TURNING PARAMETERS OPTIMIZATION FOR EN8 STEEL USING PARTICLE SWARM OPTIMIZATION (PSO)

P. VINAY KUMAR REDDY,
M.Tech student, Department of Mechanical Engineering,
JNTUA College of Engineering, Pulivendula.
E-Mail:vinaymec420@gmail.com

SRI Y. RAMESWARA REDDY (PH.D.),
Asst. Prof., Department of Mechanical Engineering., JNTUA College of Engineering, Pulivendula.
E-Mail: rameshrdd@yahoo.co.in

SRI. M. RAJESH,
Adhoc. Lecturer, Department of Mechanical Engineering.,
JNTUA College of Engineering, Pulivendula
E-Mail:rajeshmurkur9@gmail.com

ABSTRACT:

As the competitions increases in today's manufacturing industry, customer is looking for high demands of quality and surface finish. So, it is important to have am optimized performance in machining parameters to improve from better production to best production. In this present study of turning speed, feed, depth of cut and nose radius are taken as input parameters and surface roughness, cutting force and tool tip temperature are taken as output parameters. The effects of input parameters on output parameters are studied, during turning of En8 medium carbon steel in HMT Precision Lathe. Three levels of input parameters were chosen and L27 design of experiments is designed from Response Surface Methodology (RSM) of Box-Behnken design using Minitab17 software. Significance of the cutting parameters was determined using statistical analysis of variance (ANOVA). Second order full quadratic equation is developed in RSM method. The optimization of cutting parameters is executed using Particle Swarm Algorithm in MATLAB Software.

Keywords: *Surface roughness, Cutting force, Tool tip temperature, EN8 medium carbon steel, precision lathe, ANOVA, RSM, PSO.*

I INTRODUCTION

In today's market environment, manufactures are seeking to remain in the market must rely on their manufacturing engineers who can quickly setup manufacturing processes for new products. In industrialized countries, more than 20% of amount is utilised for machining compared to the value of manufactured products. So it is important to investigate the machinability of different materials by changing the input parameters of machining process in order to obtain optimal results. Machinability provides an indication to know its adoptability to manufacture the material by any manufacturing process. The optimal combination of parameters for good Machinability is low cutting force, good surface finish, low tool tip temperature and low power consumption. The process of removing the unwanted excess material from metal in the form of chips to produce any desired shape is known as machining. Creation of new objects is done from the metal due to machining.

Generally, manufacturing process is classified as primary and secondary. The primary manufacturing process consists of casting, welding, forging etc. Generation of starting material takes place by this process which is known as workpiece. The secondary manufacturing process consists of machining. Machining is one such field which is showing its never ending growth in past 60 years. Different types of machining process are available in the present industrialised sectors. Turning is most widely used among all machining process. In turning, the workpiece is rotated while a cutting tool is moved parallel to the axis of rotation. It is used to reduce the diameter of the workpiece to specified dimension to produce a smooth finish on the metal. Turning operation that produces cylindrical objects is shown in figure1.1

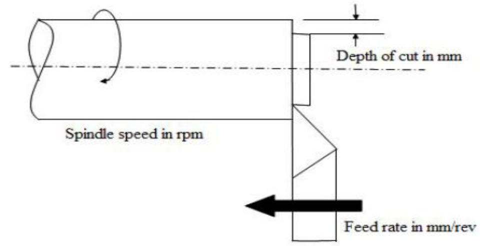

Fig: 1.1 turning process

The work material used for the present study is low carbon steel EN8.Its hardness is 201-255 Brinell hardness number. This low carbon steel EN8 is suitable for motor shafts, heated treated bolts, crank connecting rods, dynamo, general-purpose axles, gears, spindles, hydraulic rams, automotive and general engineering components.

II LITERATURE REVIEW

S. Jindal et.al [1], studied the effect of two values of input namely spindle speed (rpm) and feed rate (mm/rev) on Surface Roughness Analysis on the Dry Turning of En8 Steel. Here L9 based array was selected and total 9 runs of experiments were done. By Taguchi approach influence of input on output was found. The ANOVA test revealed that on feed rate was the important factor for minimization of surface roughness and as higher the feed rate value is the deeper the irregularity on the surface roughness is produced.

Anand S.Shivade et.al [2], studied the effect of two values of input namely spindle speed, depth of cut on Surface Roughness and Tool Tip Temperature in LATHE for machining En8 Steel. Here L9 based array was selected and total 9 runs of experiments were done. By Taguchi approach influence of input on output was found. The optimum combination of input parameters for output parameters was found which gives best results.

Hari Singh and Pradeep Kumar [3], find out the mathematical models of tool life and surface roughness for turning EN24 steel with tungsten carbide inserts through Response Surface Methodology (RSM).RSM method has been applied for developing the modals in the form of multiple regression equations by correlating the dependent responses Tool life and Surface Roughness with cutting speed, feed rate and depth of cut. The second order response surface design was used with central composite design. To evaluate the variation in the response, contour and surface plots were drawn using RSM method.

N Ganesh et.al [4] has investigated the optimization of cutting parameters in turning of EN8 steel using Response Surface Method and Genetic Algorithm. The experiment is designed to develop a Second order linear quadratic equation using Response surface Method (CCD). Mathematical formulation is carried out by correlating the values of output parameters such as Machining time and Surface Roughness with Spindle speed, Feed and Depth of cut to develop the linear models for the responses in form of equations. The Optimization of cutting parameters is done using Genetic Algorithm. Machining time decreases with increase in spindle speed and also with increase in Feed. Machining time shows a negligible influence of depth of cut. Surface roughness values are minimum for balance values of cutting speed, feed and depth of cut. Genetic Algorithm is best modelling as it learns the best fit of even linear models.

Mohamed Athmane Yallese et.al [7] has analyzed the surface roughness and cutting force components in hard turning of AISI H11 steel with CBN tool by considering cutting speed, feed rate, hardness and depth of cut as input parameters. Mathematical liner equations for surface roughness and cutting forces were developed using the response surface methodology (RSM). From the results, cutting force components are influenced particularly by the depth of cut and work piece hardness. Both feed rate and work piece hardness have statistical significance on surface roughness. The optimal surface roughness was produced at low feed and high speed.

III EXPERIMENTAL WORKS

3.1. PRECISION LATHE MACHINE

The L27 design turning experiments were conducted on high speed precision lathe (HMT, NH22) using uncoated carbide triangular inserts of different nose radius. The experimental setup consists of precision lathe, kistler dynamometer with amplifier and infrared thermometer.

Fig.3.1 Precision lathe machine

3.2 WORK MATERIAL

EN8 is a medium carbon steel used and composition is tabulated in 3.2

Element	Composition
Carbon, C	0.37
Manganese, Mn	0.7
Silicon, Si	0.2
Sulphur, S	0.024
Phosphorous, P	0.021
Iron, Fe	Remaining

Tab3.2 composition of EN8

3.3 CUTTING TOOLS

Carbide inserts used in machining of cast iron, steels, non-ferrous alloys and high temperature materials are made of cemented carbide. In the present study triangular carbide inserts are used which allows faster machining and better finish to metal parts and can withstand at higher temperatures compared to high speed steel tools. Uncoated carbide inserts with different nose radius are chosen to turn EN8 steel material in precision lathe machine.

Fig.3.3 uncoated triangular carbide insert

Fig.3.3 tools with different nose radius

3.4 INPUT PARAMETERS AND THEIR LEVELS
The values of input parameters are considered for EN8 steel in precision lathe by choosing 3 levels are listed in table3.3

LEVEL	1	2	3
SPEED	320	420	520
FEED	0,12	0.16	0.20
DEPTH OF CUT	0.6	0.8	1.0
NOSE RADIUS	0.1	0.2	0.3

Tab3.3 levels of input parameters

3.5 SURFACE ROUGHNESS
The average surface roughness (Ra) is mostly used in manufacturing industries which is measured in the present study by using Talysurf surface roughness tester. The experimental values are taken at three positions on the metal and the average value is taken up for analysis.

Fig.3.5 Talysurf surface roughness tester

3.6 INFRARED THERMOMETER

The temperature rise at the tip of the tool during machining is measured using infrared thermometer. The distance between the tool tip and the measuring thermometer should be minimum in order to get more accurate results. The measuring capacity of this infrared thermometer is 550^{o}C.

Fig.3.6 Infrared Thermometer

3.7 KISTLER DYNAMOMETER

The cutting force components during machining trails were measured using piezoelectric type kistler dynamometer. An amplifier is connected to amplify the output results of the dynamometer. A personal computer is connected to it to view the amplified results in the form of graphs. From the graphs mean value of each experiment is taken into consideration as main cutting force.

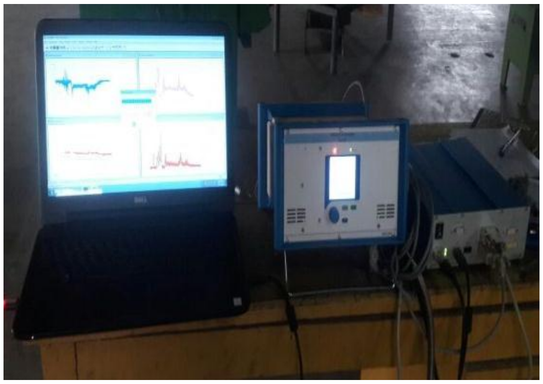

Fig.3.7 kistler dynamometer

IV EXPERIMENTAL DESIGN

Experimental design is a decision making process which decides the validation of the desired response model to find optimal cutting parameters. This present research work is done using Response surface methodology. Box-Benhken design and Central Composite Design (CCD) are the design methods comes under Response surface methodology.

4.1 RESPONSE SURFACE METHODOLOGY

Response surface methodology is a statistical method in which quantitative data from the experiments is used to determine and solve multi-variable equations. In this method, each response is influenced by several input parameters and the main desire is to find optimized input values of cutting parameters for minimization or maximization of response.

In this present work, Box-Benhken design has been applied for the experimental investigation of cutting parameters. Box-Benhken design is mostly used for cutting parameters more than three when compared to Central Composite Design (CCD) with less number of design experiments

The second order responses representing the output parameters can be expressed as a function of cutting input parameters such as feed (F), cutting speed (V), depth of cut (D) and nose radius (R).

$$Y=\beta_0+\beta_1(V)+\beta_2(F)+\beta_3(D)+\beta_4(R)+\beta_5(FD)+\beta_6(FV)+\beta_7(FR)+\beta_8(DV)+\beta_9(DR)+\beta_{10}(VR)+\beta_{11}(F^2)+\beta_{12}(V^2)+\beta_{13}(D^2)+\beta_0(R^2)$$

Where Y is the output parameters and β_0 to β_{14} are the coefficients of the responses.

V EXPERIMENTAL RESULTS

5.1OUTPUT PARAMETERS

Run	Speed (V)	Feed (F)	Depth of Cut (D)	Nose Radius (R)	Ra	Force (F_z)	Temp
1	320	0.06	0.75	0.2	4.170	118.0	55.8
2	320	0.08	0.75	0.1	3.612	104.7	57.9
3	420	0.04	0.75	0.2	3.597	144.9	57.0
4	320	0.06	0.75	0.2	7.428	117.3	56.9
5	320	0.04	0.75	0.3	4.097	173.5	54.2
6	320	0.06	0.50	0.1	4.828	102.6	52.6
7	220	0.06	0.75	0.3	4.838	169.2	52.4
8	320	0.08	0.50	0.2	3.182	109.1	58.5
9	420	0.08	0.75	0.2	4.025	134.4	62.4
10	320	0.06	1.00	0.1	5.284	106.7	54.4
11	220	0.06	1.00	0.2	3.373	161.8	52.8
12	320	0.08	0.75	0.3	5.413	178.7	61.1
13	320	0.08	1.00	0.2	3.882	108.8	62.7
14	420	0.06	0.75	0.1	3.400	115.8	59.2
15	320	0.06	1.00	0.3	4.897	142.5	60.4
16	220	0.06	0.75	0.1	5.041	149.2	51.2
17	320	0.04	0.50	0.2	3.149	107.4	50.9
18	320	0.06	0.75	0.2	3.225	120.4	57.4
19	420	0.06	1.00	0.2	4.727	152.2	63.2
20	420	0.06	0.75	0.3	3.741	141.2	61.8
21	220	0.08	0.75	0.2	4.314	163.6	49.2
22	320	0.06	0.50	0.3	4.487	138.6	55.3
23	420	0.04	0.5	0.3	2.663	117.5	52.7
24	220	0.04	0.5	0.1	6.661	154.9	45.6
25	420	0.06	0.50	0.2	4.202	126	58.1
26	220	0.06	0.50	0.2	5.893	119.2	47.2
27	320	0.04	0.5	0.1	3.536	94.3	49.1

5.2 ANALYSIS OF VARIANCE FOR SURFACE ROUGHNESS

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% C
Model	14	12.56	0.897	0.55	0.85	39.300
S	1	3.44	3.443	2.13	0.170	10.77
F	1	0.043	0.043	0.03	0.872	0.137
D	1	0.069	0.069	0.04	0.839	0.218
R	1	0.261	0.261	0.16	0.695	0.818
S^2	1	0.004	0.004	0.00	0.959	0.014
F^2	1	2.914	2.914	1.80	0.204	9.117
D^2	1	1.007	1.007	0.62	0.445	3.152
R^2	1	0.063	0.632	0.04	0.847	0.197
S*F	1	1.952	1.952	1.16	0.297	6.106
S*D	1	2.318	2.318	1.43	0.254	7.251
S*R	1	0.074	0.073	0.05	0.834	0.231
F*D	1	0.351	0.351	0.22	0.649	1.099
F*R	1	0.384	0.384	0.24	0.635	1.202
D*R	1	0.000	0.000	0.00	0.986	0.001
Error	12	19.40	1.616			
Total	26	31.96				100

5.2 ANALYSIS OF CUTTING FORCE

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% cont
Model	14	11901	850.0	3.24	0.024	79.05
S	1	892.7	892.7	3.40	0.090	6.930
F	1	0.6	0.6	0.00	0.964	0.003
D	1	620.6	620.6	2.36	0.150	4.122
R	1	5896	5896	22.45	0.000	39.16
S^2	1	2834	2834	10.79	0.007	18.83
F^2	1	191.5	191.5	0.73	0.410	1.272
D^2	1	259.1	259.1	0.99	0.340	1.72
N^2	1	448.2	448.2	1.71	0.216	2.977
S*F	1	92.2	92.2	0.35	0.565	0.612
S*D	1	66.4	66.4	0.25	0.624	0.441
S*N	1	7.3	7.3	0.03	0.870	0.048
F*D	1	26.3	26.3	0.10	0.758	0.174
F*N	1	0.2	0.2	0.00	0.981	0.001
D*N	1	0.1	0.1	0.00	0.975	0.000
Error	12	3152.	262.6			20.94
total	26	15053				100

5.3 ANALYSIS OF TOOL TIP TEMPERATURE

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% cont
Model	14	1998.67	141.619	1.61	0.207	65.769
S	1	342.40	342.40	3.89	0.072	11.267
F	1	154.40	154.40	1.76	0.209	5.080
D	1	415.36	415.36	4.72	0.051	13.668
R	1	383.07	383.07	0.59	0.059	12.605
S^2	1	2.20	2.20	0.02	0.877	0.072
F^2	1	3.34	3.34	0.04	0.849	0.109
D^2	1	87.30	87.300	0.99	0.339	2.872
R^2	1	83.04	83.04	0.94	0.351	2.732
S*F	1	0.25	0.250	0.00	0.958	0.0082
S*D	1	0.06	0.06	0.00	0.979	0.0019
S*R	1	0.49	0.490	0.01	0.942	0.016
F*D	1	1.44	1.44	0.02	0.900	0.047
F*R	1	0.90	0.90	0.01	0.921	0.029
D*R	1	477.42	477.42	5.42	0.038	15.710
Error	12	1056.23	88.019			34.757
total	26	3038.89				100

The regression equations are

Roughness=14.4- 0.049 S+ 38 F- 3.1 D- 7.5 N- 0.000003 S*S - 1848 F*F- 6.96 D*D- 10.9 N*N + 0.347 S*F + 0.0304 S*D + 0.0136 S*N+ 59 F*D+ 155 F*N- 0.5 D*N

Cutting force=243- 1.323 S- 616 F+ 279 D-181 N +0.0023 S*S + 14981 F*F-112 D*D+ 917 N*N- 2.40 S*F 0.163 S*D + 0.135 S*N- 510 F*D-100 F*N - 2 D*N

Temperature = -98 + 0.002 S - 140 F+ 202 D + 545 N + 0.000064 S*S+ 1979 F*F- 64.7 D*D- 395 N*N + 0.13 S*F - 0.005 S*D+ 0.035 S*N+ 120 F*D - 238 F*N - 437 D*N

5.4 SURFACE PLOTS OF SURFACE ROUGHNESS

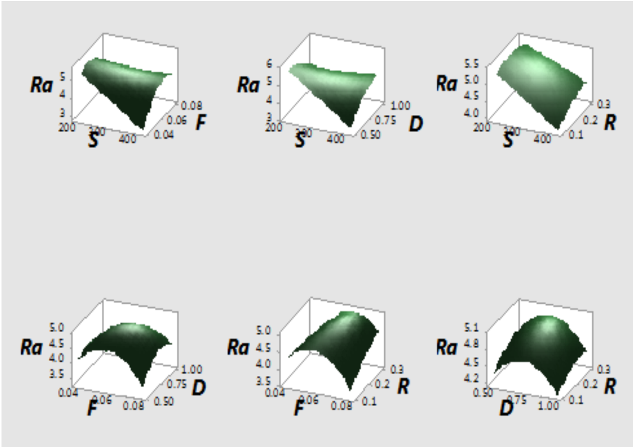

Fig.5.4 surface plots of surface roughness

5.5 SURFACE PLOTS OF CUTTING FORCES

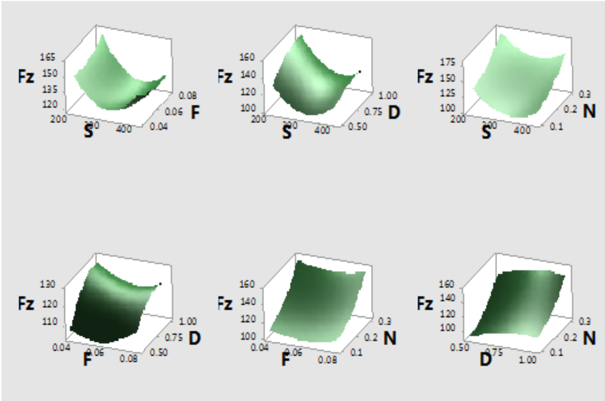

Fig.5.5 surface plots of cutting forces

5.5 SURFACE PLOTS OF TOOL TIP TEMPERATURE

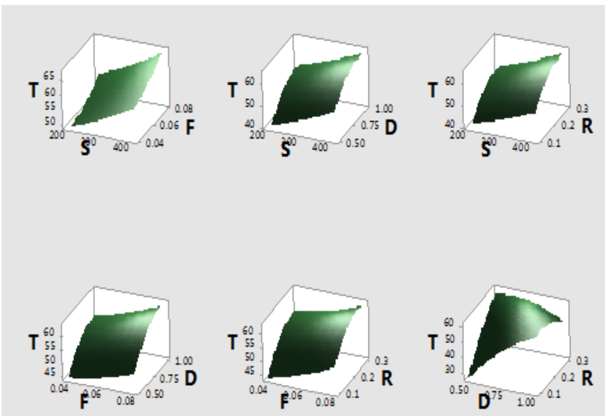

Fig5.6 surface plots of tool tip temperature

VI PARTICLE SWARM OPTIMIZATION

Optimization is the technique most needed in the current scenario of competitive growth in productivity, quality and cost of a product in order to obtain a best fit combination of values of cutting parameter that to lead effective improvement in responses.

Particle Swarm Optimization (PSO) methodology is applied to optimize machining parameters while turning of EN8 medium carbon steel. PSO algorithm is highly efficient, robustness and accurate type Evolutionary optimization method applied to difficult real world problems. Particle Swarm Optimization is a robust, meta-heuristic based direct search method which is evolved from social behaviour and social learning of group of biological populations such as bird flocks, fish schools etc.

The Particle swarm algorithm is applied in this present research is to find optimal cutting parameters is executed using MATLAB 2013a software.

The Graphical performance of PSO for finding best individuals of cutting parameters for Surface roughness, Cutting Force and Tool Tip Temperature are

6.1 SURFACE ROUGHNESS

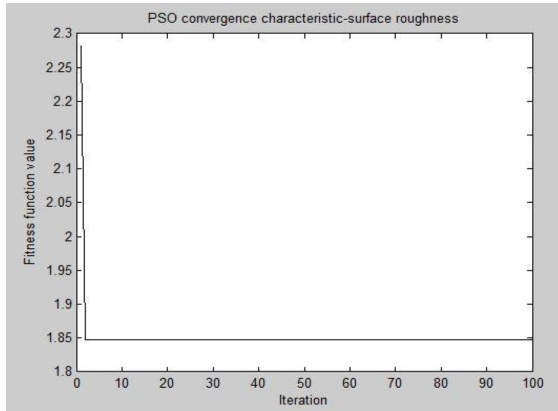

Fig.6.1 Performance of PSO for Surface Roughness

6.2 CUTTING FORCE

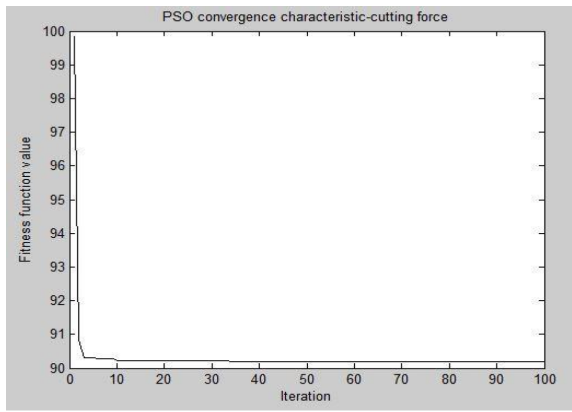

Fig.6.2 Performance of PSO for Cutting Force

6.3 TOOL TIP TEMPERATURE

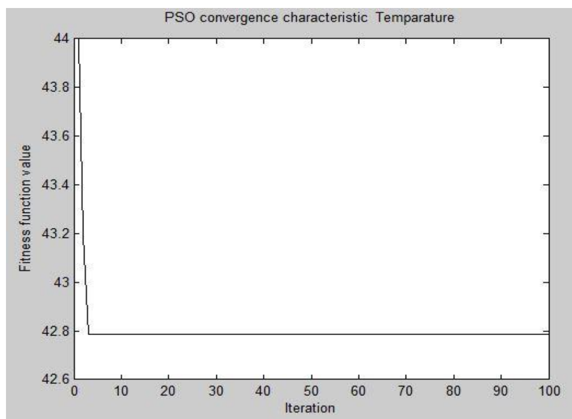

Fig.6.3 Performance of PSO for Tool Tip Temperature

VII RESULTS

The Optimal results from RSM are

Responses	Speed	feed	Depth of cut	Nose radius	Optimal value
Surface roughness	420	0.04	0.5	0.3	1.936
Cutting force	331.111	0.055 75	0.5	0.1	90.7617
Tool tip temp	220	0.04	0.5	0.1	42.567

The Optimal results from PSO are

Responses	Speed	feed	Depth of cut	Nose radius	Optimal value
Surface roughness	420	0.04	0.5	0.3	1.842
Cutting force	331.5903	0.056	0.5	0.1	90.1964
Tool tip temp	220	0.04	0.5	0.1	42.7860

VIII CONCLUSIONS

This paper presents the findings of an experimental investigation into the effect of feed, speed and depth of cut on the surface roughness when turning EN8 steel. Particle Swarm Algorithm is best modeling as it learns the best fit of even linear models. It unveils better performance in enhancement of output parameters in Particle Swarm Algorithm.. From the values, it is easily predictable that the PSO search to find optimal cutting parameters. The optimal response values from RSM and PSO are compared. It concludes that, the results obtained from PSO are better than that of RSM.

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1. **Vinay Kumar Reddy**
M. Tech (CAD/CAM)
Reg. No 14191D0420,
Department of Mechanical Engineering,
JNTUACEP (Autonomous) Pulivendula
Kadapa (Dist.), Andhra Pradesh.

2. **Sri. Y. Rameswara Reddy, (Ph. D)**
Asst. Prof.
Department of Mechanical Engineering,
JNTUACEP (Autonomous) Pulivendula,
Kadapa (Dist.), Andhra Pradesh.
3. **Sri. M. Rajesh M. Tech**
Adhoc. Lecturer,
Department of Mechanical Engineering,
JNTUACEP (Autonomous) Pulivendula
Kadapa (Dist.), Andhra Pradesh.