OPTIMIZATION OF PROCESS PARAMETERS FOR TEMPERATURE DISTRIBUTION IN ORTHOGONAL METAL CUTTING

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ABSTRACT

Process parameters demands optimal conditions to achieve surface finish and desired quality level. The temperature produced during cutting plays significant role in the machining and directly influences process parameters and surface finish of work piece. An investigation has been carried out to see impact of temperature at different process parameters using mild steel AISI 1018 with HSS (Co 10%) cutting tool using a Tool Work thermocouple technique. The analysis is done by using the Taguchi method which optimizes different machining parameters used in turning process for optimizing temperature of tool-chip interface. The parameters are also modeled in GA method and coded in MATLAB. The results obtained from the Taguchi's method shows that the cutting speed comes out to be the most significant parameter among the parameters. The results obtained from Taguchi method are also evaluated by ANOVA.

Keywords: *Process Parameters; Turning, Optimal Seeking; Taguchi Method; GA method*

1. INTRODUCTION

A lot of heat is generated during machining process when the deformation of tool or work piece takes place. The temperature is termed as tool temperature which is produced on the surface of tool when cutting tool comes in contact with the job. Temperature is a parameter that affects the tool performance during the machining operation. High level of heat generation takes place in the result of power consumed during machining.

Rise in the temperature during machining operations is important because temperature depends upon the cutting forces and frictional forces. During machining, approximately most of the heat produced is converted into job material and tool. Thus the power losses remain an important issue to control it. High temperature produced during machining badly affect on tool life and desired quality of product. High temperature increases tool wear and hence surface roughness of job so to reduce cutting temperature during machining is very important objective of this research work.

To control the parameters affecting on machining temperature is significant. Mainly there are major three very distinct zones where heat is produced,(1) shear zone or the primary deformation zone, at this zone plastic deformation occurs,(2) the second zone is tool-chip interface and here the secondary plastic distortion occurs because of frictional rubbing between cutting tool and the heated chip, (3) there is another third zone where heat is produced at work-tool interface, actually this is at the flanks where the strong frictional rubbing occurs.

Flux of heat generated at the secondary zone influences the contacting mechanism by varying situations of the frictional forces, in a result it imparts its role on the position and shape of primary and secondary zone. In the secondary zone, the rise in temperature is a result of power consumed in the deformation of metal chips. The final zone, heat produced at tertiary zone because of work done against forces to overcome the rubbing friction.

Tool work thermocouple K-Type has been used for measuring temperature. A designed approach of Taguchi Method is adopted for seeking optimality and a GA code has been developed in MATLAB to compare the results. The upcoming section presents a brief literature related to previous work followed by experimentation, design of experiments, results and GA optimization.

2. LITERATURE REVIEW

Temperature affects the process parameters during the machining operation. The high temperature in machining influences on surface finish and quality of product. . High level of heat generation takes place in the result of power consumed during machining and transformed into the heat flux. Some experimental methods have been reviewed to find the heat involved in machining operations [1]. Accurate temperature measurement is a challenging task to find the effect of process parameters involved [2]. The rise in the temperature during machining operations is important because temperature depends upon the tool-chip interface [3]. It has been learnt that cutting and frictional forces between the cutting tool and machined chip also play a significant role [4].

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Different factors affect on cutting temperature like cutting speed [3], Feed [5], nose radius [4], depth of cut [3], proper lubrication and Tool angles [12]. It was investigated that mechanism of chip formation and dispersion during machining affects on machining temperatures [5], these parameters play important role in the thermal distortion of the machining tool that is supposed to be the major cause of error in the cutting operation [6]. It was learnt that out of all these parameters speed, feed and depth of cut were more influencing factors on cutting temperature as discussed by A. Fata[3], S. M. Cotterell (2013) [9] and N.Abukhashim et. al. [21].

Three distinct zones where heat is produced the shear zone or the primary deformation zone, at this zone plastic deformation occurs [7], the second is the chip-tool interface zone and here the secondary plastic deformation occurs because of the force of friction due to rubbing is produced between the cutting tool and the heated chips takes place [2] and there is another third zone where heat is produced is at the work-tool interface, actually this is at the flanks where the strong frictional rubbing occurs [8].

Also the high temperature of the job material imparts an important role in the primary deformation zone [9] as it softens the material; ultimately the cutting forces as well as the energy which is required to do the further shear [10].

It is seen that the heat generation in primary as well as in the secondary zones strongly depends upon cutting conditions [11] on the other hand heat produced in tertiary deformation zone is highly affected by tool flank wear and tear [12].It is noted that heat generation and the power consumption in metal cutting machining operation depends upon properties of job material [13] and tool material i.e. chemical and the physical properties [14] the tool geometry of cutting tool and the related cutting conditions [15].

Flux of heat generated at the tool–chip interface [16] influences the contact mechanism by varying situations of the frictional forces [17] ,in a result it imparts its role on the position and shape of primary and secondary deformation zones [18]. The rise in temperature in the secondary zone is due to power dissipation in deforming the metal chips [12] which are generated due to the rubbing friction. The final zone, the heat produced at tertiary zone because of work done against forces to overcome the friction [19] occurs [20, 21].

To measure the temperature along the tool, there are different techniques which have been developed [18]. The major techniques which have been developed to measure temperature during cutting are metallographic, Infra red radiation and thermocouple [22].

The embedded thermocouple method is difficult to perform because the holes are difficult to machine, e.g. carbides, High Speed Steel tools and ceramics also required thermocouple is far from point of contact so it is a disadvantage. The hole made by EDM is also at a distant from the contact point that don't allow proper readings as it is limitation because of tool wear and tear the hole damage [18].

Another technique was developed by Sekulić, Gostimirović et al. [22] to measure the temperature along tool using a cutting tool of two materials (sandwich) consists of very fine powder having a definite melting point (constant M.P.). Metallographic is not commonly used method it involves to check and identify the boundary between the melted and un melted. The temperature can easily be found depending upon nature of material and its melting point. R. Komanduri [18] used a thermal radiation micro detector to calculate the temperature in elasto hydrodynamic. In this method the radiation's intensity is detected and measure after bouncing back from the surface of material under consideration.

In this research work K-Type thermocouple is used, the temperature measuring range of K type is up to 1250 ^oC and it works on seebak effect where the tool acts as hot junction and work piece as cold junction and an electromotive emf establish in between hot-cold junction as discussed by Sekulić, Gostimirović et al. [22] .

The analysis carried out by Taguchi method for optimization of process parameters. This method is good approach for the robust design which gives rise to the different combination and the set of factors as well as levels in an efficient way that reduces the time and experimental cost [22].

There are many optimization techniques which had been studied and implemented by researchers. Response surface methodology had used for process optimization by R. H. Myers, D. C. Montgomery, and C. M. Anderson-Cook(2009) [23] similarly benefits and drawbacks of Factorial design were discussed in detail by M. E. Capella-Peiró et. al (2006) [27]. Unlike Factorial and Response Surface methodology Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The Taguchi method is a famous optimization technique that provides a very efficient and precise methodology for process optimization and this is a powerful tool for the design of high quality systems. This is an engineering methodology for obtaining product and process condition, which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs [22]. This technique reduce experimentation time and hence product cost. Signal to noise ratio and orthogonal array are two major tools used in robust design.

Taguchi results have been compared with GA method. Genetic algorithm is used to find out optimized function variables and objective function using MATLAB. The Taguchi method is evaluated using the software Minitab 15. The cutting temperature is experimentally measured during turning of AISI 1018 Mild steel and HSS tool by using tool work thermocouple method. The process parameters evaluated are speed, feed and depth of cut. Results of Taguchi method are compared with Genetic Algorithm method. ANOVA is carried out to analyze the effects of machining parameters on the cutting temperature.

3. EXPERIMENTAL DETAIL

The aim is to optimize cutting parameters for low tool chip interface temperature. The experiments were designed on the basis of Taguchi method. The analysis of experiment data is carried out using S/N ratio analysis and ANOVA.

To find optimum machining conditions, signal to noise ratio is used. The ANOVA is performed to find the percentage contribution process parameters on machining temperature.

3.1 Work piece material

For investigation AISI 1018 steel was selected. AISI 1018 was identified due to its broad usage and machining applications in the field of manufacturing industries [4]. The chemical composition of AISI 1018 steel is given in the Table-1. The length and diameter of the work piece was 160mm and 25.5mm respectively as shown in Fig.1

Table-1 Chemical composition of AISI 1018 work piece (in %age)

Carbon	Iron	Manganese	Phosphorus	Sulphur
0.20	99.26	0.90	≤ 0.04 %	≤ 0.05

Fig.1 Work piece material for machining

3.2 Experimental procedure

The experiments were conducted on Lathe with a variable speed between 90 and 150 m/min with a power rating of 12kw. Prior to actual machining, sand paper was used to remove rust layers from the work piece.

The cutting tool used was high speed steel (HSS) tool. Temperature measurements were carried out using tool-work thermocouple method. EDM machine is used to drill a hole of 1mm in HSS tool and a K-type thermocouple of 0.8 mm was seated inside HSS tool as shown in Fig.3. The thermocouple was positioned in 1 mm hole made inside the tool by using Electric discharge machining. The EDM die sinker machine used for carrying out hole is shown in Fig.2

Fig.2 Electrical Discharge Machine (EDM) Die Sinker

Fig.3 Thermocouple arrangements on tool

The experiments were carried out under dry cutting conditions. Dry cutting is selected as use of the oil based cooling lubricant/fluid has proven to be one of the most unsustainable element of the machining process [12]. Furthermore, steel work piece is considered as a good candidate for dry machining [17]. The schematic of the thermocouple arrangement on tool as shown in the Fig.4

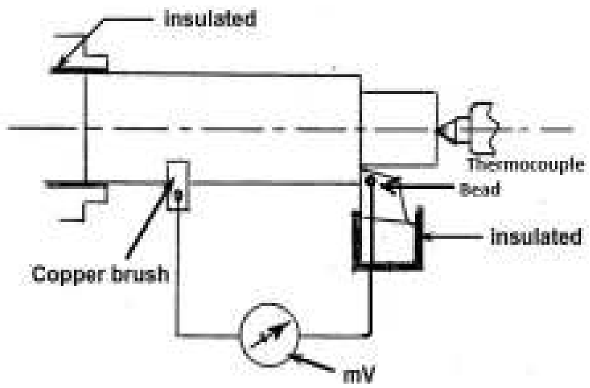

Fig.4 Schematic of experimental Procedure

3.3 Experimental Plan

For turning different machining parameters affect on cutting temperature like cutting speed, nose radius, feed, lubricants, coated and uncoated tools etc. Out of these three main factors feed, speed and DOC have been selected as these factors impart major role in increasing cutting temperature [3]. For turning AISI 1018 steel by using high speed steel, machining parameters ranges were selected as per the standard published by Sandvik Catalogue.

Experiments were planned on the basis of Taguchi orthogonal array that reduces extra effort and the number of experiments. The designed experiments were conducted using Taguchi approach according to a three level, three factors orthogonal array $L_9(3^4)$.

The experiments were conducted at three different cutting speeds (90, 120 and 150m/min), three different feed rate (0.09, 0.12 and 0.15mm/rev) and three different depth of cut (0.30, 0.45 and 0.6mm).The cutting factors and their levels are shown in Table-2. The experimental layout of the L9 orthogonal array is shown in Table-3.

Table-2. Designed parameters at 3 three levels

Coded symbol	Factors	Levels		
		*L1	*L 2	*L 3
A	Cutting speed v, m/min	90	120	150
B	Feed f, mm/rev	.09	.12	.15
C	Depth of Cut d, mm	.3	.45	.6

*L1, *L2, *L3 are 1st ,2nd and 3rd level of cutting parameters

Table-3 Experimental layout using L_9 orthogonal array

Experiments	Turning parameters levels		
	v (m/min)	f (mm/rev)	D (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3.4 Analysis of S/N ratio

Signal to Noise ratio denoted by S/N is used to find the response deviating from the desired value. The term Signal represents the desirable value (mean) for response and the term noise represents undesirable value (standard deviation). So, ratio of mean and standard deviation is expressed in term of S/N ratio. S/N ratio can be measured as:

$$\eta = -10 log(M.S.D.)$$

Here M.S.D mean standard deviation. The goal of this research is to optimize the turning parameters so that low temperature can be achieved. Thus the observed value of temperature was set to minimum. This means the objective function, S/N ratio is based on smaller the better characteristic as given by the following equation discussed by Yang and Tarng [4].

$$M.S.D. = \frac{1}{m}\sum_{i=1}^{m} T_i^2$$

Here m=no. of the experiments, T_i^2 shows the value of the tool chip interface temperature for the ith experiment. The S/N ratio estimated from experimental data was used to measure and predict response at the optimal level. S/N ratio of response variable at optimum level $\hat{\eta}$ was calculated by the following equation discussed by Yang and Trang[4].

$$\hat{\eta} = \eta_m + \sum_{i=1}^{k}(\eta_i - \eta_m)$$

η_m = mean S/N ratio, η_i = S/N ratio at the optimal level, k = no. of parameters that affect on response.

3.5 ANOVA:

Analysis of variance was carried out significant factors can be identified that influence on response. The following equation is used to calculate total sum of squared deviation.

$$SST = \sum_{i=1}^{n} (\eta_i - \eta_m)^2$$

n= no. of experiments

Taguchi orthogonal array is used to perform the experiments and the experiments were planned and implemented using orthogonal array $L_9(3^4)$. Taking orthogonal arrays and corresponding 3 levels (coded by:1,2,3) as shown in Table 2. In the Taguchi orthogonal arrays the selected factors are leveled and best chosen orthogonal array in this experiment is L_9 containing 3 number of factors and 3 levels. These levels have been carefully selected by considering hardness of material and its influence on cutting parameters.

The principle of thermocouple is based on the (Seebak Effect) which states, an electromotive force (emf) is set in the circuit when two different metals come in contact with each other by conducting media provided that there should be a hot junction as well as a cold one. Thus electromotive force is generated in the circuit due to temperatures difference of both cold and hot junction.

Most commonly used method is tool work thermocouple [22]. Experimental setup and conditions are discussed here. The lathe was used for turning operation and the AISI 1018 MS round bar work piece of 160mm in length. For temperature measurement the tool work K type thermocouple (ranges up to 1250 °C) is mounted on the work piece.

There is a difficulty of tool work thermocouple to set up an accurate junction between the pair of work piece and tool for establishment of correct readings. From mV after mounting it on thermocouple with the cutting tool, average cutting temperature is evaluated. The thermocouple is calibrated so that a proper relation could be established between tool and work piece. In this case tool acts as hot junction while work piece acts as the cold junction.

Standard thermocouples monitored junction temperature directly [AlCr-Al]. During machining operation, the determination of temperature distribution on tool is included in set of experiments. The set of experiment carried out using Taguchi approach hence combinations of parameters at their different levels are formulated as discussed in Table-4.

Table-4. Design Matrix

No	Factors			Parameters			T , °C	S/N
	v	f	d	v m/min	f mm/rev	d mm		
1	1	1	1	90	0.09	0.3	298	-49.4843
2	1	2	2	90	0.12	0.45	300.6	-49.5598
3	1	3	3	90	0.15	0.6	298.1	-49.4978
4	2	1	2	120	0.09	0.45	297.8	-49.4785
5	2	2	3	120	0.12	0.6	298.9	-49.5105
6	2	3	1	120	0.15	0.3	300.6	-49.5598
7	3	1	3	150	0.09	0.6	299.3	-49.5021
8	3	2	1	150	0.12	0.3	305.2	-49.6917
9	3	3	2	150	0.15	0.45	301.6	-49.5986

There are 3 levels of each process parameter and mean signal to noise ratio is calculated against each level. Total nine experiments were performed and the S/N ratio for each experiment was also found then listed in graph for machining temperature. Signal to Noise ratio corresponds to lower variance of output characteristics near desired value.

The S/N ratio characteristics can be divided into three categories when the characteristic is continuous: nominal is the best, smaller the better and larger is better characteristics. For the minimal cutting temperature, the solution is "smaller is better", and S/N ratio is determined according to the following

equation 4:

$$\frac{S}{N} = -10 log\left(\frac{1}{n}\sum_{i=1}^{n} {y_i}^2\right) \text{ ....Equation: 4}$$

where n is the number of replication and yi is the measured value of output variable. The "minimal temperature" can be achieved using the cutting parameters where S/N ratio is "maximal". In fig.5 it is clear that on x-axis there are cutting parameters in increasing order from 90-150,0.09-0.15 and 0.3-0.45 similarly on y-axis S/N ratio values in ascending order up to the minus 49.50. Hence maximal value of S/N ratio in Fig.5 is at 90 m/min(1st level of speed,) at 0.09mm/rev(1st level of feed) and at 0.6mm(3rd level of depth of cut)

The value of cutting speed decreases and up to the 150, the larger value of S/N ratio corresponding to speed is 90 m/min cutting speed. So the optimal spindle speed is at level 1.The feed's influence on machining temperature, is decreasing up to the level 2 then it increase again up to the level 3. So the optimum feed corresponding to S/N value is at level 1 (0.09 mm/rev). Similarly effect DOC value is increasing up to the level 3. The optimum DOC is at level 3 (0.6 mm). The influence of turning factors on the cutting temperature for S/N ratio is given in Fig.**5**

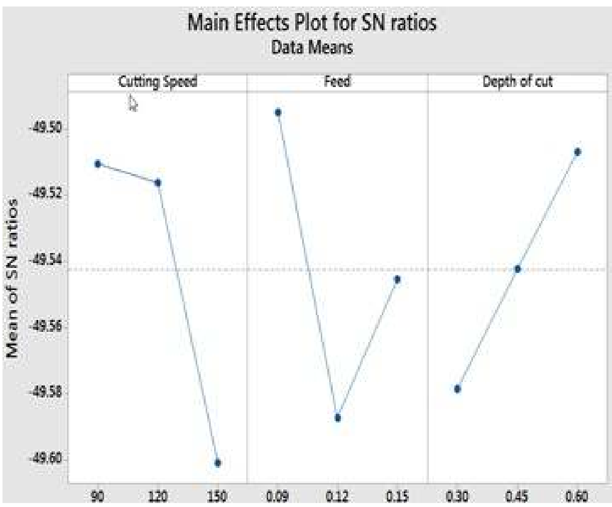

Fig.5 S/N Response Graph for cutting parameters

4. RESULTS AND DISCUSSIONS:

From the S/N response graphs as shown in the Fig.5, optimum process parameters can be found. In graph desired temperature is at the higher Signal to Noise values. The value of speed at its first level (90 m/min), value of feed at its 1st level (0.9 mm/rev) and value of DOC at its 3rd level are selected to be the optimal parameters.

ANOVA test was performed on the data obtained from the experimental results to assure and identify control parameters that influence on the performance measures. After performing ANOVA results are obtained shown in Fig.6. In this ANOVA analysis was done at α=0.10 (significance level) i.e. 90% confidence level. Also those factors have significant contribution to performance measure having P-value< 0.10.

It is evident that the P-value of depth of cut (0.074) and is less than (α=0.10) while the P-value of cutting speed i.e. 0.062 is least. So speed has major effect on performance measure on the other hand feed has least effect. The detailed ANOVA results are mentioned in Table 4.1.

Use your mouse to right click on individual cells for definitions.

Response 1 R1

ANOVA for selected factorial model

Analysis of variance table [Classical sum of squares - Type II]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	0.036	6	5.979E-003	11.66	0.0811
A-CS	0.015	2	7.654E-003	14.93	0.0628
B-DOC	0.013	2	6.417E-003	12.51	0.0740
C-F	7.733E-003	2	3.867E-003	7.54	0.1171
Residual	1.026E-003	2	5.128E-004		
Cor Total	0.037	8			

Fig. 6 Analysis Of Variance of work surface temperature by Software DX 8.

Note: *A-CS = cutting speed, *B-DOC=depth of cut, *C-F=feed , *df=Degree of freedom

Table. 4.1 Analysis of Variance (ANOVA)

Factors	DOF	Sum of Squares	Mean Square	F-value	P-value
speed	2	50.469	25.234	14.93	0.062
DOC	2	42.229	21.114	12.51	0.074
feed	2	26.462	13.231	7.54	0.117
ERROR	2	3.429	1.714		
TOTAL	8	122.6			
S = 1.3 R-sq = 96.90 % R-sq(adj) = 90%					

It is evident that P-value of speed and DOC are less than 0.10 explaining that the speed and DOC has significant effect on temperature. Also the rank or the degree of contribution of the parameters at their different levels is the speed ≥ depth of cut ≥ feed respectively.

When ANOVA test performed using Design Software DX.9 (shown in fig.6) , the linear equation resulted by regression analysis. The relationship of factors by multiple linear regressions is obtained:

Temperature T = 294.020+0.052*v+29*F-8.311*DOC Eq………..4.1.

Temperature T =294.020+0.052*90+29*.09-8.311*0.6 =298.06

Where v is cutting speed, F is feed and DOC is depth of cut. It is evident from above results that out of all cutting parameters, cutting speed is most contributing factor to the response. Hence Optimal setting of control factors are obtained. From Fig.5 optimal values of control factors obtained from Taguchi method i.e. speed, feed and DOC are put into the multiple linear equation 4.1. Thus the temperature 298.06 obtained which is our desired temperature. Results obtained from ANOVA closely match with Taguchi method.

Thus the optimal setting of control parameters is arranged in Table-5.

Table-5 Optimal setting of control Factors

Control Parameters	Levels	Parameter Setting
Cutting Speed v, m/min	1	90
Feed f, mm/rev	1	0.09
Depth of Cut d, mm	3	0.6

5. GENETIC ALGORITHM METHOD

The GA is used to validate the results obtained from the Taguchi method and the cutting parameters with lower bound to upper bound range of cutting speed 90-150 m/min, range of Depth of cut is 0.3-0.6 mm and Feed range 0.09-0.15 mm/rev are under consideration respectively. The chromosome is defined as the chromosome consists of 3 genes (cutting speed, feed and depth of cut) Our variable bound are:

90 m/min ≤ v ≤ 150 m/min

0.3mm ≤ DOC ≤ 0.6 mm

0.09 mm/rev ≤ f ≤0. 15 mm/rev

$$x_{il} \le x_i \le x_{iu}$$

Where x_{il} lower bound and x_{iu} is upper bound

Table-6. Process parameters used in experimentation

Sr. #	Factors	Units	Level 1 (L 1)	Level 2 (L 2)	Level 3 (L 3)
1	Speed, v	m/min	90	120	150
2	Depth of Cut, d	mm	0.3	0.45	0.6
3	Feed, f	mm/rev	0.09	0.12	0.15

Genetic algorithm is a good method to find out the individual solutions out of random population. Population size varies and the size variation depends upon the nature of the problem, also it is interesting that it give rise to hundreds or thousands of possible solutions. GA method coded in MATLAB. The Fig.7 presents generation sequence and fitness value. There are Replication of Chromosomal generations (random experimentations) on abscissa while on ordinate fitness values (optimized values) are mentioned. It is found that the best fitness value (optimized temperature) after several experimentation obtained is 298.5 which is closer to that obtained from Taguchi method i.e. 297.8 It comes out that from the generation(up to 51 experiments), 298.5°C is best fitness value (optimal value, denoted by blue dots) with a mean of 296.334.

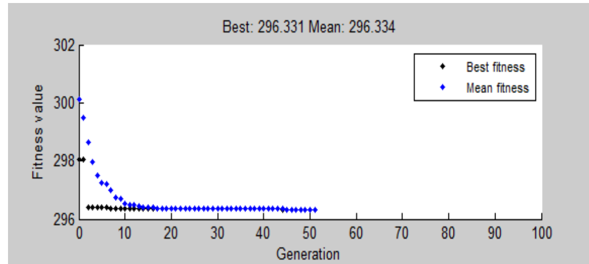

Fig.7 Fitness value versus Generation plot

From the GA method the final points corresponding to the different levels of cutting parameters are identified as 90, 0.09 and 0.6 respectively and our objective function is 298.5.The objective function is basically multiple linear regression equation 4.1 at the optimized levels of function variables i.e. first level of cutting speed 90 m/min, first level of feed .09 mm/rev and third level of depth of cut 0.6 mm which is met (as shown in fig.8).

The Fitness value vs Generation values plot of Fig.7 shows that there are the different fitness values and the curve consists of blue dots showing the mean fitness values while on the other hand the line containing the small black dots representing the best fitness values.

In the Fig.8 on x-axis there is individual's population (no. of factors or variables) while on y-axis best individuals are mentioned. In this plot our individual population/ variables on x-axis are (1) speed (2) Depth of cut and (3) feed respectively. And on y-axis first column goes up to 90, 2nd smaller column up to 0.3and 3rd smallest goes up to 0.12. These three values of parameters are closest to the values obtained from Taguchi method (fig.5). Hence it is validated that the optimal control parameters obtained in both methods are same. Also from plot 7 it is clear the more no. of solutions exists in narrow range i.e. there values are very closer.

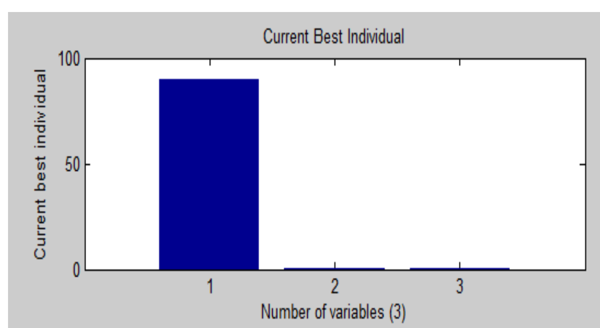

Fig.8 Current best individual versus Number of variables

Note: 1*=speed, 2*=depth of cut, 3*=feed

In Fig.8 current best individual versus number of variables plot shows that best individuals are at 90, 0.9 and 0.6 corresponding to the 1st, 2nd and 3rd variable. In this case these three variables i.e. v, DOC and f are found at their first level, third level and first level respectively.

At the 50th generation the objective function is obtained at function variables 1st level (cutting speed 90 m/min) 3rd level of depth of cut (0.6 mm) and 1st level of feed (0.09 mm/rev).

6. RESULTS AND DISCUSSIONS:

The experimental results were analyzed by using the GA Method which used for identifying the factors significantly affecting the performance measures. In the Fig. 8 the graphical results are obtained using GA Method.

From the GA method the final points corresponding to the different levels of cutting parameters are identified as 90 m/min (v, cutting speed,) , 0.09 mm/rev (f, feed) and 0.6 mm (d, DOC) respectively and objective function obtained is 298.5.

The Fitness value versus Generation values plot shows that there are the different fitness values at different generations and the curve consists of blue dots showing the mean fitness values while on the other hand the line containing the small black dots representing the best fitness values which is 2985.

In Fig.8 after selection and crossover, now there is a new population full of individuals. It can be loop through all the alleles of all the individuals, and if that allele is selected for mutation, then it can either change it by a small amount or replace it with a new value. The plot shows that best individuals are at 90, 0.9 and 0.6 corresponding to the 1st, 2nd and 3rd variable. In this case these three variables i.e. cutting speed, depth of cut and feed are found at their first level, third level and first level respectively.

By producing a "child" solution (new combination of function variables i.e. cutting speed, feed, depth of cut) using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each child, and the process continues until at 50th generation, the objective function is obtained at function variables 1st level (cutting speed 90 m/min) 3rd level of depth of cut (0.6 mm) and 1st level of feed (0.09 mm/rev) with a new population of solutions of appropriate size is generated.

6.1 Results Comparison of Taguchi and GA method

After comparing the results obtained from Taguchi and GA Method it is found that the optimal control parameters found from the Taguchi method are same as were selected from the GA method as given in Table 7. Hence it is also confirmed that the 1st level of speed, 3rd level of depth of cut and 1st level of feed are optimal control factors for optimized machining temperature.

In Taguchi method the output temperature was found 297.8 while 298.5 obtained in GA method which is closer to the Taguchi's output temperature.

Table-7 Results Comparison of Taguchi and GA method

Method	Speed, m/min	Depth of cut, (mm)	Feed mm/rev	Outpt Temp. (^oC)	Differ-ence
Taguchi Method	90 m/min	0.6mm	0.09	297.8	0.7 ^{o}C
GA Method	90 m/min	0.6mm	0.09	298.5	

7. CONCLUSIONS

After solving the solution obtained from the turning of AISI 1018 work piece with K Type thermocouple it is observed that the technique adopted in this research work was an effective technique to determine the optimized control factors for obtaining the reduced temperature. Hence conclusions have been drawn. The control factors which played a very prominent and significant role were v, DOC and f. Out of these parameters the speed has maximum role in increasing the surface temperature during machining. The order of effectiveness of control parameters on the temperature is speed > DOC >f respectively. Feed has the least influence in rising the machining temperature during turning operation. temperature. Also the contribution of error was not significant and it is very low explaining that the speed, feed and depth of cut are major contributing factors. The experimentally obtained results were very accurate explaining that Taguchi technique adopted in this research work was an effective technique to determine the optimized control factors for obtaining the reduced temperature.

The results obtained from the GA method showed that the optimal parameters for cutting temperatures are cutting speed (1st level, 90 m/min) ,feed (1st level,0.09 mm/rev) and depth of cut at 3rd level i.e. 0.6 mm. Same values of control factors were identified in GA method. Hence it is confirmed that the 1st level of speed, 3rd level of depth of cut and 1st level of feed are optimal control factors for optimizing machining temperature in this experiment.

After comparing the results it is found that the optimal parameters found from the Taguchi method are very close as were identified from the GA method. In Taguchi method the output temperature were found 297.8 while 298.5 in GA method. The relationship was established b/w control factors v, f, DOC and formulated by regression equation which is verified by Genetic algorithm method that can be further used to find the optimum results.

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