RESEARCH ARTICLE OPEN ACCESS

A Review on Experimental Investigation of Machining Parameters during CNC Machining of OHNS

Surabhi Lata[1], Ashish Gupta[2], Aditya Jain[3], Sonu Kumar[4], Anindya Srivastava[5], Ramakant Rana[6], Roop Lal[7]
[1](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[2](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[3](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[4](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[5](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[6](Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi-86)
[7](Department of Mechanical Engineering, Delhi Technological University, Delhi-42)

ABSTRACT
This review paper aims towards the optimization of CNC turning operation when used over an OHNS material. The lathe machine was chosen because of its widespread availability and its ability to perform various tasks without much change in its structure. Also using lathe machines is very cheap and hence it is beneficial from economic point of view as well. The turning operation was specifically chosen because of the various advantages that it offers. It can be used for machining a large variety of materials and it is cheaper than milling. OHNS (Oil Hardened Non Shrinking) tool was chosen due to its hardness. These materials are used only for dies so it was chosen so that its industrial usage could be exploited. To comprehend the usage, all the input and output parameters that could affect the machining process, namely input parameters like feed, cutting conditions, speed, etc. and output parameters like surface roughness, surface finish, material removal rate were analyzed using the researches that had already been done on CNC turning. After careful study of a variety of research papers on this topic, it was decided that several input as well as the output parameters would be considered which included feed, depth of cut and cutting speed were taken as the input parameters whereas Material Removal Rate (MRR) and surface finish were taken as the output parameters. From the results of the research papers, it was concluded that feed, depth of cut and cutting speed could be chosen as input parameters whereas MRR and surface finish would be the output parameters.
***Keywords*–**OHNS, CNC,

I. INTRODUCTION

Today, CNC machining has turned out to be an indispensable part of machining industry. The accuracy and precision achieved through CNC cannot be achieved by the conventional manufacturing machines. Although there is a room for errors in a CNC machine, these errors depend on the skill, experience and the cutting parameters used by the worker to get the proper dimensions. The machine performance and product characteristics are not always acceptable. Out of the various parameters which could be considered as the manufacturing goal, the material removal rate (MRR) was considered for the present work as the factor directly affects the cost of machining and the machining hour rate. Cutting speed, feed rate and depth of cut were considered to be the cutting parameters. The objective was to find the optimized set of values for maximizing the MRR and surface finish using various methodologies proposed by different authors.

In this paper, we have tried to compare various optimization techniques to identify the best among those. The Taguchi method emphasizes over the selection of the most optimal solution (i.e. MRR) over the set of given inputs (i.e. cutting speed, feed rate and depth of cut) with a reduced cost and increased quality.

To diminish the error while using an increased number of inputs, the orthogonal matrix of Taguchi is preferred, this can be selected as per the requirements of the person. In this technique, different levels of Orthogonal Array can be used to obtain optimized and economical results. The Taguchi method for the Design of Experiments also emphasizes over the use of Loss function, which is the deviation from the desired value of the quality characteristics. Based on the obtained Loss functions, the S/N ratio for each experimental set is evaluated and accordingly the optimal results are derived. ANOVA is then generated for the results and finally, the confirmations results are obtained between the experimental values and the determined values.

Response Surface Methodology (RSM) focuses on the optimization of the input parameters models based on either experimental observations, physical experiments or simulation experiments. These models need to be assessed statistically for their adequacy, and then they can be utilised for an optimisation of the initial model. RSM also quantifies relationships between the controllable input parameters and the obtained response surfaces. The input parameters are called independent variables, and the performance, measure or quality characteristic is the response. By using the results of a numerical experiment in the points of orthogonal experimental design, response surface analysis proves to be less expensive than a solution using the traditional method. With this analytical model, the objective function problem can be easily solved and a lot of time in computation can be saved. Response surface methodology problems have a functional relationship between responses and independent variables, and this relation can be explained using the second-order polynomial model given below:

$$\eta = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_i \sum_j \beta_{ij} X_i X_j + \varepsilon \quad (1)$$

Whereη, is the estimated response (surface roughness), β_0 is constant, β_i, β_{ii} and β_{ij} represent the coefficients of linear, quadratic, and cross-product terms, respectively. X reveals the coded variables.

The common approach in the RSM is to use regression methods based on least square methods. The method of least squares is typically used to estimate the regression coefficient, which is shown in the following equation.

$$\beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \dots \\ \dots \\ \beta_n \end{bmatrix} = (X^T X)^{-1} X^T \eta = \left[\frac{1}{k}\sum_{j=1}^{k} \eta_j, \frac{\sum_{j=1}^{k} X_{1j}\eta_j}{\sum_{j=1}^{k} X_{ij}^2}, \dots, \frac{\sum_{j=1}^{k} X_{nj}\eta_j}{\sum_{j=1}^{k} X_{nj}^2}\right]^T \quad (2)$$

Where η, is the number of objective function and k is the number of factors. The β terms comprise the unknown parameter set which can be estimated by collecting experimental system data. These data can either be sourced from physical experiments or from numeric experiments. The parameter set can be estimated by regression analysis based upon the experimental data.

II. Literature Review

Bagawade and Ramdasi (2014), analyzed the effect of the cutting parameters on the material removal rate (MRR), cutting power and material removal rate per cutting power during turning of AISI 52100 steel when using polycrystalline cubic boron nitride tools (uncoated PCBN (MITSUBISHI) insert). They concluded the following after analyzing the data from their experimentation:

- They found depth of cut to be the most important parameter affecting the material removal rate (MRR), followed by feed rate while cutting speed has the least effect.
- The optimal parameters for maximum MRR, found by them were as follow:
    - Cutting speed 350m/min., feed rate 0.05mm/rev., and depth of cut of 0.3mm.
    - The cutting speed is found to be the most important parameter effecting on cutting power (*PC*), followed by depth of cut while feed rate has the least effect.
- They recommended the following levels of process parameter, to get the good power consumption:
    - The lowest level of cutting speed, 250 m/min, the medium level of feed rate, 0.04 mm/rev and the medium level of depth of cut,0.2 mm.
- The cutting speed was found to be the most important parameter influencing the material removal rate (MRR) per cutting power (*PC*), followed by depth of cut while feed rate has the least effect in the optimization. The optimal parameters for the maximum MRR/cutting power were: Cutting speed 350 m/min., feed rate 0.05mm/rev., and depth of cut of 0.3mm. Machining with lowest cutting speed had a positive effect on material removal rate (MRR) per cutting power (*PC*).

Muthukrishnan et.al (2014), focused their study on optimizing turning parameters for Oil Hardened Non Shrinkable steel (OHNS) steel rod. They made use of the Taghuchi's technique with L9 orthogonal array as the methodology of design of experiment. For process parameters, feed, cutting speed and depth of cut were used as the process parameters. Surface roughness and material removal rate (MRR) were taken as the response parameters. S/N ratio was used for the optimization of process parameters and output results were analyzed using ANOVA.
They identified the problems associated with the turning of OHNS steel rods and listed them as:

- Poor surface finish
- Difficulty in achieving close tolerance
- Machining distortion
- Poor chip breaking
- High cutting pressure for machining.
- High hardness cutting tool required

On the basis of their experimental results the conclusion made was that cutting speed is the most significant parameter while considering surface roughness as a response parameter and feed was the most significant parameter for material removal rate.

K. Saraswathamma and MadhuDurgam (2014), they made a detailed study through a statistical

design of experiments which were carried out to study the effect of machining parameters such as Pulse current, Pulse on time(Ton) and Pulse pause time(T_{off}) on responses variables such as Material Removal Rate(MRR) and Tool Wear Rate (TWR) on OHNS Tool Steel. They designed the experiments using Response surface methodology (RSM) - Central Composite Design (CCD) involving three variables with three levels. They attempted to develop a mathematical model for relating the MRR and TWR to the input parameters.
Separate Analysis of Variance (ANOVA) was conducted and contribution of each parameter affecting improvement in MRR and TWR was calculated. They concluded that MRR and TWR increases with increase in pulse current and pulse on time.

After analyzing the results of the experiments of OHNS tool steel with copper electrode, they concluded:

- The increase in pulse current leads to a sharp increase in the material removal rate. And also it was observed that, tool wear rate are also increases with increasing the current. So, current was the most significant factor in both MRR and TWR.
- The increase in pulse on time leads to an increase in material removal rate and there is slight increase was observed with tool wear rate.
- The increase in pulse pause times both material rate and tool wear was decreasing.

R. Deepak Joel Johnson et.al (2014), they aimed to optimize cutting fluid usage in machining of Oil Hardened Non shrinkable Steel (OHNS) by Taguchi method. There are various methods of application of coolants, the major one being deluge or flood cooling which is essentially an application of cooling fluid in bulk. The huge amount of usage of cutting fluid increases production cost and also puts a pressure on the environment.

The result of the experiments was compared with wet and dry cutting conditions and it was concluded that:

- Cutting performance was improved with minimal cutting fluid application and was comparable to wet and dry turning.
- From their analysis of the results produced by Taguchi method and ANOVA, it was concluded that feed was the prominent factor which influenced surface roughness.
- They observed that surface roughness can be improved by tuning fluid application parameters.
- They also concluded that their experimentation results in lesser usage of cutting fluid which reduced manufacturing costs as well as promoted green shop floor and lesser health hazards to the operators.

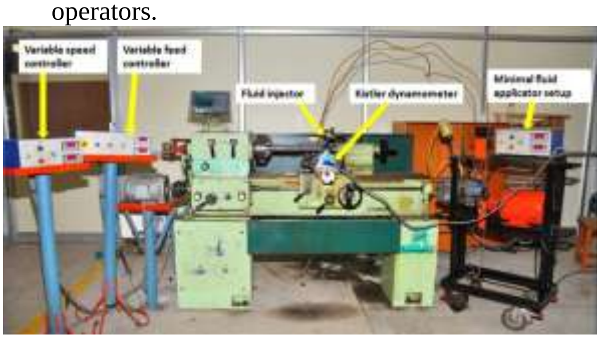

Figure 1- Experimental setup containing lathe and minimal cutting fluid applicator

Aouici et.al (2012), they conducted their experimental investigation to determine the effects of cutting conditions on surf-ace roughness and cutting forces in hard turning of X38CrMoV5-1. This steel was hardened at 50 HRC and machined with CBN tool. Combined effects of three cutting parameters, namely cutting speed, feed rate and depth of cut, on the six performance outputs-surface roughness parameters and cutting force components, are explored by analysis of variance (ANOVA). A relationship between the variables and the technological parameters was determined through the response surface methodology (RSM), using a quadratic regression model.

Their results showed that surface roughness is mainly influenced by feed rate and cutting speed. The depth of cut exhibits maximum influence on cutting force components as compared to the feed rate and cutting speed, whereas the cutting speed has negative effect and depth of cut a negligible influence.

Aggarwal et.al (2008), they experimented on CNC turning of AISI P-20 tool steel considering the effects of cutting environment, cutting speed, nose radius, feed rate, and depth of cut using Tin coated tungsten carbide inserts. Response surface methodology (RSM) and Taguchi's technique were used as design of experiment techniques to accomplish their objective. They used Face Centered Central Composite Design for conducting experiment along with L27 orthogonal array. Their results of 3D surface plots of RSM and Taguchi's technique revealed that the most significant factor in minimizing power consumption was cryogenic environment followed by cutting speed and depth of cut (DOC). On the basis of comparison they found that the effects of nose radius and feed rate were found insignificant. Although their results are predicted by the two techniques used by them were close to each other but, RSM technique was found to be more advantageous over Taguchi's technique.

They concluded after analysis by two techniques that, RSM displayed the significance of all possible interaction between the parameter and square of individual parameters whereas Taguchi's technique showed the significance of only few interactions thus 3D surface plots helps to analyze the response in the entire limit for an input parameter whereas Taguchi determines only the average values whereas Taguchi's technique is advantageous over RSM only in terms of the number of experiments performed as the number of experiments to be performed in Taguchi is much less than that in RSM.

Figure 2- Photograph of experimental setup

Ahilan et.al (2012) in this paper, they proposed the development of neural network models for optimization of machining input parameters in CNC turning process. Taguchi's Technique was used for the Design of Experiments (DoE) and experiments were conducted by them with feed rate, cutting speed, nose radius and depth of cut as the process parameter and performance parameters were taken as surface roughness and power consumption. Results from experiments were used by them to develop neuro based hybrid models .The influences of input parameters using ANOVA is identified by calculating the responses of Signal-to-noise (S/N) ratios.

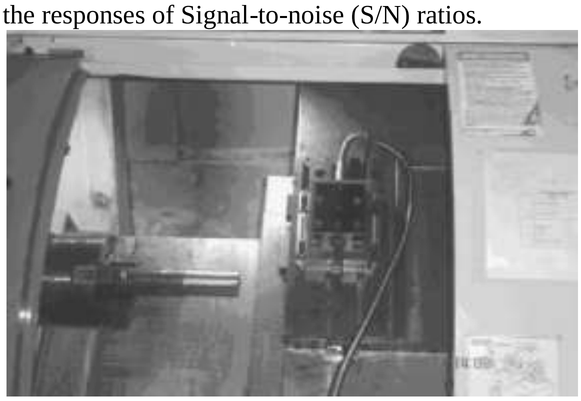

Figure 3 -Photograph of CNC experimental set-up

Neural network hybrid model developed and tested were:-

- Back propagation neural network model
- Neural network model trained with genetic algorithm
- Neural network with particle swarm optimization (NNPSO)

They concluded that among the 3 models developed NNPSO requires minimum time for computation as the number of epochs are minimum and is the most accurate, i.e., accuracy of the error is hardly within 2% among the three hybrid neural network models developed as it stores the P_{best} and G_{best} solutions.

Gowd et.al (2014) aimed at finding the optimal process parameters for turning process of EN-31.They chose EN-31 as the work material because of its wide applicability as material and because it has a very high resistance nature against wear and can be used for components subjected to severe abrasion, wear or high surface loading and as material for Ball and roller bearings, spinning tools, Beading rolls, Punches and dies. The experiments were performed as per their design of experiments, that is L-27, and then ANN is applied to predict the models for the chosen output responses. Then the ANOVA Analysis was used to test their adequacy.

Depth of cut, Cutting speed and Feed were taken as process parameters and the output responses were $F_x$and temperature. For different network configurations, as per the value of performance error obtained, the best model was identified and selected. The models were evaluated by calculating the percentage deviation using predicted values and actual values. The models were developed to predict the MRR and tool wear resistance through ANN. Their study optimizes the force and Temperature by adjusting the speed, feed, and depth of cut.

They concluded that:

- The speed and the depth of cut have great significance on the force and Temperature, whereas the feed has less significance on both the outputs.
- The best model was selected based on the best performance error for different network configurations.
- They also concluded that the developed ANN model can be further integrated with optimization algorithms like GA to optimize the turning parameters.

Routara et.al (2012), they used response surface methodology (RSM) to optimize parameters of cutting operation in CNC turning operation on EN-8 steel to minimize surface roughness. On the basis of their experimental results second order mathematical model was developed using RSM methodology. Coated carbide tool was used as tool material. They used the F-Test to check the validation of optimized condition. Optimization of parameters for surface roughness was also achieved with Genetic Algorithm. In the experimental readings the surface roughness of the machined part was checked using three methods i.e.

- Centre line average roughness (R_a)
- Mean line peak spacing (R_{sm})
- Root mean square roughness (R_q)

Surface roughness is a smaller yet better type of parameter in machining operation.
It was finally concluded that with an increase in spindle speed and depth of cut, surface roughness was observed to be decreasing but is increasing with the increase of feed.

Makadia et.al (2012), in their study they chose parameters such as feed rate, tool nose radius, cutting speed and depth of cut on the surface roughness of AISI 410 steel. A mathematical prediction model of the surface roughness was developed in terms of above parameters & their effect on the surface roughness was investigated by using Response Surface Methodology (RSM). They constructed Response surface contours for determining the optimum conditions for a required surface roughness. Their developed prediction equation showed that:

- The feed rate is the main factor followed by tool nose radius influences the surface roughness.
- The surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius.
- Response surface optimization shows that the optimal combination of machining parameters are(255.75 m/min, 0.1 mm/rev, 0.3 mm, 1.2 mm) for cutting speed, feed rate, depth of cut and tool nose radius respectively.
- They carried out verification experiment to check the validity of the developed model that predicted surface roughness within 6% error.

Mukherjee et.al (2014), they employed Taguchi method with L25 (5^3) Orthogonal Array for three parameters namely Speed, Feed and Depth of cut. For each of these parameters five different levels were used to perform the turning parameters for maximization of material removal rate on an EMCO Concept Turn 105CNC lathe. The material selected for machining was SAE 1020 with carbide cutting tool. The MRR is observed as the objective to develop the combination of optimum cutting parameters.

They produced a predictive equation for determining MRR with a given set of parameters in CNC turning. They concluded that with their proposed optimal parameters it is possible to increase the efficiency of machining process and decrease production cost in an automated manufacturing environment. Their analysis showed that Depth of Cut had the most significant effect on MRR followed by Feed and with an increase in Depth of Cut, MRR increased in the studied range.

Saini et.al (2014), in their research work CNC turning operation is carried out using L27 Taguchi orthogonal arrays on Aluminum alloy 8011 with carbide insert and influence of CNC turning process parameters like Cutting Speed, Feed and Depth of Cut are analyzed for two output objectives like material removal rate and surface roughness. They estimated optimum sets of turning process parameter as well as combined effect of considered response using Taguchi-Fuzzy application. In their analysis they found that feed is the mostsignificant process parameter followed by depth of cut and cutting speed on the selected response parameters.
They calculated SNR of objective functions using Taguchi quality method and amongst selected independent parameters, feed is found to be the most significant parameter followed by depth of cut and spindle speed for surface roughness while depth of cut is most significant parameter for material removal rate followed by feed and spindle speed. They further concluded that, using fuzzy reasoning, surface roughness and MRR which were taken as fuzzy crisp input and COM which was taken as output and the influence of selected independent parameters are estimated on fuzzy crisp output using Taguchi SNR analysis.
They found feed is most significant parameter on COM followed by depth of cut and spindle speed.

Goswami and Kumar (2014), they presented their investigation on wire wear ratio, surface finish and material removal rate using WEDM process taking Nimonic 80A as work piece and Taguchi's technique as design of experiments for planning and designing the experiments. Taguchi method was selected by them as DOE methodology as it tests only pairs of combinations instead of all possible combinations which allow estimation of relevant factors affecting the output, with little experimentation.

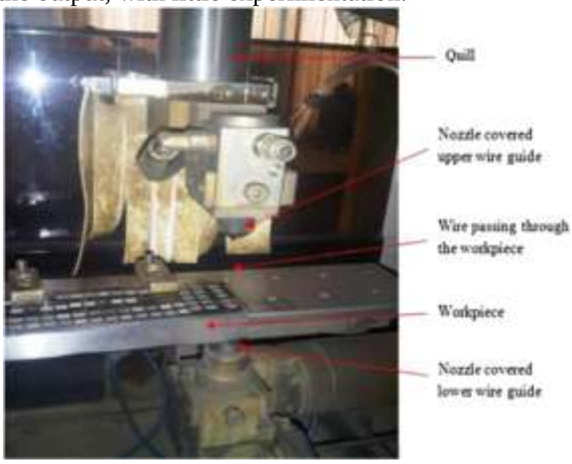

Figure 4 - Experimental setup of the WEDM

Sarikaya and Güllü (2013), studied the effect of cutting environment on the cutting conditions. The adverse effect of cutting fluids has been known on the environment, productivity and health for machining operations such as turning, facing etc. Surface finish was used as a performance parameter of machining processes and cutting speed, cooling condition, depth of cut and feed rate as process parameters. They used Taghuchi's L16 technique for Design of Experiment & 3 levels of cooling conditions i.e. conventional wet cooling (CC), dry cutting (DC), and minimum quantity of lubrication (MQL). They measured surface roughness using 2 methods mainly Arithmetic average roughness and Average maximum height of the profile (mm). Main effect graphs of means, 3D surface graphs and signal-to-noise ratios (S/N) were used to study the experiment results and optimize the process parameters. Response surface methodology was used to develop the mathematical model for R_z and R_a for optimization.

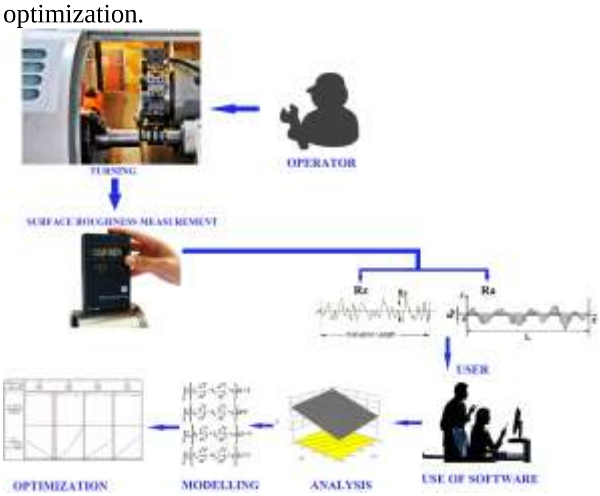

Figure 5- A schematic diagram of the experimental set-up

They concluded that the most effective parameters observed for surface roughness was feed rate. Effect of cooling conditions was also found to be a significant factor on the surface roughness. MQL was observed as an excellent tool to increase of the machined surface quality for machining operations.

AsilturkIlhan and NeseliSuleyman (2011), they checked surface roughness (Ra and Rz) of AISI 304 austenic stainless steel under dry conditions for CNC turning. They considered feed, depth of cut and cutting speed as parameters and tool used was IC 3028 grade carbide insert (SNMG 120408 PP). They designed the experiment by Taguchi method and then response surface analysis was done on it and they proved its adequacy further by ANOVA. S/N ratio was calculated by them and concluded that the plot with steepest ascent was the dominant factor.
They took following process parameters i.e. cutting tool parameters which took into account tool geometry and tool material; work piece parameters, namely metallography and hardness, and cutting parameters which were feed, depth of cut, cutting speed and cutting conditions.
They concluded:

- Feed rate is the dominant factor for surface roughness & its effect lowers when feed & depth of cut lowers and & cutting speed is set to highest level.
- Optimum cutting parameters for Ra were, cutting speed=50mm/min, feed=0.15mm/rev& depth of cut=1.5mm and optimum cutting parameters for Rz were, cutting speed=150mm/min, feed=0.15mm/rev & depth of cut=1mm.

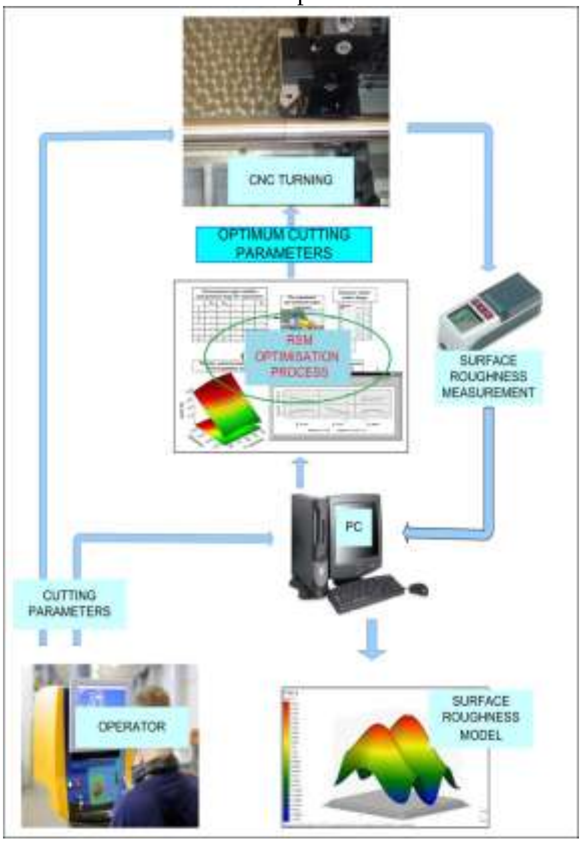

Figure 6- Experimental set up to measure the vibration of the process

KarayelDurmus (2008), they took surface roughness as the primary parameter and initially, the process parameters were kept at their highest values, so they also considered MRR. The experiment was to predict the roughness hence 1 parameter was variable and 2 were kept constant and iterations were done. 8000 iterations were considered and no smoothening was applied to it. They used Neural network approach for Design of experimentation. They used MATLAB for the formulation and tabulation of results. The specifications of the work piece used are 25mm (dia.) x100mm St50.2 steel. They concluded that feed is the most prominent factor in surface roughness followed by cutting speed. Depth of cut shows variable character or rather parabolic as the roughness first reduces and then increases again.

Gupta Anil et.al (2011), they used a hybrid approach of Taguchi and fuzzy logic to make a design of experiment. Work piece used was AISI P-20 tool steel and tool material was a tin coated tungsten carbide inserts. They considered cutting speed, feed, depth of cut, nose radius & cutting environment as machining parameters. The performance parameters were surface roughness, tool life, power consumption, cutting force. For optimum results, they used ANOVA, S/N ratio was calculated and concluded that the optimum values of the machining parameters were cutting speed= 160m/min, nose radius=0.8mm, feed=0.1mm/min, depth of Cut= 0.2mm& cutting environment= Cryogenic.

Raaste d. Koyee et.al (2014), theycombined the Taguchi approach with fuzzy-multiple attribute decision making methods for accomplishing a better surface quality in constant cutting speed face turning of EN 1.4404 austenitic, EN 1.4462 standard duplex and EN 1.4410 super duplex stainless steels. They used two conventional multiple attribute decision making techniques were concurrently to determine multi-surface quality characteristics indices. The distinction in rankings among derived indices are solved through converting each crisp values into trapezoidal fuzzy number and unifying them using fuzzy simple additive weight method. The fuzzy numbers are then deffuzified into crisp values employing techniques like; the spread, mode and area between centroid of centroids. Through this procedure, the decision maker is provided with necessary tools to optimize the cutting conditions with less sensitivity to the change of weights and no dissimilarity in ranking among the deffuzification techniques. Their outcomes of analyses of means and the validation experiments confirm that the optimum cutting conditions resulting from this method produce far better surface finish than the best finish obtained during the experiment. Analyses of variance results have shown the predominant effect of feed rate on surface quality. Finally, the collected chip at regular cutting speed and irregular feed rates and depth of cuts has shown that friendlier-to-machine chips are obtained when machining austenitic stainless steels rather than duplex stainless steel grades.

Zhang and liang (2006), in this paper, they discussed an orderly tactic for designing the optimal tool geometry and cutting conditions for hard turning, integrating the consideration of part finish, tool wear, and material removal rate. Their experiment has demonstrated that optimization scheme is presented at two levels: the first is to authenticate the process prediction results and the second is to validate the optimization results. Hardened AISI 1053 steel was selected as the work piece material in this study and its material property related parameters, including the Johnson–Cook constants and wear coefficients, were determined based on the machining tests. The authors saw that the cutting force and tool wear progression agrees well with the predictions from 3-D oblique cutting model, and the machined surface roughness can be predicted with a surface kinematic model incorporating the plowing effect. Their experiment also demonstrated that the process configuration as derived from the analytical optimization procedure gives superior results in comparison to other experimental results under non-optimal configurations.

In this paper, a systematic methodology to solve for the tooling solution and process planning decisions for finish hard turning process was presented and its validity examined experimentally. Firstly, the process planning problem was formulated and experimental validation scheme introduced. Then, the material property related parameters for hardened AISI 1053 steel were determined based on the machining tests. Afterwards, the process prediction results were compared with the experimental results. The authors found that the 3-D oblique cutting force model and tool flank wear model used gave reasonably good results, while surface roughness values strayed greatly from the measured results if the plowing effect was not accounted for. Also, there were no clear samples for the variation of surface roughness with the progression of the tool wear. An empirical model is established to add to the basic kinematic model in this study in predicting the average surface roughness value. Based on the validated process models, the optimal results are solved by a mixed integer evolutionary algorithm. The optimal configuration was further validated experimentally and found to be the best amongst all the experimental results under various combinations of process parameters.

Mctsai et.al (2003), they believed that the cutting occurs around the cutter contact (CC) point so the efficiency and quality of CNC machining can be improved considerably if the CC velocity along the surface is kept constant. They aimed to develop a real-time interpolation algorithm based on Taylor's expansion to bring to fruition a NURBS (non-uniform rational beta-spline) surface interpolator to achieve high-precision and high-speed CNC machining. The main point of a NURBS surface interpolator is to adjust the NURBS surface segments into each axis' motion command in order to synchronize all axes motion with the desired feed rate (CC velocity). The system's hardware includes a three-axis positioning table maneuvered by three servomotors, with built-in incremental encoders (2500 × 4 pulses/rev) for position feedback, and a PMC32-6000 motion control that incorporates a high

performance DSP, the TI TMS320C32 floating point processor. This setup can implement the following algorithms in real-time: (1) NURBS surface representation; (2) NURBS surface interpolator; and (3) servo controller. Experimental results have indicated that the proposed NURBS surface interpolator is capable of real time generation of CL (cutter location) motion commands for the servo controller and maintains the desired feed rate (CC velocity) along the CC paths and CC path intervals.
The authors have attempted to develop a novel NURBS surface interpolator for real-time CL motion command generation of parts represented in NURBS surface forms. This method was proposed to maintain a constant CC velocity rather than a constant CL velocity, in which an invariable CC velocity along a NURBS surface can enhance the machining efficiency and quality significantly. Their experimental results have signified that the proposed NURBS surface interpolator is competent enough for real time generation of CL motion commands for the servo controller and also maintains the required feed rate (CC velocity) along the CC paths and CC path intervals. Therefore, the machining efficiency and quality can be improved through the use of the proposed novel NURBS surface interpolator

III. Conclusion

This paper reviews the effect of various machining parameters on the performance parameters during turning operation. It further displays modern techniques of optimization as the powerful and popular tools for solving complex engineering problems.

1. In the turning operation, the machining parameters i.e. cutting speed, feed rate and depth of cut play a major role in deciding the performance parameters such as surface roughness, power consumption, tool wear and material removal rate.
2. The material removal rate (MRR) and power consumption shows a significant effect of depth of cut followed by feed rate and then by cutting speed. Increase in any of the input parameter increases the MRR as well as power consumption hence, optimization process requires any of the two performance parameters to be considered in one combination.
3. Surface roughness (SR) was found to be dependent on all these machining parameters. A decrease was exhibited by SR with an increase in cutting speed and feed rate while an increase was noted with the increase in depth of cut.
4. Depth of cut has the major impact on tool wear followed by cutting speed and feed rate.
5. The detailed study of various techniques shows that response surface methodology (RSM) is the most appropriate technique for machining operation because of its high accuracy and ability to consider input parameter in a particular range rather than at specific points for optimization. It further proves to be useful as a lot of information can be derived with few simulations.
6. 3^3 is considered as the most prominent design for experimentation as it has high accuracy within specific limit with minimum number of experiments.
7. The main difficulty was to turn OHNS with high surface finish and low tool wear. The feasible solution to this was the use of either CBN or PCD as turning tool.

In the paper, it was found that machining of OHNS was difficult and was usually carried out for milling operation. Turning of OHNS was done with the help of either CBN or PCD turning tools. Turning of OHNS using carbide tip as turning tool material though decreased the cost of machining but this was achieved at the cost of surface finish. Identifying appropriate combination of machining parameters to optimize turning of OHNS using carbide turning tool can increase the application of OHNS in small industries.

References

[1]. Aggarwal Aman, Singh Hari, Kumar Pradeep, Singh Manmohan, "*Optimizing power consumption for CNC turned parts using response surface methodology and Taguchi's technique—A comparative analysis*", Journal of Materials Processing Technology, 200, 2008, pp. 373–384.

[2]. Ahilan C., Kumanan, Somasundaram, Sivakumaran N., Dhas J. Edwin Raja*," Modeling and prediction of machining quality in CNC turning process using intelligent hybrid decision making tools*", Applied Soft Computing ,13 2013,pp. 1543–1551.

[3]. Gowd G. Harinath, Goud M. Venugopal, Theja K. Divya , Reddy M. Gunasekhar*," Optimal Selection Of Machining Parameters In CNC Turning Process Of EN-31 Using Intelligent Hybrid Decision Making Tools*", Procedia Engineering, 97 2014,pp. 125 – 133.

[4]. Routara B.C., Sahoo A.K., Parida A.K., Padhi P.C., *"Response Surface Methodology and genetic algorithm used to optimize the cutting condition for surface roughness parameters in CNC turning"*, Procedia Engineering ,38 2012, pp.1893 – 1904

[5]. N Muthukrishnan, T M Kannan, M Robert Sahayadoss, J Madhan, P Vijaya Kumar and R Makesk Kumar, "*optimization of turning parameters of ohns (aisi o-1) steel rods*

using taguchi methodology" Int. J. Mech. Eng. & Rob. Res.2014 346-352.

[6]. D. Bagawade, P. G. Ramdasi, "*Effect of cutting parameters on material removal rate and cutting power during hard turning of AISI 52100 steel*", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 1, January – 2014, SSN: 2278-0181.

[7]. AmiteshGoswami, Jatinder Kumar, *"Investigation of surface integrity, material removal rate and wire wear ratio for WEDM of Nimonic 80A alloy using GRA and Taguchi method"*, Engineering Science and Technology, an International Journal 17 (2014) 173-184.

[8]. Anil Gupta, Hari Singh, Aman Aggarwal, "*Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-20 tool steel*", Expert Systems with Applications 38 (2011) 6822–6828.

[9]. H. Aouici, M. A. Yallese, A Belbah, M. Fameur, M. Elbah, **"***Experimental investigation of cutting parameters influence on surface roughness and cutting forces in hard turning of X38CrMoV5-1 with CBN tool"*, *Sa¯dhana¯* Vol. 38, Part 3, June 2013, pp. 429–445. Indian Academy of Sciences.

[10]. K. Saraswathamma, MadhuDurgam, *"Parametric analysis of CNC EDM on OHNS tool steel"*, 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014) December 12th–14th, 2014, IIT Guwahati, Assam, India 561-1 – 561-6.

[11]. Durmus Karayel, *"Prediction and control of surface roughness in CNC lathe using artificial neural network*", journal of materials processing technology 209 (2009) 3125–3137.

[12]. Ashvin J. Makadia, J.I. Nanavati, "*Optimization of machining parameters for turning operations based on response surface methodology*", Measurement 46 (2013) 1521–1529

[13]. Sayak Mukherjee, Anurag Kamal, Kaushik Kumar, "*Optimization of material removal rate during turning of SAE 1020 material in CNC Lathe using Taguchi technique*" Procedia Engineering 97 (2014) 29 – 35.

[14]. Surendra Kumar Saini, Sharad Kumar Pradhan, "*Optimization of Multi-Objective Response during CNC Turning using Taguchi-Fuzzy Application*", Procedia Engineering 97 (2014) 141 – 149.

[15]. Murat Sarıkaya, AbdulkadirGüllü, "*Taguchi design and response surface methodology based analysis of machining parameters in CNC turning under MQL*", Journal of Cleaner Production 65 (2014) 604-616.

[16]. R. Deepak Joel Johnson , K. Leo Dev Wins, Anil Raj , B. Anuja Beatrice, "*Optimization of cutting parameters and fluid application parameters during turning of OHNS steel*", Procedia Engineering 97 (2014) 172 – 177.

[17]. M.C. Tsai, C.W. Cheng, M.Y. Cheng, "*A real-time NURBS surface interpolator for precision three-axis CNC machining*", International Journal of Machine Tools & Manufacture 43 (2003) 1217–1227.

[18]. Rastee D. Koyee, Rocco Eisseler, Siegfried Schmauder, "*Application of Taguchi coupled Fuzzy Multi Attribute Decision Making (FMADM) for optimizing surface quality in turning austenitic and duplex stainless steels*", Measurement 58 (2014) 375–386.

[19]. Jing Ying Zhang & Steven Y. Liang," *Process Optimization of Finish Turning of Hardened Steels, Materials and Manufacturing Processes*, 22: 107–113, 2007.

[20]. Ilhan Asiltürk, Süleyman Neseli, "*Multi response optimization of CNC turning parameters via Taguchi method-based response surface analysis*", Measurement 45 (2012) 785–794.