# Effect of Machining Parameters & Tool Types on Surface Roughness using Ball End Milling

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## 1. Introduction

### 1.1 Abstract

This work aims towards the optimization of CNC milling operation when used over an OHNS material. OHNS (Oil Hardened Non Shrinking) was chosen due to its mechanical properties like Thrust resistance, good durability & excellent wear resistant. 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 & tool coating were analysed using the researches that had already been done on CNC milling. 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, cutting tool type and cutting speed were taken as the input parameters whereas surface finish and selection of tool type for better surface finish were taken as the output parameters. From the results of the research papers, it was concluded that feed, cutting tool type and cutting speed could be chosen as input parameters whereas surface finish and selection of tool type for better surface finish would be the output parameters.

**Keywords:** OHNS, CNC

### 1.2 Introduction

The surface roughness of a milled surface is an important response parameter in finishing milling. The Ra parameter is one of the most commonly used criteria to determine the quality of milled steel. The input parameters were the spindle speed, cutting tool type, feed rate. The contact angle varied using a special device to simulate the several inclinations in a free-form surface. The results showed that the milled surface is a three dimensional geometry that is influenced by many parameters. The most important input parameter for the surface roughness, however, is the feed rate, and depending on the measuring direction; the feed rate can have a significant influence on the finishing [1].

Surface roughness plays a critical role in evaluating and measuring the surface quality of the machined a product in today's manufacturing industry. Surface roughness greatly affects the functional attributes of products which are friction, wear resistance, fatigue, lubricant, light reflection, and coating. Surface roughness is not only a quality indicator but is also the final stage in controlling the machining performance and the operation cost. End milling is one of the most popular and efficient operations for removing metal from the material surfaces highly used in automotive parts, moulds/dies, electronic devices, medical components, and other engineering applications. End milling operation is associated with surface roughness due to some requirements such as machining efficiency, high-quality surfaces, dimensional accuracy, and the process reliability [2,3].

According to Souza [4], the contact point between the cutter and the free-form surface is of great influence on the finishing. The authors support that not only can the feed rate and radial depth of cut influence the finishing quality, but also that the contact point can change the cutting mechanism. Figure 4 shows different contact points during the milling of a free-form surface. It can be noted that, when the machine tool has three axes, the feed rate and spindle speed are constant, but the cutting speed ($Vc_1$) changes constantly based on the cutter/work piece contact point. Furthermore, the cutting direction creates different cutting conditions, as can be seen in Figure 1. Upward and downward cutting have the same contact point and cutting speed, but different cutting mechanism due to the direction of displacement of the ball nose. According to Figure 1.1, the worst cutting situation occurs with the contact point (b) because the ball nose removes material with its centre, and because it has the lowest cutting speed.

For this reason the variation of work piece geometry regarding the surface inclination can influence the finishing. This study idelling separately the influence on the finishing of the variation of different inclinations provided by three contact angles. The inclination was defined complex processes such as through-feed centerless grinding to monitor dressing operation and that it provides information about form errors, such as roundness, surface roughness, and circularity. The variation of work piece geometry regarding the surface inclination can influence the finishing. This study idelling separately the influence on the finishing of the variation of different inclinations provided by the contact angles. The surface roughness was measured in two directions considering the feed rate direction and the radial depth of cut direction. The Ra parameter was chosen in this study due to the arithmetic average deviation from the mean line and because it represents the most accurate representation without the interference of peak and valleys from scratches and lines.

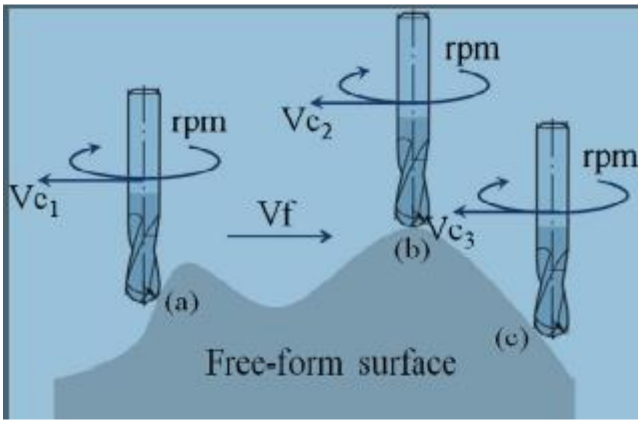


Figure 1.1: Contact Points During the Milling of a Free-Form Surface; (A) Upward End Milling, (B) Cutting with the Center of the Ball Nose, and (C) Downward End Milling [4].

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 surface roughness 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 cutting tool type were considered to be the cutting parameters. The objective was to find the optimized set of values for maximizing the 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 Factorial design method emphasizes over the selection of the most optimal solution (i.e. Surface finish) over the set of given inputs (i.e. cutting speed, feed rate and cutting tool type) with a reduced cost and increased quality.

## 2. Literature Survey

1) A. Bhattacharya, A. Batish and G. Singh have obtained more reliable global weight of different alternatives, and described various powder-mixed electric discharge machining (EDM) process. Seven different process parameters were tested to study their effect on material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) using a specially designed Taguchi orthogonal array that could accommodate factors with varying number of levels. A three-level array L27 was modified to include two-level factors using dummy treatment. The process conditions that affected the three responses were identified and optimized together using AHP for high carbon high chromium (HCHCr), EN31 and hot die steel (HDS) workpiece material. Addition of powder in the dielectric improved the MRR as the electrical conductivity of powder reduces the dielectric insulating strength. Current, powder, and electrode material significantly affected the TWR. Kerosene as dielectric was observed to be a superior alternative than EDM oil. Graphite electrode worked best for HCHCr and EN31 and W–Cu electrode worked best for HDS as they globally optimize the three output variables. Also, Cu powder suspended in the dielectric resulted in an optimal solution for HCHCr and HDS and tungsten powder was seen to be a better choice for EN31 to globally optimize the responses.
2) J. Pradeep Kumar, P. Packiaraj proposed utilizing taguchi method to investigate the effects of drilling parameters such as cutting speed (5, 6.5, 8 m/min), feed (0.15, 0.20, 0.25 mm/rev) and drill tool diameter (10, 12, 15 mm) on surface roughness, tool wear by weight, material removal rate and hole diameter error in drilling of OHNS material using HSS spiral drill. Orthogonal arrays of taguchi, the Signal–to-Noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are employed to idelling the effect of drilling parameters on the quality of drilled holes. A series of experiments based on L18 orthogonal array are conducted using DECKEL MAHO-DMC 835 V machining center. The experimental results are collected and idelling using commercial software package MINITAB 13. Linear regression equations are developed with an objective to establish a correlation between the selected drilling parameters with the quality characteristics of the drilled holes. The predicted values are compared with experimental data and are found to be in good agreement.
3) Nixon Kuruvila, H. V. Ravindra have determined the parametric influence and optimum process parameters of wire electro discharge machining (WEDM) using Taguchi's technique and genetic algorithm. The variation of the performance parameters

with machining parameters was mathematically modelled by regression analysis method. The objective functions are dimensional error (DE), surface roughness (SR) and volumetric material removal rate (VMRR). Pulse-on duration, current, pulse-off duration, bed-speed and flushing rate have been considered as the important input parameters. The matrix experiments were conducted for the material oil hardened non-shrinking steel (OHNS) having the thickness of 40 mm. The heat affected zone (HAZ) characteristics of the eroded material was assessed by scanning electron microscope (SEM) and the microhardness of the material was tested using Vickers microhardness tester. The results of the study reveal that among the machining parameters it is preferable to go in for smaller pulse-off duration for achieving over all good performance. Finally, the validation exercise performed with the optimum levels of the process parameters. The results confirm the efficiency of the approach employed for optimisation of process parameters in this study.

4) Amoljit Singh Gill1, Amit Thakur, Sanjeev Kumar: The use of Wire-cut electrical discharge machining (WEDM) has grown tremendously because of its capabilities to meet the requirements in various manufacturing fields, especially in the field of precision die industry. Surface finish is one of the most sort-out output parameter in field of precision die manufacturing. It is a machining characteristic that plays a very critical role in determining the quality of engineering components. Good quality surfaces improve the fatigue strength, corrosion and wear resistance of the workpiece. Cryogenic processing makes changes to the crystal structure of materials. The major results of these changes are to enhance the abrasion resistance and fatigue resistance of the materials. Present research work is an idelling to compare the surface roughness during wire electric discharge machining (WEDM), before and after cryogenic treatment of OHNS die steel work piece using Taguchi design approach. Input parameters were pulse on time, current, voltage and wire feed rate. It is found out that deep cryogenic treatment significantly improve surface finish.

5) Ajeet Bergaley, Narendra Sharma studied EDM machining used for very hard and complex cutting of conducting materials with higher surface finish and close dimensions. EDM process parameters are affected by both electrical and non electrical parameters. In these paper cutting of hard material high carbon high chromium (HCHcr) D3 steel is done on electro discharge machine with copper as cutting tool electrode. This paper presents a work on the performance parameter optimization for material removal rate (MRR) and electrode wear rate (EWR). There are electrical and non electrical factors which influences MRR and EWR such as voltage ,current pulse on time , pulse off time , dielectric fluid material , flushing pressure, tool rotation etc. In these paper both the electrical factors and non electrical factors has been focused which governs MRR, EWR and there optimization. Paper is based on Design of experiment and optimization of EDM process parameters .The technique used is Taguchi technique which is a statistical decision making tool helps in minimizing the number of experiments and the error associated with it. The research showed that the peak current has significant effect on material removal rate.

6) M. Melin, Jagadeesh Sridhar, M. Manickam, V. Kalaiyarasan, M. Abdul Ghani Khan and T. Kannan proposed a work on metal removal rate, which is an important performance factor to be considered in grinding process. Research activities, that include experimental work and statistical analysis, help in improving quality standards of manufacturing of components. Surface quality of OHNS steel after cylindrical grinding process is proposed to be studied in this experimental work using L9 orthogonal array selected for three levels and three input parameters. The inputs parameters are considered in this Experimental study are work speed, depth of cut and number of passes and response parameter is metal removal rate (MRR) during cylindrical grinding process. Higher metal removal rate is the main objectives of this machining process. The different machining parameters of OHNS steel of cylindrical grinding process are optimized by Signal to noise ratio and idelling by Analysis of variance (ANOVA’s)

7) R. Deepak, Joel Johnson, K. Leo, Dev Wins, Anil Raj, B. Anuja Beatrice; studied cutting fluids widely used in metal cutting to perform two major functions namely cooling and lubrication. The most common method of application of cutting fluid is flood or deluge cooling which involves bulk application of cutting fluid in the cutting zone. The copious usage of cutting fluid not only increases the production cost but also creates serious environmental and health hazards. In this present study, an effort was made to reduce the quantity of usage of cutting fluid and to optimize the cutting parameters and fluid application parameters while turning of Oil Hardened Non shrinkable steel (OHNS) with minimal cutting fluid application using Taguchi technique. The optimized results were compared with dry turning and conventional wet turning under similar cutting conditions. The results clearly indicated that minimal cutting fluid application enhanced the cutting performance by improving surface finish compared to dry and wet turning.

8) S Nizam Sadiq, T R Raguraman, D Thresh Kumar, R Rajasekaran observed that Oil-Hardened Non-Shrinkable (OHNS) steel has many applications in Manufacturing parts like Shaft, Gears and Tooling due to their excellent Mechanical properties. The continuous development of carbide milling cutter and its coating technology are great concern with manufacturing Environment. Titanium Aluminum Nitrite coating play an important role in milling cutter to produce better surface finish and tool life with minimum cost. In this Experimental investigation of face milling operation of OHNS steel plates with different process parameters like spindle speed, feed rate and depth of cut and to find optimal machining conditions of minimum surface roughness (Ra).The experiments are designed and conducted based on Taguchi’s design of experiments using L9 orthogonal array and idelling by ANOVA.

9) V. B. Pansare, S. B. Sharma have observed that the miniaturization of machine component can be perceived as a requirement for the future technological development of a broad spectrum of products. Micro-component fabrication requires reliable and repeatable methods, with accurate analysis tools. Surface roughness is one of the most important parameter in machining process. This study presents the results of test done with high-speed face milling tool. Also this research discusses an experimental approach to the development of mathematical model for surface roughness prediction before milling process by using ant colony optimization algorithm. This mathematical model is validated by optimization of cutting parameters for minimum surface roughness.

10) V. Sathiyamoorthy, T. Sekar and N. Elango studied the formation of spike sprevents achievement of the better material removal rate (MRR) and surface finish while using plain $NaNO_3$ aqueous electrolyte in electrochemical machining (ECM) of die tool steel. Hence this research work attempts to minimize the formation of spikes in the selected workpiece of high carbon high chromium die tool steel using copper nanoparticles suspended in $NaNO_3$ select catalytic, that is - nanofluid. These lected influencing parameters are applied voltage and electrolyte discharge rate with three levels and tool feed rate with four levels. Thirty-six experiments were designed using Design Expert 7.0 software and optimization was done using multi objective genetic algorithm (MOGA). This tool identified the best possible combination for achieving the better MRR and surface roughness. The results reveal that voltage of 18 V, tool feed rate of 0.54 mm/min, and nano fluid discharge rate of 12 lit/min would be the optimum values in ECM of HCHCr die tool steel. For checking the optimality obtained from the MOGA in MATLAB software, the maximum MRR of 375.78277 $mm^3$/min and respective surface roughness Ra of 2.339779 $\mu$m were predicted at applied voltage of 17.688986 V, tool feed rate of 0.5399705 mm/min, and nano fluid discharge rate of 11.998816 lit/min. Confirmatory tests showed that the actual performance at the optimum conditions was 361.214 $mm^3$/min and 2.41$\mu$m; the deviation from the predicted performance is less than 4% which proves the composite desirability of the developed models.
11) Sujeet G. Chaudhari, Prof. M. S. Harne have studied the crucialness of selection of optimum process parameters for machining processes. In this paper, a review of machining process parameters for different materials is done in cylindrical grinding. Machining of different materials is done by different researchers using cylindrical grinding. Various input parameters: wheel parameters such as abrasives, grain size, grade, etc. and work parameters such as: work speed, depth of cut, number of passes, feed rate, etc. are studied by researchers. This is revealed from the various research works that the above said parameters plays a vital role in achieving optimum value of MRR and Surface finish.
12) B. R. Dabhi, K. V. Parmar experimentally investigated the effects of output parameters for Tool Life and Material Removal Rate by varying machining parameters for Face Milling Tool. Design of experiment is created by Taguchi method using Minitab software. The signal-to-noise ratio is applied to find optimum process parameter for CNC Face milling. Experiment is carried out on OHNS AISI EO 300 by Face Milling Tool. Cutting Tool is Carbide tool with coating of TiCN with nose radius of 1.6 mm. A L 27 orthogonal array and analysis of variance are applied to study the performance characteristics of machining parameter (Spindle Speed, Depth of cut and Feed rate) with consideration of high MRR and maximum Tool Life have been identified. Result obtained by Taguchi Method and signal-to-noise ratio match closely by analysis of variance. Depth of cut is most effecting parameter for MRR and Tool Life.
13) S. M. Deshmukh, R. D. Shelke and C. V. Bhusare studied the cylindrical grinding metal cutting processes. It comes under finishing process. For that purpose Metal removal rate and Surface Roughness are the major output parameters in the production to maintain quantity and quality respectively. CNC cylindrical grinding machine is used for performing the experiments with Response Surface Methodology with input machining parameters as work speed, feed rate and depth of cut. The Surface Roughness will be studied in mathematical model by using response surface methodology (RSM). To check the validity of the model Analysis of variance (ANOVA) will used. The influences of all decided input parameters on Surface Roughness can be studied based on the developed mathematical model. Accuracy of the model can be checked with the testing data. The new model can be used in the different manufacturing firms by selecting right combination of machining parameters to achieve an optimal metal removal rate (MRR) and Surface Roughness (Ra). The results will show that the effect of work speed, feed rate and depth of cut are influencing parameters on the output responses metal removal rate (MRR) and surface roughness (Ra). The results would be further confirmed by conducting confirmation experiments.
14) S. Nallusamy: Electrical Discharge Machining is a machining method primarily used for hard metals or those that are impossible to be machined with the traditional techniques. The experimental investigation of material removal rate and tool wear rate during machining of oil hardened non-shrinking steel with brass and copper electrodes using EDM machine was carried out in this paper. This investigation presents the analysis and evaluation of heat affected zones and surface finish of the work piece using different tool electrodes and varying the machine parameters. The commercial grade kerosene oil has been used as dielectric fluid. The effect of various important EDM parameters such as discharge current (Ip) 2 to 12 A, pulse duration (Ton and Toff) and sparking voltage (V) of 80±5% have been used to yield the response in terms of Material Removal Rate (MRR) and Tool Wear Rate (TWR). Further a detailed analysis of the heat affected regions was also been carried out by using scanning electron microscopy.
15) Goutam Kumar Bose, Pritam Pain researched on Oil Hardened Naturally Shrinking (OHNS) work-material which is commonly used in plastic industries, and is considered for machining by WEDM process. Four different control parameters are deliberated to study the effect on the responses like material removal rate, overcut and surface roughness. To reduce the total number of experiment, L27 orthogonal array is used. Analysis of Variance is applied to attain the significant process parameters affecting the responses. The effect of the responses with the control parameters is plotted through S/N ratio graphs. To find the effect of the parameters on the responses and thereby developing a mathematical model regression analysis is done. The response data are examined using artificial neural network. Single objective parametric combination for each response is obtained using simulated annealing. A multi response optimization for the responses is done initially by using genetic algorithm and finally by applying Grey relational analysis.
16) Shaikh Abdul Haseeb, S. D. Ambekar: Near dry machining is the goal of today's metal cutting industry that tirelessly endeavours to reduce machining costs and impact from chemicals in the environment. Hard turning is a turning process done on materials with Rockwell C hardness greater than 45. It is typically performed after the work piece is heat treated. The process is intended to replace or limit traditional grinding operations. Hard turning can be applied for purely stock removal purpose or finishing purpose. In Hard turning, high amount of heat is generated at the tool chip interface which not only increase the tool wear but also deteriorates the job quality in terms of surface finish. In this study, MQL setup used for Near Dry Machining (NDM) in turning round bars of 25 mm diameter of Oil-Hardening Non-Shrinking Die Steel (OHNS – AISI

O1 grade) hardened to 53-57 HRC by TNMG 160404 MT TT5080 insert. The machining was carried out at three levels of Cutting Speed , Feed Rate (f), and Depth of cut to investigates the performance of MQL setup on Surface Roughness (Ra) and Machining time in hard turning of OHNS O1 grade. Full factorial (3k) DOE was employed and 27 experiments were idelling by using Response Surface Methodology (RSM) and regression equations were developed. ANOVA was used to find out the significant parameters. Feed rate is the most influential factor in increasing the surface roughness and decreasing machining time. Second influential factor for surface roughness is cutting speed which improves surface quality as speed increases and decreases machining time. Depth of cut has very less or no significance on both surface roughness and machining time. The optimum responses are at cutting speed of 190 m/min, feed rate of 0.0584616 mm/rev, 0.5 mm depth of cut and optimum machining time found to be 21.6065 sec producing surface roughness Ra to be 0.459032 µm.

17) Rahul Shivajirao Desai, M. V. Kavade optimized the tool used in industrial area for increasing quality of product by reducing the cost of product. In this paper, the experimental investigation of material removal rate (MRR), electrode wear rate (EWR) and surface roughness during machining on OHNS St1eel observed by using copper electrode on EDM machine. The input parameters used for experimental work are Peak Current (Ip), Pulse-On (Ton), Pulse-Off (Toff) and Rotation of ram. Based on the input parameters, the design of experiments are L9 orthogonal array. The optimization has been carried out by using Taguchi method as well as Grey relational analysis or Multi response optimization. Firstly single optimization has been carried out and then Multi response optimization has been carried out, for that Grey relational generation and coefficient are find out and then Grey relational grade is carried out. Then the confirmation experiments are carried out. According to this machining parameters are carried out to be optimized for combined objectives of higher MRR, lower EWR and lower SR. The results obtained from this optimization shows that GRA is very effective optimization technique than Taguchi method. Sensitivity analysis also used as a post analysis method.

18) E. Arun Kumar studied the manufacturing technology that is a driving force behind the modern economies since the industrial revolution. Although, manufacturing techniques have become more sophisticated in the improvement of industrial products and processes, the quality is designed, not manufactured into the product. The key element for achieving high quality and low cost is - parameter design. Through parameter design, levels of process factors are determined, product's functional characteristics are optimized and the effect of noise is minimized. The objective of that work is to apply Taguchi method to investigate the effects of milling parameters such as cutting speed, depth of cut and feed rate on surface roughness, MRR. The present work carrying on vertical milling machine and High Speed Steel is selected as cutting tool to machine the OHNS Steel.

19) Mangesh R. Phate, Shraddha B. Toney and Vikas R. Phate studied the Wire Electrical Discharge Machining (WEDM) of oil hardening die steel materials, a complicated machining process. Determining the best set of process parameters is an important step in the wire EDM process. In the present work, multi-response optimization of machining parameters was done by using a technique called desirability function analysis coupled with the dimensional analysis (DA) approach. The experimentations were carried out as per Taguchi's L27 orthogonal array for (Oil Hardening NonShrinking Die Steel) the OHNS die steel material. Parameters of the WEDM process, such as pulse on time, pulse off time, input current, wire feed rate, and the servo voltage, were optimized by a multiresponse optimization technique to optimize the responses such as material removal rate and surface roughness. Based on desirability analysis, the set of most idelling levels of parameters has been identified. The significant contribution of parameters is determined by dimensional analysis. From the experimental results, it has been observed that the DA approach is in good agreement with the measured responses. The correlation up to 99% has been achieved between the developed model and the measured responses by using dimensional analysis approach. Thus, the presented methodology can be used in the future for the critical analysis of any engineering process.

20) N. Sathiya Narayanana, N. Baskar, M. Ganesan studied the Oil-Hardened Non-Shrinking Die Steel (OHNS/AISI H13) employed in the production of callipers, plug gauges, thread gauges, punches and milling cutters for its hardness and good machinability performance. This experimental works focused on maximizing metal removal rate (MRR) and minimizing surface roughness (Ra) by choosing the optimal turning parameters. L27 Orthogonal array based experiments were conducted in CNC Supertech 6.2 turning centre using carbide insert CNMG 120408. The individual and interaction effects of cutting speed (v), feed rate (f) and depth of cut (ap) on MRR and Ra is idelling in Design Expert 9.0 Software. Empirical models are framed which reveals the relationship between the turning parameters and output responses. Non-Traditional optimization technique genetic algorithm is used with multi objective function to find the optimum parameters in turning AISI H13 steel materials. Confirmation experiments are performed to validate the optimum results of genetic algorithm and it is within the acceptance limit.

21) M. Rajesh, M. Sudhahar studied the Electrical discharge machining (EDM), a nonconventional machining process used to manufacture intricate profiles, complex shapes, process hard materials that are extremely difficult to machine by conventional machining processes. This thermo electric machining technique is continuously emerging from a mere tool and dies making process to a micro scale machining applications. In recent years, researches have emphasized on process performance like material removal rate (MRR), tool wear rate (TWR), surface roughness (SR). Powder mixed electrical discharge machining (PMEDM) has emerged as one of the advanced techniques in the direction of the enhancement of the capabilities of EDM. The use of powder mixed electrical discharge machining helps overcome this drawback and increases the efficiency of the machining process. A suitable selection of tool can reduce the cost of machining. In the present experimental work, a study has been made to optimize the process parameters of powder mixed electrical discharge machining (PMEDM). This study focused on the machining of OHNS using graphite powder. The experiments were carried out as per L9 orthogonal array with DOE principle. Each experiment was performed under different conditions such as Ampere rating, pulse on time and pulse off time. The optimal factor for Surface Roughness was obtained, when Pulse on time is 8 µs, Pulse Off time 6 µs and Amps-

12 and Machining timing was Pulse on time is 10 μs, Pulse Off time 8 μs and Amps-10 and MRR was obtained Pulse on time is 10 μs, Pulse Off time 4 μs and Amps-14. Particularly surface roughness depending on the pulse on time.

22) Doneti Gopi Krishna, Naligani Sandeep, Oddarapu Kalyani, P. Revanth, Rokkam Aravind Kumar, Sandeep Kumar Raj studied the OHNS high carbon steel. Its machining is hindered, due to higher hardness value. The present experimental work is focused on optimizing the machining parameters in milling OHNS material with carbide insert for a best parametric combination to render the lowest cutting force using a Taguchi method. The cutting speed, feed rate & depth of cut were used as process parameters whereas Cutting force is selected as performance characteristics. Based on Taguchi's L9 orthogonal array, nine experimental runs have been executed, accompanied by ANOVA method to solve the multi-response optimization problem. Based upon S/N ratio values & ANOVA results, best levels of parameters have been identified. The percentage contribution of influence of each process parameter on individual performance characteristic was idelling with the help of experimental results obtained using Taguchi Method. The depth of cut and speed were identified as the most influential process parameters on cutting forces.

23) B. Baskar, B. Shanmugasundaram, P. Lakshmanan, K. Balakannan. Their work concerned an experimental study of turning on Steel grade of EN8, Mild steel and OHNS by a Tungsten and cemented coated carbide insert tool. The primary objective of the ensuing study was to use the Taguchi Methodology in order to determine the effect of machining parameters viz. cutting speed, feed, and depth of cut, On the Temperature, Hardness and Surface roughness of the machined material. The objective was to find the optimum machining parameters so as to minimize the surface roughness and Temperature for the work materials in the chosen domain of the experiment. Temperature was measured using a digital thermometer; Surface Roughness was measured using a Mitutoyo surface tester and hardness with the help of a Brinell hardness tester. The data was compiled into Minitab 18 for analysis. Taguchi and Analysis of Variance (ANOVA) were used to investigate the significance of these parameters on the response variables with the machining parameters as the independent variables, with the help of a Minitab. Results showed that cutting speed is the most significant factor affecting the surface roughness and hardness, closely followed by feed and depth of cut, while the only significant factor affects the temperature was found to be the depth of cut.

24) Jafrey Daniel, James Dhilipa, J. Jeevana, D. Arulkirubakaranb and M. Ramesh. Their work focusses on turning of hardened material which has idelling hardness of C scale ranging from 45 to 70. Oil Hardened Non-Shrinking Die Steel (OHNS) finds its application in manufacturing of punches and cutters for milling due to its hardness and better machining. This work focuses on maximizing the material removal rate (MRR) and minimizing machining time and surface roughness. Turning was done using a carbide insert out using a computer numerical control machine. The experiments were done according to L'9 array and the output characteristics were idelling. The percentage of contribution of input parameters when compared with output parameters were idelling using analysis of variance. Grey relational analysis was used for optimizing the output characteristics. After idellingon confirmation experiment was carried out for validation of results.

25) Mangesh Phate, Shraddha Toney and Vikas Phate studied the Wire EDM is a complicated machining process that is used for producing complex 2D and 3D shapes. In this work, the process parameters associated with the wire electrical discharge machining (WEDM) of oil hardening non-shrinkage (OHNS) die steel material were investigated through response surface method (RSM) and an artificial neural network (ANN). A quadratic model developed through RSM was used to predict material removal rate (MRR) with appreciable precision. The various input variables, viz. pulse on time (PON), pulse off time (POFF), wire feed rate (WFR) and input current (I), have been considered. A comparison between the predicted and measured values of MRR was performed for each experiment. It was noted that the RSM predicted values are in a 95%confidence interval. Statistical analysis shows the capabilities of the developed models to predict the MRR more accurately. Also, ANN model estimates MRR with high precision compared using the RSM model. Support vector regression (SVR) is also used to idellig the impact of various process parameters. The results show that all approaches are strongly capable of predicting the response. Analysis the WEDM is a very effective. Of the three approaches ANN is superior.

26) M. Prabhakaran, D. Madam, K. Anandan, C. Sivakandhan studied the essential role of cryogenic treatment played in fabrication of the products with high quality and improved substance properties. The present experimental work has to improve the substance properties of Oil Hardened Non Shrinkage (OHNS) steel. Through conventional treatment, there was no possibility to increase the substance properties of steel. In cryogenic treatment process, the OHNS steel was processed under —190 °C. The cryo processor was used to treat the OHNS steel. The substance properties such as hardness and wear rate was measured through the variation of cooling rate, flow rate of liquid nitrogen and holding time.

## 3. Objective

### 3.1 Literature Gap

The largest amount of money spent on any one class of cutting tools. Therefore, from the viewpoint of cost and productivity, idelling and optimization of drilling processes are extremely important for the manufacturing industry (S.A. Jalali et.al 1991). Amongst traditional machining processes, milling is one of the most important metal cutting operations, comprising all metal cutting operations (Chen W C et.al, 1999). Although modern metal cutting methods have tremendously improved in the manufacturing industry. After the study of literature survey we found that, Many researcher's are focused their work on process optimization on different machining, There is less attension given in optimization of cutting parameters for the study of surface roughness in OHNS material using ball nose end mill. So there is need of more work in this topic.

### 3.2 Problem Statement

OHNS steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools such as Blanking and stamping dies, Punches, Shedder used in compound press tool, Chilvent use in Die-Casting-Die, Rotary shear blades, Thread cutting tools, Milling cutters, Reamers, Measuring tools, Gauging tools, Wood working tools, Broaches and Chisels. The specific properties of OHNS steels are hardness, resistance to abrasion, ability to hold a cutting edge, and resistance to deformation at elevated temperatures

The OHNS Steel which cannot machined using conventional technique due to the problem be such as:

- High surface roughness
- Difficult to achieve close tolerance
- Poor chip breaking

Figure 3.2.1: Stamping Dies

Figure 3.2.2: Chill-vent usage in Die-casting Die

Figure 3.2.3: Forming Tool Dies

**3.3 Objective**

- To analyse and optimise the milled surface quality considered in Ra surface roughness.
- Comparative study in between TiAln coated & Carbide end mill cutter for better surface finish.

## 4. Experimental Resources

### 4.1 Experimental Materials

In the research, the work piece material selected for machining is Oil Hardened Non-Shrinkage steel (OHNS) Shown in Figure 4.1.1. OHNS steel is a general purpose tool steel that is typically used in applications where alloy steels cannot provide sufficient hardness, strength and wear resistance. Chemical composition of OHNS is Carbon 0.94%, Manganese 1.2%, Silicon 0.30%, Chromium 0.50% and Vanadium 0.15% [6].

Strength of a metal determines the extent to which it may deform when load is applied on it. Strength can be measured based on various parameters, such as the maximum ability to take strain, resistance to wear and tear, impact handling, or how the material performs when subjected to frequently changing load conditions. Strength generally increases as the carbon and manganese content increases. Given the high percentage of both of those, OHNS Tool Steel is strong. Hardness of a material indicates its resistance to get indented that is not temporary (i.e.; it persists even after the load conditions are removed, as opposed to the strength that is an indication of its performance only when the load is applied), and carbon is also the primary hardening element in steel. The Rockwell method measures the hardness of OHNS Tool Steel to be in the range of 52 HRC to 54 HRC (this is the most commonly used measurement technique).

Toughness of a material determines whether it can be subjected to shock conditions, and the extent to which it may undergo deformity in shape but still not snap. If subjected to a proper treatment process, OHNS Tool Steel tends to be very tough. As opposed to toughness, brittleness measures whether a material will snap instead of getting deformed, when load is applied. Alloy steels like OHNS Tool Steel are less brittle than cast or pig iron because of the presence of magnesium.

Figure 4.1.1: Finished Workpeice OHNS Material

### 4.2 Tool/Workpiece Material and Equipment

Rectangular blocks of Heat treated having material OHNS with raw dimensions are approximately 160 mm × 70 mm × 40 mm were used with a hardness of 52-54 HRC, The Rockwell hardness tester is shown in figure 4.2.1 . All the cutting tools used were 6 mm diameter ball nose end mills with two teeth. These had a 30° helix angle and 10° rake angle and were manufactured from K10 grade carbide. The tools employed commercial carbide and TiAlN coatings and were collect mounted in a BT40-CTH10-60 Mizoguchi toolholder. Table 4.2.1 details selected mechanical and physical properties for the coatings [7]. A longer than normal tool overhang of 40 mm was employed in order to simulate industrial practice when machining turbine blades. All the machining trials were carried out on a DECKEL MAHO DMU 50 T CNC machining centre shown in figure 4.2.2, with continue speed up to 14000 rpm and 14 kw spindle power, a feed rate up to 13 m/min.

The mean surface roughness Ra is measured with a Mitutoyo surftest SJ-201 Series 178-portble surface tester instrument shown in figure 8.

| Mechanical/Physical property | TiAlN |
|---|---|
| Hardness (HV) at 20 °C | 3000-3300 |
| Oxidation Resistance (°C) | 840 |
| Coefficient of fraction | 0.4 |

Table 4.2.1 Mechanical and Physical Properties of PVD Coating Employed

Figure 4.2.1: Rockwell Hardness Tester


Figure 4.2.2: DECKEL MAHO DMU 50 T CNC Machining Centre

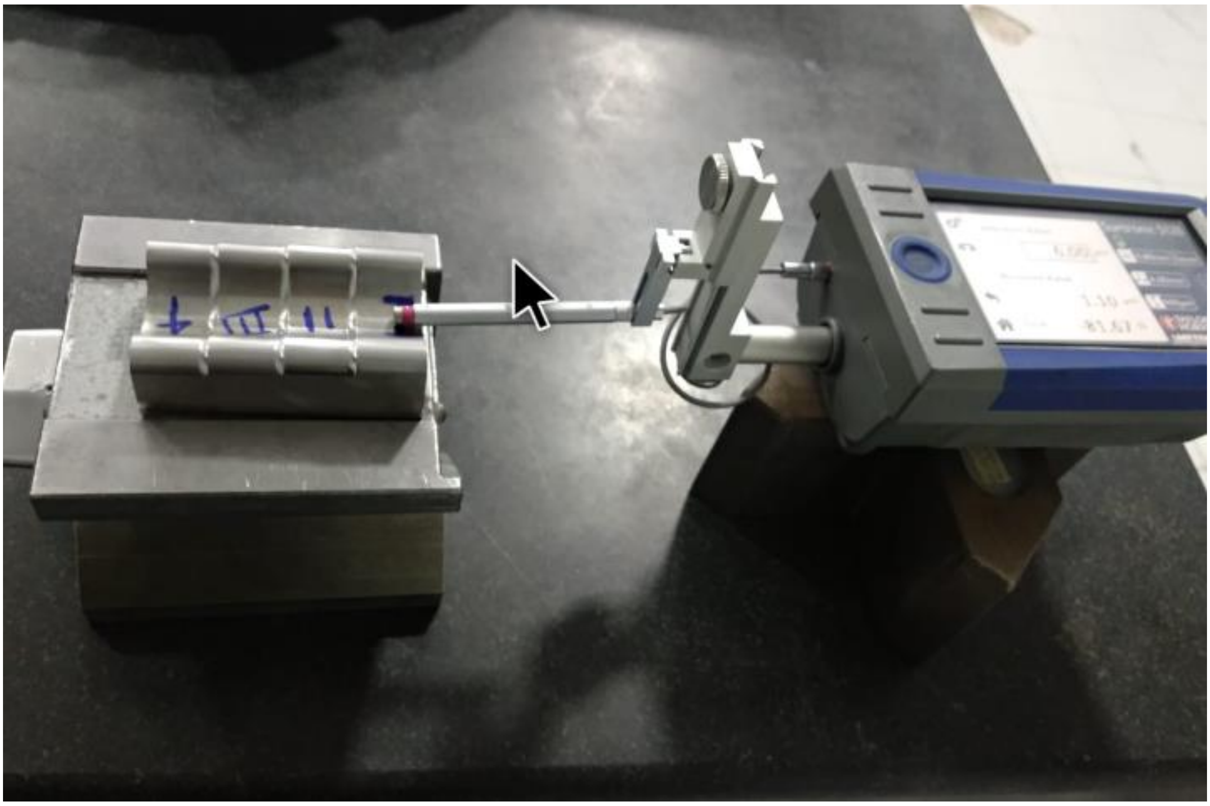

Figure 4.2.3: Mitutoyo Surftest SJ-201 Series 178-portble Surface Tester Instrument

## 5. Experimental Methodology

### 5.1 Experimental Procedures

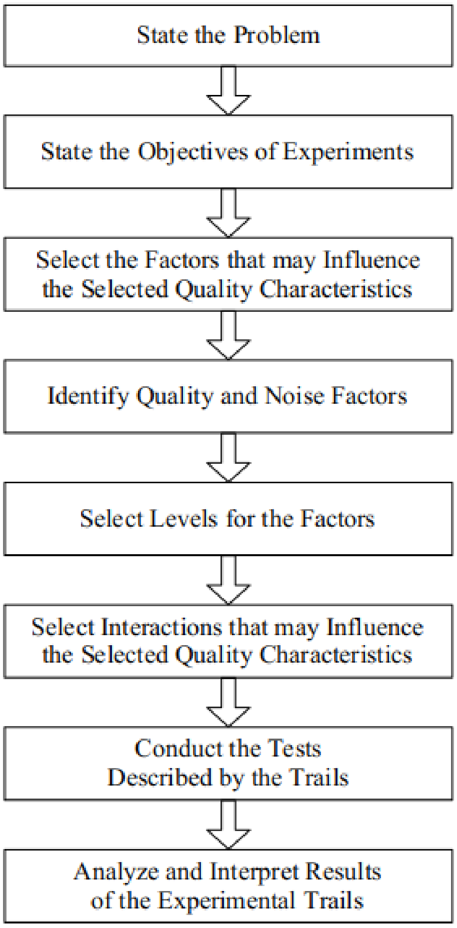


Figure 5.1.1: Steps Involves to Execute the Project

Machining trials were designed to investigate tool wear when cutting with the workpiece at an angle from the horizontal. In this configuration, the centre of the ball nose end mill, which was effectively at zero cutting speed, was not engaged. Depths of cut of 0.08 is constant for all operation, were used throughout the trials together with a feed rate of 1000 & 1146 mm/min. In addition, all trials were performed with Servo cut lubrication cutting oil and the tool cutting in a horizontal downwards climb milling configuration. A list of variable operating factors and levels is shown in Table 2. The cutter approach to the workpiece (horizontal downwards) was shown to be the best, in terms of tool life, by a parallel study [8]. A $2^3$ full factorial experiment was undertaken which entailed 8 trials. During the trials, ISO 8688-2 [9] was followed as closely as possible. Horizontal cuts of 160 mm in length were taken across the workpiece. Surface roughness measurements were made at intervals of cut curvature depending on the level of wear experienced. The tests were stopped when the maximum wear/chipping at any point on the tool reached 0.1 mm. A statistical analysis was subsequently carried out based on tool life/length cut, together with SEM tool wear evaluation. The programs are created by employing Unigraphics NX-10 CAD/CAM software on a personal computer. The mean surface roughness Ra is measured with a Mitutoyo surftest SJ-201 Series 178-portble surface tester instrument.

Table 5.1.1: Variable Operating Factors and Levels for the Machining Trials

| Sr No | Variable factor | Levels |
|---|---|---|
| 1 | Spindle Speed (RPM) | 6000, 6370 |
| 2 | Feed (mm/min) | 900, 1146 |
| 3 | Coating | Carbide, TiAlN |

### 5.2 Data Analysis

$2^3$ full factorial experiment was undertaken which entailed 8 trials on minitab Software, and we get the further Results from that:

| Sr No | Cutter Type | Speed (RPM) | Feed (mm/min) | Surface Roughness, Ra Value (µ) | FITS1 | RESI1 |
|---|---|---|---|---|---|---|
| 1 | TiAln | 6170 | 1000 | 0.560 | 0.55950 | 0.00050 |
| 2 | TiAln | 6370 | 1000 | 0.690 | 0.70525 | -0.01525 |
| 3 | Carbide | 6370 | 1146 | 0.834 | 0.83875 | -0.00475 |
| 4 | TiAln | 6170 | 1146 | 0.606 | 0.56975 | 0.03625 |
| 5 | TiAln | 6370 | 1146 | 0.694 | 0.71550 | -0.02150 |
| 6 | Carbide | 6170 | 1000 | 0.656 | 0.68275 | -0.02675 |
| 7 | Carbide | 6170 | 1146 | 0.683 | 0.69300 | -0.01000 |
| 8 | Carbide | 6370 | 1000 | 0.870 | 0.82850 | 0.04150 |

Table 5.2.1: $2^3$ Full Factorial Experiment Run Table

| Factor | Levels | Values |
|---|---|---|
| **Cutter Type** | 2 | TiAln, Carbide |
| **Spindle Speed** | 2 | 6170, 6370 |
| **Cutting Feed** | 2 | 1000, 1146 |

Table 5.2.2: Factor Information

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| **Model** | 3 | 0.073077 | 0.024359 | 21.32 | 0.006 |
| **Linear** | 3 | 0.073077 | 0.024359 | 21.32 | 0.006 |
| **Cutter Type** | 1 | 0.030381 | 0.030381 | 26.59 | 0.007 |
| **Spindle Speed** | 1 | 0.042486 | 0.042486 | 37.19 | 0.004 |
| **Cutting Feed** | 1 | 0.000210 | 0.000210 | 0.18 | 0.009 |
| **Error** | 4 | 0.004570 | 0.001142 | | |
| **Total** | 7 | 0.077647 | | | |

Table 5.2.3 Analysis of Variance

| S | R-sq | R-sq (adj) | R-sq (pred) |
|---|---|---|---|
| 0.0337990 | 94.12% | 89.70% | 76.46% |

Table 5.2.4: Model Summary

| Term | | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|---|
| **Constant** | | 0.6991 | 0.0119 | 58.51 | 0.000 | |
| **Cutter Type** | **TiAln** | -0.0616 | 0.0119 | -5.16 | 0.007 | 1.00 |
| **Spindle Speed** | **6170** | -0.0729 | 0.0119 | -6.10 | 0.004 | 1.00 |
| **Cutting feed** | **1000** | -0.0051 | 0.0119 | -0.43 | 0.009 | 1.00 |

Table 5.2.5: Coefficients

**Regression Equation**

Surface Roughness = 0.6991 – 0.0616 Cutter type_TiAln + 0.0616 Cutter type_Carbide
- 0.0729 Spindle Speed_6170 + 0.0729 Spindle Speed_6370
- 0.0051 Cutting feed_1000 + 0.0051 Cutting feed_1146

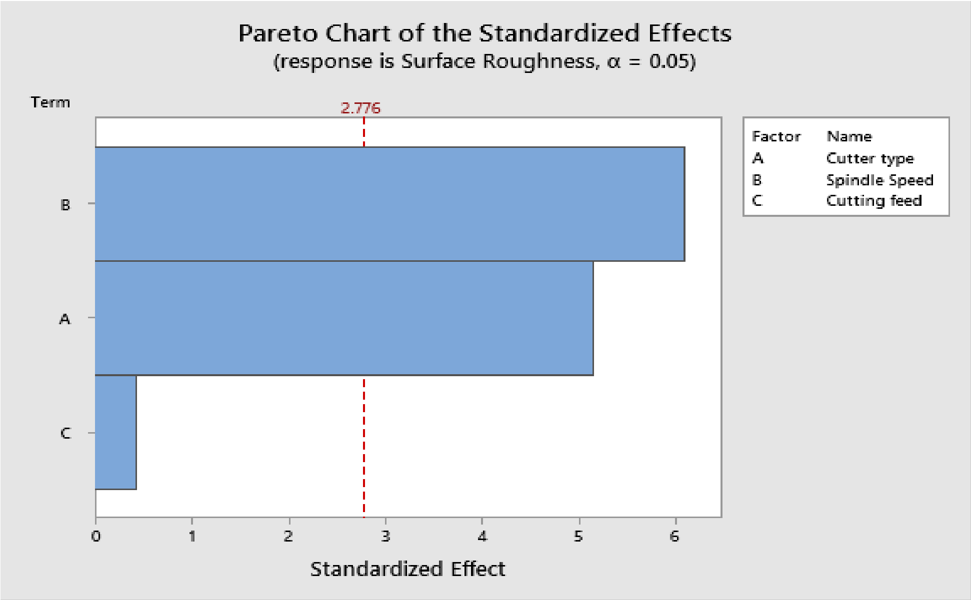


Figure 5.2.1: Pareto Chart of the Standardize Effect

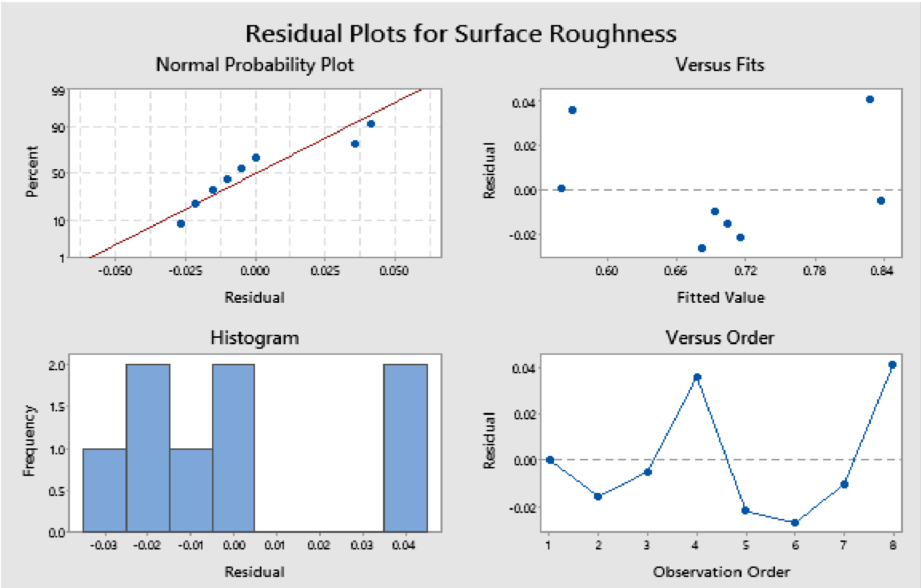


Figure 5.2.2: Residual Plots for Surface Roughness

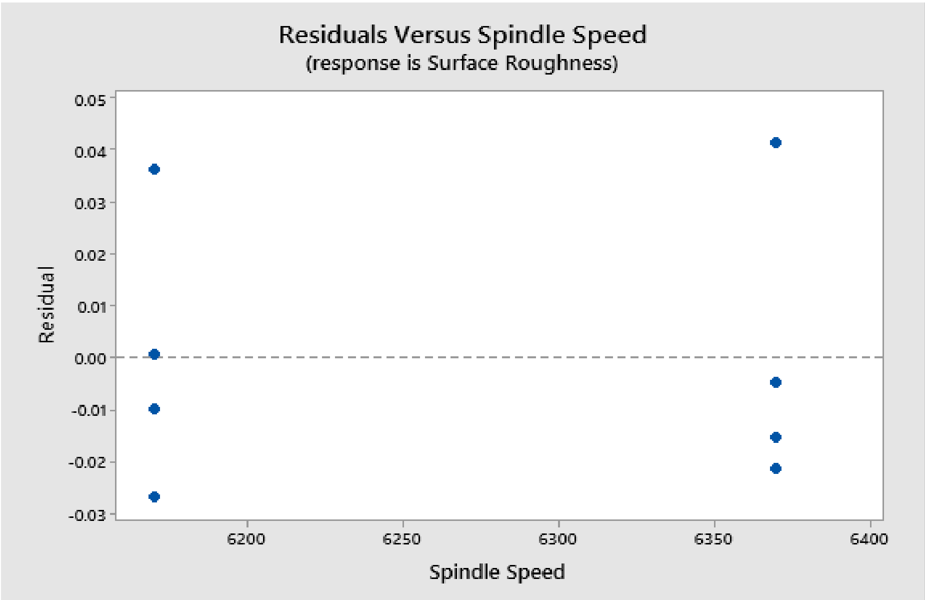


Figure 5.2.3: Residual versus Spindle Speed Response

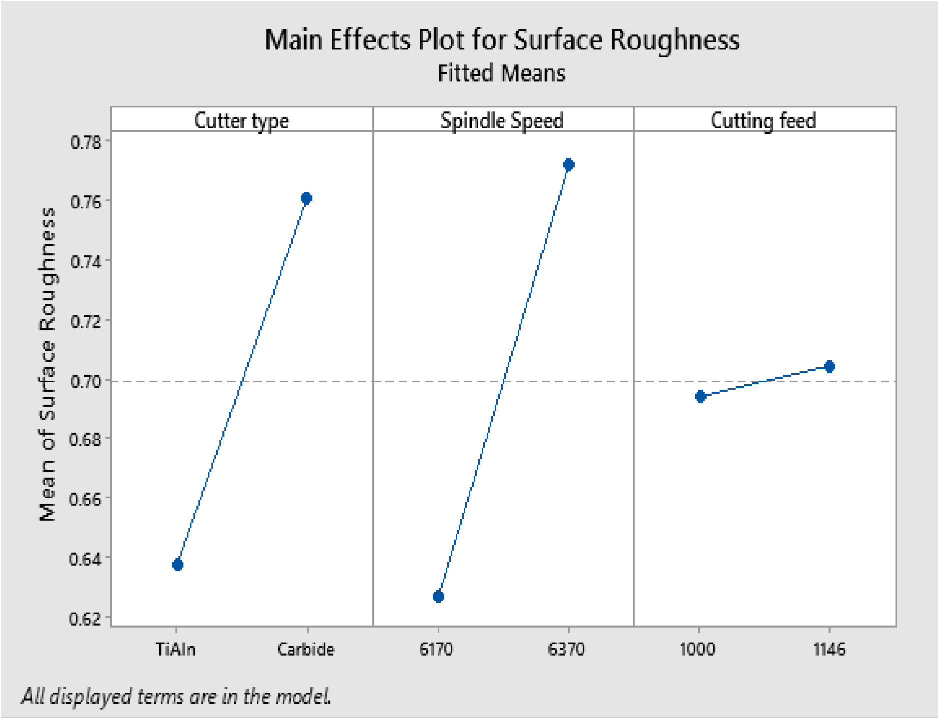


Figure 5.2.4: Main Effect Plot for Surface Roughness

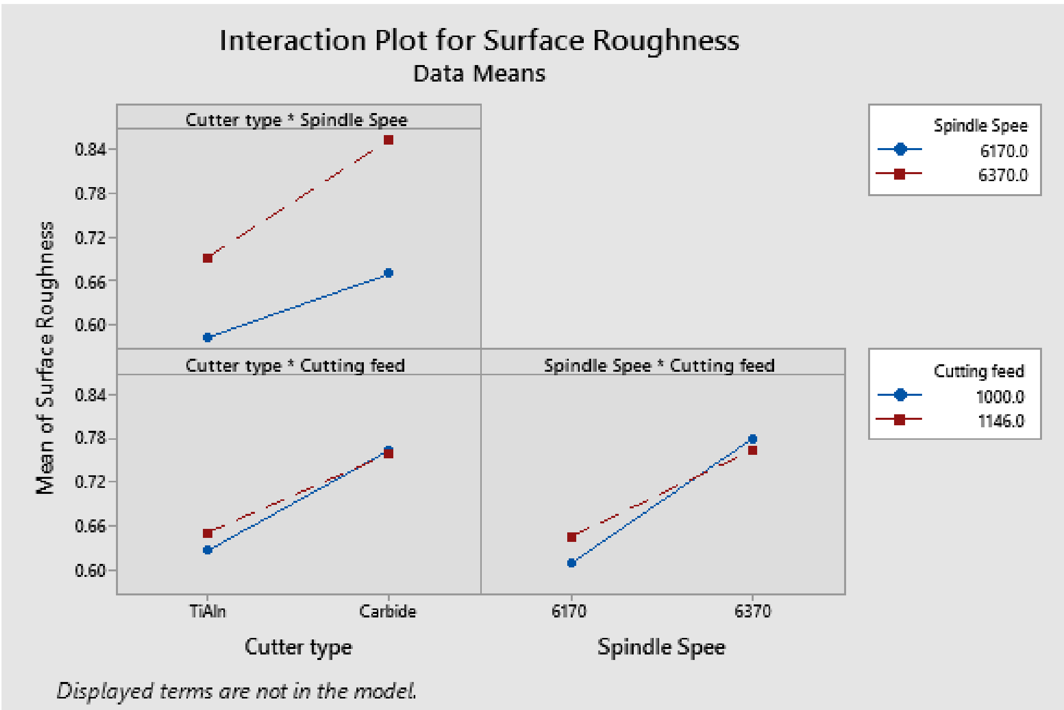


Figure 5.2.5: Interaction Plot for Surface Roughness

## 6. Result and Discussion

### 6.1 Surface Roughness

After conducting the experiments of milling operation on OHNS steel Plates (160 x 70 x 40 mm) of surface roughness values are predicted and optimum parameters are found.

- Feed rate and spindle speed is a dominating parameter of milling process of OHNS steel plates.
- The optimum parameter of milling operation of OHNS steel plates were 6170 RPM of spindle speed, 1000 mm/min of Feed and 0.08 mm Depth of cut for both TiAln coated & no coating carbide end mill cutting tool but it is affected the roughness.
- However OHNS Steel plate having good machinability characteristic and Produce reasonable surface finish.
- Obtained Good surface integrity and minimum wear occur during milling operation of OHNS steel plates.
- During milling processes all parameters are interact and dependant able the milling operation of OHNS steel plates.

- Response table indicate the Feed rate is a dominating parameter of milling process of OHNS steel and also mention Rank of surface roughness are Feed rate, Spindle speed and cutting tool coating type of milling process in the basis Of smaller the best concept.
- Analysis of variance table indicate the milling parameters and Feed rate is a dominating parameter of milling process of OHNS steel based on R square Value of 94.12%.
- The interaction plot indicate the dependant parameters of surface roughness of milling process of OHNS steel plates are end mill cutter type, spindle speed and feed rate and 3rd level parameters are independent in milling process.
- Control plot for milling parameters indicate the 2$^{nd}$ level of feed rate and 2$^{nd}$ level of spindle speed are the optimum parameters of milling process of OHNS steel plates.
- However the OHNS steel plates are probable for manufacturing tools and having good machinability property by using TiAlN coated milling cutter with optimum cutting parameters.

## 7. Conclusion

This study has discussed an application of Full factorial method for investigating the effects of milling parameters on surface roughness. From the analysis of results in the milling process the following can be concluded from the present study:

- Statistically designed experiments based on Full factorial method to analyse the effect of drilling parameters on surface roughness, tool wear.
- Thus it is essential to employ suitable combination of cutting speed and feed so as to reduce the variations that can affect the quality of the surface roughness that are on OHNS material.
- However the OHNS steel plates are probable for manufacturing tools and having good machinability property by using TiAlN coated milling cutter with optimum cutting parameters.
- it is found that the feed, speed are important process parameters & also tool coating is control to surface roughness.
- The optimum parameter of milling operation of OHNS steel plates were 6170 RPM of spindle speed, 1000 mm/min of Feed and 0.08 mm Depth of cut for both TiAln coated & no coating carbide end mill cutting tool.
- It is found that the Surface roughness found in TiAln coated end mill cutter is better than no coating simple carbide endmill cutter.

## 8. Future Scope

We have studied the different operations are to be performed on engineering workshop's and tool room on OHNS Steel material, we found that Cylindrical grinding also plays important role on machining of OHNS steel material. There less study found in Cylindrical Grinding of OHNS Steel material.

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