation
Fitness Scaling
Expectation
Raw scores
Individual
Generation
Best, Worst, and Mean Scores
Generation
Score Histogram
Number of individuals
Score (range)
Fitness of Each Individual
Selection Function
Number of children
Individual
Stopping Criteria
Stall (T)
Stall (G)
Time
Generation
% of criteria met
zero nonlinear constraint
Stop
ENG
US
14:46
04-04-2016

GA TOOL


Optimization Tool
File Help
Problem Setup and Results
Solver: ga - Genetic Algorithm
Problem
Fitness function: @three_laser
Number of variables: 3
Constraints:
Linear inequalities: A: b:
Linear equalities: Aeq: beq:
Bounds: Lower: [3 0.7 3] Upper: [5 1.1 5]
Nonlinear constraint function:
Run solver and view results
Use random states from previous run
Start Pause Stop
Current iteration: 51 Clear Results
Optimization running.
Optimization terminated.
Objective function value: 1.4979999999999998
Optimization terminated: average change in the fitness value less than options.TolFun.
Final point:
1 2 3
3 0.7 3
Options
Population
Population type: Double Vector
Population size: Use default: 20
Specify:
Creation function: Use constraint dependent default
Initial population: Use default: []
Specify:
Initial scores: Use default: []
Specify:
Initial range: Use default: [0;1]
Specify:
Fitness scaling
Scaling function: Rank
Selection
Selection function: Stochastic uniform
Quick Reference
Genetic Algorithm Solver
This tool corresponds to the ga function.
Click to expand the section below corresponding to your task.
Problem Setup and Results
Problem
Constraints
Run solver and view results
Options
Specify options for the Genetic Algorithm solver.
Population
Fitness scaling
Selection
Reproduction
Mutation
Crossover
Migration
Algorithm settings
Hybrid function
Stopping criteria
Plot Functions
ENG US
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04-04-2016

CONCLUSION

- The cutting speed and power are the most significant parameters effecting the surface roughness where gas pressure is much smaller.

- It was observed that the cutting speed and power should be kept in low level and gas pressure should be in intermediate level.

- It was observed that the cutting speed should be kept at the (3 m/min), assist gas pressure at the (4 bar), while laser power should be kept at (0.9 kW) for obtaining minimal surface roughness.

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- Links –

https://en.wikipedia.org/wiki/Carbon_dioxide_laser

https://en.wikipedia.org/wiki/Taguchi_methods

www.ee.iitb.ac.in/~apte/CV_PRA_TAGUCHI_INTRO.htm

http://www.amada.com/america/fom2ri-3015

THANK YOU