Optimization Of Turning Process Parameters Using Various Optimization Techniques- Literature Review

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Abstract*—Now days increasing the productivity and the quality of the machined parts are the main challenges of metal cutting industry. In order to optimize the turning operation by considering the various constraints it is very necessary to be familiar with the previous work done by the various researcher i.e. it is necessary to do the literature survey, so the main objective of this work is to do literature review in order to have directional efforts. From the literature review it can be concluded that In order to optimize the turning operation various optimization techniques are used out of which Taguchi method is widely used by the various researchers. Genetic Algorithm approach can be successfully used for the multi objective optimization. There is good scope for the simulation. In order to optimize the turning operation the various constraints consider by various researcher are speed, feed, depth of cut, type of lubrication used, material removal rate (MRR), tool vibration, power requirement, temperature generation, cost effectiveness, tool wear relationships., productivity improvement, diameter and length of the work piece, hardness of the material, shape of the tool, type of material for work piece and tool, tool signature In order to optimize the turning operation the various material considered by various researcher are ANSI 1080 Steel,ANSI D2 Steel,ANSI 1050, Steel EN8 EN24,Aluminum 6061,Oil hardened Non shrinkable steel(OHNS), Austenitic Stainless Steel(AISI 202),AISI 1045,Aluminum 6063.In order to optimize the turning operation the various tools considered by various researcher are HSS and cemented tipped tool,SN MGO 90204,Coated cemented carbide, Cermet's -titanium carbonitride, Molybdenum high speed steel, Ceramics - Oxide ceramics like Mixed ceramics, Whisker-reinforced ceramics , Silicon nitride ceramics (Si_3N_4) ,Polycrystalline cubic boron nitride(CBN).

Index Terms*—Constraints, Genetic Algorithm, Taguchi, productivity, Material.

I. INTRODUCTION

Present days increasing the productivity and the quality of the machined parts are the main challenges of metal cutting industry. [10] Black defined metal cutting as the removal of metal chips from a work piece in order to obtain a finished product with desired characteristics of size, shape, and surface roughness. [1] The challenge that the engineers face is to find out the optimal parameters for the preferred output and to maximize the output by using the available resources. Turning is one of the most main manufacturing processes in metal removal, it is the process whereby a single point cutting tool removes unwanted material from the cylindrical work piece and the tool is fed parallel to the axis of rotation .Optimization methods in turning processes, considered being a vital role for continual improvement of output quality in product and processes include modeling of input-output and in process parameters relationship and determination of optimal cutting conditions. The challenge of modern machining industries is mainly focused on the achievements of high quality in terms of work piece dimensional accuracy, surface finish, high production rate, less Wear on the cutting tool, economy of machining in terms of cost saving and increase the Performance of the product with reduced environmental impact.

In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the work piece material, tool material, tool size, and more. Turning parameters that can affect the processes are: [2]

a) Cutting speed - The speed of the work piece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).
b) Spindle speed - The rotational speed of the spindle and the work piece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the work piece where the cut is being made. In order to

maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

c) Feed rate - The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in mm per revolution.

d) Depth of cut - The depth of the tool along the radius of the work piece as it makes a cut, as in a turning or boring operation. A large depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is often machined in several steps as the tool moves over at the depth of cut. [2]

II. OBJECTIVE

Traditionally, the selection of cutting conditions for metal cutting is left to the machine operator. In such cases, the experience of the operator plays a major role, but even for a skilled operator it is very difficult to attain the optimum values each time, so in order to optimize the turning operation by considering the various constraints it is very necessary to be familiar with the previous work done by the various researcher i.e. it is necessary to do the literature survey, so the main objective of this work is to do literature review in order to have directional efforts.

The various constraints in the optimization are speed, feed, depth of cut, type of lubrication used, material removal rate (MRR), tool vibration, power requirement, temperature generation, cost effectiveness, tool wear relationships., productivity improvement, step whether single or multistep, diameter and length of the work piece, hardness of the material, shape of the tool, type of material for work piece and tool, tool signature

III. THE VARIOUS OPTIMIZATION METHODS ARE:

- Taguchi techniques.
- Genetic Algorithm (GA).
- Ant Colony Optimization Algorithm (ACO).
- Swarm Optimization.
- Real coded GA.
- Differential Evolution.
- ANOVA.
- Simulated Annealing (SA).
- Tabu Search (TS).
- Response surface methodology (RSM).
- Artificial Neural Network.
- Multi Variate methods such as Principal Component Analysis.
- Acoustic Emission (AE)

IV. TAGUCHI METHOD

The scientific approach to quality improvement is becoming more widespread in industrial practice. Designing high quality products and processes at low cost is an economical and technical challenge to the engineer. Robust design is an engineering methodology for improving productivity during design and development so that high quality products and performance can be produced at low cost. The main idea of Robust design method is to choose the levels of design factors to make product or process performance intensive to uncontrollable variations such as manufacturing variations, deterioration and environmental variations. Dr. Genichi Taguchi has popularized the robust design method which employs experimental design techniques to help identify the improved factor levels. [1]The robust design method uses a mathematical tool called Orthogonal Array (O.A) to study large number decision variables with a small number of experiments. It also uses a measure of quality called Signal-to-Noise (S/N) ratio, to predict the quality. The principle of robust design methodology is to minimize the variation without eliminating the causes and maximizing S/N ratio. This is achieved by optimizing the product and process designs to make the performance insensitive to the various causes of variations.

Conventional methods for experimental design are of complex in nature and difficult to use. In addition to that, these methods also require a large number of experiments when the process parameters increase. Taguchi approach to design of experiments has got high adoptability and hence users can be applied with confined knowledge of statistics, hence gained wide popularity in engineering application. Taguchi method uses a set of orthogonal arrays to investigate the effect

of various process parameters on response characteristic to decide the optimal setting of process parameters. Taguchi method is based on 8-steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control parameters. Those eight steps are given as follows.
Identify the performance characteristics (responses) to optimize and process parameters to control (test).

Determine the number of levels for each of the tested Parameters

i) Select an appropriate orthogonal array, and assign each tested parameter into the array.
ii) Conduct an experiment randomly based on the arrangement of the orthogonal array.
iii) Calculate the *S/N* ratio for each combination of the tested parameters.
iv) Analysis the experimental result using the *S/N* ratio and ANOVA test.
v) Find the optimal level for each of the process parameters.
vi) Conduct the confirmation experiment to verify the optimal process parameters. [4]

V. THE LITERATURE REVIEW ASSOCIATED WITH THE TAGUCHI METHOD

1) Dr.S.S.Chaudhari, Dr.S.S. Khedkar and N.B. Borkar had carried out the study on Optimization of process parameters using Taguchi approach with minimum quantity lubrication for turning**;** they stated that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness [5]
2) Yadav and Narang had conclude from ANOVA analysis and Taguchi method that for medium carbon steel, parameters making significant effect on surface roughness are feed rate and cutting speed. They shown that with the increase in feed rate the surface roughness also increases & as the cutting speed decreases the surface roughness increases. [6]
3) Tejender pal singh had used aluminum bar for turning and by mathematical model shown that surface roughness decreases with increase in rack angle. [7]
4) Mustafa gunay has shown that negative rack angle produces poor surface finish and positive rack angle produce good surface finish with less surface roughness using anova. [8]
5) S. Thamizhmanii studied on Analyses of Surface Roughness using Taguchi Method. They stated that depth of cut plays a very significant role in producing lower surface roughness followed by feed and cutting speed has lower role on surface roughness from the tests. Purpose of this research was to analyze the optimum cutting conditions to get lower surface roughness in turning process. [9]
6) Ghani had done a study of tool life, surface finish and vibration, while turning nodular cast iron using ceramic tool. They found that surface finish was to be almost constant with the progression of the flank wear under different cutting conditions. They also observed that as the speed increases, the vibration during cutting decreases and at low depth of cut, the vibration remains almost constant with the increase of flank wear. [11]
7) Hasan studied to analyze the optimum cutting parameters to minimize the roughness in turning SCM 440 alloy steel by Taguchi method. Experiment was designed using Taguchi method and 18 experiments were designed and they found that depth of cut has the significant effect on producing [12]
8) Diniz presented a study on correlating tool wear, tool life, surface roughness and tool vibration in finish turning with coated carbide tools. The work piece machined was AISI 4340 steel and tool coated with carbide insert. Two accelerometers are attached to the tool to measure the vibration and r.m.s signal was used to correlate with the surface roughness. They concluded that the feed didn't influence the vibrational signal and had a little effect on surface roughness. The surface roughness value decreases slightly after a short cutting time due to chamfering of the edge radius. [13]
9) Thomas M**.** studied the effect of tool vibration on surface roughness during lathe dry turning process on mild carbon steel samples at different levels of speed, feed, depth of cut, tool nose

radius, tool length and work piece length. Roughness was measured in Motutoya SurfTest201 apparatus and for vibration triaxial accelerometer is being used. Vibration analysis shows that the dynamic force, related to the chip thickness variation acting on the tool, is related to the amplitude of tool vibration at resonance and to the variation of tools natural frequency while cutting. The analogy of effect of cutting parameters between tool dynamic force and surface roughness was studied. After the analysis of variance it is shown that there exist a relation between surface roughness and tool dynamic force when operating in a built up edge range.[14]

VI. GENETIC ALGORITHM (GA)

Genetic algorithms (GA) were developed with the primary intention of imitating the processes that exist in nature. Basic principles of genetic algorithms were published in 1962 (Holland) and the mathematical framework for their development was published in 1975 by the same author. [17] The genetic algorithm (GA) is a population-based search optimization technique. In general, the fittest individuals of any population tend to reproduce and survive to the next generation, thus improving successive generations. However, inferior individuals can, by chance, survive and also reproduce. Genetic algorithms have been shown to solve linear and nonlinear problems by exploring all regions of the state space and exponentially exploiting promising areas through mutation, crossover and selection operations applied to individuals in the population. [18].In the fields of optimization, these algorithms were used to: optimize functions, process of images, solve trade man problem, identification systems and control and so on. In the area of machine learning, GA was used to implement simple “If-Then” rules in an arbitrary environment .Genetic algorithms are robust and adaptive methods, successfully used for solving optimization problems. They are powerful tools for the optimization of functions that can more easily locate the global optimum. The reason lies in the fact that GA seeks an optimal solution in the space of solutions, starting from groups of points, rather than a starting point.

GA use only the objective function to search optimal solutions (derivatives or other additional information on the function are not necessary). The basic building block in the GA is a population of individuals, which is usually between 10 and 200. Each individual represents a possible solution of the problem. The data processed by GA are represented by an array of strings (or chromosomes) with finite length, where each bit is called allele or gene. A value of the fitness function is attached to each individual, in order to evaluate its quality. A collection of strings is called population, and the population at a certain point of time is referred as generation. The generation of the initial population of strings is done in a random way. The basic operators on the genes in the chromosome are crossover and mutation. Reproduction of some selected chromosomes is a process in which certain binary strings are transformed and passed to the next generation. Selection is usually implemented through the so called process roulette wheel. The crossover is the main operator, which generates new strings, eventually with better fitness values. After crossover, mutation is performed to ensure some randomness in the new chromosomes. In fact, even though crossover generally leads to better results, this does not bring new quality of information on the level of bits. As a source of different quality, the mutation of bits is usually performed. Mutations can lead to degenerative solutions (which probably will be soon eliminated by the process), or to a completely new solution. These basic operators, as well as many other operators which can be applied depending on the problem, generate a new population, starting from the initial population and passing through an iterative process. This process creates a new population, which is estimated according to predefined criteria. The procedure repeats until the stopping criterion is satisfied.

The Genetic algorithm has to provide a way to permanently improve, from generation to generation, the absolute fitness for each individual in the population and the average adaptability of the whole population. This is achieved by successive application of genetic operators of selection, crossing and mutation, thus getting better and better solutions to the problems under consideration. Since a genetic algorithm is a stochastic search method, it is difficult to specify some convergence criteria. Fitness of the whole population may remain unchanged through

generations, while superior individuals appear. Because of that, the termination of the algorithm in the classical way (conditions satisfying) becomes problematic. Most often, in practice, genetic algorithm is stopped after a certain number of generations or after a certain time interval, after which the quality of the best individuals is tested. If the result is not acceptable, we can start again to search for new (better) solutions. [17]

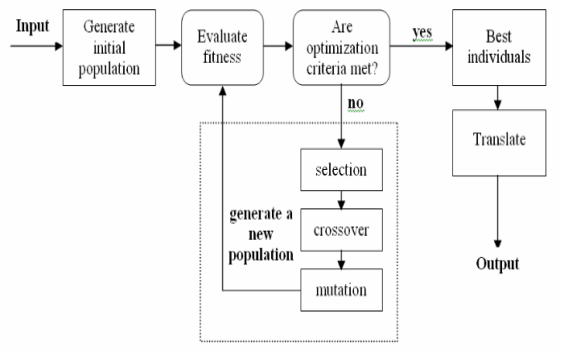

Fig1: flowchart showing the Genetic algorithm process

VII. THE LITERATURE REVIEW ASSOCIATED WITH THE GENETIC ALGORITHMS

1)Dusan petkovic, miroslav radovanovic had studied on mild steel used the GA for the optimization by considering the objective of cost minimization and concluded that Cost of machining in turning process, depending on cutting speed and feed was minimized under some nonlinear constraints. [17]

2)N.Zeelan Basha, G.Mahesh, N.Muthuprakash had studied effect of process parameter on Aluminum 6061,they had developed second order mathematical model is developed using regression technique of Box-Behnken of Response Surface Methodology (RSM) in design expert software 8.0 and optimization carried out by using genetic algorithm.[18]

3)Ramón Quiza Sardinas, Marcelino Rivas Santana, Eleno Alfonso Brindis had studied multi-objective optimization technique, based on genetic algorithms, to optimize the cutting parameters in turning processes: cutting depth, feed and speed. Two conflicting objectives, tool life and operation time, are simultaneously optimized. [19]

4) K.Saravanakumar, M.R.Pratheesh Kumar had carried out the work on Inconel718 by using the GA; they used the MINITAB software to solve the regression equations they had optimized input parameters such as cutting speed, feed rate, and depth of cut, etc., the output parameters like surface finish and metal removal rate can also be optimized for economical production. [20]

VIII. RESPONSE SURFACE METHODOLOGY (RSM)

Response Surface Methodology is combination of mathematical and statistical technique it is used develop the mathematical model for analysis and optimization. By conducting experiment trails and applying the regression analysis, the output responses can be expressed in terms of input machining parameters namely table speed, depth of cut and wheel speed. Response Surface methodology (RSM) has been adopted to express the output parameters (responses) that are decided by the input process parameters. RSM also quantifies the relationship between the variable input parameters and the corresponding output parameters. RSM designs allow us to estimate interaction and even the quadratic effects, and hence, give us an idea of the shape of the response surface we are investigating.

The major steps in Response Surface Methodology are:

- Identification of predominate factors which influences the surface roughness, Metal removal rate.
- Developing the experimental design matrix, conducting the experiments as per the above design matrix.
- Developing the mathematical model.
- Determination of constant coefficients of the developed model.
- Testing the significance of the coefficients.
- Adequacy test for the developed model by using analysis of variance (ANNOVA).
- Analyzing the effect of input machining parameters on output responses, surface roughness and metal removal rate

In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. RSM also quantifies the relationship between the controllable input parameters and the obtained response surfaces. [22]

IX. THE LITERATURE REVIEW ASSOCIATED WITH THE RESPONSE SURFACE METHODOLOGY

1)C. Ramudu, Dr.M.Naga Phani Sastry had carried out study on the aluminum alloy to evaluate the surface roughness and MRR and concluded that i) increase in wheel speed tends to improve the finish. With carbide tools particularly, slow speed is not at all desirable since it means wastage of time and money and tools wear out faster, increase in depth of cut makes the finish poor. Hence smaller values of table speed and depth of cut and larger value of wheel speed must be selected in order to achieve better surface roughness during the process.It is observed that increase in wheel speed tends to increase the MRR, depth of cut plays more vital role on MRR & Increasing the table speed, wheel speed and depth of cut leads to an increase in the amount of Material removal rate.[22]

2)Tanveer Hosssain Bhuiyan, Imtiaz Ahmed had carried out study for the cutting force on the AISI 1040 Steel in the dry lubrication keeping the depth of cut constant. The author had developed mathematical model with the help of RSM and also used GA approach for the cutting force optimization. The author has implemented MATLAB GA tool for the simulation. [23]3)Suleiman Abdulkareem1, Usman Jibrin Rumah and Apasi Adaokoma had carried out study on the mild steel in the investigation of the influence of the three most important machining parameters of depth of cut, feed rate and spindle speed on surface roughness by using the Box Behnken experimental design method as well as analysis of variance (ANOVA) and concluded that The feed rate is found to be the most important parameter effecting *Ra*, followed by cutting speed while spindle speed has the least effect [24]

4)M Manohar, Jomy Joseph, T Selvaraj, D Sivakumar had carried out study and used Box Behnken design approach to plan the experiments for turning Inconel 718 alloy with an overall objective of optimizing the process to yield higher metal removal, better surface quality and lower cutting forces and concluded that the region showing optimum conditions for achieving surface roughness is almost same in all the three cases (when v, f and d are kept constant) and are in agreement with each other. As the feed and the depth of cut are approaching minimum, the cutting forces generated are minimum and the obtained surface roughness is better.

X. ACO-ANT COLONY OPTIMIZATION.

Ant colony optimization is a new approach to solve complex optimization problem. It is a population based technique. This technique is based on behavior of real ants. ACO was presented as an effective optimization procedure by introducing bi-level search procedure called local and global search. The proposed ant colony algorithm for optimization of cutting conditions in multi-pass turning is shown as scheme in Figure 2. The distribution of ants [26]

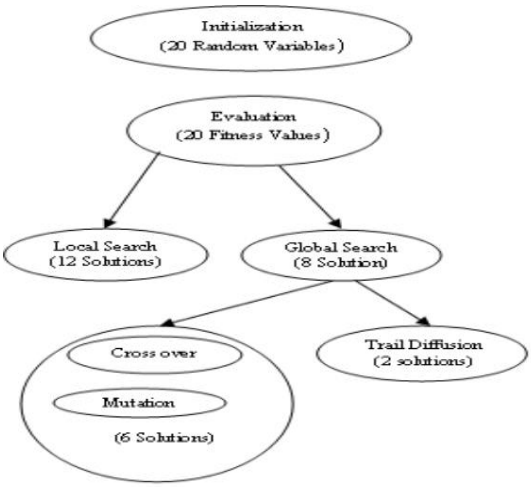

Fig 2: General Flowchart for Ant colony optimization

XI. ACOUSTIC EMISSIONS

Acoustic Emission, according to ASTM, refers to the generation of transient elastic waves during the rapid release of energy from localized sources within a material. The source of these emissions in metals is closely associated with the dislocation movement accompanying plastic deformation and the initiation and extension of cracks in a structure under stress. Other sources of Acoustic Emission are: melting, phase transformation, thermal stresses cool down cracking and stress build up acoustic emission

phenomena in non-distractive testing and tool monitoring. Acoustic emissions have become an important tool for instrumentation and monitoring due to the great advances in signal classification, instrumentation, and sensors.

XII. AE SIGNAL SOURCE

Research has shown that AE, which refers to stress waves generated by the sudden release of energy in deforming materials, has been successfully used in laboratory tests to detect tool wear and fracture in single point turning operations. Dornfeld (1989) pointed out the following possible sources of AE during metal cutting processes;

a) Plastic deformation during the cutting process in the work piece;
b) Plastic deformation in the chip;
c) Frictional contact between the tool flank face and the work piece resulting in flank wear;
d) Frictional contact between the tool rank face and the chip resulting in crater wear;
e) Collisions between chip and tool;
f) Chip breakage;
g) Tool fracture. [27]

XIII. THE LITERATURE REVIEW ASSOCIATED WITH THE ACO AND AE

1)Vaibhav B. Pansare, Mukund V. Kavade had carried out study to obtain optimum turning parameters for minimum surface roughness value by using Ant Colony Optimization (ACO) algorithm in multipass turning operation. ACO is problem independent so that it can be easily modified to optimize this turning operation under various conditions. It requires less number of iteration to reach to optimal solution [26]

2)Prof. Atul dhale, Fahim khan had proposed AE as non-contact and indirect technique for in-process surface roughness assessment in turning. Three cutting conditions dry cut, cutting with water as coolant and normal coolant were used. The material used in study is EN8. Three cutting parameters namely feed rate, depth of cut, cutting speed are optimized with consideration with surface roughness and concluded that i) It is found that feed rate is most important parameter effecting Ra followed by depth of the cut and spindle speed.ii) Machining with high spindle speed has positive effect on Ra as against the feed rate. Iii) As surface roughness increases AE rms value also increases. iv) Wet cutting condition during the turning has been proved better than dry cutting v) The appropriate selection of the cutting parameters will give better surface finish.[27]

3)Yigit Kazancoglu, Ugur Esme, Melih Bayramo glu, Onur Guven,Sueda Ozgun had carry out the study of the multi-response optimization of the turning process for an optimal parametric combination to yield the minimum cutting forces and surface roughness with the maximum material-removal rate (MRR) using a combination of a Grey relational analysis (GRA) and the Taguchi method and concluded that i) a proper selection of the cutting parameters produces a high material-removal rate with a better surface roughness and a lower cutting force.ii) the most effective parameters with respect to the material-removal rate, the cutting force and the surface roughness are the feed rate, the depth of cut and the cutting speed.[28]

4)R.A. Mahdavinejad, H. Sharifi Bidgoli had carry out the study for the analysis of the parameters affecting the surface finish in the dry machining by using neural network and concluded that i) when the cutting speed is increased the machined surface quality is improved. The quality of machined surface is decreased with the feeding rates and the depth of cut ii) in machining without any coolant, the plastic deformation of chips takes place so that, the friction between tool and chip surfaces will be decreased according to increasing of temperature zone. [29]

5)T. Tamizharasan had developed a mathematical model using multiple regression analysis and artificial neural network (ANN) model for artificial intelligent model. They found that depth of cut is most significant parameter followed by cutting speed, hardness of material and lastly feed rate. The mathematical model developed by multiple regression method shows accuracy of 97.41% which is reliable to be used on AE signal prediction. The result from this research is useful to be implemented in industry to reduce time and cost in AE signal prediction. [30]

6) R S Pawade has found that analysis of AE Signal during the machining could help to determine the quality of the machine surface. Frequency amplitude of the AE signal is influence by the cutting speed. The feed rate and edge geometry are found to influence the number of count generated during machining deformation. [31]

7) T S Reddy has done the turning operation using HSS tool on mild steel. The result shows significance relation between surface roughness and AE signals parameters. The conclusions are made for predicting surface roughness by suggesting consistence values and ranges for on-line monitoring of AE signals parameters .[32]

8) J Bhaskaran in study of hard turning used the skew and kurtosis parameters of AE signals to monitor tool wear. The moment parameters of AE rms signals such as skew and kurtosis can be used to reliably monitor the tool wear and surface roughness. [33]

CONCLUSION

From the brief literature review it can be concluded that

- In order to optimize the turning operation we can use various optimization techniques out of which Taguchi method is widely used by the various researchers.
- Genetic Algorithm approach can be successfully used for the multi objective optimization. There is much scope for the simulation.
- In order to optimize the turning operation, the various constraints consider by various researcher are speed, feed, depth of cut, type of lubrication used, material removal rate (MRR), tool vibration, power requirement, temperature generation, cost effectiveness, tool wear relationships., productivity improvement, step whether single or multistep, diameter and length of the work piece, hardness of the material, shape of the tool, type of material for work piece and tool, tool signature
- In order to optimize the turning operation the various material considered by various researcher are ANSI 1080 Steel,ANSI D2 Steel,ANSI 1050 Steel EN8 EN24T EN353 Aluminum 6061,Oil hardened Non shrinkable steel(OHNS), Austenitic Stainless Steel(AISI 202),AISI 1045,Aluminum 6063
- In order to optimize the turning operation the various tools considered by various researcher are HSS and cemented tipped tool,SN MGO 90204,Coated cemented carbide, Cermets - titanium carbonitride, Molybdenum high speed steel, Ceramics -Oxide ceramics like Mixed ceramics, Whisker-reinforced ceramics , Silicon nitride ceramics (Si_3N_4) ,Polycrystalline cubic boron nitride(CBN),Polycrystalline diamond (PCD

FUTURE SCOPE

From this brief literature review the many identified area for the optimization of turning are

i) From this brief literature review, it is observed that there is need of multi objective optimization for the parameters like “MRR, surface finish & the cost reduction”. Many researcher had till studied the single objective optimization by using the various optimization techniques but still the multi objective optimization particularly with the material like INCONEL 718,Aluminium had much scope for the further research. For the multi objective optimization there is need of universal program which can be done in MATLAB as well as in various languages.

ii) For the multi objective optimization the combination of RSM and GA is best for which the simulation can be done in the MATLAB

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